Offshore Wind **Leasing Round 4**

THE CROWN ESTATE

Resource and Constraints Assessment for Offshore Wind:

Methodology Report

38255-TCE-REP-024

38255-TCE-REP-024: Resource and Constraints Assessment for Offshore Wind: Methodology Report		
Version	Status	Issue date
1.1	Draft	July 2018
1.2	Draft	November 2018
1.3	Final	September 2019

The Crown Estate has undertaken the analysis in this report using evidence available to it, internal expertise and support from external advisers where appropriate. The analysis does not obviate any potential need for any Habitats Regulations Assessment or any project level consideration of the potential impact of development. The analysis does not supersede any statutory policies or marine plans. The analysis including the data and information contained in it may be updated and revised subsequently and particularly following stakeholder feedback.

This report is provided for information purposes only and no party may rely on the accuracy, completeness or fitness of its content for any particular purpose. The Crown Estate makes no representation, assurance, undertaking or warranty in respect of the analysis in the report including all data and information contained in it.

CONTENTS

Resource and constraints assessment to inform potential new offshore wind leasing

1. Background

In November 2017, The Crown Estate announced that it would be considering a process for awarding new seabed rights in the waters off England, Wales and Northern Ireland[1]. In February 2018[2] we provided an update on potential new leasing, which (among other things) set out our view that when considering plans for a potential leasing round, there is benefit in early engagement with statutory and wider stakeholders regarding spatial constraints. It also set out our view that sharing knowledge and data can improve site selection. In response to this, we have undertaken extensive spatial analysis of technical resource and constraints to the development of offshore wind, such as other sea users and environmental sensitivities, through a combination of Geographic Information System (GIS) and qualitative analysis.

Our work on potential new leasing has culminated in the launch of Offshore Wind Leasing Round 4 ('Round 4'. The purpose of our characterisation work has been to develop a common evidence base to inform potential applicants to the Round 4 process and to support the spatial design elements of the leasing round. We have engaged with statutory and non-statutory stakeholders, regulatory authorities and planning authorities to validate and build on the detailed spatial analysis to identify and characterise areas of seabed for offshore wind development.

Engagement has been structured in two phases with market and statutory stakeholder meetings held in July 2018 and a second phase in November 2018 which included engagement with wider stakeholders. Work has been ongoing during this period and is now provided to applicants in the Round 4 process, to inform site selection on a non-reliance basis. This report sets out the methodology used to inform the analysis carried out.

1.1 Aims and objectives

The aim of this analysis is to characterise the potential planning and consenting related risk to offshore wind development on the English, Welsh and Northern Irish seabed. This is with the purpose of indicating to developers and stakeholders our analysis of the relative constraint across the resource area, and to identify strategic planning related risks that could be considered at an early stage in the development process.

The objectives of the work undertaken are:

- Support early engagement with stakeholders to enhance understanding of spatial constraint to development.
- Provide a spatial context to inform statutory marine planning and other policy development.
- To enable a stakeholder validated evidence base to be provided (on a non-reliance basis) to offshore wind developers in the interests of supporting their identification of appropriate potential development sites for Leasing Round 4.

[1] http://www.thecrownestate.co.uk/en-gb/media-and-insights/news/2017-the-crown-estate-to-consider-new-leasing-for-offshore-wind-projects/

[2] https://www.thecrownestate.co.uk/news-and-media/news/2018/update-on-potential-new-offshore-wind-leasing/

This document describes the analysis steps that were undertaken and is accompanied by several annexes that go into elements of the analysis in more detail.

The outputs of the analysis consist of 18 characterisation areas (see Figure 5). These are the outputs of modelling combining available technical resource, undevelopable areas and other constraints. Each characterisation area has an accompanying characterisation report attached. These provide a detailed characterisation of the constraints that are present in each area. These documents consider all the current activities, designations, assets and sensitivities that were present in the area at the time the work was carried out. They also indicate a rating to signify the level of mitigation that may be required to make impacts from offshore wind development in these areas acceptable.

The initial spatial constraints analysis was carried out between September 2017 and June 2018 with different stages taking place at different points within this timeframe. The characterisation documents have been updated and reviewed up until August 2019. The data and information supplied in this analysis and the accompanying characterisation documents is therefore supplied subject to the fact that activities, designations and assets data may have changed during this time. Anyone using this information should seek out the most up to date data and evidence to support their proposals.

2. Introduction to the analysis

2.1. Scope

The resource and constraints assessment completed by The Crown Estate is based on the following scope:

- Only investigating the 'favourable' resource area for fixed foundation offshore wind[3];
- No prerequisites in terms of size of turbines or project;
- Analysis is limited to consideration of offshore array i.e. excluding export cable routes and terrestrial infrastructure; and,
- Analysis is limited to English, Welsh and Northern Irish waters.

The analysis we have undertaken has been an internal process drawing on expertise and knowledge within The Crown Estate where available. It has then been subject to an external peer review process by Everoze Partners Limited (technical resource area) and RPS Energy (constraints analysis).

2.2. Overall approach to the analysis

The analysis follows several steps, each of which focusses on progressively smaller, less constrained and technically attractive areas of seabed. These steps are described in Figure 1. The list below summarises each stage:

- Technical resource model: this is the starting point of the analysis and defines the area of seabed that is most favourable for offshore wind development within the scope defined in section 2.1. This model is mainly driven by water depth, wave climate and geology (note that the 'favourable' resource area is only driven by water depth and wave climate).
- Exclusions model: this forms part of the constraints analysis and removes activities and receptors that will preclude development such as existing infrastructure and rights, and areas where health and safety or policy reasons mean development is unfeasible. These activities and receptors (input criteria) in this model are termed 'hard constraints'.
- Restrictions model: this model includes all other criteria which are structured and weighted in terms of the constraint each presents to development. The input criteria in this model are termed 'soft constraints'.
- Characterisation areas: these are defined from the result of combining the first three stages in the list. Detailed consideration and analysis has subsequently been performed on these areas. The aspects that are introduced in this stage of work are termed 'review layers'.

Each step will be described in more detail throughout this report and in appendices.

[3] http://crownestate.maps.arcgis.com/home/item.html?id=6b8211c4cf55485cbcadc7d38483d4ad

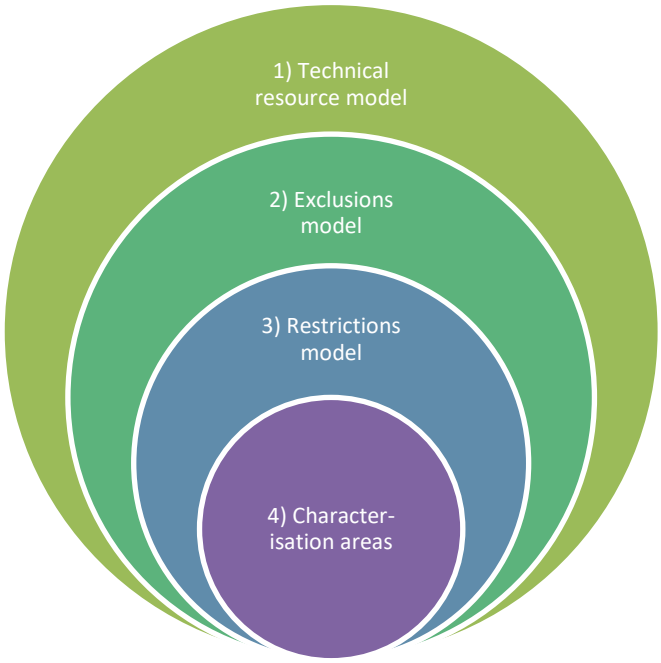

Figure 1: High level stages of resource and constraints assessment showing decreasing footprint at each stage.

2.3. Peer review

A discrete peer review has been carried out at each major stage of the analysis; the purpose being to have experts – who have been involved in consenting and developing projects in the UK - check and validate the assumptions and analysis steps used. A summary of the peer review stages carried out are included in Table 1, with the findings and actions undertaken after each review being summarised at the end of each relevant section of this report.

Table 1: Peer review stages

Review stage	Peer reviewer	Brief description of activities completed in the review	References
Technical resource model	Everoze Partners Limited	Assessment and validation of criteria to classify appropriate technical resource.	Appendix A - KRA Criteria peer review http://crownestate.maps.arcgis.com/home/item.html?id=6b8211c4cf55485cbcadc7d38483d4ad
Spatial modelling of constraints	RPS Energy	Validation of data audit and selection of constraints. Performed a mirroring exercise of the pairwise analysis of constraints and provided recommendations to improve analysis.	Appendix F – Offshore wind constraints analysis and characterisation peer review http://crownestate.maps.arcgis.com/home/item.html?id=2768a6f3cf9f44c58d909e5edd915cb9
Characterisation documents	RPS Energy	Full review of all the characterisation documents to ensure accuracy and consistency.	Appendix F – Offshore wind constraints analysis and characterisation peer review http://crownestate.maps.arcgis.com/home/item.html?id=2768a6f3cf9f44c58d909e5edd915cb9

3. Spatial modelling of resource and constraints

This section of the report describes the analysis that was carried out using GIS tools. In the case of the technical model, these utilised the standard suite of ArcGIS geoprocessing tools (section 3.1), with the constraints analysis (comprising of the exclusions and restrictions models) completed using our Marine Resource System (MaRS) tool (section 3.2). The outputs of this section of the analysis were the 18 characterisation areas that are mapped in Figure 5.

It should be noted when reading this section that some layers were deemed unsuitable for inclusion in the constraints model due to the nature of the constraint being too complex or appropriate data being unavailable. These constraints have been considered in the characterisation analysis described in section 4.2.

3.1. Technical resource model

To support the identification of technically viable, lower constraint offshore wind resource, the starting point is to identify areas of seabed with suitable technical conditions to support economic development.

Supported by peer review from Everoze Partners Limited (see **Appendix A**), the following criteria were identified as significant in defining the technical viability of fixed foundation offshore wind development.

3.1.1. Water depth

Water depth primarily affects the capital cost associated with the wind turbine foundations and the installation of the wind farm. Deeper waters require larger and more costly foundations to support the wind turbines as well as requiring specialist vessels capable of operating in such conditions during the construction phase. Beyond ~60m below Lowest Astronomical Tide (LAT), conventional “bottom-fixed” foundations become un-economic and/or technically unfeasible. Experience from early UK offshore wind projects has shown that sites with very shallow water depths of less than ~5m below LAT, incur significant installation challenges and operational risks.

3.1.2. Quaternary thickness

Quaternary thickness, broadly speaking, determines the likelihood that a piled foundation (be it a monopile or jacket) will intersect with rock in the seabed. “Quaternary” refers to near-surface deposits laid down in the last ice age over underlying bedrock. A thinner quaternary layer will increase installation costs due to the increased probability of expensive drilling equipment needing to be deployed during installation.

3.1.3. Bedrock lithology

Bedrock lithography describes the type and strength of material present in the bedrock. In general terms, this determines the duration of drilling required for piled foundation installation if the foundation intersects with bedrock.

3.1.4. Accessibility due to wave climate

Accessibility (due to wave exceedance) describes the proportion of the year when it is possible to access the offshore wind site, assuming a typical working limit of 2.5m significant wave height. This affects the efficiency and therefore the cost of the construction phase and Operations & Maintenance (O&M) activities.

3.1.5. Other considerations

It could be argued that both wind resource and distance from shore should be considered in this technical resource model. Distance to shore impacts offshore wind economics principally in three ways:

1. The capital cost of the electrical system connecting the asset to the grid increases with distance to shore as cable length, specification and overall system design are all affected.
2. Operational costs associated with O&M increase with distance to shore due to the additional logistical requirements needed to achieve reasonable levels of access.
3. Electrical losses increase with distance to shore, thus reducing net energy production.

However, the cost implications of moving further away from shore are to a greater or lesser extent mitigated by the higher wind resource typically found further from shore. In addition, the net capacity factor delivered for a given mean wind speed is dependent on technology selection. For this reason, a crude filtering of low wind speed sites could introduce unrepresentative results for each classification. Distances from shore and wind resource were therefore not included in the technical resource model.

3.1.6. Classification of technical resource model

The technical resource model data layer was then split into three classes denoting favourable, limited and marginal locations for offshore wind deployment which are described as:

1. Favourable classification: the proposed criteria are considered to be consistent with the classification of “Favourable” because while significant variations in engineering solutions and project economics can be expected, technical feasibility is likely to be high and conditions are in line with the potential to bring forward a competitive offshore wind development.
2. Limited classification: the proposed criteria are considered to be broadly in line with a classification of “Limited” in that the technical favourability of sites fulfilling these criteria are likely to be sub-optimal, without being entirely unfeasible.
3. Marginal classification: the proposed criteria are considered to be consistent with the classification of “Marginal” because the combination of onerous technical conditions would in the majority of cases make substantive development of an offshore wind scheme highly challenging due to the risk of weak economics and/or non-feasibility.

The classification criteria for each of these classes is shown in Table 2 with the output maps shown in section 6 – Map Figures.

CLASSIFICATION	CRITERIA-SET	WATER DEPTH (m LAT)	QUATERNARY THICKNESS	BEDROCK LITHOLOGY[1]	ACCESSIBILITY DUE TO WAVE EXCEEDANCE OVER 2.5M
FAVOURABLE	1	5 to 50			>=80%
LIMITED	2	50 to 60	Thick		
Or	3	50 to 60	Thin	All but: Ig, Pal and Met	
Or	4	5 to 50			<80%
MARGINAL	5	50 to 60	Thin	Ig / Pal / Met	

1. Ig – Igneous, Pal – Palaeozoic, Met - Metamorphic

Table 2: List of classification criteria for the technical resource area.

3.2. Constraints analysis

The constraints analysis has been conducted using the MaRS tool. This is a scalable, flexible and auditable decision support tool that uses multi-criteria decision-making and GIS to perform analysis. The MaRS system analyses many layers of spatial information, combining them to help answer key resource planning questions. Data layers can be prioritised and combined in different ways through a user defined scoring system to

support a variety of studies. This can include identifying areas of technical opportunity or identifying areas where other users or interests might limit access to given resources.

The assessment of constraints is subjective and relies on expert opinion to assess relative importance of input data layers and apply given scores equally across each data layer (or sub classification if the data describes intensity or density). This means that the analysis is a relative assessment and cannot identify specific thresholds of "consentability"; however, the output provides a strategic indication of the relative level of potential planning constraint to development, in relation to the activities and receptors included in the GIS model.

MaRS has been used in several previous leasing and marine planning exercises including Round Three offshore wind, wave and tidal stream demonstration zones and the Marine Management Organisation's (MMO's) marine planning options process for the East Marine Plans.

Details of the peer review activity that was undertaken on the constraints analysis steps are included in **Appendix F**.

3.2.1. Exclusion model

The exclusion model included features that should be avoided since they would prevent a development from taking place. The exclusion model was used to remove areas from the model. Features in this category are due to one of three reasons:

1. There is existing infrastructure in place that would preclude development.
2. Safety reasons would inhibit development (e.g. International Maritime Organisation (IMO) shipping routes and oil and gas safety zones).
3. Existing rights have been granted over the seabed which precludes granting rights for offshore wind development.

A full list of the data included in the exclusion model (i.e. considered to be hard constraints) is provided in Appendix B. This data was collated, flattened and removed from the analysis.

A general rule was implemented to determine that all our assets (agreements, options, Agreements for Lease (AfLs) and Preferred Bidder Letters) were included as hard constraints. The exception to this were Carbon, Capture and Storage (CCS) and Evaporates Agreements, as it was felt there is potential for co-location between these activities and offshore wind, albeit by agreement with both parties.

3.2.2. Restrictions model

The restrictions model contains data on activities and sensitivities that may provide variable constraints on the development of fixed foundation offshore wind, but not necessarily preclude development (i.e. soft constraints). This included data on environmental designations, fishing and visibility from landscape designations. A full list of data included in the restrictions model is included in Appendix C. This data was modelled and combined on a cell by cell basis with all total scores (weight multiplied by the score) being summed together to produce a combined opportunity output for the restrictions model.

Learning from previous resource and constraints assessment exercises (Round Three offshore wind and wave and tidal demonstration zones) highlighted opportunities to improve the way in which groups of criteria and data layers were used in the constraints analysis. In response to this, Analytical Hierarchical Processing (AHP) was implemented to define a tiered structure to allow comparison of similar criteria and provide a method of producing weights with statistical rigor for implementation in the MaRs model. More information on this and the experience of previous resource and constraints assessment exercises is included in **Appendix D.**

To complete the analysis, data is arranged and grouped into four tiers. These are described in Figure 2.

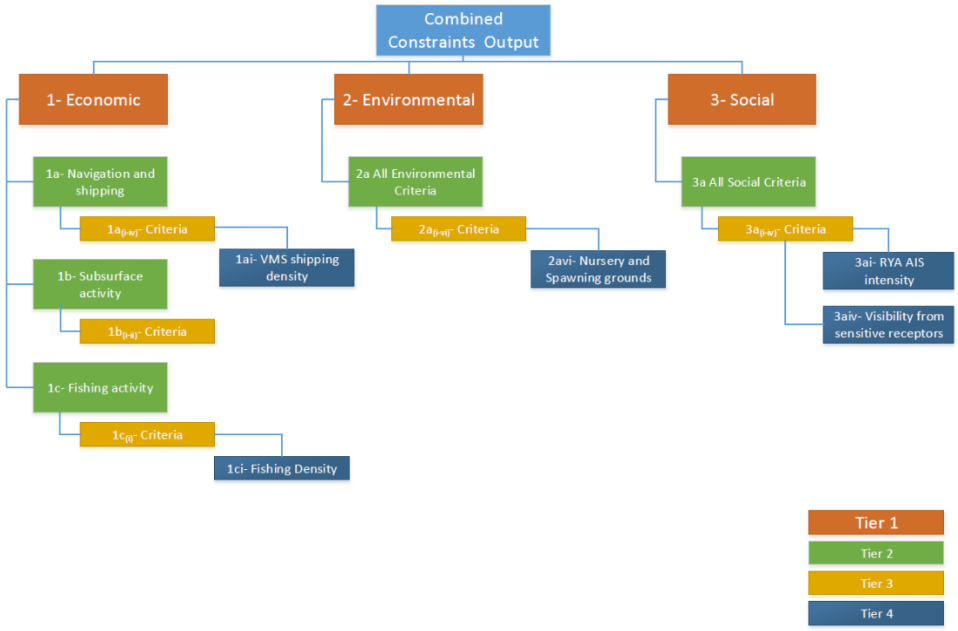

Figure 2: Hierarchy used in the constraints analysis.

Tier 1, represented in the hierarchy as the orange boxes, represents the high-level themes into which all the criteria (data layers) are grouped at the first stage analysis. These are economic, environmental, and social themes. These themes are weighted against each other at the top of the hierarchy and dictate the relative influence the sub-criteria can have. For example, if the economic theme is weighted significantly higher than the social theme, then the criteria in the social theme will have a lower influence on the output than those in the economic theme (this example is for illustrative purposes only).

Tier 2 has been added to accommodate the large number of criteria that form the economic Tier 1 theme. This applies the same principle described in the paragraph above but only amongst the 3 economic subthemes. The Tier 2 groups for environmental and social themes are effectively bypassed by weighting them as 1.

Criteria and (individual data layers) sit in Tier 3 with separate groupings for each Tier 2 heading. For example, all the navigational criteria sit under the “navigation and shipping” subtheme and all designation and environmental data sits under the environmental theme. The criteria and data layers in each of these Tier 3 groups are weighted against each other to establish which present the most constraints to development.

The input criteria (data layers) are held in Tier 3 for discrete layers (i.e. lines, polygons), but data that is variable across the area of interest, termed “continuous layers” is split up further in Tier 4 - examples of continuous data layers include shipping density and Vessel Monitoring System (VMS) data describing fishing activity. This data is split into classes of intensity, then assessed in Tier 4 to define the levels of influence the higher intensity of activity should have over lower classes in the final output.

A full list of data used and how the Tier 4 criteria were categorised is included in **Appendix C**.

3.2.3 Pairwise calculations

A pairwise comparison between the relevant themed criteria in each tier was conducted through several workshop sessions with The Crown Estate internal experts. These used the nine-point scoring criteria described in

to produce weightings for all input criteria used in the restrictions model.

1	1= **Equal** constraints to development of offshore wind
3	3= *Criterion A* presents **moderately** more constraints to development of offshore wind than *Criterion B*
5	5= *Criterion A* presents **strongly** more constraints to development of offshore wind than *Criterion B*
7	7= *Criterion A* presents **very strongly** more constraints to development of offshore wind than *Criterion B*
9	9= *Criterion A* presents **extremely** more constraints to development of offshore wind than *Criterion B*

Table 3: Pairwise scoring scheme.

Table 4 is the pairwise comparison for Tier 1 of the analysis.

For the row "1-Economic" the following comparisons are made:

- *Economic* against *economic* is prepopulated as a score of one as it is comparing with itself.
- *Economic* presents equal constraint to *environment* so results in a pairwise score of one.
- *Economic* presents between equally and moderately more constraint to *social* so results in a pairwise score of two.

For the "2- Environmental" row the following comparisons are made:

- *Environment* against *economic* has already been assessed so is the reciprocal (1/x) of the above comparison, in this case this would be 1/1= 1.
- *Environment* against *environment* is prepopulated as a score of one as it is comparing with itself.
- *Environment* presents between equally and moderately more constraints than *social* so results in a pairwise score of two (note this has to be equal to that of the *economic* assessment as *environment* and *economic* are assessed as equal).

For the "3- Social" row the following comparisons are made:

- *Social* against *economic* has already been assessed so is the reciprocal (1/x) of the above comparison, in this case this would be 1/2= 0.5.
- *Social* against *economic* has already been assessed so is the reciprocal (1/x) of the above comparison, in this case this would be 1/2= 0.5.
- *Social* against *social* is prepopulated as a score of 1 as it is comparing with itself.

The justification for this assessment is that the economic and environmental criteria should be weighted equally as both themes have significant amounts of data that detail constraints to development. The social theme was weighted at a slightly lower level due to the contents of the theme being a subset of true social constraint. For example, there is no consideration of sensitivity of landscapes to development

or analysis of economic typologies of coastal communities that may be impacted (positively and negatively) by development.

The calculations described in Appendix d.2. were then performed to produce the "calculated weight". As this is Tier 1, this resultant number dictates the maximum weight that the top criteria in each of the three themes can be assigned.

Model Name	Calculated Weight	Pairwise Comparisons		
		Economic	Environmental	Social
1- Economic	0.4	1.00	1.00	2.00
2- Environmental	0.4	1.00	1.00	2.00
3- Social	0.2	0.50	0.50	1.00

Table 4: Tier 1 pairwise comparison.

Pairwise matrices were completed for all subthemes, groups of criteria (data layers), and the Tier 4 layers. Each generated a maximum weighting which is then passed down to each criteria (data layer) in the hierarchy. This produced a consistency score ensuring the statistical robustness of the analysis. A full list of the pairwise comparisons is provided in Appendix E. This lists the user defined pairwise scores, calculated weightings and includes explanations for the scoring of each tier and criteria.

Two layers were made specifically for inclusion in the restrictions model. We created the 'visibility from landscape designations' data layer to inform this analysis. Details of how this was produced are included in section 4.2.3. 'High intensity fish nursery and spawning overlap count' was a data layer created that counted the number of high intensity spawning and nursery ground areas for available species in Ellis et al 2012[4]. This produced a count of 1-9 which were adopted as the classes of data and then pairwise compared against each other to produce weightings.

Two layers were deliberately down weighted in the constraints analysis, namely:

1. 'Visibility from landscape designations'; and,
2. 'Fishing intensity 2015 (total kilo Watt hours)'.

In the case of 'visibility from landscape designations', this was due to the constraints being complex to portray, and there being insufficient assessment of sensitivity of each landscape designation. More information on this analysis and its limitations is included in section 4.2.3.

Recognising the complexity of this issue, visibility from sensitive receptors was weighted lower than might be expected and was explored more fully in the characterisation documents and through stakeholder engagement.

Fishing intensity was based on the 2015 VMS data produced by the MMO. This only describes a proportion of vessels in the fishing fleet over 12m. The data has been presented in terms of effort in kilowatt hours to reflect the MMO's approach to presenting fishing data in the marine planning evidence base[5]. This puts more emphasis on larger vessels but does not accurately attribute value of a fishery.

[4] Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Cefas Lowestoft, 147: 56 pp.
[5] http://defra.maps.arcgis.com/apps/webappviewer/index.html?id=2c2f6e66c0464fa99d99fd6d8822ddef

Recognising these shortcomings, the decision was made to down weight the VMS data in the restrictions model and rely on engagement with experts and stakeholders to accurately portray the nature and value of the activity during the characterisation phase of work and subsequent stakeholder engagement.

3.2.4 Implementation in Marine Resource System (MaRS)

The scores defined by the pairwise modelling process were then input into MaRs with any pre-processing steps applied, as summarised below. MaRS requires both a weighting and a score for each criteria, and for both to be integers (whole numbers).

The global weights calculated by the AHP tool are long decimals so were multiplied by 10,000 and inputted as weights, with the score set to one for all values. A detailed description of GIS procedures used in pre-processing steps and to set up the MaRS models is included in Appendix F.

The three component parts of the analysis (technical model, exclusion model and restrictions model) were then combined in the GIS. The process followed was to:

1. Set the area of analysis to the favourable technical resource area;
2. Run the restrictions model and normalise the output; and,
3. Extract the exclusions model from the restrictions model output.

The output of combining these models is shown in section 6 - Map Figures. This has been normalised and split into four groups with equal number of features representing the suitability of the area of search. I.e. the top 25 per cent (least constrained), the 25 to 50 per cent, 50-75 per cent, the remaining features which are the most constrained areas. This output identifies inshore and embayment areas as generally being the most constrained areas due to the number of receptors overlapping in these areas.

4. Characterisation of areas

The spatial modelling of constraints described in section 3 is a useful tool to narrow down areas of search at a strategic level. However, the modelling does have several caveats. The most significant is that the modelling relies on subjective assessment and applies flat weightings across all features in a data layer (e.g. no consideration of the sensitivity of features within a designated site to offshore wind development has been applied in the restrictions model, only a flat assessment across designation types). The GIS output should therefore only be viewed as an indication of where lower constrained areas with suitable technical resource characteristics may be situated. To apply more consideration to individual constraints to development identified in the exclusion and restriction models, and to elaborate with further analysis to strategically characterise each area, a further step was taken.

The top 50 per cent of the model output shown in Figure 4 was taken. This was then split into 18 areas which follow marine plan area boundaries and were also subdivided into coherent areas e.g. resource around the Dogger Bank. The resultant characterisation areas are described in Figure 5.

Each of these ‘characterisation areas’ is described in significantly more detail in the following aspects which are termed review layers:

- Everything that was included in the exclusion and restriction models.
- High level assessment of the sensitivity of environmental designations.
- Visibility analysis including detailed consideration of visibility from landscape designations layer and coastal buffers.
- Ornithology outside of Special Protection Areas (SPAs) for selected high risk species.
- Ministry of Defence (MoD) activity.
- Fisheries activity.
- Oil and gas helicopter consultation zones.
- Marine plans.
- Water Framework Directive (WFD).
- Cultural heritage.
- National Air Traffic Services (NATs) radar and aerodromes.
- The Crown Estate key resource areas (KRA) for other sectors.

This work was then collated into characterisation documents for each of the 18 areas. This assessment is described in subsequent sections of this report.

4.1 Characterisation area rating methodology

Each characterisation document describes the component criteria that drove the spatial modelling, as well as several other criteria that were not included in the model to provide an in-depth description of the key issues and characteristics present in each area.

These were rated at a receptor and an area level. The receptor rating was completed by looking at what mitigation would be required within an area of influence for each receptor to enable offshore wind development. The area rating looked at how the receptors would impact development across the whole area.

Table 5 details the rating mechanism that was applied.

Receptor rating		Area rating	
Receptor assessed but no interaction noted		Receptor assessed but no interaction noted at an area level	
Interaction with receptor acceptable with best practice/accepted mitigation		The constraint will present the need to implement best practice/accepted mitigation measures to enable acceptable development within the whole area	
Interaction with receptor acceptable with moderate mitigation		The constraint will present the need to implement moderate mitigation measures to enable acceptable development within the whole area	
Interaction with receptor acceptable with significant mitigation		The constraint will present the need to implement significant and/or strategic level mitigation measures to enable acceptable development within the whole area	
Significant/insurmountable issue that would be challenging to mitigate within the area of influence of a receptor		Significant/insurmountable issue that would be challenging to mitigate for any development within the whole area	
No data coverage across the area		No data coverage across the area	

Table 5: Rating definitions for characterisation analysis.

4.2 Characterisation analysis

4.2.1 Characterisation of the exclusion and restriction models

GIS reports were generated for each individual characterisation area. These detailed features that were included in restriction and exclusion models which were intersecting or within one nautical mile (NM) buffer of each characterisation area. This buffer was chosen to pick up features situated outside the characterisation area but that may be impacted by development within an area. As this is a strategic level, this buffer was deemed appropriate however, when completing more detailed site selection, consideration of impact pathways, and how development may impact on remote protected sites and species, should be included.

Each feature that was returned in the GIS report was described in terms of location and nature of activity or receptor, commentary provided on the features sensitivity to offshore wind development and given an area and receptor rating (as shown in Table 5).

4.2.2 Environmental designations

Recognising the variable sensitivities of environmental designations to offshore wind development, further analysis was undertaken on a site by site basis. This was completed for Site of Specific

Scientific Interest (SSSIs) and Area of Scientific Special Interest (ASSIs) (Northern Ireland), Marine Conservation Zones (MCZs), Ramsars, Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and any sites progressing through the designation process that have statutory weight (e.g. potential SPAs, candidate SACs).

The analysis was conducted by Anne Westwood Consulting with advice structured under the following headings:

- Type of designation;
- Name of designation;
- Distance from offshore wind region;
- List of designated features/species;
- Whether the designated features are terrestrial, intertidal, marine or bird related;
- Comments on conservation objectives/site condition status;
- Commentary on the sensitivity of the site to development of offshore wind;
- Rating at the receptor level; and,
- Links to some relevant documents.

Where sites have been assessed to need moderate mitigation or above, all the commentary has been pulled through into the characterisation reports. Where sites have been assessed as low constraint, commentary has not been provided in characterisation reports.

Sites were included in this assessment if they intersected or were within 1NM of the characterisation area. This is a simple method of identifying designations that may be impacted by offshore wind development, but suitable for the strategic resource and constraints analysis. The Habitats Regulations Assessment (HRA) that will support the leasing process will provide more significant analysis, including consideration of impact pathways for each designation.

4.2.3 Visibility from landscape designations and distance from the coast

Visual sensitivity is an important consideration for appropriate siting of offshore wind farms, however, assessment of sensitivity involves substantial analysis which draws on the sensitivity of a landscape designation to development of offshore wind (i.e. if a landscape is designated for marine views or setting). This information can be found in National Park and Area of Outstanding Natural Beauty (AONB) management plans.

Our analysis approach has been to perform visibility analysis from four types of landscape designations and apply analysis using distance from shore thresholds referenced in the Offshore Energy Strategic Environmental Assessment 3 (OESEA3) (2016)[6].

The analysis to determine how visible areas of sea are from landscape designations (National Parks, AONB, Heritage Coasts and World Heritage sites) was completed using the same methodology as the inter-visibility analysis described in the seascape assessment for the South Marine Plan Areas Report[7]. This drew on a terrestrial digital elevation model with an offset of 2m to account for viewer's height.

[6] BEIS (2016), OESEA3 Environmental Report. Crown copyright 2016, p 291. URN 16D/033.

[7] MMO (2014). Seascape Assessment for the South Marine Plan Areas: Technical Report. A report produced for the Marine Management Organisation, pp 88. MMO Project No: 1037. ISBN: 978-1-909452-25-1.

A 500m by 500m grid was then constructed and applied within landscape designation to allow a count of visibility to be conducted. The output presents a heat map based on the number of 500m by 500m points that can see each point at sea surface.

There are several known limitations with this approach. The shape of a designation will impact on the number of points that fall within the boundary of the designation, and therefore the resultant output of how strongly viewed marine space is around that designation. For example, Heritage Coasts are usually narrow strips of coastline and therefore may not present highly viewed areas due to the small number of viewer analysis points that fall in the designation. In addition, this sort of visibility analysis tends to highlight embayed areas and downplay headlands. This may be correct in the context of the analysis, however should not be used as a proxy for sensitivity.

Finally, the analysis has been conducted as visibility of sea surface and not at the height of turbines. This is due to unknowns such as turbine height, layout and potential difference in atmospheric effects in each area. Site specific analysis should be undertaken at the project level to address these shortcomings when proposals are developed.

To supplement the visibility analysis, distance from shore thresholds were used to assess the proximity of resource to land and what size turbines may be appropriate based on analysis in the OSEA3 (2016). Although no specific buffers or exclusions were formally recommended by the OSEA3 (2016), it referenced work completed by the White Consultants (2016)[8] which identified distances and potential for significant impacts to be assumed at different distances from shore. The recommendations were: "that for high value and high sensitivity coastlines, a distance of 30km from the coast (the limit of visual acuity) could be attributable to developments for a range of sizes (e.g. 3.6MW to 15MW), whereas distances for areas of medium value and sensitivity may be in the order of 13km (3.6MW turbines), 20km (4-8MW turbines) or 20+km (10-15MW turbines)." These distances were overlaid with the characterisation areas and statistics produced to inform commentary.

4.2.4 Ornithology outside of SPAs for high risk species

To allow assessment of ornithological sensitivity outside of SPAs, the European Seabirds at Sea (ESAS) database was used for at sea distribution alongside foraging ranges. The ESAS data and foraging ranges used were the same as those used in the Natural England (2013)[9] report.
This analysis was limited to: gannet, kittiwake, lesser black-backed gull, great black-backed gull and herring gull.

These species were selected on the basis that they are found widely around UK coasts in most months and spend a significant proportion of their time at potential collision height (i.e. >22m), with the consequence that they usually have the highest collision risk estimates in offshore wind farm assessments.
Commentary to determine the potential impacts of development within each characterisation area focussed on:

[8] White Consultants (2016). Review and update of Seascape and Visual Buffer study for Offshore Wind farms. White Consultants, 73pp. plus appendices.
[9] Natural England (2013). Seabird sensitivity mapping for English territorial waters: Spatial modelling, wind farm sensitivity scores and GIS mapping tool, pp71.

- Which species mean and maximum foraging ranges intersect each characterisation area;
- The size of the foraging range and how many other characterisation areas intersect the foraging range;
- Existing and planned development in the foraging area; and,
- Summer density distribution and how this intersects the characterisation area. Summer density was used due to the higher densities observed and to reflect what has been identified as higher risks in previous Environmental Impact Assessments (EIAs).

4.2.5 MoD activity

Commentary was provided by the Defence Infrastructure Organisation (DIO) of the MoD drawing on advice from subject matter experts. Areas that were commented on were:

- Air traffic control;
- Air defence radar;
- Threat radar;
- Low flying;
- Ranges, danger and exercise areas; and,
- DIO safeguarding position.

Commentary was provided by DIO against the following scale:

- Red – Objection and would require mitigation;
- Amber – Likely to be objected to; and,
- Green – No objection.

The DIO commentary has been translated into the scale described in

Table 5. The table considers the location of each identified sensitivity, and the potential for mitigation to be applied.

Due to the long lead in times to gain feedback on MoD activity, broad areas covering much of the favourable technical resource area were provided to DIO for comment rather than specific characterisation area boundaries. The commentary on these areas has subsequently been translated into the relevant characterisation documents.

4.2.6 Fishing activity

Aside from including VMS data in the restrictions model, extra commentary was sought to allow reflection of the importance of characterisation areas to the whole fishing fleet. Initial commentary across all characterisation areas was provided by Colin Warwick, the Chair of Fisheries Liaison with Offshore Wind and Wet renewables (FLOWW) group. This commentary was split into commentary on mobile and static gear with information on the species targeted in each area, the ports that these are often landed at and type of capture method deployed in each area.

This commentary will be the focus of targeted stakeholder engagement work to ground truth and ensure the priorities in each area are accurately reflected.

4.2.7 Oil and Gas helicopter consultation zones

In accordance with CAP 764[10], the nine NM consultation buffer around helidecks on oil and gas platforms has been considered in the characterisation documents. This was not included in the spatial analysis model due to uncertainties around the potential decommissioning picture and potential solutions for development within the nine NM zone. Analysis to quantify the overlaps between consultation buffers and the characterisation areas was undertaken. This implemented radial buffers to inform the commentary on the nature of the overlaps at three, six and nine NM.

4.2.8 Marine Plans

There is an adopted Marine Plan in place for the East and South marine plan areas in England while the Welsh National Marine Plan and Northern Ireland Marine Plan have completed public consultation. Policies were analysed to establish potential further work a developer would need to undertake to be compliant with marine plans.

4.2.9 The Crown Estate key resource areas (KRAs) for other sectors

We undertook analysis and data collection to form a view on the distribution of potential resources for each sector that utilises the seabed. These areas are used to enable the consideration of the impacts of development on potential resources. Those sectors for which KRAs are produced are listed below with sources of information noted:

- Cables - highlights very broad scale landing areas mainly based on previous cable landing locations;
- CCS stores - highlights extensively characterised stores that have been completed through Front End Engineering and Design (FEED) work and the further site characterisation work completed by Pale Blue Dot (2016);[11]
- CCS infrastructure - drawing on our internal analysis to identify CCS stores and potential sources of carbon to highlight potential infrastructure corridors;
- Minerals - drawing on British Geological Society (BGS) (2011)[12] work, marine minerals resource around the UK and, potential sand and gravel resources;
- Pipelines - highlights broad scale landing areas mainly based on previous pipeline landing locations;
- Sandscaping- includes potential sites that could be suitable for sandscaping coastal management based on our internal analysis;
- Tidal range - based on projects identified through Department of Energy and Climate Change (DECC) (2010);[13]
- Tidal stream - based on our 2013 analysis of tidal stream potential in the UK;[14] and,

[10] CAA (2016), CAP 764: CAA Policy and Guidelines on Wind Turbines, pp 43-46. Published by the Civil Aviation Authority, 2016

[11] Pale Blue Dot (2016), Progressing the Development of the UK's Strategic Carbon Dioxide Storage Resources, pp 48. Published online: https://onedrive.live.com/?authkey=%21ANk4zmABaDBBtjA&id=56FC709A2072366C%211559&cid=56FC709A2072366C.

[12] Bide, T. P., Balson, P. S., Mankelow J.M., Shaw R.A., Walters A. S., Green, S. and Campbell, E. 2011. The Mineral Resources of the East Inshore and East Offshore Marine Plan Areas, Southern North Sea. British Geological Survey Open Report, OR/12/095. 22pp.

[13] DECC (2010), Severn Tidal Power: Feasibility Study Conclusions and Summary Report, pp 75. ©Crown Copyright URN 10D/808.

[14] The Crown Estate (2013), UK Wave and Tidal Key Resource Areas Project: Technical Methodology Report, pp 57.

- Wave - based on our 2013 analysis of wave potential in the UK.[15]

These KRAs were assessed with consideration of confidence in the resource identified in each KRA, the abundance of resource in the UK and potential sensitivity to development of offshore wind over each KRA. The conclusions of this section will be tested through stakeholder engagement.

4.2.10 NATS radar overlap

The National Air Traffic Services (NATS) is the main air navigation service provider in the United Kingdom. It provides en route air traffic control services to flights within the UK Flight Information Regions and provides air traffic control services to fourteen UK airports.

A series of self-assessment maps have been made available on the NATS website to support the potential impacts of windfarm development on radar lines of sight[16]. Analysis was completed on the line of sight from Primary Surveillance Radars (PSR) assessment buffer using a 200m turbine scenario. Overlap within this line of sight indicates that further impact assessment and potential mitigation is required, which would be determined on a project specific basis. Commentary on each characterisation area is presented alongside the percentage of the characterisation areas that overlaps the line of sight boundary.

Self-service maps are also available for secondary radar, air-ground-air communications and navigation aids. These were not specifically referenced due to minimal overlaps with the characterisation areas and due to the primary radar being deemed as the most significant constraint.

4.2.11 Water Framework Directive (WFD)

WFD management information was also analysed. We commissioned RPS to create a data layer that brings together information on water bodies across England, Wales and Northern Ireland. This reported on the following information:

- Water bodies intersection or within one NM of a characterisation area;
- Water body type (e.g. marine, estuarine);
- If the water body is heavily modified;
- The current overall status of the water body;
- Ecological status;
- Chemical status; and,
- When the water body is targeted to get to ‘good’ status.

The characterisation assessed sensitivity of water bodies based on the current modification status of the body of water. Heavily modified water bodies were assessed as less of a constraint on new development and those targeted for ‘good’ environmental status were deemed more constrained if a specific targeted date was presented.

Due to WFD water bodies only extending to one NM, direct intersection with characterisation areas will be limited. This information is of more interest to cable laying activities, which is outside the scope of this analysis.

[15] Ibid.
[16] NATS website: https://www.nats.aero/services/information/wind-farms/self-assessment-maps//.

4.2.12 Marine cultural heritage

The UK Marine Policy Statement (MPS)[17] and UK High Level Marine Objectives (HLMO) set out the importance of cultural heritage (i.e. the marine historic environment) as a component of delivering sustainable development in the UK. In addition, the MPS states that non-designated heritage assets with archaeological interest should be considered subject to the same policy principles as applied to designated heritage assets.

Analysis of the potential for characterisation areas to play host to heritage assets was completed by Marine Space Ltd with commentary provided on:

- Shipwreck and other physical evidence of maritime activity;
- Crashed aircraft at sea (aviation archaeology); and,
- Submerged prehistoric sites, features, and deposits.

The last bullet point includes features and artefacts that are representative of past human activity in areas of the marine environment that were dry land during times of lower sea-levels. It also includes the submerged palaeo landscapes and deposits that have potential to inform understanding of past human occupation and activity.

Risk ratings were applied to reflect how a developer may mitigate impact on assets if identified in site investigation.

[17] HM Government (2011), UK Marine Policy Statement, pp 21-23. ISBN: 978 0 10 851043 4.

5. Summary of resource and constraints assessment

The main outputs of our work are the 18 characterisation area documents. These provide a detailed characterisation of the constraints that are present in each area. The areas that these documents relate to are underpinned by significant spatial analysis, combining technical resource and constraints, to identify areas for potential development.

The characterisation documents build on the spatial analysis by presenting information on current activities, designations, assets and sensitivities that are present in the area. They included a rating to indicate the level of mitigation that may be required to make any impacts associated with offshore wind development acceptable.

However, while many of the identified constraints may be mitigated using existing or developing practice, it is noted that the cumulative impacts of development are becoming a significant issue in some areas and that innovative solutions may be required to enable development.

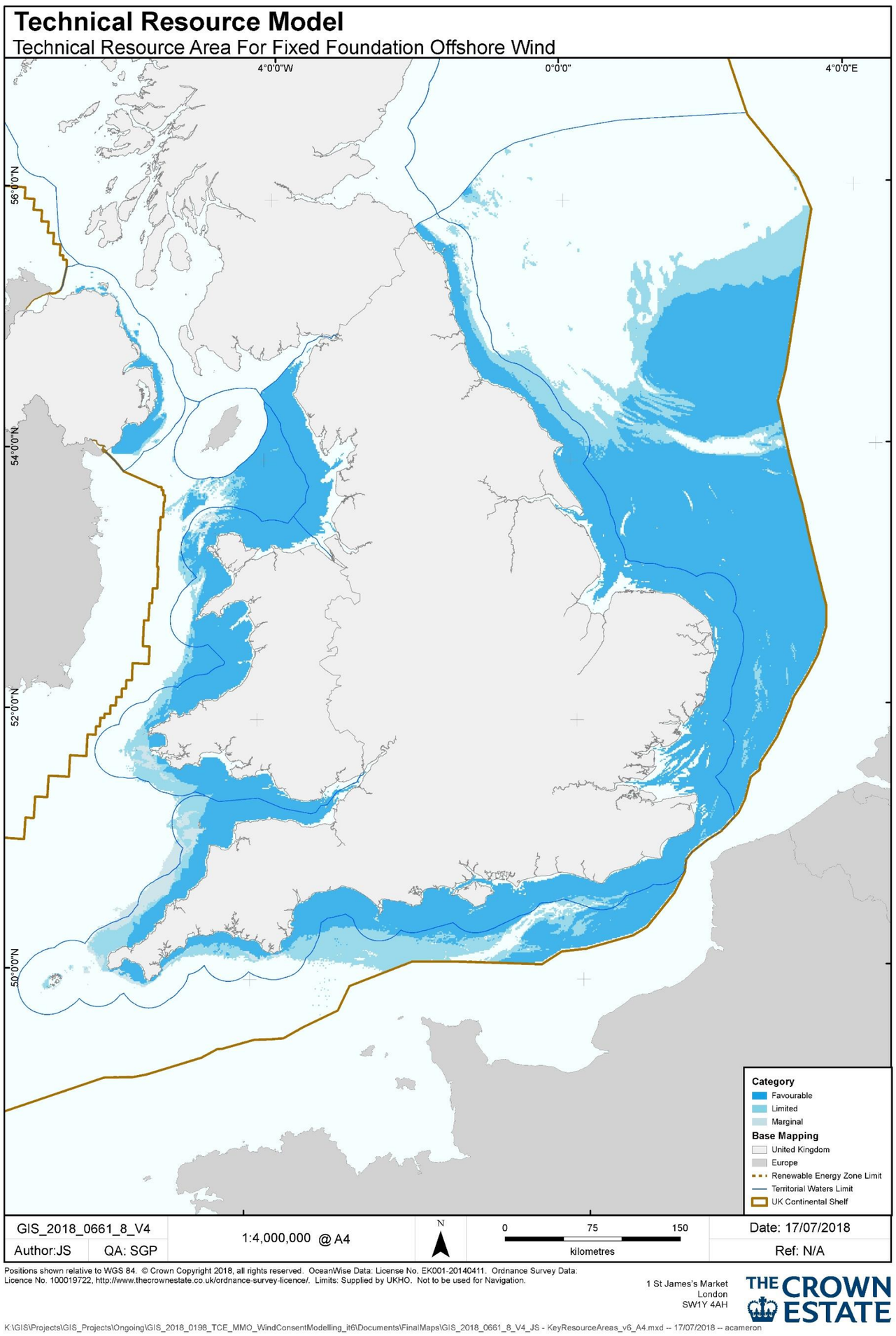

Figure 3: Technical resource model output.

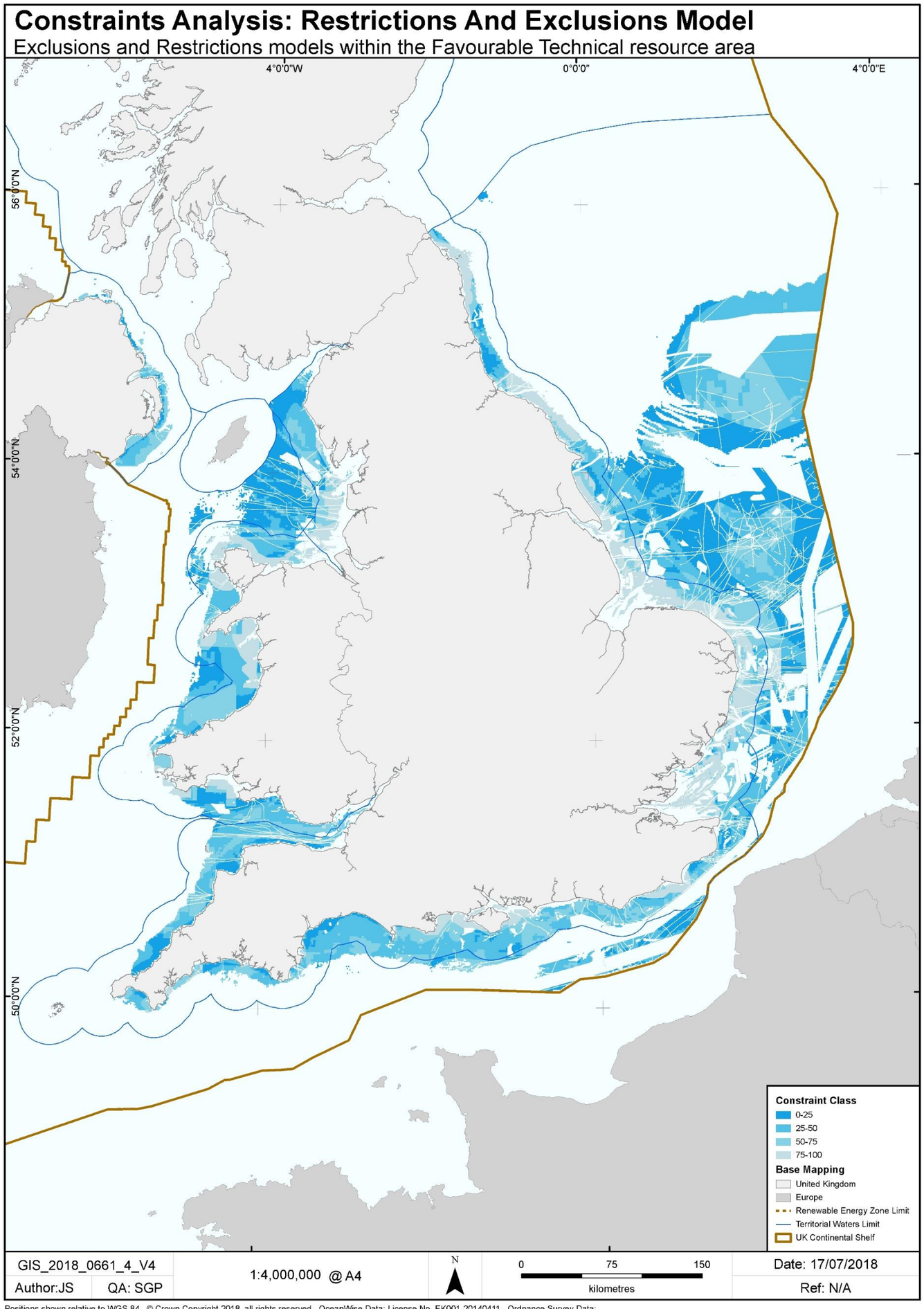

Figure 4: Constraints analysis output combining the exclusions and restrictions models within the favourable technical area.

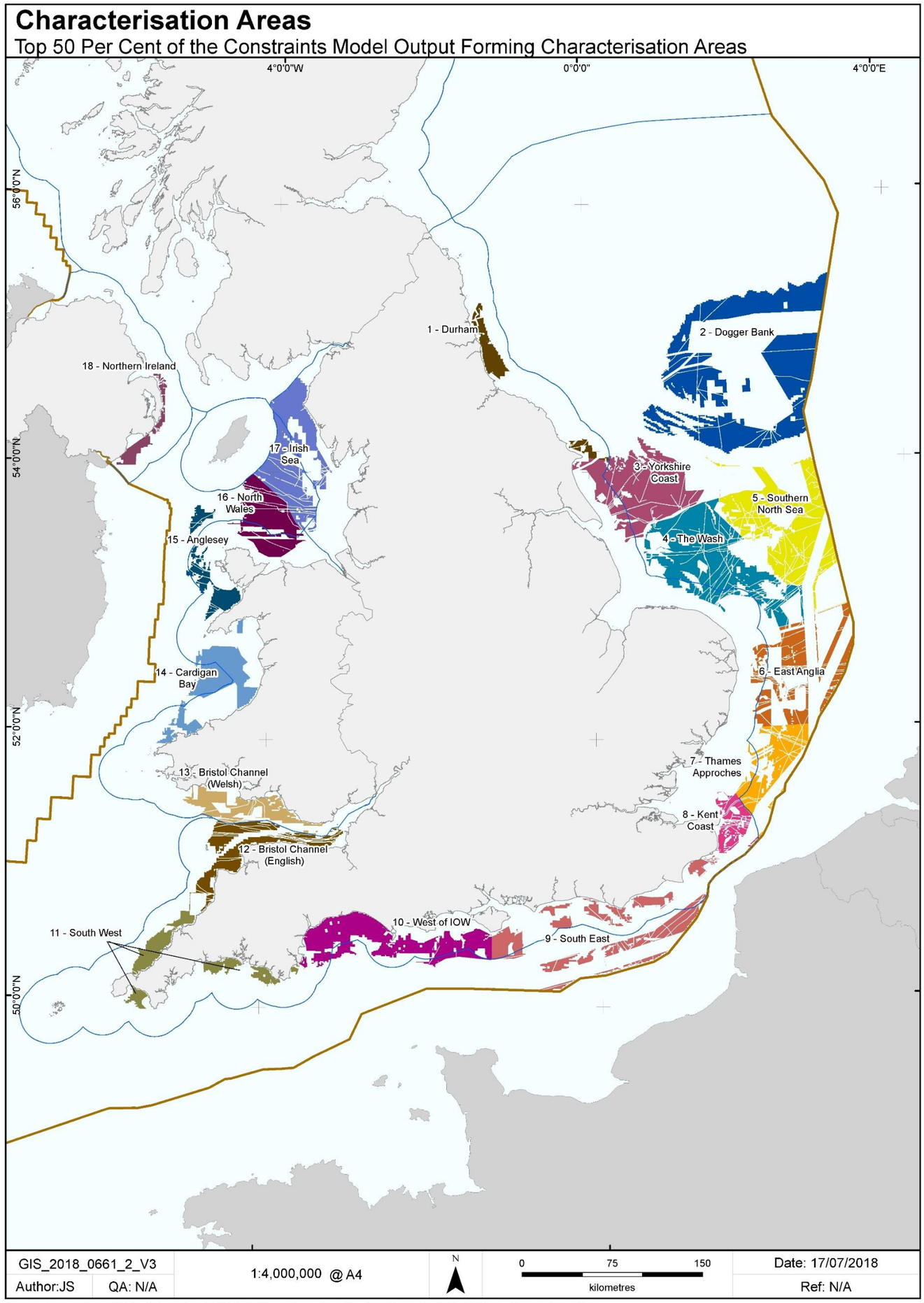

Figure 5: Characterisation areas which present the 0-25 and 25-50 classes of the constraints analysis output. This has been split into characterisation areas based on marine plan boundaries and areas where constraints are similar.

7. Glossary

AfLs	Agreements for Lease
Agrm	Agreement
AHP	Analytical Hierarchical Processing
AIS	Automatic Identification System
AONB	Area of Outstanding Natural Beauty
ASSIs	Area of Special Scientific Interest
BGS	British Geological Survey
CADW	The Welsh Government's historic environment service
CCS	Carbon Capture and Storage
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CfD	Contracts for Difference
cSAC	Candidate Special Area of Conservation
DAERA	Department of Agriculture, Environment and Rural Affairs (Northern Ireland)
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DIO	Defence Infrastructure Organisation
DOENI	Department of the Environment Northern Ireland
EIAs	Environmental Impact Assessment
ESAS	European Seabirds at Sea database
FEED	Front End Engineering and Design
FLOWW	Fisheries Liaison with Offshore Wind and Wet renewables group

GIS	Geographic Information System
HLMO	UK High Level Marine Objectives
HRA	Habitats Regulations Assessment
IMO	International Maritime Organisation
JNCC	Joint Nature Conservation Committee
KRAs	Key Resource Areas
kWh	Kilowatt hour
LAT	Lowest Astronomical Tide
MaRS	Marine Resource System
MCA	Maritime Coastguard Agency
MCS	Marine Conservation Society
MCZs	Marine Conservative Zones
MIS	Marine information system
MNR	Marine Nature Reserve
MoD	Ministry of Defence
MPS	UK Marine Policy Statement
MW	Mega watt
NATS	National Air Traffic Service
EWNI	England, Wales and Northern Ireland
NM	Nautical Mile
OESEA3	Offshore Energy Strategic Environmental Assessment 3
O&M	Operations & Maintenance

PEV	Priority Eigen Vector
pSAC	Possible Special Area of Conservation
pSPA	Potential Special Protection Area
PSR	Primary surveillance radar
Ramsar	Ramsar Convention on wetlands of international Importance especially as waterfowl habitat, also known as the 'Convention on Wetlands'.
REZ	Renewable Energy Zone
RYA	Royal Yachting Association
SACs	Special Areas of Conservation
SCI	Site of Community Importance
SEA	Strategic Environmental Assessment
SNH	Scottish Natural Heritage
SPA	Special Protection Areas
SSSI	Site of Specific Scientific Interest
STRM	Shuttle Radar Topography Mission
totkWhr	Total Kilowatt hours (annual fishing effort aggregated for all vessels)
UKCS	United Kingdom Continental Shelf
VMS	Vessel Monitoring System
WFD	Water Framework Directive
WHS	World Heritage Site

Appendix A

Peer review of technical resource layer

See - “Appendix A – Key resource assessment (KRA) criteria peer review.”

REVIEW OF KEY RESOURCE AREA CRITERIA

A REPORT FOR THE CROWN ESTATE

CLIENT	THE CROWN ESTATE
DOCUMENT NO.	TCE010-R-01
REVISION	E
DATE	27th June 2017
STATUS	Final
PREPARED BY	Joe Phillips
CHECKED BY	Nick Baldock
APPROVED BY	Joe Phillips

TABLE OF CONTENTS

DISCLAIMER & CONDITIONS

1. INTRODUCTION

The Crown Estate (TCE) is reviewing the resource potential of the UK seabed around England, Wales and Northern Ireland for the deployment of offshore wind projects. TCE has engaged Everoze to provide an independent review of the technical criteria which have been selected by TCE for the identification of Key Resource Areas (KRAs) for offshore wind deployment. The objective of this review is to ensure that the selected criteria are suitable for the identification of favourable locations for offshore wind deployment as well as those with limited and marginal potential.

The review is based on the extensive experience of the Everoze team in the development and front-end engineering of offshore wind projects across the UK and Europe over the last 15 years.

Consideration of other non-technical factors (e.g. other activities, social considerations and environmental sensitivities), which can have an important bearing on project siting, are outside of the scope of this review.

2. CRITERIA REVIEW

2.1 KRA CRITERIA

TCE has selected the following criteria for the identification of the Key Resource Areas (KRAs).

CLASSIFICATION	CRITERIA-SET	WATER DEPTH (m LAT)	QUATERNARY THICKNESS	BEDROCK LITHOLOGY[1]	ACCESSIBILITY DUE TO WAVE EXCEEDANCE OVER 2.5M
FAVOURABLE	1	5 to 50			>=80%
LIMITED	2	50 to 60	Thick		
Or	3	50 to 60	Thin	All but: Ig, Pal and Met	
Or	4	5 to 50			<80%
MARGINAL	5	50 to 60	Thin	Ig / Pal / Met	

1. Ig – Igneous, Pal – Palaeozoic, Met - Metamorphic

TABLE 2.1: SELECTED CRITERIA FOR EACH KRA CLASSIFICATION

As can be seen above, three classifications have been defined for the KRAs in terms to their technical attractiveness for development: Favourable, Limited and Marginal. Within each classification, mutually exclusive criteria-sets have been defined, corresponding to each of the rows in Table 2.1. Within each of the Favourable and Marginal KRAs, there is a single criteria set (sets 1 and 5, respectively) whereas the Limited KRA has three criteria-sets (sets 2-4).

Before presenting Everoze's comments on the suitability of the values selected within the criteria-sets, the following provides a basic outline of the technical significance of each of the criteria:

- **Water Depth** primarily affects the capital cost associated with the wind turbine foundations and the installation of the wind farm as whole. Deeper waters require larger and more costly foundations to support the wind turbines as well as requiring specialist vessels capable of operating in such conditions during the construction phase. Beyond ~60m below Lowest Astronomical Tide (LAT), conventional "bottom-fixed" foundations become entirely un-economic and / or technically unfeasible. Experience from early UK offshore wind projects has shown that sites with very shallow water depths of less than ~5m below LAT, incur significant installation challenges and operational risks.
- **Quaternary Thickness** broadly speaking determines the likelihood that a piled foundation (be it a monopile or jacket) will intersect with rock in the seabed ("Quaternary" refers to near-surface deposits laid down in the last ice age over underlying bedrock.) A thinner quaternary layer will increase installation costs due to the increased probability of expensive drilling equipment needing to be deployed during installation.
- **Bedrock Lithography** describes the type and strength of material present in the bedrock. In general terms, this determines the duration of drilling required for piled foundation installation, if the foundation intersects with bedrock.
- **Accessibility** (due to Wave Exceedance over 2.5m) describes the proportion of the year for which it is possible to access the offshore wind site, assuming a typical working limit of 2.5m significant wave height. This affects the efficiency and therefore the cost of the construction phase and O&M activities.

Whilst Everoze considers the 4 adopted criteria to be suitable for the characterisation of basic technical feasibility and project cost, it could be argued that both wind resource and distance from shore should also be addressed. Distance to Shore impacts offshore wind economics principally in three ways. Firstly, the capital cost of the electrical system connecting the asset to the grid increases with distance to shore as cable length, specification and overall system design are all affected. Secondly, operational costs associated with the Operations & Maintenance (O&M) increase with distance to shore due to the additional logistical requirements needed to achieve reasonable levels of access. Thirdly, electrical losses increase with distance to shore, thus reducing net energy production. Overall, the cost implications of moving further from shore are to a greater or lesser extent mitigated by the higher wind resource typically found further from shore. In addition, the net capacity factor delivered for a given mean wind speed is dependent on technology selection and for this reason a crude filtering of low wind speed sites could introduce unrepresentative results for each classification. For these reasons, it is considered reasonable to neglect both distance from shore and wind resource from the KRA classification.

2.2 FAVOURABLE CLASSIFICATION

Within the Favourable Classification, there is a single criteria-set to consider.

Criteria-set 1: Water Depths of 5m to 50m below LAT

AND Accessibility (due to wave climate) is greater than or equal to 80%

In general, water-depths in the range 5-50m below LAT provide for low foundation costs which is in-line with a favourable designation from a project economics perspective. The 5m below LAT minimum water depth criterion removes shallow water sites which have proven to introduce elevated levels of technical risk during installation and operation. Towards the deeper end of the Water Depth range, sites will incur slightly higher capital costs associated with foundation supply and installation elements of the project. These additional costs may in some cases be offset by access to higher wind resource. In any case, 50m below LAT represents the deeper end of the depth range for marginal feasibility, in the context of current and anticipated future bottom-mounted offshore wind foundations. The addition of a lower limit on Accessibility of 80% is a sensible precaution to prevent more technically challenging and expensive sites to be included in the Favourable classification.

Criteria-set 1 is considered to be consistent with the classification of "Favourable" because, though significant variations in engineering solutions and project economics can be expected, in general technical feasibility is anticipated to be high and conditions in line with the potential to bring forward a competitive project.

2.3 LIMITED CLASSIFICATION

Within the Limited Classification, there are three different criteria-sets to consider.

Criteria-set 2: Water Depths of 50m to 60m below LAT

AND "Thick" Quaternary Thickness

These criteria describe a site pushing the limits of technical feasibility from the perspective of water depths. Not only would a bottom-mounted foundation solution, if feasible, be relatively expensive, the installation activity on site would require specialist vessels and equipment with very high associated day rate costs. The specification of a "Thick" quaternary layer suggests that soils would at least be suitable for driving techniques without recourse to expensive drilling, by way of cost mitigation.

Criteria-set 3: Water Depths of 50m to 60m below LAT

AND "Thin" Quaternary Thickness

AND All Bedrock Lithologies other than Igneous, Palaeozoic, and Metamorphic

A similar rationale is inherent in Criteria-set 4 albeit with some variation in the soils assumptions. Here, the switch to a "thin" quaternary layer introduces additional drilling risk, pushing costs up further. This is mitigated by the exclusion of the most onerous forms of bedrock which would otherwise hamper economics and feasibility significantly.

Criteria-set 4: Water Depths of 5m to 50m below LAT

AND Accessibility is less than or equal to 80%

This Criteria-set provides for sites with more attractive water depths albeit in combination with an onerous wave climate. The latter will introduce significant cost and risk into the construction programme as well as increasing logistics costs during operations.

In summary, whilst Criteria-sets 2 & 3 capture deep water sites with challenging soil conditions, Criteria-set 4 represents moderate depth sites but with difficult access conditions. All three are considered to be broadly in line with a classification of "Limited" in that the technical favourability of sites fulfilling these criteria is considered to be sub-optimal, without necessarily being entirely unfeasible.

2.4 MARGINAL CLASSIFICATION

Within the Marginal Classification, there is a single criteria-set to consider:

Criteria-set 5: Water Depths of 50m to 60m below LAT

AND "Thin" Quaternary Thickness

AND All Bedrock Lithology is Igneous, Palaeozoic or Metamorphic

This combination of criteria is similar to Criteria-set 3, constituting a deep water site with difficult soil conditions. However, in this case the soil conditions are made significantly more onerous by the inversion of the Bedrock Lithography criteria, which in this case is limited to the most difficult bedrock types, thus increasing drilling time and increasing costs further.

This Criteria-set is considered to be consistent with the classification of "Marginal" because the combination of onerous technical conditions would in the majority of cases make substantive development of an offshore wind scheme highly challenging, in light of the risk of very weak economics and / or non-feasibility.

2.5 SUMMARY FINDINGS

The technical criteria proposed by TCE for the identification of Key Resource Areas are considered to be suitable for the identification of favourable, limited and marginal locations for offshore wind deployment. Specifically, Everoze draws the following findings from the review:

1. **Favourable classification:** the proposed criteria are considered to be consistent with the classification of "Favourable" because though significant variations in engineering solutions and project economics can be expected, in general, technical feasibility is likely to be high and conditions are in line with the potential to bring forward a competitive offshore wind development.

2. **Limited Classification:** the proposed criteria are considered to be broadly in line with a classification of "Limited" in that the technical favourability of sites fulfilling these criteria is likely to be sub-optimal, without necessarily being entirely unfeasible.

3. **Marginal Classification:** the proposed criteria are considered to be consistent with the classification of "Marginal" because the combination of onerous technical conditions would in the majority of cases make substantive development of an offshore wind scheme highly challenging, in light of the risk of very weak economics and / or non-feasibility.

Appendix B

Hard constraints data included in the Exclusion model

Name	Source	Date of update	Comments
UK Deal Safety Zones	UK Oil and Gas Data	14/08/2017	These are the 500m exclusion zones around platforms that would be inappropriate for development.
OceanWise Shipping Routes	OceanWise	13/04/2018	This data shows where shipping designations are in place that restricts shipping movements and infrastructure development to enhance safe navigation.
Traffic Separations Schemes (International Maritime Organisation)	UKHO	25/11/2016	This data shows where shipping designations are in place that restricts shipping movements and infrastructure development to enhance safe navigation.
All Wrecks Protected Exclusion Zones	CADW, EH, HS, DAERA	03/02/2017	Wrecks protected by statutory legislation.
The Crown Estate — Pipes Infrastructure	The Crown Estate	18/01/2018	Hard infrastructure that would prohibit development.
The Crown Estate — Cables Infrastructure	The Crown Estate	18/01/2018	Hard infrastructure that would prohibit development.
The Crown Estate — Cables agreements	The Crown Estate	18/01/2018	Hard infrastructure that would prohibit development.
The Crown Estate —Tidal Stream agreements	The Crown Estate	18/01/2018	Hard infrastructure that would prohibit development.
The Crown Estate — Wind agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate — Wave agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate — Minerals and Aggregates agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate —Pipelines agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.

The Crown Estate — Natural Gas Storage agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate — Minerals Capital and Navigation agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate — Meteorological Equipment agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
The Crown Estate — Infrastructure Oil and Gas agreements	The Crown Estate	18/01/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
EDF — UK Nuclear Power Stations	EDF, via MAGIS	14/03/2018	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
MMO — MCMS Navigational Dredging	Marine Management Organisation	04/10/2017	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
EWNI Lease Outfalls Export 29092017 250m	The Crown Estate	17/02/2017	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.
Aquaculture Extract 29092017	The Crown Estate	17/02/2017	Where agreements or actual infrastructure exists that would inhibit development of offshore wind farms.

Appendix C

Soft constraints data used in the Restrictions model and layers used for characterisation

Restrictions model

Name	Source	Date of update	Comments
MMO Vessel Density Grid 2015 UKCS	Marine Management Organisation	03/10/2017	This data describes shipping activity based on Automatic Identification System (AIS) data over an annual average.
OW Harbour Authority Areas	OceanWise	13/04/2018	Describes the extent of harbour authority areas.
OW Anchorage Area	OceanWise	13/04/2018	Describes the extent of anchorage areas.
CEFAS Disposal Sites Within UKCS	CEFAS	25/04/2017	Describes the extent of disposal sites.
The Crown Estate — Minerals Evaporites agreements	The Crown Estate	18/01/2018	Describes the extent of evaporates agreements that we (The Crown Estate) are party to. This has not been included as a hard constraint as rights do not extend completely to the seabed. The nature of activity below also means that it may be feasible to co-locate offshore wind farms over the top with permission of the evaporates tenant.
The Crown Estate —Carbon Capture and Storage agreements	The Crown Estate	18/01/2018	Described the extent of the CCS agreement that we (The Crown Estate) are party to. This has not been included as a hard constraint as rights do not extend completely to the seabed. The nature of activity below also means that it may be feasible to co-locate offshore wind farms over the top with permission of the evaporates tenant.

MMO Fishing Activity 2015 UKCS	Marine Management Organisation	03/10/2017	Fishing activities symbolised as total kWhrs to demonstrate unit effort of activity.
Cefas 2010 High Intensity Nursery and Spawning Overlaps Vector AHP Score Classes	CEFAS	02/09/2014	An overlap count of all high intensity areas for fish spawning and nursery grounds based on Cefas data.
RYA AIS Intensity AHP Score Classes	Royal Yachting Association	04/10/2017	Data licensed from RYA which uses AIS to portray recreational vessel activity.
RYA Marinas	Royal Yachting Association	04/10/2017	Describes the extent of marinas. These were buffered by 1NM.
MCS — Bathing beaches	Marine Conservation Society	08/12/2010	Describes the extent of bathing beaches. These were buffered by 1NM.
JNCC — Harbour porpoise cSAC	JNCC	14/10/2016	The cSACs that are in the process of being designated for mobile species.
All UK SSSI	NE, NRW, DAERA, SNH	14/03/2018	Describes the extent of SSSIs.
NRW MNR Wales	NRW	11/04/2018	Describes the extent of Marine Nature Reserves in Wales. This has subsequently been designated as a Marine Conservation Zone.
DOENI MCZ	DAERA	14/03/2018	Describes the extent of Marine Conservation Zones in Northern Ireland.
NE MCZs All	Natural England and The Crown Estate	04/10/2017	Describes the extent of Marine Conservation Zones in England.
ALL SAC Offshore	JNCC, NE, NRW, DAERA, SNH	14/03/2018	Describes the extent of Special Areas of Conservation.
ALL SAC Inshore	JNCC, NE, NRW, DAERA, SNH	14/03/2018	Describes the extent of Special Areas of Conservation.
ALL SPA	JNCC, NE, NRW, DAERA, SNH	14/03/2018	Describes the extent of Special Protection Areas.

ALL RAMSAR	JNCC, NE, NRW, DAERA, SNH	14/03/2018	Describes the extent of RAMSARs.
VA srtm 500m All Receptors pts500m EWNI Diss	The Crown Estate Derived	23/11/2017	Analysis to assess the visibility of sea surface to landscape designations: AONBs, National Parks, Heritage Coasts and Scheduled Ancient Monuments.

Review layers used in characterisation

Heading	**Source**	**Comments**	**Date of update**
Key resource assessment	Wave exceedance	ABPmer	22/01/2014
	Water depth	DEFRA	27/10/2017
	Bedrock lithology	BGS	04/03/2015
	Quaternary thickness	BGS	04/03/2015
Ornithology outside SPAs	ESAS bird density data	Natural England	06/01/2015
	Foraging ranges	Natural England	06/01/2015
Visibility analysis	Digital terrain model	Ordnance Survey	14/06/2017
	Shuttle Radar Topography Mission terrain model	STRM / NE / NRW / DAERA / CADW / HE	03/11/2014
Water Framework Directive	Water bodies and attributes	Environment Agency / RPS Ltd	06/03/2018

Appendix D

Previous learning and AHP methodology

d.1. Learning from previous constraints analysis

We developed the Marine Resources System (MaRS) to support the definition of Round Three zones and input into the developing marine planning systems in the UK. At a basic level the system is a multi-criteria analysis tool which overlays layers (criteria) by applying weightings, scores and exclusions. The tool generates raster files that spatially present the relative suitability of areas to the input criteria.

The system has been used in several analysis projects since being developed. Methodologies have developed over time to match the understanding of how the system can be utilised to support planning processes. The processes to date are described in Table 6.

Name of approach	Examples of where this approach has been used	Lessons learned from the approach
Big models	- Round Three zone definition - Scottish Territorial Waters leasing round - Pentland Firth and Orkney Waters Wave and Tidal Strategic Area	a. Users have to weight all layers/criteria against every other input in the model meaning that it can be difficult to follow logically or coherently the weighting criteria. b. The more layers that are included, the more the influence of each layer is diluted. c. Weightings are multiplied by scores to get an overall value to weight the layer by. This means that a layer with a W10:S1 = W1:S10. Scores are included to allow the inclusion of continuous data alongside discrete data. The multiplier relationship makes it difficult to weight these effectively. d. There is only one output, meaning it can be difficult to interrogate and understand the drivers for a particular result. e. It can be difficult to demonstrate logic in weightings and scores consideration process, and the resultant influence of different criteria to stakeholders.
Nested models	- Marine Scotland Regional Locational Guidance - MMO options process - Wave and Tidal Demonstration Zone identification	a. The use of themed models where criteria describing similar activities are grouped into themes (e.g. environmental receptors, economic activity etc.) resolves points a and b above. b. Grouping into themes limits the dilution of each layer and allows the more logical weighting of similar criteria against each other. This in turn makes it easier to weight criteria logically and then describe the output to stakeholders. c. It is also easier to show different scenarios by combining themes together with different weightings. d. The multiplier relationship issue described in point c. above remains.

Table 6: List of previous approaches to modelling and associated issues using the MaRS system.

Despite improvements to processes, there is still an ambition to improve the statistical rigor and logic applied in the analysis especially when dealing with more complex analyses, combining continuous and discrete datasets in the one analysis, and structuring of models to allow communication with stakeholders. This is why AHP has been used – see below.

d.2. Analytical Hierarchical Processing (AHP)

Introduction to AHP

Analytic Hierarchy Processing (AHP) is a structured technique for dealing with complex decisions developed by mathematician Thomas L. Saaty in 1977[18]. AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements; relating those elements to overall goals; and, for evaluating alternative solutions.

It was decided that it was appropriate to use AHP to develop the input structure and define weights for processing restrictions models in MaRS. The methodology ensures that a robust, traceable, repeatable and defendable weighting and scoring process can be implemented.

The theory behind AHP states that it is generally only possible to compare the significance of inputs across seven criteria at a time. AHP uses a tree structure to define mini multi criteria analysis calculations that feed up into a more complex analysis.

Criteria that represent constraints are organised into themes and subthemes. These are then structured into a hierarchy grouping similar criteria together. Examples of themes would be environmental, social and economic criteria sets. Subthemes allow for the categorising of assessment criteria e.g. a subtheme for environmental may be mobile species with assessment criteria combining information on the presence and sensitivity of different species.

This allows the relative importance of data layers to be defined in a coherent, structured format with statistical rigor applied to how the input criteria will impact on the final output. It also has the benefit of breaking models down for stakeholders. This allows focussed discussions about the relative importance of similar assessment criteria and clearer incorporation of stakeholder views into analysis. As a result, a more transparent modelling methodology is utilised.

Process of AHP

The structure required to conduct AHP starts by grouping a number of criteria into themes which can then be built up in tiers and combined. This means that diverse criteria can fit into the analysis without having to be directly weighted against each other. The step-by-step procedure to complete the calculation of weightings and scores is as follows:

1. Define the criteria that will be used in the analysis and arrange these into a structure where comparable criteria are together in groups of up to seven.
2. Assess the criteria against each other using a pairwise comparison. The scale that should be used is:

    1= **Equal** importance
    3= Criteria A **moderately** more important than Criteria B
    5= Criteria A **strongly** more important than Criteria B
    7= Criteria A **very strongly** more important than Criteria B
    9= Criteria A **extremely** more important than Criteria B

3. Populate a reciprocal matrix with the pairwise scores for the top half and 1/ the pairwise score on the bottom half. This should then be decimalised.
4. Square the matrix using a dot product function.
5. Sum each of the rows of each of the criteria.

[18] Saaty, T.L., (1977). A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15 (3)

6. Normalise these so that they total one. This will result in what is termed a Priority Eigen Vector (PEV). The normalisation formula for a three by three matrix where X, Y and Z are the summed rows would be:

$$PEV_x = \frac{X}{(X + Y + Z)}$$

7. Repeat from step four until the PEVs do not change.
8. These PEVs will form local weights for the AHP structure.

This process has been summarised in Figure 6.

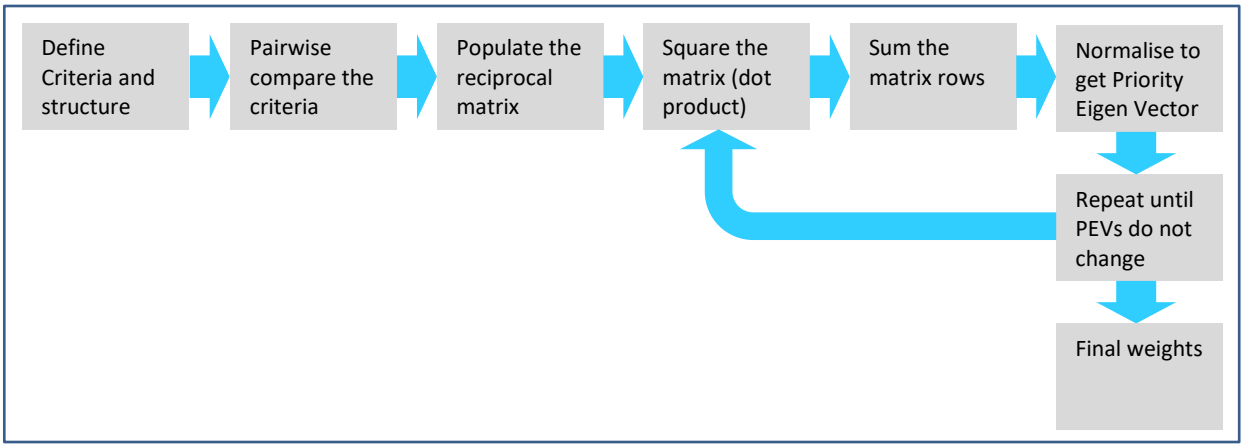

Figure 6: Diagram of procedure to define PEV for criteria and themes.

A consistency test has been developed to ensure the assessment applied in the pairwise comparison is statistically and logically robust. This uses the following formula:

$$CI = \frac{(\lambda max - n)}{(n - 1)}$$

$$Where:$$

$$CI = Consistancy\ Index$$

$$\lambda = \text{sum of PEV} * \text{sum of columns for each criteria: e. g.}$$

$$\{\text{PEV for criteria A} * \text{sum column criteria A}\} + \{\text{PEV for criteria B} * \text{sum column criteria B}\}\text{etc.}$$

$$\text{n} = \text{Number of columns in the matrix}$$

$$CR = {}^{CI}/_{RI}$$

$$Where:$$

$$CR = \ the\ Consistency\ ratio\ which\ should\ be\ < 10\%$$

RI= Randomness Index which is available from a lookup table

This process provides PEV or local weightings (i.e. weights within each group at each tier) for each of the criteria based on the pairwise inputs. The consistency ratio should always be below 10 per cent to ensure that the priority eigen vectors are statistically robust.

Methods of applying AHP to a structure

There are two methods of combining the local weights within tiers of the wider structure to produce combined results referred to from here in as global weights. These are the standard AHP method as proposed by Saaty (1977) and an approach termed B-G modified, proposed by Belton Gear in 1982[19].

The standard approach takes the weighting of each criteria and multiplies it by the covering weight (referred from here on as parent weight) in the tier above. This is demonstrated in Figure 7. This means that the sum of all the sub-criteria will equal the parent weight.

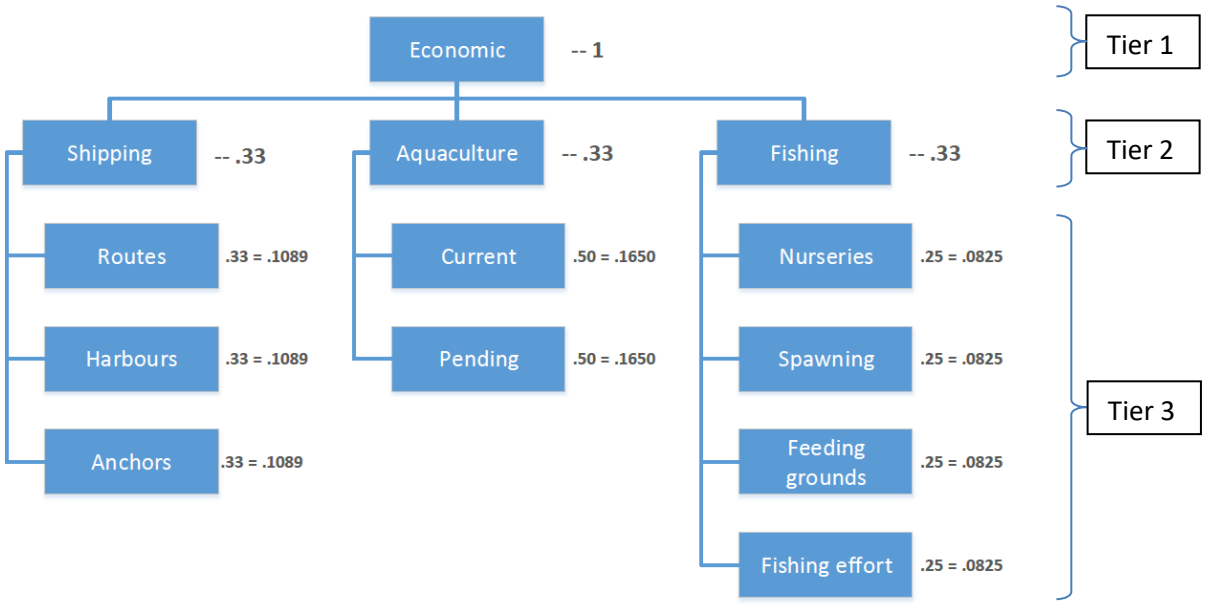

Figure 7: Example hierarchy demonstrating the standard approach to global weighting.

There are several issues that must be considered when using this approach:

- To achieve the full weight in Tier 2 as shown in Figure 7, all of the criteria in Tier 3 will have to overlap. In the case of the aquaculture criteria, it is impossible for current and pending aquaculture licences to overlap meaning that the aquaculture criteria will be unintentionally down weighted.
- The more criteria in a Tier 3 group, the more diluted the influence of those criteria will have. This is due to all the weights having to sum the parent weight and is demonstrated in the example by trying to weight all criteria equally. The result is that the global weights for aquaculture criteria are higher than those of fishing criteria.

[19] V. Belton, T. Gear (1982), On a shortcoming of Saaty's method of analytic hierarchies, Omega, 11 (3), pp. 226-230

The B-G modified approach gives the full weight of the covering weight in Tier 2 to the highest weighted criteria in Tier 3 with the remaining criteria weighted proportionately. This avoids the issues noted above but adds a layer of complexity to the calculations that may be harder to explain to stakeholders.

A demonstration of the calculation of global weights using the B-G modified approach is shown in Figure 8.

The formula used is:

$$T3_w = \left({}^{T3_x}/_{T3_{max}}\right) * T2_w$$

$$where:$$

$$T3_w = The\ Tier\ three\ weight\ for\ each\ criteria$$

$$T3_x = The\ Eigen\ Vector\ weight\ multiplied\ by\ T2_w$$

$$T3_{max} = The\ maximum\ T3_x in\ each\ Tier\ 3\ group$$

$$T2_w = \ The\ Tier\ 2\ covering\ weight$$

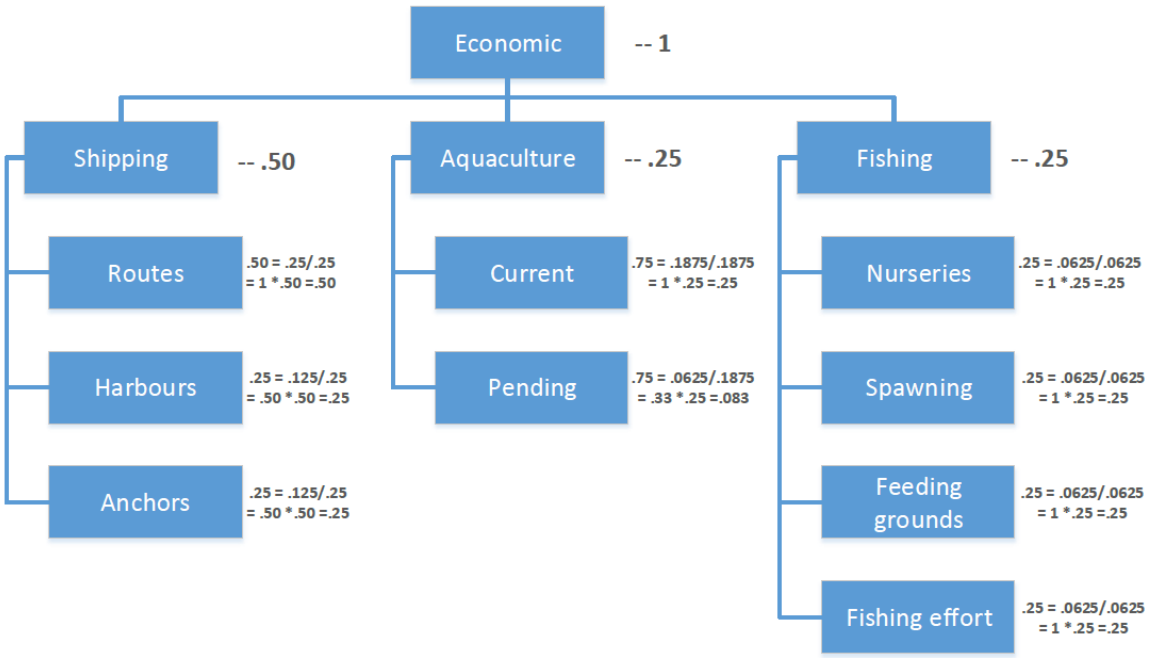

Figure 8: Example hierarchy demonstrating the B-G modified approach to global weighting.

After running initial models and comparing standard AHP outputs against B-G modified outputs, it was decided to use the B-G modified approach. This is because it is better suited to spatial analysis and the results using this method demonstrating a higher influence from parent weights which produced outputs closer to expected results.

d.3. Data Audit

In advance of completing the analysis, a review of all data holdings including third party and asset data was undertaken to ensure that appropriate and up to date information was used. Updates included:

- Downloading new data on: the locations of Nuclear Power Stations, the shipping policy area for PS2 from the East Marine Plan and MCZ data;
- Sourcing updates to data on Royal Yachting Association Automatic Identification System for recreational craft and VMS fishing effort; and,
- Reviewing and updating all internal and external data held within our knowledge data including updates to the latest pSACs and cSACs and the latest oil and gas licensing round.

Tier 4 was created to enable the inclusion of continuous data layers. These are defined as layers where the weighting varies dependant on attributes in the data (i.e. the data is on a continuous scale, for example intensity, rather than just being resent or absent as a polygon or line would be). There are 5 layers included in this constraints analysis with various methods used to split and weight them using pairwise. These are:

- VMS shipping density;
- MMO fishing activity 2014 UK Continental Shelf;
- Cefas 2010 high intensity nursery and spawning overlaps; and,
- Visibility from landscape designations
- RYA AIS Intensity.

This data is produced by the MMO based on the Maritime Coastguard Agency (MCA) AIS network. The classification of the data has been completed to reflect how the data is presented on the MMO's Marine Information System (MIS). The weighting using pairwise reflects a much higher weighting for the areas of significant shipping activity.

The MMO fishing activity describes fishing effort based on VMS data. This data has been classified based on the total calculated effort in kWhrs. The data was split to reflect UK Sea Fisheries Statistics 2015 report from the MMO[20]. The data was then manually weighted to pick out areas of significant fisheries effort. The fisheries data will be reviewed again later in the process.

The spawning and nursery grounds were created by combining the separate Cefas high intensity spawning and nursery grounds species counts together to provide an overview of which areas are most used by different species for both spawning and nursery. This was then weighted linearly across the data range.

The RYA intensity shows the intensity of recreational vessels traffic. This data was split into classes using an equal interval approach and weighted linearly.

The visibility from landscape designations data has been produced to identify areas of sea surface that are highly visible from terrestrial sensitive receptors. These receptors are: AONBs, National Parks, Heritage Coasts and World Heritage sites. These reflect the aim of designations to protect landscape and character of areas. The output has been generated by placing a 500m grid within these receptors and applying a viewshed analysis using a Digital Elevation Model (DEM) to identify how visible areas of sea are. This has then been classified using a quantile method and weighted so that areas of high visibility from landscape designations are weighted significantly higher than lower classification groups.

Full lists of data used in the exclusion and restriction models are included in Appendix B and Appendix C.

[20] MMO (2015), UK Sea Fisheries Statistics 2015. National Statistics Publication, pp 113-132

d.4. Implementation of AHP process

Pairwise calculations

A calculator was commissioned from Geospatial Enterprises to perform the process of calculating the weightings for standard and B-G modified methods as described in section d.2.

MaRS Modelling

The outputs of the calculator were used to inform spatial analysis using the MaRS system. Data models were structured to reflect the input themes, tiers and criteria as defined in Figure 2 with definition queries used to extract certain attributes and merges used to create flattened input criteria formed from several input data layers. MaRS requires both a weight and a score for each criteria and both must be integers. The global weights calculated by the AHP tool are long decimals, so they were multiplied by 10,000 for to provide an appropriate level of precision.

d.5. Outputs of the constraints analysis

Visual classification of outputs

Two methods of classifying the output for display purposes were investigated: grouping data in equal intervals and grouping data in quantiles.

> *Equal interval classification:* this method splits the data into equal intervals based on the range of data i.e. if there are classes over a data range of 0-1, breaks would occur at 0.2, 0.4, 0.6, 0.8 and 1. This method takes no account of the distribution of data across the range so could result in 90 per cent of data displayed as one class.
>
> *Quantile Classification:* This method defines breaks at points which ensure there is an equal number of features within each class. This ensures an even distribution of the data across each class but means that the break points will be at non-uniform points throughout the data.

Inspection of both sets of outputs revealed the quantile distribution method as providing a better view of data with trends in the data and allowed a better visual output to interpret the relative constraint. The outputs of the constraints analysis have therefore been classified using the quantile method.

Appendix E

Pairwise comparison of constraints

Tier 1

Model Name	Tier 2 ID	Weight	Pairwise Comparisons		
			Economic	Environmental	Social
1 - Economic	1	0.4	1.00	1.00	2.00
2 - Environmental	2	0.4	1.00	1.00	2.00
3 - Social	3	0.2	0.50	0.50	1.00

At the highest themed level of different criteria, it was deemed that the economic and environmental criteria should be weighted equally. Both themes have significant amounts of data that detail constraint to development well. The social theme was weighted at a slightly lower level due to the contents of the theme being a subset of true social constraint e.g. there is no consideration of sensitivity of landscapes to development or analysis of economic typologies of coastal communities that may be impacted (positively and negatively) by development.

Tier 2

Tier 2 ID	Model name	Tier 3 ID	Group name	Weight	Pairwise comparisons		
					Navigation	Subsurface	Fishing
1	1 - Economic	1a	Navigation	1	1.00	1.00	5.00
1	1 - Economic	1b	Subsurface	1	1.00	1.00	5.00
1	1 - Economic	1c	Fishing	0.2	0.20	0.20	1.00
2	2 - Environmental	2a		1	1.00		
3	3 - Social	3a		0.5	1.00		

In Tier 2, navigation constraints and subsurface constraints have been weighted equally, with both presenting significant potential constraints to development. Data in these two groups is of good quality and accurately describes the nature and extent of constraint. Fishing has been weighted much lower in comparison, mainly due to inadequacies with VMS data in describing the activities of the full fleet active in English, Welsh and Northern Irish waters. Fishing activity will be considered further in the characterisation process and through stakeholder engagement. Environmental and social groups are passed through to Tier 3 due to having fewer criteria to describe constraint.

Tier 3

Tier 3 ID	Group name	Tier 4 ID	Layer name	Pre-processing	Weight	Pairwise comparison			
						AIS	Hrb Auth	Anch	Dis
1a	Navigation	1ai	AIS shipping density	Categories defined in tier 4	1	1.00	2.00	7.00	9.00
1a	Navigation	1aii	Harbour Authority Areas		0.7	0.50	1.00	6.00	9.00
1a	Navigation	1aiii	Anchorage Area		0.1	0.14	0.17	1.00	2.00
1a	Navigation	1aiv	Disposal Sites	STATUS= 'Open' AND STATUS='Not for waste disposal'	0.1	0.11	0.11	0.50	1.00

Within the navigation group, it was concluded that the density of shipping traffic was the most constraining criteria (noting that this weight will be applied only to the top class of the data as defined in Tier 4), with harbour authority areas identified as the next most constraining. This is due to these layers being a good indication of important areas for shipping activity across the study with strong policy drivers to protect this important economic activity (e.g. East Marine Plans). Cumulative impacts of multiple developments have not been considered here but are discussed in the characterisation documents.

Anchorage areas are constrained in location to where suitable technical conditions are found e.g. shelter, appropriate seabed type and proximity to ports. It was considered that these presented a lower level of constraint than the two criteria above as it was deemed that suitable alternative locations could be sought if proposals were brought forward in these areas. Disposal sites were deemed to be the lowest constraint as they are easiest to relocate.

Tier 3 ID	Group name	Tier 4 ID	Layer name	Pre-processing	Weight	Pairwise comparison	
						Ev'tes	CCS
1b	Subsurface	1bi	The Crown Estate evaporites agreements		1	1.00	2.00
1b	Subsurface	1bii	The Crown Estate CCS agreements		0.5	0.50	1.00

The evaporates agreement were deemed to present slightly more of a constraint over CCS agreement due to the rights granted for each however, both would present a significant constraint that would require negotiation to allow co-existence of developments in these areas.

Tier 3 ID	Group name	Tier 4 ID	Layer name	Pre-processing	Weight	
1c	Fishing	1ci	VMS fishing activity 20185 (totkWhr)	Categories defined in tier 4	1	1.00

As there is only one layer in the fishing group, this has a weighting of 1 as no pairwise analysis can be performed.

Tier 3 ID	Group name	Tier 4 ID	Layer name	Pre-processing	Weight	Pairwise comparison					
						SPA+ RAM	SAC+ SCI	MCZ	cSAC	SSSI	N&S gnds
2a	Environmental	2ai	SPAs and Ramsars	Flattened SPAs & Ramsars	1	1.00	3.00	5.00	9.00	9.00	9.00
2a	Environmental	2aii	SACs and SCIs	Flattened SACs & SCIs (excluding mob species cSACs)	0.5	0.33	1.00	3.00	6.00	6.00	8.00

2a	Environmental	2aiii	MCZs	Merge these MCZs into one flat layer.	0.3	0.20	0.33	1.00	5.00	5.00	7.00
2a	Environmental	2aiv	Mobile species cSACs	Only those that are designated for mobile species (harbour porpoise)	0.1	0.11	0.17	0.20	1.00	1.00	3.00
2a	Environmental	2av	SSSIs		0.1	0.11	0.17	0.20	1.00	1.00	3.00
2a	Environmental	2avi	High intensity nursery & spawning ground overlaps	Defined in Tier 4	0.05	0.11	0.13	0.14	0.33	0.33	1.00

The environmental tier largely consists of environmental designation with the features for which they are designated, and the sensitivity of these to offshore wind development considered in more detail in the characterisation documents. SPAs and Ramsars have been highlighted as the most constraining as they are European designations covering birds and intertidal habitats respectively. In the context of constraint to development of an offshore array within these designations, it was deemed that SPAs and Ramsars presented a potentially significant constraint to development.

SACs, although containing features and biotopes that are potentially sensitive to development, have been proven to be able to accommodate development in the past (e.g. Teesside and Creyke Beck projects within the Dogger Bank SAC). It is acknowledged that this is highly site specific but demonstrates a potential for development. MCZs have been weighted as slightly lower constraint to SACs - as SACs are a European designation rather than a National designation - so were deemed more significant. It should be noted that MCZs potentially cause a significant constraint, especially when considering cumulative impacts.

cSACs and SSSIs have been weighted as presenting the same level of constraint. In the case of cSACs, in the absence of management measures at the time of completing the restrictions model and acknowledging the likely mitigation will include limits to the amount of concurrent piling activity, it was deemed that the temporal constraint was not as significant a constraint on development as the requirement to avoid potential damage to sensitive habitats in SACs and SCIs. SSSIs, would generally only be impacted by cable landing as they are intertidal and terrestrial.

The nursey and spawning ground data was deemed to be the least constraining due to the lower quality of the data and that mitigation measures have been successfully applied in several previous offshore wind farm constructions.

Tier 3 ID	Group name	Tier 4 ID	Layer name	Pre-processing	Weight	Pairwise comparison			
						Visual	RYA	Marinas	BBch
3a	Social	3ai	Visibility from landscape designations		0.5	1.00	7.00	9.00	9.00
3a	Social	3aii	RYA AIS intensity	Defined in Tier 4	0.1	0.14	1.00	3.00	3.00
3a	Social	3aiii	Marinas	Buffer by 1NM	0.04	0.11	0.33	1.00	1.00
3a	Social	3aiv	Bathing beaches	Buffer by 1NM	0.04	0.11	0.33	1.00	1.00

Visibility from landscape designations is the strongest constraining criteria in this group due to the potential for the criteria to impact on development of offshore wind farm projects.

Recreational sailing routes have been weighted as the most constraining criteria of the remaining three data layers. This is due to the data being of good quality but noting that recreational sailing has not proven to be an insurmountable risk in previous development, and that standard mitigation is proven.

Marinas and bathing beaches have been included with a buffer of one NM to avoid areas that host marine recreational activities. These have been weighted at the lower level in this group due to these criteria not being ideal for projection at this scale and acknowledging that this data is a poor proxy for the real constraint of how potential developments may inhibit on current coastal uses. Local and inshore recreational use should be considered in much greater detail at the project level.

Tier 4

Tier 4 ID	Layer name	Classification	Weight	Pairwise comparison matrices				
		Ships per year		>10000	10000-1000	1000-500	500-200	200-0
1ai	AIS shipping density.	>10000	1.00	1.00	3.00	5.00	7.00	9.00
1ai	AIS shipping density.	10000-1000	0.51	0.33	1.00	3.00	5.00	7.00

1ai	AIS shipping density.	1000-500	0.25	0.20	0.33	1.00	3.00	5.00					
1ai	AIS shipping density.	500-200	0.12	0.14	0.20	0.33	1.00	3.00					
1ai	AIS shipping density.	200-0	0.07	0.11	0.14	0.20	0.33	1.00					
		totKWH		Pairwise comparison matrices									
				25,001-304,785	10,001 - 25,000	5,001-10,000	2,001-5,000	1,001 - 2,000	351-1,000	>350			
1ci	Fishing activity (totkWhr).	25,001-304,785	0.20	1.00	3.00	4.00	5.00	6.00	8.00	9.00			
1ci	Fishing activity (totkWhr).	10,001-25,000	0.12	0.33	1.00	3.00	4.00	5.00	6.00	8.00			
1ci	Fishing activity (totkWhr).	5,001-10,000	0.08	0.25	0.33	1.00	3.00	4.00	5.00	6.00			
1ci	Fishing activity (totkWhr).	2,001-5,000	0.05	0.20	0.25	0.33	1.00	3.00	4.00	5.00			
1ci	Fishing activity (totkWhr).	1,001-2,000	0.03	0.17	0.20	0.25	0.33	1.00	3.00	4.00			
1ci	Fishing activity (totkWhr).	351-1,000	0.02	0.13	0.17	0.20	0.25	0.33	1.00	3.00			
1ci	Fishing activity (totkWhr).	>350	0.01	0.11	0.13	0.17	0.20	0.25	0.33	1.00			
		Count		Pairwise comparison matrices									
				9	8	7	6	5	4	3	2	1	
2avi	High intensity nursery and spawning ground overlaps.	9	0.05	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	
2avi	High intensity nursery and spawning ground overlaps.	8	0.04	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	
2avi	High intensity nursery and spawning ground overlaps.	7	0.03	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	
2avi	high intensity nursery and spawning ground overlaps.	6	0.02	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00	
2avi	High intensity nursery and spawning ground overlaps.	5	0.01	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00	
2avi	High intensity nursery and spawning ground overlaps.	4	0.01	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00	

2avi	High intensity nursery and spawning ground overlaps.	3	0.01	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00
2avi	High intensity nursery and spawning ground overlaps.	2	0.00	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00
2avi	High intensity nursery and spawning ground overlaps.	1	0.00	0.11	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00
		Visibility		Pairwise comparison matrices								
				class1	class2	class3	class4	class5	class6	class7	class8	class9
3ai	Visibility from landscape designations.	Class 1	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
3ai	Visibility from landscape designations.	Class 2	0.36	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
3ai	Visibility from landscape designations.	Class 3	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00
3ai	Visibility from landscape designations.	Class 4	0.17	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00
3ai	Visibility from landscape designations.	Class 5	0.12	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00
3ai	Visibility from landscape designations.	Class 6	0.08	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00
3ai	Visibility from landscape designations.	Class 7	0.06	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00
3ai	Visibility from landscape designations.	Class 8	0.04	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00
3ai	Visibility from landscape designations.	Class 9	0.03	0.11	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00

		Intensity		Pairwise comparison matrices								
				4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5
3aii	RYA AIS intensity.	4.5	0.11	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
3aii	RYA AIS intensity.	4	0.08	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
3aii	RYA AIS intensity.	3.5	0.05	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00
3aii	RYA AIS intensity.	3	0.04	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00	6.00
3aii	RYA AIS intensity.	2.5	0.03	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00	5.00
3aii	RYA AIS intensity.	2	0.02	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00	4.00
3aii	RYA AIS intensity.	1.5	0.01	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00	3.00
3aii	RYA AIS intensity.	1	0.01	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00	2.00
3aii	RYA AIS intensity.	0.5	0.01	0.11	0.13	0.14	0.17	0.20	0.25	0.33	0.50	1.00

Tier 4 has been used to split parent weights over continuous data layers, such as intensity and density layers. This means that parent weights are only applied to the highest classes in the data. These have all been weighted linearly to remove the subjective element of trying to highlight certain areas above others.

In terms of data classification, all data layers have been split into nine classes to enable an easier distribution of weight in the pairwise assessment. This is with the exception of AIS shipping data and the VMS fishing data which have been classified to match the MMO methodology of presenting the data on the marine planning evidence base[21].

[21] MMO (website), available at: http://mis.marinemanagement.org.uk/marine-planning-evidence-base. Accessed 12/05/2017

Appendix F

Peer review

See - “Appendix F - Offshore wind constraints analysis and characterisation review.”

The Crown Estate

Offshore Wind Constraints Analysis and Characterisation Review

Date: *June 2018*
Revision: *REV02*






The Crown Estate

Offshore Wind Constraints Analysis and Characterisation Review

DATE	VERSION	DESCRIPTION	PREPARED	CHECKED	APPROVED
29/05/18	REV00a	Draft for internal review	NS	AW	AW
14/06/18	REV01	Draft for TCE review	NS	AW	AW
14/06/18	REV02	2nd Draft for TCE review	NS	AW	AW
File Reference: Projects\EOR0715 Crown Estate Constraints Analysis\03_Deliverables\01_Constraints Analysis\02_Final					

Prepared by:
Nicola Simpson
Alun Williams

14th June 2018

Riverside Court
Beaufort Park
Chepstow
NP16 5UH
Tel +44 (0)1483 746 500
Fax +44 (0)1483 746 505
Email simpsonn@rpsgroup.com

RPS Energy

Table of Contents

1 Introduction

1.1 The Crown Estate

The Crown Estate is a diverse property business with a capital value of £13.1 billion[1]. It has a statutory duty under The Crown Estate Act 1961 to maintain and enhance the value of the estate and the returns obtained from it, with due regard to the requirements of good management. The net revenues generated by The Crown Estate go the UK Treasury. As managers of the seabed out to the 12-nautical mile (NM) limit, and with rights to the exploitation of natural resources to generate electricity within the Exclusive Economic Zone (EEZ) around England, Wales and Northern Ireland, the Crown Estate plays a major role in the development of the offshore renewable energy industry[2]. The Crown Estate, since 2000, has run six rounds of offshore wind leasing in UK waters.

1.2 Background

The Crown Estate (TCE) announced 7th November 2017 that *'…we will be working with the offshore wind sector and stakeholders to consider making new seabed rights available to offshore wind developers'*. https://www.thecrownestate.co.uk/news-and-media/news/2017/the-crown-estate-to-consider-new-leasing-for-offshore-wind-projects/. Further detail was presented to the Offshore Wind Industry Council (OWIC) 6th February 2018. https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/offshore-wind-energy/working-with-us/potential-new-leasing/.

If TCE conclude that it is appropriate to do so, a formal process could commence in late 2018, into 2019, for offshore wind deployment in the 2020s. To support this process, TCE has undertaken an internal exercise to review offshore planning and consenting spatial constraints. This constraints analysis has been reviewed and discussed with the Marine Management Organisation (MMO) the Welsh Government and the Department of Agriculture, Environment and Rural Affairs (DAERA), Northern Ireland (NI), marine planning teams [3]. It is TCE's intention to share this analysis with both stakeholders and the market prior to and/or as part of a formal process. The approach to the spatial constraints analysis has been described in TCE report *'Resource and constraints assessment to support offshore wind leasing'*, and this RPS Energy report should be read in conjunction with the TCE report.

The work undertaken by TCE involved the analysis of marine spatial constraints to identify areas of least constraint in English, Welsh and Northern Irish Waters with respect to the potential for offshore wind development. This analysis considered the offshore array area only i.e. offshore and onshore cable routes or grid connection have not been considered. Further, only fixed structure offshore wind has been considered in this exercise i.e. excluding floating wind[4].

1.3 RPS Commission

In November 2017, RPS Energy was commissioned by TCE to undertake a peer review and validation of the draft spatial constraints analysis completed by TCE for offshore wind, as referred to above. RPS has experience and expertise in the consenting of offshore wind developments and the assessment of the environmental impact of offshore wind farms, and our staff are therefore well positioned to provide expert opinion on the level of constraint that economic, environmental and social factors can have on offshore wind development. This RPS study and its

[1] The Crown Estate Annual Reports and Accounts 2017: https://www.thecrownestate.co.uk/media/1097892/integrated-annual-report-2016-17.pdf

[2] The Crown Estate also hold rights for marine aggregate extraction, salt and potash, gas storage, cables and pipelines.

[3] Through the Marine and Coastal Access Act 2009, the MMO, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs, Northern Ireland, marine planning teams, have a lead role in marine spatial planning and is responsible for preparing marine plans in England, Wales and Northern Ireland respectively.

[4] It is not TCE's intention to exclude floating offshore wind from future development; any decision on technology parameters will be made following engagement with the market. However, for this spatial analysis has focussed on fixed structure offshore wind potential development areas and associated constraints to date, as it is assumed at this stage that this is where the emphasis will be.

outputs were intended to provide an external independent view of the work undertaken by TCE, and to inform the ongoing development of the work during the process.

RPS Energy was subsequently (in April 2018) commissioned to undertake a peer review of 18 draft regional characterisations documents produced by TCE to cover the EEZ around England, Wales and Northern Ireland, and the RAG (red-amber-green) analyses presents therein.

1.4 Study Aims and Objectives

The marine spatial constraints analysis, including scoring of these constraints was undertaken by TCE, using internal staff via a series of workshops. The constraints analysis was undertaken using the Crown Estate Marine Resource System (MaRs) GIS tool. This is a multi-criteria analysis tool that takes numerous input data layers, applies a user defined scoring system and produces a combined output which is the result of where input criteria overlap and the additive score of each (see the TCE report '*Resource and constraints assessment to support offshore wind leasing''*).

As described in section 1.2, this constraints analysis had previously been discussed between TCE and the MMO, Welsh Government and DAERA NI, but beyond that had not been externally validated or consulted on prior to RPS's review. It was recognised by TCE that the data included/excluded in the GIS constraints analysis and, more importantly, the scoring (or weighting) of constraints is highly subjective (i.e. influenced by the specific areas of knowledge, experience and perception of individual scorers). The GIS constraints model used by TCE is also more complex to explain to a non-technical audience than previous models used by TCE for this type of study. TCE therefore requested that RPS undertake an independent review and validation of the GIS constraint analysis. TCE used this independent 'opinion' to validate the GIS analysis, and where considered necessary, to refine the scoring and/or to address any clear differences in opinion by providing a more detailed explanation and justification of the approach and scoring for a non-technical audience. In this way, the validation was used to identify areas where there was a high degree of variance in expert opinion (between TCE and RPS) within the analysis. The additional explanation was then used to further evidence TCE's selected approach to the GIS constraints analysis, the inclusion/exclusions of data from the GIS constraints analysis, and the constraints scorings themselves. This RPS review and validation study was therefore undertaken with the following objectives:

- Review and provide commentary on the process used in the constraints analysis (e.g. data sources, tiering and normalising);
- Undertake an independent scoring exercise for each of the constraint theme/sub themes used in the GIS analysis;
- Provide commentary on where RPS and TCE constraint scorings differed; and
- Provide support and review to TCE in forming justifications for the approach taken to the GIS spatial analysis and specifically to the constraint scoring where a high variance was noted.

RPS Energy was subsequently also commissioned to review the 18 regional Characterisation Documents produced by TCE and the RAG (red-amber-green) analyses presents therein, to provide feedback on the Receptor and Area RAGs and whether the commentary within each of the draft characterisations provided sufficient justification for each of the RAG ratings.

2 Methodology

2.1 Spatial Constraints Analysis

The approach used by TCE to score each constraint layer prior to inputting into of the GIS placed the data into a series of tiered themes i.e. tier 1: Economic, Environmental and Social, and sub theme within these. For example, under Economic the tier 2 sub themes: shipping and navigation, subsurface activity and fishing activity were included to accommodate the large number of criteria that forms the Economic tier 1 theme, but is 'by-passed' for Environmental and Social as these do not contain as many data layers. Subsequent tiers were used to house the data layers for discreet data i.e. polygons and lines (tier 3) and for continuous data layers i.e. data with full coverage over an area (tier 4). Each of these themes and subthemes were then scored against each other (pairwise comparison) using a 9-point scale of relative constraint of one theme to another (see the TCE report '*Resource and constraints assessment to support offshore wind leasing''* for more detailed explanation).

These scorings, were then normalised, and applied through an algorithm to the data layers (see the TCE report '*Resource and constraints assessment to support offshore wind leasing''* for details) and then inputted to GIS. The output of the (soft) constraints model (together with a technical resource model (peer reviewed by others) and an exclusion model (hard constraints)) was split into equal number of features representing the suitability of the area of search as four quantiles i.e. the top 25% is represented by red (areas of highest constraint), the next 25% by orange, thereafter by light green, and the bottom 25% by dark green (areas of least constraint). The area within the top 50% (dark green and light green) i.e. least constrained areas, were then used as the boundaries of the regions further characterised by TCE using the GIS data, and other data available not used in the GIS constraints model in a series of descriptive Characterisation Documents (see Section 2.2).

The RPS study reviewed both the process used in the constraints analysis (e.g. data sources, tiering and normalising), the 'scoring' applied within this analysis (i.e. within the pairwise comparisons), and the reasoning for the TCE scorings applied.

2.1.1 Data Audit

RPS undertook a review of the data layers used to characterise each 'theme' (i.e. Economic, Environmental and Social) and 'sub-theme' (e.g. navigation and shipping) within the analysis. This review considered, challenged and provided commentary on the applicability of data sources used and / or suggested other potential data sources that could be included as hard or soft constraints (and therefore used in the GIS constraints analysis) or could be used in the characterisation documents.

2.1.2 Constraints Structuring and Scoring

RPS held an internal workshop (mirroring the TCE approach) using individuals from within the RPS offshore wind consenting team with relevant expertise to ensure a spread of knowledge across each of the themes considered. TCE also attend to present the approach and answer any questions on the process, but did not influence the scoring. RPS considered how data had been structured (themes and sub-themes) and considered whether this structure was appropriate to enable 'comparisons' to determine the degree of constraint imposed. RPS reviewed the relative importance and level of constraint of each dataset within each theme/subtheme to check, agree or rearrange the running order of the constraints i.e. highest constraint at the top, lowest constraint at the bottom. Pairwise comparisons were then made between criteria (constraints) within each of the themes or sub themes grouped within each tier i.e. for tier 1, Economic was compared to Environmental, and Social, and scored using the TCE scoring scale. This exercise was undertaken 'blind' (i.e. without having viewed TCE's constraint scoring) following initial discussion and testing of the scoring approach to align with how the scoring had been undertaken. This approach allowed the scorings to be compared to establish where there was variance in opinion (scoring) and what the degree of variance was.

2.2 Characterisation Documents

RPS undertook a review of each of the 18 regional Characterisation Documents. RPS reviewed the assessed constraints for each Area and Receptor based on our expert knowledge and through reviewing spatial data. Where spatial data describing each of the constraints were held by RPS, these were used to inform the spatial evidence for the peer review. Where RPS data highlighted or omitted a receptor described in the documents, these were noted. Where data were not held or available to RPS, TCE provided these GIS shapefiles. The constraint class (Red-Amber-Green (RAG)) assigned and commentary for each constraint and review data layer was peer reviewed by RPS. The RPS review also looked at consistency across the 18 Characterisation Documents.

It should be noted that some aspects of the Characterisation documents were incomplete at the time of RPS's review. These included sections on Ministry of Defence (MoD), cultural heritage, and analysis of the physical conditions (geology, distance from shore etc.) in each area.

3 RPS Review and Recommendations

3.1 Spatial Constraints Analysis

3.1.1 Data Audit

The data included in the TCE spatial constraints analysis as hard and soft constraints are described in the TCE report '*Resource and constraints assessment to support offshore wind leasing''*. Data included as a 'review' layer (included in the Characterisation Documents) have also described in the same report. RPS provided commentary on these data sources and other data sources we suggested TCE use, and our comments are summarised below for each type of constraint i.e. hard and soft constraints (data used in the GIS constraints analysis) and for review/characterisation data used in the characterisation documents.

- **Hard Constraints.**
  - **O&G infrastructure.** TCE to consult with the Oil and Gas Authority (OGA). Consider including active & suspended wells and removing plugged and abandoned wells.
  - **Shipping routes and Traffic separation schemes**. TCE to consult with Maritime and Coastguard Agency (MCA). Consider including pilot boarding areas.
- **Soft Constraints.**
  - **Shipping (ABPmer AIS density).** TCE to consult MCA on prioritising high shipping density 'routes' by type e.g. bad weather routes, important passage routes. Note overlap for small vessels between the AIS ABPmer density and recreational Royal Yachting Association (RYA) density dataset.
  - **Disposal sites.** Consult with Ministry of Defence (MoD). Note that MoD disposal sites have not been included within the Cefas disposal site layer.
  - **Commercial Fisheries (Fishing Activity, 2015.** Suggest use landings/catch dataset instead of activity (dataset available), or Catch per Unit Effort (CPUE) (dataset would require calculating) to provide more accurate representation of commercial fisheries as a constraint to offshore wind. This was discussed with TCE, and they noted that this dataset had been provided by the Marine Management Organisation (MMO) and aligns with their selected approach.
  - **Designated sites.**
    - **Natura 2000 – SACs/SPAs.** Split SACs and SPAs/Ramsars so that these can be scored independently. SPAs and associated bird species have the potential to impact upon offshore wind development within and beyond the SPA boundaries. This is not to say however, that offshore wind developments have not occurred within SPAs. RPS suggested potentially scoring SPAs higher than SACs in the pairwise comparisons. Consult with Statutory Nature Conservation Bodies (SNCBs) on this approach.
    - **Natura 2000 – Harbour porpoise cSACs.** Harbour porpoise cSACs are considered separately to other SACs. RPS suggested that TCE consider adding to the reasoning for this split in constraints that these sites are to be designated for a mobile species which do not have an affinity to a discrete geographic location and therefore encompass large sea areas (as opposed to habitat and/or species based SACs which are more localised). This reasoning also applies to SPAs.
- **Review/Informative.**
  - **Shipping (ABPmer AIS density).** Ferry routes to be described in characterisation.
  - **Radar.** Primary radar which include height defined shading, navigational aids and secondary radar. The latter two are available as a single data layer for all development (not height defined). These datasets are available from the National Air Traffic Services (NATS) and RPS suggested that these data be referenced in the characterisation documents.

- **Offshore helidecks.** Helicopter consultation zones (3, 6 & 9 nm) for O&G. Required out to 9 nm under CAP 764 but this is purely from a consultation zone and not a constraint to development. The closer to a platform the greater the operational requirements to that platform but there is no legal rule (other than 500 m safety zone) that can be applied. TCE to consult with the Civil Aviation Authority (CAA) and Oil OGA.
- **Offshore helidecks.** Helicopter consultation zones (3, 6 & 9 nm) for offshore wind farms (OWF). Dataset not Publicly Available. As above. TCE to consult with the CAA, RenewablesUK and OWF developers.
- **Marine Plan Key Resource Areas (KRAs).** To include wave & tide, aquaculture and aggregates.
- **O&G.** Include approved field development plans. Data layer does not exist so would need to be collected and collated through consultation with the OGA.
- **Cables.** Include interconnectors not under agreement but available in the Public Domain. Of relevance will be landfalls and grid connection.
- **MoD.** Include MoD areas e.g. MoD munition dump sites, low flying routes, military practice areas.
- **Commercial Fisheries.** Soft constraint dataset does not capture European vessels where catch is not landed in the UK. Less than 12 m fleet / inshore fisheries (within 6 nm) not captured. TCE to consult with Inshore Fisheries and Conservation Associations (IFCAs), local fisheries and international fisheries groups, or maybe more appropriate to be undertaken by site developers at a project level.
- **Designated sites.**
  - **Natura 2000 – SACs.** Suggest map and describe Annex 1 habitats in the characterisations (where datasets are available).
  - **MCZs**. Reference cMCZs in characterisations. Next tranche (tranche 3) of MCZs are due for consultation in Q2 2018. Consult with SNCBs.
  - **Fish spawning and nursery**. Review Coull *et al.,* 1998 and Ellis *et al.,* 2012[5] for individual fish spawning and nursery for characterisation documents. The International Herring Spawning (IHLS) dataset for herring for some sea areas will also be useful at a project level.
  - **Social.** Marine users such as recreational fisheries, scuba diving, surfing etc not included in GIS as no national dataset. To be consulted but most likely to be appropriate at a project level.
  - **Aerodromes/airfields.** TCE to consult with the CAA and the MoD to identify where safe guarding zones around technical sites and military aerodromes for the MoD and civil airfields for the CAA would be required.
  - **Marine mammal and bird data.** SCANs I, II and III, SCOS, Seabirds at sea, SEAs datasets etc., for use in Characterisation Documents. Also, to consult with SNCBs and Non-Government Organisations (NGOs).
  - **Cumulative.** Note concern amongst stakeholders, including the SNCBs regarding cables making landfall along the coast of the southern North Sea and the influence that grid connection location has on cable route selection and associated landfalls. To consult with SNCBs and other stakeholders.

3.1.2 Constraints Structuring and Scoring

The pairwise scoring of constraints is subjective and completing scoring independently from the TCE scoring resulted in some differences in outputs. In general, however, RPS produced a very

[5] Ellis *et al.* 2012 https://www.cefas.co.uk/publications/techrep/TechRep147.pdf as well as Coull *et al.* 1998. https://www.cefas.co.uk/media/52612/sensi_maps.pdf. For herring spawning specifically, there are also the International Herring Spawning (IHLS) datasets, which is a good long term/quality dataset) http://www.ices.dk/marine-data/data-portals/Pages/Eggs-and-larvae.aspx.

similar priority ordering of constraints (i.e. RPS and TCE both ordered the constraints from most to least constraining to OWF in the same order) albeit with some different scores but in most cases, scores were within +/-2 and therefore deemed not to be significant. This was an important finding, and showed, that whilst the scoring is subjective, and that there were inevitably minor scoring differences due to the inherent subjectivity in scoring of constraints against one another in this manner, overall, with some exceptions (see Table 3-1), RPS and TCE agreed on which constraints were of greater constraint to OWF than other constraints. Because of this, RPS's review became more focused on detailed recommendations on specific aspects of the scoring. RPS provided TCE with several key recommendations through the peer review and validation of the spatial constraints analysis exercise. These recommendations, and RPS's reasoning for implementing these recommendations are summarised in Table 3-1.

Table 3-1 RPS peer review recommendations and response to the spatial modelling analysis steps

RPS Recommendation	RPS Reasoning	TCE Response
RPS recommended that TCE consider further how the characterisation area output will be perceived by developers and ways in which this could be presented to avoid placing too much onus on the top 50% of the constraints model[6]. This could include other cut offs e.g. 25% and 75% as separate plots but only characterise at 50%. RPS also recommended presenting the distinction between what is a hard constraint and what was not considered in the model due to being outside of the favourable technical resource area.	This was a more subjective recommendation, but given the arbitrary nature of the 50% cut off, we believed there was merit in providing a range of constrained mapped model outputs (potentially 25%, 50% and 75% (or other similar figures). The risk of not doing this could be that the 50% maps create the impression (no matter how carefully the map is described/caveated) that these are the only areas for development and that other areas are not available for development. This could be a disadvantage (or perhaps discourage) certain locations being progressed even if they had other over-riding advantages (such as being adjacent to an existing site). Alternatively, presenting a broad range of GIS model outputs may not provide for sufficient guidance, which may be a perceived risk, particularly for new site developers.	This has been completed with presentation of the data presented at quartiles on the scale of highest to lowest constraint.
RPS recommended that TCE revisits and revises the tier 1 scoring so that the economic theme is more important than the environmental theme (namely designations). RPS scoring for tier 1 was based on the economic data being better at presenting the degree of constraint than the environmental data (as opposed to the fact that the theme is more important). RPS considered it important that Natura 2000 sites were not excluded from the 50% least constrained areas GIS output.	This had an impact on whether Natura 2000 sites were included/excluded from the 50% displayed in the GIS output and therefore included in the characterisation. RPS recommended that Natura 2000s not excluded from 'developable' areas (prior to stakeholder consultation). The risk is of creating a perception in the constraint evaluation process that these areas have been excluded from development, when historically developments have gone ahead in these	This was discussed by TCE however, it was agreed that the specific concern raised was around offshore SACs being removed from the less constrained percentiles. The level of constraint that an SPA or a Ramsar would exert is significant however there is precedent for development within SACs. As such, where before all Natura 2000 designations were included as one data layer, the SACs are now split out and weighted lower than

6

RPS Recommendation	RPS Reasoning	TCE Response
	areas (in terms of array areas and transmission infrastructure - as well as other industry activities). This could be perceived to set a precedent or definitive view.	the SPAs and Ramsars data layer. This still showed that the SAC presents a constraint but are only excluded from the characterisation areas where they overlap with other constraints. All environmental designations are considered on a site by site basis in the characterisation phase, which provides detail on the designated features, their management measures and the potential sensitivity to offshore wind development.
RPS recommended that the tier 4 layer 'visibility from landscape designations' be scored based on perceived risk from viewing the GIS data i.e. by grouping categories within this theme having viewed which geographic areas this highlights, rather than applying a linear method of defining pairwise scores.	It was not clear to RPS whether the subjective scoring of visuals at tier 4 would have an influence on the GIS analysis. It is most likely that the tier 1 scoring was of greater importance and therefore any adjustments at tier 1 were recommended over those at tier 4. However, minor amendments at tier 4 may be required depending on GIS analysis outputs from revised Tier 1 scoring to achieve the desired outcome i.e. to reflect areas of constraint for visibility.	This is a complex area due to the subjectivity of the subject matter and the need to understand what the landscape designations have been designated for (i.e. marine views). This level of analysis cannot be accurately undertaken at this stage so applying a subjective scoring regime to this layer would make the analysis significantly more subjective but without clear evidence. As such, this recommendation has not been adopted.
RPS suggested that It would be more appropriate to remove this 'subjectivity' from Tier 4 by applying a linear scale across all the classifications for each dataset.	The scoring of tier 4 continuous datasets is very subjective with the 'scorer' able to manipulate the scoring to reflect which areas are constrained more so than in other parts of the constraints model.	TCE has adopted this recommendation. Prior to the peer review, shipping intensity and fishing intensity were scored in the pairwise analysis to pull out the highest levels of activity significantly stronger than the other classes, now these are scored linearly so that the relative importance of each class in the data reduces the score linearly.

3.2 Characterisation Documents

RPS provided reviewer comments on each of the 18 Characterisation Documents. RPS reviewed for consistency of assessment across the 18 regional Characterisation Documents, and provided detailed comments which were delivered in a comment log, with TCE addressing/responding to each of these comments. Our key comments across these Characterisation Documents are provided in Table 3-2.

Table 3-2 RPS peer review recommendations and response to the characterisation documents

Consideration	RPS Recommendation	TCE Response
Hard/Soft Constraints	Trigger distances, where used, should be defined.	In the characterisation documents, when returning whether a constraint that was included in the exclusions and restrictions models, a standard buffer distance of 1nm has been implemented. This was to allow consideration of constraints which didn't intersect the characterisation areas but are more than likely within an area of influence. More complex buffers were not implemented due to the impact pathways being too difficult to accurately establish at this strategic level of assessment.
Type of Designations	Clarity to be provided on which Special Protection Areas (SPAs)/pSPAs have been considered in each regional Characterisation Document and justification for inclusion of these sites e.g. trigger distances.	SPAs and pSPAs that were available at the time of running the restrictions model were included (14/03/2018). When considering these sites in the characterisation work, a buffer of 1nm was implemented as described above. When considering ornithology outside of SPAs and pSPAs in the review layers sections, the sites that were included were defined by foraging ranges but limited to "high risk species" as defined in a McArthur Green report for TCE (unpublished).
Type of Designations	Consideration of cumulative collision risk modelling should be made as part of the plan level Habitat Regulation Assessment (HRA).	This will be picked up.
Type of Designations	Recommended Marine Conservation Zones (MCZs). These have not been included in the GIS constraints analysis (see above) nor in the Characterisation Documents. Recommended MCZs (rMCZs) are not a material consideration for new developments until designation proposals are put out for public consultation. Site promotors however need to be aware of rMCZs which may come forward during future tranches of MCZ designations.	These have now been included in the characterisation documents in the review layers section.
Type of Designations	The risk associated with migration of qualifying fish features of SACs will need to be considered at a project level by site promotors.	This type of impact pathway will be considered at HRA level. Complex migratory pathways have not been considered due to being too difficult to accurately portray at this strategic level of assessment.
Spawning and Nursery Grounds	Site promotors will need to consider the risks of specific fish nursery and spawning grounds, for example herring spawning	The specific commentary that was highlighted by the RPS peer review on nursery and spawning grounds has been adopted. Other impacts will be considered

	grounds, which could have implications for offshore wind development.	at the project level by developers.
Fishing Commentary	Source data references should be provided.	These have been described in the methodology report
Water Framework Directive, Bathing Waters and other inshore data layers	Some aspects of the characterisation are more relevant to the siting of offshore export cables than the OWFs themselves. This is particularly relevant to inshore areas (where cables will make landfall) e.g. Water Framework Directive water bodies, Bathing Waters, Marinas. Export cables were not considered within the TCE constraints analysis, but the siting of this associated infrastructure will need careful consideration by site promotors at the project level.	Detailed analysis of cable routes were classed as out of scope for this characterisation work. There will be more consideration through the HRA process and at the project level.

RPS also noted that there was no, and nor is there intended to be, consistency across the TCE study area in terms of specific constraints causing areas to fall into each of the quartile constraint classes, because the number of constraints acting on any one area differs, as does the additive effect of the different constraints and their weightings in that area. This means, for example, that it may appear that an MCZ is below the 50% cut off in some areas, and above it in others, and therefore, for the latter, the area would be excluded from further consideration in the Characterisation Documents.