ForthWind Demonstration Site,
Methil, Fife.

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FORTHWIND

APPENDIX 5A – SLVIA METHODOLOGY

1. SLVIA METHODOLOGY

1.1. Introduction

This appendix describes the methodology used within the seascape, landscape and visual impact assessment (SLVIA) of the EIA for the Proposed Development.

This SLVIA methodology appendix has been structured as follows:

- 1.2 - Overview of SLVIA methodology;
- 1.3 - Iterative assessment and design;
- 1.4 - Guidance, data sources and site surveys;
- 1.5 - Assessing seascape/landscape effects;
- 1.6 - Assessing visual effects;
- 1.7 - Evaluation of significance;
- 1.8 - Nature of effects;
- 1.9 - Assessing night-time visual effects;
- 1.10 - Assessing cumulative seascape, landscape and visual effects; and
- 1.11 - Visual representations.

1.2. Overview of the SLVIA methodology

1.2.1. Introduction

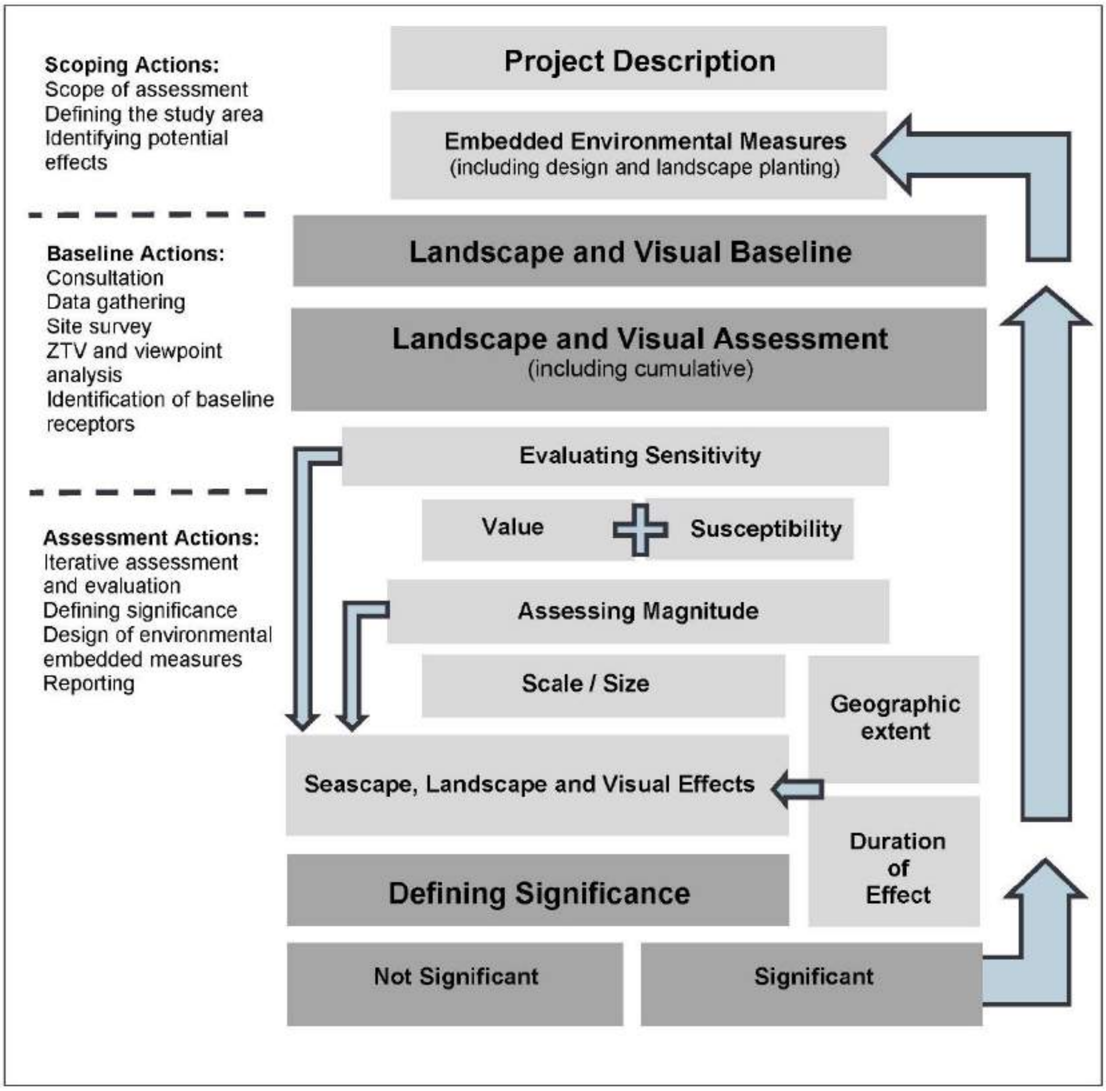
The assessment has been undertaken in accordance with the Landscape Institute and IEMA (2013) Guidelines for Landscape and Visual Impact Assessment, 3rd Edition (GLVIA3), and other best practice guidance. An overview or summary of the SLVIA process is provided here and illustrated, diagrammatically in Plate 1.

The SLVIA assesses the likely effects that the construction and operation of the Proposed Development on the seascape, landscape and visual resource, encompassing effects on seascape/landscape character, designated landscapes, visual effects and cumulative effects.

SLVIA is based on the Rochdale Envelope described in Chapter 4 The Proposed Development. In compliance with EIA regulations, the likely significant effects of a realistic ‘worst case’ scenario are assessed and illustrated in the SLVIA. This worst-case scenario is described in Chapter 5: Seascape, landscape and visual impact assessment.

The evaluation of sensitivity takes account of the value and susceptibility of the receptor to the Proposed Development. This is combined with an assessment of the magnitude of change which takes account of the size and scale of the proposed change. By combining assessments of sensitivity and magnitude of change, a level of seascape, landscape or visual effect can be evaluated and determined. The resulting level of effect is described in terms of whether it is significant or not significant, and the geographical extent, duration and the type of effect is described as either direct or indirect; temporary or permanent (reversible); cumulative; and beneficial, neutral or adverse.

Plate 1 Overview of approach to Seascape, Landscape and Visual Impact Assessment



The assessment has also considered the cumulative effects likely to result from additional changes to the seascape, landscape and visual amenity caused by the Proposed Development in conjunction with other developments that occurred in the past, present or are likely to occur in the foreseeable future.

In each case an appropriate and proportionate level of assessment has been undertaken and agreed through consultation at the scoping stage. The level of assessment may be 'preliminary' (requiring desk-based data analysis) or 'detailed' (requiring site surveys and investigations in addition to desk-based analysis).

The seascape, landscape and visual assessment unavoidably, involves a combination of quantitative and qualitative assessment and wherever possible a consensus of professional opinion has been sought through consultation, internal peer review, and the adoption of a systematic, impartial, and professional approach.

1.2.2. Defining the Study Area

The SLVIA Study Area covers a radius of 50km from the Proposed Development, as illustrated in Figure 5.1.

The SLVIA Study Area is defined to extend far enough to include all areas within which significant effects could occur, using professional judgement. It is an outer limit to where significant effects could occur.

IEMA Guidance (IEMA, 2015 and 2017) recommends a proportionate ES focused on the significant effects and a proportionate ES topic chapter. An overly large SLVIA Study Area may be considered disproportionate if it makes the understanding the key impacts of the Proposed Development more difficult.

This is supported by LVIA Guidance produced by the Landscape Institute (GLVIA3) (Landscape Institute, 2013) (para 3.16). This guidance recommends that *'The level of detail provided should be that which is reasonably required to assess the likely significant effects'.*

Para 5.2 and p70 also states that '*The study area should include the site itself and the full extent of the wider landscape around it which the proposed development may influence in a significant manner'.*

Other wind farm specific guidance, such as NatureScot's Visual Representation of Wind Farms Guidance (NatureScot, 2017) recommends that ZTV distances are used for defining study area based on wind turbine height. This guidance recommends a 45km radius for wind turbines greater than 150m to blade tip (para 48, p12), however it does not go beyond turbines above 150m in height. The height of current offshore wind turbine models has now exceeded the heights covered in this guidance. The NatureScot guidance recognises that greater distances may need to be considered for larger wind turbines used offshore, as is the case for the SLVIA Study Area for the Proposed Development.

Beyond the SLVIA Study Area, the SLVIA generally focuses on locations from where it may be possible to see the Proposed Development, as defined by the Blade Tip ZTV (Figure 5.8).

The ZTV shown in Figure 5.8 (and Figure 5.9 at A1 scale) are based on turbines of 280m to blade tip (above HAT) and represents the Maximum Development Scenario (MDS) considered in the assessment. The ZTV illustrates where there will be no visibility of the Proposed Development, as well as areas where there the Proposed Development will be theoretically visible.

Consideration of the blade tip ZTV (Figure 5.8) indicates that theoretical visibility of the Proposed Development mainly occurs within 50 km and that beyond 50 km, the geographic extent of visibility becomes very restricted. At distances over 50 km, the lateral (or horizontal) spread of the Proposed Development also occupies a small portion of available views and the apparent height (or 'vertical angle') of the Proposed Development will also appear very small, therefore significant visual effects are unlikely to arise at greater than this distance, even if the Proposed Development is theoretically visible.

The influence of earth curvature begins to limit the apparent height and visual influence of the wind turbines visible at long distance (such as over 50km), as the lower parts of the turbine will be partially hidden behind the apparent horizon, leaving only the upper parts visible above the skyline.

In considering the SLVIA Study Area, the sensitivity of the receiving seascape, landscape and visual receptors has also been reviewed, taking particular account of the landscape designations shown in Figure 5.3 and other principal visual receptors. It is clear that the principal issues for the SLVIA are the location of the Proposed Development in the Firth of Forth, off the Fife coast and therefore its exposure to and visibility from visual receptors along the Fife and East Lothian coastlines.

Potential cumulative effect interactions with other offshore wind farms have also influenced the definition of the SLVIA Study Area. Other offshore wind farms within the SLVIA Study Area are shown in Figure 5.19.

The SLVIA Study Area has been reviewed and defined in response to feedback from consultation and has been agreed with NatureScot.

1.3. Iterative assessment and design

The SLVIA is part of an iterative EIA process which aims to 'design out' significant effects via a range of environmental measures including avoidance and design that aim to reduce or eliminate significant effects. Design is an integrated part of the SLVIA process and environmental measures related to landscape design and management can be an important tool to mitigate significant effects. The EIA process can also call on a range of environmental and technical specialists that contribute other forms of mitigation that may also bring a range of benefits. Potentially significant seascape, landscape and visual effects and the constraints and opportunities connected with their resolution are identified through the SLVIA process. Where possible embedded environmental measures (Commitments) are incorporated into the Proposed Development in order to mitigate seascape, landscape and visual effects.

Potential effects during construction and decommissioning

Potential effects on the seascape, landscape and visual resource are likely during the construction and decommissioning of the Proposed Development during the construction and decommissioning periods, including:

- **Seascape/coastal character effects**:
    - Effects on perceived seascape/coastal character, arising as a result of the construction and decommissioning activities (including laying new offshore export cables to shore) and structures located within the array area, which may alter the seascape character of the array area itself and the perceived character of the wider seascape through visibility of these changes.
- **Landscape effects**:
    - Effects on perceived landscape character, arising as a result of the construction and decommissioning activities and structures, including laying new offshore export cables to shore, which will be visible from the coast and may therefore affect the perceived character of the landscape.
    - Effects on the special landscape qualities and integrity of designated landscapes as a result of the above construction and decommissioning activities.
- **Visual effects**:
    - Effects on views and visual amenity experienced by people from principal visual receptors and representative viewpoints, arising as a result of the construction and decommissioning activities and structures, including laying new offshore export cables to shore, which will be visible from the coast.

Potential effects during operation

Potential effects on the seascape, landscape and visual resource are likely during the operation of the Proposed Development over its operational lifetime, including:

- **Seascape/coastal character effects**: Effects on perceived seascape/coastal character of Coastal Character Areas (CCAs), arising as a result of the Proposed Development, which may alter the perceived seascape/coastal character.
- **Landscape effects**: Effects on perceived landscape character (LCAs and Designations), arising as a result of the Proposed Development, which will be visible from the coast and may therefore affect the perceived character of the landscape. Effects on defined special qualities of designated landscapes.
- **Visual effects**: Effects on views and visual amenity experienced by people as principal visual receptors and representative viewpoints, arising as a result of the Proposed Development.
- **Cumulative effects**: Effects of operation of the Proposed Development that have the potential to contribute to cumulative seascape, landscape and visual effects including effects on seascape/coastal character, landscape character and visual amenity due to inter-visibility with other planned developments.

1.4. Guidance, data sources and site surveys

1.4.1. Guidance on methodology

This assessment has been carried out in accordance with the principles contained within the following documents:

- Landscape Institute and IEMA (2013) - Guidelines for Landscape and Visual Impact Assessment: Third Edition (GLVIA3).
- Landscape Institute (2019). Visual Representation of Development Proposals.

- NatureScot (2012). Assessing the Cumulative Impact of Onshore Wind Energy Developments.
- NatureScot (2012). Offshore Renewables – Guidance on Assessing the Impact on Coastal Landscape and Seascape. Guidance for Scoping an Environmental Statement.
- NatureScot (2017). Visual Representation of Wind farms, Guidance (Version 2.2).
- NatureScot (2018). Guidance Note. Coastal Character Assessment (Version 1a).

This methodology accords with GLVIA3. Where it diverges from specific aspects of the guidance, in a small number of areas, reasoned professional justification for this is provided as follows.

GLVIA3 sets out an approach to the assessment of magnitude of change in which three separate considerations are combined within the magnitude of change rating. These are the size or scale of the effect, its geographical extent and its duration and reversibility. This approach is to be applied in respect of both landscape and visual receptors. It is considered that the process of combining all three considerations in one rating can distort the aim of identifying significant effects of wind farm development. For example, a high magnitude of change, based on size or scale, may be reduced to a lower rating if it occurred in a localised geographical area and for a short duration. This might mean that a potentially significant effect could be overlooked if effects are diluted down due to their limited geographical extents and/ or duration or reversibility.

The consideration of the size or scale of the effect, its geographical extent and its duration and reversibility are kept separate, by basing the magnitude of change primarily on size or scale to determine where significant and non-significant effects occur, and then describing the geographical extents of these effects and their duration and reversibility separately. Duration and reversibility are stated separately in relation to the assessed effects (i.e. as short/medium/long-term and temporary/permanent) and are considered as part of drawing together conclusions about significance and combining with other judgements on sensitivity and magnitude, to allow a final judgement to be made on whether each effect is significant or not significant.

OPEN's assessment methodology utilises six word scales of magnitude of change – high, medium-high, medium, medium-low, low and negligible; which are preferred to the 'maximum of five categories' suggested in GLVIA3 (3.27), as a means of clearly defining and summarising magnitude of change judgements.

These are not new diversions and follow practice established on other offshore wind farm projects such as Moray East, Moray West, East Anglia TWO, Norfolk Vanguard and Thanet Extension.

1.4.2. Data sources

The data sources that have been collected and used to inform this SLVIA are summarised in Table 1.1.

Table 1.1 Data sources used to inform the SLVIA

Source	Date	Summary
Campaign to Protect Rural England (CPRE)	2016	Interactive maps of the UK's light pollution and dark skies as part of a national mapping project (LUC/CPRE, 2016). Open Source data used to understand and illustrate baseline lighting levels. (Available at: https://www.nightblight.cpre.org.uk/)
East Lothian Council	2018	East Lothian Local Development Plan (Adopted 2018) (Available at: https://www.eastlothian.gov.uk)
East Lothian Council	2018	East Lothian Local Development Plan (Adopted 2018) Special Landscape Areas Supplementary Planning Guidance (Available at: https://www.eastlothian.gov.uk)
Fife Council	2017	Fife Local Development Plan (Adopted 2017) (Available at: https://www.fife.gov.uk)
Fife Council	2021	Local Landscape Areas (GIS Dataset) (Available at: https://data.gov.uk)
Forth and Tay Offshore Wind	2011	Forth and Tay Offshore Wind Developers Group (FTOWDG) (2011) Regional Seascape Character Assessment: Aberdeen to Holy Island

Source	Date	Summary
Developers Group (FTOWDG)		https://nngoffshorewind.com/files/offshore-environmental-statement/Appendix-21.3---Regional-Seascape-Character-Assessment.pdf
Forthwind Ltd	2015	Forthwind Offshore Wind Demonstration Project Environmental Statement
Google Earth Pro	2020	Aerial photography
Historic Environment Scotland	2021	Designations Map Search (Available at: https://historicscotland.maps.arcgis.com)
Historic Environment Scotland	2021	Inventory of Gardens and Designed Landscapes (Available at: http://portal.historicenvironment.scot)
Historic Environment Scotland	2021	Inventory of Gardens and Designed Landscapes (GIS dataset) (Available at: http://portal.historicenvironment.scot/downloads);
Historic Environment Scotland2021	2021	World Heritage Sites (GIS dataset) (Available at: https://portal.historicenvironment.scot/downloads)
Long Distance Walkers Association	2020	Overview map for Long Distance Paths and Walks (Available at: https://www.ldwa.org.uk)
Met Office	2010-2020	Visibility Data. Visibility bands every 1km up to 30km, then every 5km up to 50km, then every 10km up to 70km, and >70km
National Trust	2020	Any specific visitor attractions / tourist destinations (Available at: https://www.nationaltrust.org.uk/days-out)
NatureScot	2019	National Landscape Character Assessment (GIS Dataset) (Available at: https://data.gov.uk)
NatureScot	2021	Local Landscape Areas (GIS Dataset) (Available at: https://data.gov.uk)
NatureScot	2010	National Coastal Character Map (Available at: https://www.nature.scot)
NatureScot	2019	Onshore Wind Farm Proposals (Available at: https://gateway.snh.gov.uk);
Oceanwise		Marine and coastal mapping data, ferry routes.
OPEN internal dataset	2020	Public Rights of Way
Ordnance Survey	2019	1:50,000 scale mapping
Ordnance Survey	2019	1:25,000 scale mapping
Ordnance Survey Open Data	2019	OS County Region, Local Unitary Authority, Railways, Road and Settlements
Ordnance Survey	2019	OS Terrain 5 Digital Terrain Model (DTM)
Sustrans	2020	National Cycle Network (GIS dataset) (Available at: https://www.sustrans.org.uk/)

1.4.3. Appropriate level of assessment

The SLVIA methodology provides for an approach to identifying receptors that could be significantly affected by the Proposed Development that need to be 'scoped in' for further assessment in the SLVIA and receptors that could not be significantly affected and that can be 'scoped out' of the assessment.

The general principle is that receptors that could be significantly affected will be identified based on their sensitivity/importance/value and the spatial and temporal scope of the assessment. Consultation has also informed the selection of potential receptors that could be significantly affected by the Proposed Development.

The assessment of whether an effect has the potential to be of likely significance has been based upon review of existing evidence base, consideration of commitments made (embedded environmental measures), professional judgement and where relevant, recommended aspect specific methodologies and established practice. In applying this judgement, use has been made of a simple test that to be significant an effect must be of sufficient importance that it should be taken into consideration when making a development consent decision.

For those matters 'scoped in' for assessment, the approach to level of assessment is tiered. A 'preliminary' or 'detailed' assessment is undertaken as follows:

- a 'preliminary assessment' approach for an environmental aspect/effect which may include secondary baseline data collection (for example desk-based information) and qualitative assessment methodologies. A preliminary assessment of all seascape, landscape and visual receptors within the ZTV is undertaken in Chapter 15, using desk-based information and ZTV analysis (Figure 5.13 – 5.16). The preliminary assessment identifies which seascape, landscape and visual receptors are unlikely to be significantly affected, which are subject to a preliminary assessment, and those receptors that are more likely to be significantly affected by the Proposed Development which require a 'detailed assessment'; and
- a 'detailed assessment' approach is undertaken for seascape, landscape and visual receptors/effects that are identified in the preliminary assessment as requiring detailed assessment. This detailed assessment may include primary baseline data collection (for example through site surveys), quantitative and qualitative assessment methodologies, and modelling such as ZTV analysis (Figure 5.13 – 5.16) and wireline/photomontage visualisations (Figure 5.21 – 5.46).

To ensure the provision of a proportionate EIA and an ES that is focused on likely significant effects, the assessment takes into account the considerable levels of existing environmental information available, local geographical knowledge and understanding of the site and surroundings gained from ongoing environmental surveys. The spatial and temporal scope of the assessment enables the identification of receptors which may experience a change as a result of the Proposed Development.

1.4.4. Desk-based and site survey work

The SLVIA undertaken as part of the ES has been informed by desk-based studies and field survey work undertaken within the SLVIA Study Area. The landscape, seascape and visual baseline has been derived from a desk-based review of landscape and seascape character assessments and the ZTV, to identify receptors that may be affected by the Proposed Development and produce written descriptions of their key characteristics and value.

Interactions identified between the Proposed Development and seascape, landscape and visual receptors have been used to predict potentially significant effects arising, with measures proposed to mitigate effects, where relevant.

Primary data acquisition has been undertaken through a series of surveys. These surveys include field survey verification of the ZTV from terrestrial landscape character areas (LCAs), micro-siting of viewpoint locations, panoramic baseline photography and visual assessment survey from all representative viewpoints. The viewpoint photography and visual assessment surveys were undertaken during August and September 2021. Sea-based offshore surveys have not been undertaken as part of the SLVIA.

1.5. Assessing Seascape/Landscape Effects

1.5.1. Approach to Assessment of Seascape and Landscape Effects

The Marine Policy Statement (MPS) (UK Government, 2011) states *"references to seascape should be taken as meaning landscapes with views of the coast or seas, and coasts and the adjacent marine environment with cultural, historical and archaeological links with each other."*

In England, seascape characterisation includes both the sea surface and what lies below the waterline, however in Scotland, *'the focus is on the coast and its interaction with the sea and hinterland, relationships that are quite distinctive in the Scottish context'* (NatureScot, 2018).

Given the definition in the MPS and the NatureScot coastal character assessment guidance, the assessment of seascape character effects in this SLVIA focuses on areas of onshore landscape with views of the coast or seas/marine environment, in other words the 'coastal character', on the premise that the most important effect of offshore wind farms is on the perception of the character of the coast.

Coastal character is the *'distinct, recognisable and consistent pattern of elements on the coast, land and sea that makes one part of the coast different from another'* (NatureScot, 2018) and is made up of the margin of the coastal edge, its immediate hinterland and areas of sea.

The extent of the coast is principally influenced by the dominance of the sea in terms of physical characteristics, views and experience. The landward extent of the coast can be narrow where edged by cliffs or settlement; or broad where it includes raised beaches, dunes or more open coastal pasture or machair. The major determinant in defining the landward and seaward components of the coast is the sea - the key characteristic.

The coastal character of the SLVIA study area is defined at the regional level within the Regional Seascape Character Assessment Aberdeen to Holy Island (Forth and Tay Offshore Windfarm Developer Group, 2011) and at the local coastal character level by the local Coastal Character Areas (CCAs) defined in the Forthwind ES 2015, i.e. recognisable geographical areas with a consistent overall character and shown as a simple colour line along the coast (Figure 15.4). This hierarchy of published coastal character assessments is shown in Figures 5.4 and 5.13.

Due to its scale, distance from shore and extent of visibility, it is necessary to consider the effects of the Proposed Development on both coastal character and landscape character. The effect of the Proposed Development on coastal (seascape) character is considered within the boundaries of defined coastal character areas (CCAs) and the immediately adjacent landscape character type (LCT) covering its hinterland, as defined in Figure 5.2, where there is a strong visual relationship with the sea/tidal waters and coastal landscapes such as dunes or cliffs.

The effect of the Proposed Development on landscape character is considered on LCTs outside and inland of these CCAs and coastal LCTs, where there may be some intervisibility of the Proposed Development, but where the land is unlikely to have a strong visual relationship with the sea/tidal waters. These LCTs are identified in Figure 5.2. In general, they are considered unlikely to experience significant character effects as a result of the Proposed Development because it is located in the sea, and these landscapes do not have a strong visual relationship with the sea and their character is fundamentally defined by other characteristics.

Where detailed assessment of CCAs is required, effects are assessed on the discrete aspects of coastal character as defined in the coastal character assessment guidance (NatureScot, 2018) including the character of the coastal edge and its immediate hinterland, extent of human activity and views. The assessment of effects on coastal character focuses upon the experiential characteristics that may be affected by the Proposed Development, rather than physical characteristics (which will not be affected by offshore development).

1.5.2. Coastal / landscape character effects

In respect of the Proposed Development, the potential coastal character / landscape effects, occurring during the construction, operation and decommissioning periods may therefore include, but are not restricted to the following:

- changes to coastal character / landscape character and qualities: coastal/landscape character may be affected through the incremental effect on characteristic elements, landscape patterns and qualities (including perceptual characteristics) and the addition of new features, the magnitude of which is sufficient to alter the overall coastal character / landscape character within a particular area;
- changes to the perceived character of designated landscapes, which will affect the special landscape qualities underpinning the designation and its integrity; and
- cumulative coastal character / landscape character effects: where more than one development of a similar type may lead to a cumulative effect.

Effects on coastal character and landscape character arising from the Proposed Development will be indirect effects, which will be perceived from the wider landscape, outside the Proposed Development array area.

1.5.3. Evaluating seascape / landscape sensitivity to change

The assessment of sensitivity takes account of the seascape / landscape value and the susceptibility of the receptor to the Proposed Development.

Seascape / landscape sensitivity often varies in response to both the type and phase of the development proposed and its location, such that sensitivity needs to be considered on a case by case basis. It should not be confused with 'inherent sensitivity' where areas of the landscape may be referred to as inherently of 'high' or 'low' sensitivity. For example, a National Park may be described as inherently of high sensitivity on account of its designation and value, although it may prove to be less susceptible (and therefore sensitive) to a particular development. The susceptibility of seascape/landscape receptors has been assessed in relation to change arising from the Proposed Development.

1.5.4. Sensitivity of seascape/landscape receptor

Overview

The sensitivity of a seascape/landscape character receptor is an expression of the combination of the judgements made about the susceptibility of the receptor to the specific type of change or the development proposed and the value related to that receptor.

Value of the seascape/landscape receptor

The value of a seascape/landscape character receptor is a reflection of the value that society attaches to that seascape/landscape. The assessment of the seascape/landscape value has been classified as high, medium-high, medium, medium-low or low and the basis for this assessment has been made clear using evidence and professional judgement, based on the following range of factors.

- **Seascape/landscape designations**: a receptor that lies within the boundary of a recognised landscape related planning designation will be of increased value, depending on the proportion of the receptor that is affected and the level of importance of the designation which may be international, national, regional or local. The absence of designations does not however preclude value, as an undesignated landscape character receptor may be valued as a resource in the local or immediate environment.
- **Seascape/landscape quality**: the quality of a seascape/landscape character receptor is a reflection of its attributes, such as scenic quality, sense of place, rarity and representativeness and the extent to which its valued attributes have remained intact. A seascape/landscape with consistent, intact, well-defined and distinctive attributes is considered to be of higher quality and, in turn, higher value, than a landscape where the introduction of elements has detracted from its character.
- **Seascape/landscape experience**: the experiential qualities that can be evoked by a landscape receptor can add to its value and relates to a number of factors including the perceptual responses it evokes, the cultural associations that may exist in literature or history, or the iconic status of the seascape/landscape in its own right, the recreational value of the seascape/landscape, and the contribution of other values relating to the nature conservation or archaeology of the area.

Seascape / landscape susceptibility to change

The susceptibility of a seascape/landscape character receptor to change is a reflection of its ability to accommodate the changes that will occur as a result of the addition of the Proposed Development without undue consequences for the maintenance of the baseline situation and/or the achievement of landscape planning policies and strategies. Some landscape receptors are better able to accommodate development than others due to certain characteristics that are indicative of capacity to accommodate change. These characteristics may or not also be special landscape qualities that underpin designated landscapes.

The assessment of the susceptibility of the seascape/landscape receptor to change has been classified as high, medium-high, medium, medium-low or low and the basis for this assessment has been made clear using evidence and professional judgement. Indicators of landscape susceptibility to the type of development proposed (construction, operation and decommissioning of the Proposed Development) are based on the following criteria.

- **Overall strength and robustness**: Collectively the overall characteristics and qualities of a particular seascape/landscape result in a strong and robust landscape that is capable of reasonably accommodating the influence of the Proposed Development without undue adverse effects on the special landscape qualities (in the case of a designated landscape) or the key characteristics for which an area of seascape/landscape character or a particular element it is valued.
- **Landscape scale and topography**: The scale and topography are large enough to physically accommodate the influence of the Proposed Development. Topographical features such as more complex, distinctive or small-scale coastal landforms are likely to be more susceptible than simple, broad and homogenous coastal landforms.
- **Openness and enclosure**: openness in the seascape/landscape may increase susceptibility to change because it can result in wider visibility, however open seascape/landscape may also be larger scale and simple, which will decrease susceptibility. Conversely, enclosed seascape/landscapes can offer more screening potential, limiting visibility to a smaller area, however they may also be smaller scale and more complex which will increase susceptibility. In general, large scale, simple and open seascapes/coastlines are likely to be less susceptible to the Proposed Development than more enclosed, complex seascapes/coasts (such as indented bays, headlands etc).
- **Skyline**: prominent and distinctive skylines and horizons with important landmark features that are identified in the landscape character assessment, are generally considered to be more susceptible to development in comparison to broad, simple skylines which lack landmark features or contain other infrastructure features.
- **Relationship with other development and landmarks**: contemporary landscapes where there are existing similar developments (wind turbines or energy developments) or other forms of development (industry, mineral extraction, masts, urban fringe / large settlement, major transport routes) that already have a characterising influence result in a lower susceptible to development in comparison to areas characterised by smaller scale, historic development and landmarks.
- **Perceptual qualities**: notable landscapes that are acknowledged to be particularly scenic, wild or tranquil are generally considered to be more susceptible to development in comparison to ordinary, cultivated or farmed / developed landscapes where perceptions of ‘wildness’ and tranquillity are less tangible. Landscapes which are either remote or appear natural may vary in their susceptibility to development.
- **Landscape context and association**: the extent to which the Proposed Development will influence the character of seascape/landscape receptors across the Study Area relates to the associations that exist between the seascape/landscape receptor within which the Proposed Development are located and the seascape/landscape receptor from which the Proposed Development is being experienced. In some situations this association will be strong, i.e., where the seascapes/landscapes are directly related, and in other situations weak (where the landscape association is weak). The context and visual connection to areas of adjacent seascape/landscape character or designations has a bearing on the susceptibility to development.

1.5.5. Seascape/landscape sensitivity rating

An overall sensitivity assessment of the seascape/landscape receptor has been made by combining the assessment of the value of the seascape/landscape character receptor and its susceptibility to change. The evaluation of seascape/landscape sensitivity has been applied for each seascape/landscape receptor - high, medium-high, medium, medium-low and low - by combining individual assessments of the value of the receptor and its susceptibility to change. The basis for the assessments has been made clear using evidence and professional judgement in the evaluation of sensitivity for each receptor. Criteria that tend towards higher or lower sensitivity are set out in Table 1.2 below.

Table 1.2 Seascape/landscape sensitivity to change

Sensitivity factor	Higher	Lower
Value	Designation: Designated seascape/landscapes with national policy level protection or defined for their natural beauty.	Seascape/landscapes without formal designation. Despoiled or degraded seascape/landscape with little or no evidence of being valued by the community.
	Quality: Higher quality seascape/landscapes with consistent, intact and well-defined, distinctive attributes.	Lower quality seascape/landscapes with indistinct elements or features that detract from its inherent attributes.
	Rarity: Rare or unique seascape/landscape character types, features or elements.	Widespread or ‘common’ seascape/landscape character types, features or elements.
	Aesthetic / scenic: Aesthetic / scenic or perceptual aspects of designated wildlife, ecological or cultural heritage features that contribute to seascape/landscape character.	Limited wildlife, ecological or cultural heritage features, or limited contribution to seascape/landscape character.
	Perceptual qualities: Seascape/landscape with perceptual qualities of wildness, remoteness or tranquillity.	Seascape/landscape where potential qualities of wildness, remoteness or tranquillity are no longer present or experienced, often as a result of existing development influences.
	Cultural associations: Seascape/landscape with strong cultural associations that contributes to scenic quality.	Seascape/landscape with few cultural associations.
Susceptibility	Strength and robustness: Fragile seascape/landscape vulnerable and lacking the ability to accommodate change.	Robust landscape that is capable of reasonably accommodating change without undue adverse effects.
	Landscape scale: A smaller scale seascape/landscape, with complex, distinctive or small-scale coastal landforms.	A seascape/landscape of a suitably large enough scale to accommodate the development, with simple, broad and homogenous coastal landforms.
	Openness / enclosure: Openness may increase susceptibility if there is wider visibility, however open seascape/landscape may also be larger scale and simple which would decrease susceptibility.	Enclosed seascape/landscapes can offer more screening potential, limiting visibility to a smaller area, however they may also be smaller scale and more complex which would increase susceptibility
	Skyline: Distinctive undeveloped skylines with landmark features.	Developed, non-distinctive skylines without landmark features.

	Relationship with other development: Little association with other contemporary development, or strong associations occur with smaller scale or historic development.	Strong or direct association with other similar contemporary developments and seascape/landscape character influenced by development.
	Perceptual qualities: Perceptual qualities associated with particular scenic qualities, wildness or tranquillity.	Contemporary, cultivated / settled or developed landscapes with fewer perceptual qualities are likely to have a lower susceptibility.
	Seascape/landscape association: Adjacent seascape/landscape character context connected by associated character and views.	Host landscape character is separate from surrounding / adjacent seascape/landscape character with weak association.
Sensitivity to change	High ◄──────► Medium ◄──────► Low	

1.5.6. *Seascape/landscape magnitude of change*

Overview

The magnitude of change affecting seascape/landscape receptors is an expression of the scale of the change that will result from the Proposed Development and is dependent on a number of variables regarding the size or scale of the change and the geographical extent over which the change will be experienced.

Size or scale of change

This criterion relates to the size or scale of change to the seascape/landscape that will arise as a result of the Proposed Development, based on the following factors.

- **Seascape/landscape elements**: The degree to which the pattern of elements that makes up the seascape/landscape character will be altered by the Proposed Development, by removal or addition of elements in the seascape/landscape. The magnitude of change will generally be higher if the features that make up the seascape/landscape character are extensively removed or altered, and/or if many new offshore elements are added to the seascape/landscape.
- **Seascape/landscape characteristics**: This relates to the extent to which the effect of the Proposed Development changes, physically or perceptually, the key characteristics of the seascape/landscape that may be important to its distinctive character. This may include, for example, the scale of the landform, its relative simplicity or irregularity, the nature of the seascape/landscape context, the grain or orientation of the seascape/landscape, the degree to which the receptor is influenced by external features and the juxtaposition of the Proposed Development in relation to these key characteristics. If the Proposed Development are located in a seascape/landscape receptor that is already affected by other similar development, this may reduce the magnitude of change if there is a high level of integration and the developments form a unified and cohesive feature in the seascape/landscape.
- **Seascape/landscape designation**: In the case of designated landscapes, the degree of change is considered in light of the effects on the special landscape qualities which underpin the designation and the effect on the integrity of the designation. All landscapes change over time and much of that change is managed or planned. Often landscapes will have management objectives for ‘protection’ or ‘accommodation’ of development. The scale of change may be localised, or occurring over parts of an area, or more widespread affecting whole landscape receptors and their overall integrity.
- **Distance**: The size and scale of change is also strongly influenced by the proximity of the Proposed Development to the receptor and the extent to which the development can be seen as a characterising influence on the landscape. Consequently, the scale or magnitude of change is likely to be lower in respect of landscape receptors that are distant from the Proposed Development and / or screened by intervening landform, vegetation and built form to the extent that the scale of their influence on landscape receptors is small or limited. Conversely, landscapes closest to the Proposed Development are likely to be most affected. Host landscapes (where the development is located within a ‘host’

landscape character unit) will be directly affected whilst adjacent areas of landscape character will be indirectly affected.

- **Amount and nature of change**: The amount of the Proposed Development that will be seen. Visibility of the Proposed Development may range from one blade tip to all of the wind turbine; generally, the greater the amount of the Proposed Development that can be seen, the higher the scale of change. The degree to which the Proposed Development is perceived to be on the horizon or 'within' the seascape/landscape. Generally, the magnitude of change is likely to be lower if the Proposed Development is largely perceived to be on the horizon at distance, rather than 'within' the seascape/landscape.

Geographical extent

The geographic extent over which the seascape/landscape effects has been experienced is also assessed, which is distinct from the size or scale of effect. This evaluation is not combined in the assessment of the level of magnitude, but instead expresses the extent of the receptor that will experience a particular magnitude of change and therefore the geographical extents of the significant and non-significant effects.

The extent of the effects will vary depending on the specific nature of the Proposed Development and is principally assessed through analysis of the extent of perceived changes to the seascape/landscape character through visibility of the Proposed Development.

Landscape effects are described in terms of the geographical extent or physical area that will be affected (described as a linear or area measurement). This should not be confused with the scale of the development or its physical footprint. The manner in which the geographical extent of the seascape/landscape effect is described for different seascape/landscape receptors is explained as follows.

- **Seascape/landscape character**: The extent of the effects on seascape/landscape character will vary depending on the specific nature of the Proposed Development. This is not simply an expression of visibility or the extent of the ZTV, but also includes a specific assessment of the extent of landscape character that will be changed by the Proposed Development in terms of its character, key characteristics and elements.
- **Landscape Designations**: In the case of a designated landscape, this refers to the extent the special landscape qualities of the designation are affected and whether this can be defined in terms of area or linear measurements, or subjectively through professional judgement (with the support of an expert topic group and / or peer review) and whether the integrity of the designation is affected.

Duration and reversibility

The duration and reversibility of seascape/landscape effects has been based on the period over which the Proposed Development are likely to exist (during construction and operation) and the extent to which these elements has been removed (during decommissioning) and its effects reversed at the end of that period. Long-term, medium-term and short-term seascape/landscape effects are defined as follows:

- long-term – more than 10 years (may be defined as permanent or reversible);
- medium-term – 6 to 10 years; and
- short-term – 1 to 5 years.

1.5.7. Seascape/landscape magnitude of change rating

The 'magnitude' or 'degree of change' resulting from the Proposed Development is described as 'High', 'High-medium', 'Medium', 'Medium-low', 'Low' or 'Negligible'. In assessing magnitude of change, the assessment focuses on the size or scale of change and its geographical extent. The duration and reversibility are stated separately in relation to the assessed effects (i.e., as short / medium / long-term and temporary / permanent). The basis for the assessment of magnitude for each receptor has been made clear using evidence and professional judgement. The levels of magnitude of change that can occur are defined in Table 1.3.

Table 1.3 Seascape/landscape magnitude of change ratings

Magnitude of change	Description/reason
High	The Proposed Development will result in a high level of alteration to the baseline characteristics or special qualities of the seascape/landscape, forming the prevailing influence and/or introducing elements that are uncharacteristic in the baseline landscape/seascape. The addition of the Proposed Development will result in a large-scale change, loss or addition to the baseline seascape/landscape.
Medium-high	Intermediate rating with combination of criteria from high or medium magnitude.
Medium	The Proposed Development will result in a medium level of alteration to the baseline characteristics or special qualities of the seascape/landscape, forming a readily apparent influence and/or introducing elements that are potentially uncharacteristic in the baseline seascape/landscape. The addition of the Proposed Development will result in a medium-scale change, loss or addition to the baseline seascape/landscape.
Medium-low	Intermediate rating with combination of criteria from medium or low magnitude.
Low	The Proposed Development will result in a low level of alteration to the baseline characteristics or special qualities of the seascape/landscape, providing a slightly apparent influence and/or introducing elements that are characteristic in the baseline seascape/landscape. The addition of the Proposed Development will result in a small-scale change, loss or addition to the baseline seascape/landscape.
Negligible	The Proposed Development will result in a negligible alteration to the baseline characteristics or special qualities of the seascape/landscape, providing a barely discernible influence and/or introducing elements that are substantially characteristic in the baseline seascape/landscape. The addition of the Proposed Development will result in negligible change, loss or addition to the baseline seascape/landscape.

1.5.8. Evaluating seascape/landscape effects and significance

The level of seascape/landscape effect is evaluated through the combination of seascape/landscape sensitivity and magnitude of change. Once the level of effect has been assessed, a judgement is then made as to whether the level of effect is 'significant' or 'not significant' as required by the relevant EIA Regulations. This process is assisted by the matrix in Table 1.6 which is used to guide the assessment. The factors considered in the evaluation of the sensitivity and the magnitude of the change resulting from the Proposed Development and their conclusion, has been presented in a comprehensive, clear and transparent manner.

Further information is also provided about the nature of the effects (whether these will be direct / indirect; temporary / permanent / reversible; beneficial / neutral / adverse or cumulative).

A significant effect will occur where the combination of the variables results in the Proposed Development having a defining effect on the seascape/landscape receptor, or where changes of a lower magnitude affect a seascape/landscape receptor that is of particularly high sensitivity. A major loss or irreversible effect over an extensive area or seascape/landscape character, affecting landscape elements, characteristics and / or perceptual aspects that are key to a nationally valued landscape are likely to be significant.

A non-significant effect will occur where the effect of the Proposed Development is not defining, and the landscape character of the receptor continues to be characterised principally by its baseline characteristics. Equally a small-scale change experienced by a receptor of high sensitivity may not significantly affect the special landscape quality or integrity of a designation. Reversible effects, on elements, characteristics and character that are of small-scale or affecting lower value receptors are unlikely to be significant.

1.6. Assessing visual effects

1.6.1. Overview

Visual effects are concerned wholly with the effect of the Proposed Development on views, and the general visual amenity and are defined by the Landscape Institute in GLVIA 3, paragraphs 6.1 as follows:

"*An assessment of visual effects deals with the effects of change and development on views available to people and their visual amenity. The concern ... is with assessing how the surroundings of individuals or groups of people may be specifically affected by changes in the context and character of views.*"

Visual effects are identified for different receptors (people) who will experience the view at their place of residence, within their community, during recreational activities, at work, or when travelling through the area. Visual effects may include changes to an existing static view, sequential views, or wider visual amenity as a result of development or the loss of particular landscape elements or features already present in the view.

The level of visual effect (and whether this is significant) is determined through consideration of the sensitivity of each visual receptor (or range of sensitivities for receptor groups) and the magnitude of change that will be brought about by the construction, operation and decommissioning of the Proposed Development.

1.6.2. Zone of Theoretical Visibility (ZTV)

Plans mapping the Zone of Theoretical Visibility (ZTV) are used to analyse the extent of theoretical visibility of the Proposed Development, across the Study Area and to assist with viewpoint selection. The ZTV does not however, take account of the screening effects of buildings, localised landform and vegetation, unless specifically noted (see individual figures). As a result, there may be roads, tracks and footpaths within the study area which, although shown as falling within the ZTV, are screened or filtered by built form and vegetation, which will otherwise preclude visibility.

The ZTVs provide a starting point in the assessment process and accordingly tend towards giving a 'worst case' or greatest calculation of the theoretical visibility.

1.6.3. Viewpoint analysis

Viewpoint analysis is used to assist the assessment and is conducted from selected viewpoints within the Study Area. The purpose of this is to assess both the level of visual effect for particular receptors and to help guide the design process and focus the assessment. A range of viewpoints are examined in detail and analysed to determine whether a significant visual effect will occur. By arranging the viewpoints in order of distance it is possible to define a threshold or outer geographical limit, beyond which significant effects will be unlikely.

The assessment involves visiting the viewpoint location and viewing wirelines and photomontages prepared for each viewpoint location. The fieldwork is conducted in periods of fine weather with good visibility and considers seasonal changes such as reduced leaf cover or hedgerow maintenance.

The SLVIA therefore includes viewpoint analysis prepared for each viewpoint and presented as supporting assessment in the SLVIA. A summary table of the findings is also provided in order of distance from the Proposed Development. This summary table assists in defining the direction, elevation, geographical spread and nature of the potential visual effects and identify areas where significant effects are likely to occur. This approach seeks to provide clarity and confidence to consultees and decision makers by allowing the detailed judgements on the magnitude of visual change to be more readily scrutinised and understood. The viewpoint analysis is used to assist the visual assessment of visual receptor locations reported in the SLVIA.

1.6.4. Evaluating visual sensitivity to change

Overview

In accordance with paragraphs 6.31-6.37 of GLVIA3, the sensitivity of visual receptors has been determined by a combination of the value of the view and the susceptibility of the visual receptors to the change likely to result from the Proposed Development on the view and visual amenity.

Value of the view

The value of a view or series of views reflects the recognition and the importance attached either formally through identification on mapping or being subject to planning designations, or informally through the value which society attaches to the view(s). The value of a view has been classified as high, medium-high, medium, medium-low or low and the basis for this assessment has been made clear using evidence and professional judgement, based on the following criteria.

- **Formal recognition** - The value of views can be formally recognised through their identification on OS or tourist maps as formal viewpoints, sign-posted and with facilities provided to add to the enjoyment of the viewpoint such as parking, seating and interpretation boards. Specific views may be afforded protection in local planning policy and recognised as valued views. Specific views can also be cited as being of importance in relation to landscape or heritage planning designations, for example the value of a view has been increased if it presents an important vista from a designed landscape or lies within or overlooks a designated area, which implies a greater value to the visible landscape.
- **Informal recognition** - Views that are well-known at a local level and/or have particular scenic qualities can have an increased value, even if there is no formal recognition or designation. Views or viewpoints are sometimes informally recognised through references in art or literature and this can also add to their value. A viewpoint that is visited or appreciated by a large number of people will generally have greater importance than one gained by very few people.

Susceptibility to change

Susceptibility relates to the nature of the viewer experiencing the view and how susceptible they are to the potential effects of the Proposed Development. A judgement to determine the level of susceptibility therefore relates to the nature of the viewer and their experience from that particular viewpoint or series of viewpoints, classified as high, medium-high, medium, medium-low or low and based on the following criteria.

- **Nature of the viewer** - The nature of the viewer is defined by the occupation or activity of the viewer at the viewpoint or series of viewpoints. The most common groups of viewers considered in the visual assessment include residents, motorists, and people taking part in recreational activity or working. Viewers, whose attention is focused on the landscape, or with static long-term views, are likely to have a higher sensitivity. Viewers travelling in cars or on trains will tend to have a lower sensitivity as their view is transient and moving. The least sensitive viewers are usually people at their place of work as they are generally less sensitive to changes in views.
- **Experience of the viewer** - The experience of the visual receptor relates to the extent to which the viewer’s attention or interest may be focused on the view and the visual amenity they experience at a particular location. The susceptibility of the viewer to change arising from the Proposed Development may be influenced by the viewer’s attention or interest in the view, which may be focused in a particular direction, from a static or transitory position, over a long or short duration, and with high or low clarity. For example, if the principal outlook from a settlement is aligned directly towards the Proposed Development, the experience of the visual receptor will be altered more notably than if the experience relates to a glimpsed view seen at an oblique angle from a car travelling at speed. The visual amenity experienced by the viewer varies depending on the presence and relationship of visible elements, features or patterns experienced in the view and the degree to which the landscape in the view may accommodate the influence of the Proposed Development.

Visual sensitivity rating

An overall level of sensitivity has been applied for each visual receptor or view – high, medium-high, medium, medium-low or low – by combining individual assessments of the value of the view and the susceptibility of the visual receptor to change. Each visual receptor, meaning the particular person or group of people likely to be affected at a specific viewpoint, is assessed in terms of their sensitivity. The basis for the assessments has been made clear using evidence and professional judgement in the evaluation of each receptor. Criteria that tend towards higher or lower sensitivity are set out in Table 1.4 below.

Table 1.4 Visual sensitivity to change criteria

Sensitivity factor	Higher	Lower
Value	Specific viewpoint identified in OS maps and / or tourist information and signage.	Viewpoint not identified in OS maps or tourist information and signage.
	Facilities provided at viewpoint to aid the enjoyment of the view.	No facilities provided at viewpoint to aid enjoyment of the view.
	View afforded protection in planning policy.	View is not afforded protection in planning policy.
	View is within or overlooks a designated landscape, which implies a higher value to the visible landscape.	View is not within, nor does it overlook, a designated landscape.
	View has informal recognition and well-known at a local level, as having particular scenic qualities.	View has no informal recognition and is not known as having particular scenic qualities.
	View or viewpoint is recognised through references in art or literature.	View or viewpoint is not recognised in references in art or literature.
	View has high scenic qualities relating to the content and composition of the visible landscape.	View has low scenic qualities relating to the content and composition of the visible landscape.
Susceptibility to change	Viewer who is likely or liable to be influenced by the Proposed Development.	Viewer who is unlikely or not liable to be influenced by the Proposed Development.
	Viewers such as walkers, or tourists, whose main attention and interest are on their surroundings.	Viewers whose main attention is not focused on their surroundings, such as people at work, or specific forms of recreation.
	Residents that gain static, long-term views of the Proposed Development in their principal outlook.	Viewers who are transient and dynamic, such as those travelling in cars or on trains, where the view is of short duration.
	Viewpoint is visited or used by a large number of people.	View is visited or gained by very few people.
	A view that is focused in a specific directional vista, with notable features of interest in a particular part of the view.	Open views with no specific point of interest, or specific directional vista away from direction of the proposed development.
	Viewers are focused on the experience of a high level of visual amenity at the location due to its overall pleasantness as an attractive visual setting or backdrop to activities.	The visual amenity experienced at the location by viewers is less pleasant or attractive than might otherwise be the case.
Sensitivity to change	**High** ◄──► **Medium**	◄──► **Low**

1.6.5. Visual magnitude of change

The visual magnitude of change is an expression of the scale of the change that will result from the Proposed Development and is dependent on a number of variables regarding the size or scale of the change and the geographical extent over which the change will be experienced. A separate assessment is also made of the duration and reversibility of visual effects.

Size or scale of change

An assessment has been made about the size or scale of change in the view that is likely to be experienced as a result of the Proposed Development, based on the following criteria:

- **Distance**: the distance between the visual receptor/viewpoint and the Proposed Development. Generally, the greater the distance, the lower the magnitude of change, as the Proposed Development will constitute a smaller scale component of the view.
- **Size**: the amount and size of the Proposed Development that will be seen. Visibility may range from small or partial visibility of the Proposed Development to all of the wind turbine and metmast being visible. Generally, the larger and greater number of the Proposed Development that appear in the view, the higher the magnitude of change. This is also related to the degree to which the Proposed Development may be wholly or partly screened by landform, vegetation (seasonal) and / or built form. Conversely open views are likely to reveal more of the Proposed Development, particularly where this is a key characteristic of the landscape.
- **Scale**: the scale of the change in the view, with respect to the loss or addition of features in the view and changes in its composition. The scale of the Proposed Development may appear larger or smaller relative to the scale of the receiving seascape/landscape.
- **Field of view**: the vertical / horizontal field of view (FoV) and the proportion of the view that is affected by the Proposed Development. Generally, the more of the proportion of a view that is affected, the higher the magnitude of change will be. If the Proposed Development extends across the whole of the open part of the outlook, the magnitude of change will generally be higher as the full view will be affected. Conversely, if the Proposed Development covers a narrow part of an open, expansive and wide view, the magnitude of change is likely to be reduced as they will not affect the whole open part of the outlook. This can in part be described objectively by reference to the horizontal / vertical FoV affected, relative to the extent and proportion of the available view.
- **Contrast**: the character and context within which the Proposed Development will be seen and the degree of contrast or integration of any new features with existing landscape elements, in terms of scale, form, mass, line, height, colour, luminance and motion. Contrasts and changes may arise particularly as a result of the rotation movement of the wind turbine blades, as a characteristic that gives rise to effects. Developments which contrast or appear incongruous in terms of colour, scale and form are likely to be more visible and have a higher magnitude of change.
- **Consistency of image**: the consistency of image of the Proposed Development in relation to other developments. The magnitude of change arising from the Proposed Development is likely to be lower if its wind turbine height is broadly similar to other developments in the seascape, in terms of its scale, form and general appearance. New development is more likely to appear as logical components of the landscape with a strong rationale for their location.
- **Skyline / background**: whether the Proposed Development will be viewed against the skyline or a background seascape may affect the level of contrast and magnitude. If the Proposed Development adds to an already developed skyline the magnitude of change will tend to be lower.
- **Number**: generally, the greater the number of separate offshore elements seen simultaneously or sequentially, the higher the magnitude of change. Further effects will occur in the case of separate developments and their spatial relationship to each other will affect the magnitude of change. For example, development that appears as an extension to an existing development will tend to result in a lower magnitude of change than a separate, new development.
- **Nature of visibility**: the nature of visibility is a further factor for consideration. The Proposed Development may be subject to various phases of development change and the manner in which it may be viewed could be intermittent or continuous and / or seasonally, due to periodic management or leaf fall.

1.6.6. Geographical extent

The geographic extent over which the visual effects will be experienced has also been assessed. This is distinct from the size or scale of effect and is described in terms of the physical area or location over which it will be experienced (described as a linear or area measurement). The extent of the effects will vary according to the specific nature of the Proposed Development and is principally assessed through ZTV, field survey and viewpoint analysis of the extent of visibility likely to be experienced by visual receptors. The geographical extent of visual effects is described as per the following examples.

The geographical extent can be described as an area measurement or proportion of the total area of the receptor affected. For example, effects on people within a particular area such as a golf course or area of common land can be illustrated via a ‘representative viewpoint’ that represents a similar visual effect, likely to be experienced by larger numbers of people within that area. The geographical extent of that visual effect can be expressed as approximately ‘5 hectares’ or ‘10%’ of an area of common land or defined recreational area.

The geographical extent can be described as a linear measurement (m or km) according to the length of route affected. For example, effects on people travelling on a route through the landscape such as a road or footpath can be illustrated via a ‘representative viewpoint’ that represents a similar visual effect, likely to be experienced by larger numbers of people along that route. The geographical extent of that visual effect can be expressed as approximately ‘2km’ or ‘10%’ of the total length of the route.

The geographical extent of a visual effect experienced from a specific viewpoint may be limited to that location alone. An example of a ‘specific viewpoint’ is a public viewpoint recommended in tourist literature such as a well visited hill summit. An example of an ‘illustrative viewpoint’ is a particular location within a built up or well vegetated area where an uncharacteristically open or restricted view exists.

1.6.7. Duration and reversibility

The duration and reversibility of visual effects are based on the period over which the Proposed Development are likely to exist (during construction and operation) and the extent to which the elements of the Proposed Development will be removed (during decommissioning), with effects reversed at the end of that period.

Long-term, medium-term and short-term visual effects are defined as follows:

- long-term – more than 10 years (may be defined as permanent or reversible);
- medium-term – 6 to 10 years; and
- short-term – 1 to 5 years.

1.6.8. Visual magnitude of change rating

The ‘magnitude’ or ‘degree of change’ resulting from the Proposed Development is described as ‘High’, ‘High-medium’, ‘Medium’, ‘Medium-low’, ‘Low’ and ‘Negligible’ as defined in Table 1.5. In assessing the magnitude of change the assessment has focused on the size or scale of change and its geographical extent. The duration and reversibility are stated separately in relation to the assessed effects (i.e., as short / medium / long-term and temporary / permanent). The basis for the assessment of magnitude for each receptor has been made clear using evidence and professional judgement..

Table 1.5 Visual magnitude of change ratings

Magnitude of change	Magnitude of change definition
High	The Proposed Development will result in a high level of alteration to the existing view, forming the prevailing influence and/or introducing elements that are uncharacteristic in the baseline view. The addition of the Proposed Development will result in a large-scale change, loss or addition to the baseline view.
Medium-high	Intermediate rating with combination of criteria from high or medium magnitude of change category.
Medium	The Proposed Development will result in a medium level of alteration to the existing view, forming a readily apparent influence and/or introducing elements that are potentially uncharacteristic in the baseline view. The addition of the Proposed Development will result in a medium-scale change, loss or addition to the baseline view.
Medium-low	Intermediate rating with combination of criteria from medium or low magnitude of change category.
Low	The Proposed Development will result in a low level of alteration to the existing view, providing a slightly apparent influence and/or introducing elements that are characteristic in the baseline view. The addition of the Proposed Development will result in a small-scale change, loss or addition to the baseline view.

Magnitude of change	Magnitude of change definition
Negligible	The Proposed Development will result in a negligible alteration to the existing view, providing a barely discernible influence and/or introducing elements that are substantially characteristic in the baseline view. The addition of the Proposed Development will result in negligible change, loss or addition to the baseline view.

1.6.9. Evaluating visual effects and significance

The level of visual effect is evaluated through the combination of visual sensitivity and magnitude of change. Once the level of effect has been assessed, a judgement is then made as to whether the level of effect is 'significant' or 'not significant' as required by the relevant EIA Regulations. This process is assisted by the matrix in Table 1.6 which is used to guide the assessment. The factors considered in the evaluation of the sensitivity and the magnitude of the change resulting from the Proposed Development and their conclusion, have been presented in a comprehensive, clear and transparent manner.

Further information is also provided about the nature of the effects (whether these will be direct / indirect; temporary / permanent / reversible; beneficial / neutral / adverse or cumulative).

A significant effect is more likely to occur where a combination of the variables results in the Proposed Development having a defining effect on the view or visual amenity or where changes affect a visual receptor that is of high sensitivity.

A non-significant effect is more likely to occur where a combination of the variables results in the Proposed Development having a non-defining effect on the view or visual amenity or where changes affect a visual receptor that is of low sensitivity.

1.6.10. Visibility

The varied clarity or otherwise of the atmosphere will reduce the number of days (the 'frequency') upon which views of the Proposed Development will be available from the coastline and hinterland, and is likely to inhibit clear views, rendering the Proposed Development as visually recessive within long distance views from the wider seascape of the SLVIA Study Area. The effects of the construction and operation of the Proposed Development will vary according to the weather and prevailing visibility. This means that effects that are may be significant in the SLVIA under 'very good' or 'excellent' (i.e. worst-case/optimum) visibility conditions, may be not significant under moderate, poor or very poor visibility conditions.

1.7. Evaluation of significance

The significance of the effect upon seascape, landscape and visual receptors is determined by correlating the magnitude of the impact and the sensitivity of the receptor, as presented in Table 1.6.

The significance of the effect on each seascape/landscape character and visual receptor is dependent on all of the factors considered in the sensitivity of the receptor and the magnitude of change resulting from the Proposed Development. Factors which influence levels of sensitivity and magnitude of change assessed in the SLVIA are set out in full above in this SLVIA Methodology. Judgements on sensitivity and magnitude of change are combined to arrive at an overall assessment as to whether the Proposed Development will have an effect that is significant or not significant on each seascape/ landscape and visual receptor.

The matrix in Table 1.6 is used as a guide to help inform the threshold of significance when combining sensitivity and magnitude to assess significance. On this basis potential impacts are assessed as of negligible, minor, moderate and major. In those instances where there would be no effect, the magnitude has been recorded as 'Zero' and the level of effect as 'None'.

For the purposes of this assessment, any effects with a significance level of major and major/moderate have been deemed significant in EIA terms (dark shaded boxed in Table 1.6). 'Moderate' levels of effect (indicated in mid-grey in Table 1.6) have the potential, subject to the assessor's professional judgement, to be considered as significant or not significant, depending on the sensitivity and magnitude of change factors evaluated. These assessments are explained as part of the assessment, where they occur.

Significance can therefore occur at a range of levels depending on the magnitude and sensitivity, however in all cases, a significant effect is considered more likely to occur where a combination of the variables results in the Proposed Development having a defining effect on the landscape/seascape character or view. Definitions are not provided for the individual categories of significance shown in the matrix and the reader should refer to the detailed definitions provided for the factors that combine to inform sensitivity and magnitude. Effects assessed as being either moderate/minor, minor, minor/negligible or negligible level are assessed as non-significant (light shaded boxes in Table 1.6).

In line with the emphasis placed in GLVIA3 upon the application of professional judgement, an overly mechanistic reliance upon a matrix is avoided through the provision of clear and accessible narrative explanations of the rationale underlying the assessment made for each landscape and visual receptor.

Table 1.6 Evaluation of seascape, landscape and visual effects

		Sensitivity				
		High	**Medium-high**	**Medium**	**Medium-low**	**Low**
Magnitude	**High**	Major (**Significant**)	Major (**Significant**)	Major / moderate (**Significant**)	Moderate (**either significant or not significant**)	Moderate / minor (**Not significant**)
	Medium-high	Major (**Significant**)	Major/ moderate (**Significant**)	Moderate (**either significant or not significant**)	Moderate (**either significant or not significant**)	Moderate / minor (**Not significant**)
	Medium	Major / moderate (**Significant**)	Moderate (**either significant or not significant**)	Moderate (**either significant or not significant**)	Moderate / minor (**Not significant**)	Minor (**Not significant**)
	Medium-low	Moderate (**either significant or not significant**)	Moderate (**either significant or not significant**)	Moderate/ minor (**Not significant**)	Minor (**Not significant**)	Minor / Negligible (**Not significant**)
	Low	Moderate / minor (**Not significant**)	Moderate / minor (**Not significant**)	Minor (**Not significant**)	Minor / Negligible (**Not significant**)	Negligible (**Not significant**)
	Negligible	Minor (**Not significant**)	Minor (**Not significant**)	Minor / Negligible (**Not significant**)	Negligible (**Not significant**)	Negligible (**Not significant**)

*Note: Moderate levels of effect may be significant or not significant subject to the assessor's opinion which shall be clearly explained.

1.8. Nature of effects

1.8.1. Overview

In this assessment the nature of effects refers to whether the landscape and / or visual effect of the Proposed Development is positive or negative (herein referred to as 'beneficial' / 'neutral' or 'adverse').

The EIA Regulations 2017 state that the ES should define '*the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the development*'.

Cumulative effects are described in Section 1.10, and 'short-term, medium-term and long-term, permanent and temporary' effects are described in Section 1.5 and Section 1.6 under the heading 'Duration of Effect'.

1.8.2. Direct and indirect effects

Direct landscape effects relate to the host landscape and concern both physical and perceptual effects on the receptor.

Indirect landscape effects relate to those landscapes and receptors which separated by distance or remote from the development and therefore are only affected in terms of perceptual effects. The Landscape Institute also defines indirect effects as those which are not a direct result of the development but are often produced away from it or as a result of a complex pathway.

Visual effects are considered as direct effects, as the view itself may be directly altered by the Proposed Development.

1.8.3. Positive and negative effects

Guidance provided by the in GLVIA3 on the nature of effect (i.e., beneficial or adverse) states that '*in the LVIA, thought must be given to whether the likely significant landscape and visual effects are judged to be positive (beneficial) or negative (adverse) in their consequences for landscape or for views and visual amenity*', but it does not provide guidance as to how that may be established in practice. The nature of effect is therefore one that requires interpretation and, where applied, this involves reasoned professional opinion.

In relation to many forms of development, SLVIA will identify 'beneficial' and 'adverse' effects by assessing these under the term 'Nature of Effect'. The seascape, landscape and visual effects of wind farms are difficult to categorise in either of these brackets as, unlike other disciplines, there are no definitive criteria by which the effects of wind farms can be measured as being categorically 'beneficial' or 'adverse'. In some disciplines, such as noise or ecology, it is possible to quantify the effect of a wind farm in numeric terms, by objectively identifying or quantifying the proportion of a receptor that is affected and assessing the nature of that effect in justifiable terms. However, this is not the case in relation to landscape and visual effects where the approach combines quantitative and qualitative assessment.

Generally, in the development of 'new' wind farms, a precautionary approach has been adopted, which assumes that significant landscape and visual effects are weighed on the adverse side of the planning balance. Unless it is stated otherwise, the effects considered in the assessment have been considered to be adverse. Beneficial or neutral effects may, however, arise in certain situations and are stated in the assessment where relevant. The following definitions have been used.

- **Beneficial effects** - contribute to the seascape, landscape and visual resource through the enhancement of desirable characteristics or the introduction of new, beneficial attributes. The development contributes to the landscape by virtue of good design or the introduction of new landscape planting. The removal of undesirable existing elements or characteristics can also be beneficial, as can their replacement with more appropriate components.
- **Neutral effects** - occur where the development fits with the existing seascape/landscape character or visual amenity. The development neither contributes to nor detracts from the landscape and visual resource and can be accommodated with neither beneficial or adverse effects, nor where the effects are so limited that the change is hardly noticeable. A change to the seascape, landscape and visual resource is not considered to be adverse simply because it constitutes an alteration to the existing situation.
- **Adverse effects** - are those that detract from the seascape/landscape character or quality of visual attributes experienced, through the introduction of elements that contrast, in a detrimental way, with the existing characteristics of the seascape, landscape and visual resource, or through the removal of elements that are key in its characterisation.

1.9. Assessing Night-time Visual Effects

1.9.1. Introduction

The assessment of night-time visual effects is based on the description of proposed wind turbine lighting set out in the project design envelope in Chapter 5 and the relevant ICAO/CAA regulations and standards, including Air Navigation Order 2016: Civil Aviation (CAA, 2016).

The effect of the visible lights will be dependent on a range of factors, including the intensity of lights used, the clarity of atmospheric visibility and the degree of negative/positive vertical angle of view from the light to the receptor. In compliance with EIA regulations, the likely significant effects of a ‘worst-case’ scenario for Proposed Development lighting are assessed and illustrated in the visual assessment.

A worst-case approach is applied to the assessment that considers the potential effects of medium-intensity 2,000 cd lights in clear visibility. It should be noted however, that medium intensity lights are only likely to be operated at their maximum 2,000 cd during periods of poor visibility. The likely residual effects is therefore likely to be lower factoring in embedded design measures, i.e. that the 2,000cd aviation lights will be dimmed to 10% of their value (200 cd) if meteorological conditions permit (when visibility is greater than 5 km).

The study area for the visual assessment of wind turbine lighting is shown in Figure 5.7 and is coincident with the 50 km SLVIA Study Area however, is particularly focused on the closest areas of the coastline.

The assessment of the lighting of the Proposed Development is intended to determine the likely effects on the visual resource i.e. it is an assessment of the visual effects of aviation lighting on views experienced by people at night. The assessment of wind turbine lighting does not consider effects of aviation lighting on landscape or seascape character (i.e. landscape or seascape effects).

ICAO indicates a requirement for no lighting to be switched on until ‘Night’ has been reached, as measured at 50 cd/m2 or darker. It does not require 2,000 candela medium intensity to be on during ‘twilight’, when landscape character may be discerned. The aviation and marine navigational lights may be seen for a short time during the twilight period when some recognition of landscape features/ profiles/ shapes and patterns may be possible. It is considered however, that level of recognition does not amount to an ability to appreciate in any detail landscape character differences and subtleties, nor does it provide sufficient natural light conditions to undertake a landscape character assessment.

The proposed aviation lighting will not have significant effects on the perception of landscape or seascape character, which is not readily perceived at night in darkness, particularly in rural areas. The matter of visible aviation and marine navigation lighting assessment is wholly a visual concern and the assessment presented focusses on that premise.

1.9.2. Significance criteria for night-time effects

The nature of the daytime and night-time effects from visible aviation and marine navigation lighting are clearly very different, in that during day light hours visibility of moving wind turbine rotors gives rise to effects that are very different to the pinpoint effects of lighting at night. It is considered therefore, that the same criteria should not be used to assess these differences in daytime and night-time effect.

In relation to the sensitivity of visual receptors, this is defined through the application of professional judgement in relation to the interaction between the ‘value’ of the view experienced by the visual receptor and the ‘susceptibility’ of the visual receptor (or ‘viewer’, not the view) to the particular form of change likely to result from the Proposed Development.

The factors weighed in reaching a decision on ‘value’ of the view are not all applicable at night-time, in the same way they may be during the day. It is not appropriate, for example, to attribute value to views at night when the detail of the view, or of elements that add value to it within a landscape, cannot readily be discerned. Furthermore, the popularity of a viewpoint during the day may be completely different to its use at night. Value factors assessed for day-time viewpoints may therefore be of less relevance to the value judgement for night-time viewpoints, which is factored into the following assessments.

In reaching a view on the significance of the likely visual effects from the visible aviation lighting, it is relevant to consider what parts of the landscape - where darkness qualities are well displayed - are likely to be affected by visibility of the aviation lights and, in turn, to understand what people might be doing in these areas at night to be susceptible to visibility of aviation lights. Descriptions of 'susceptibility' provided for daytime viewpoints and receptors in 1.5.4 are considered appropriate for the purposes of establishing receptor sensitivity at night-time, however the susceptibility of people experiencing night-time views will depend on the degree to which their perception is affected by existing baseline lighting. In brightly lit areas, or when travelling on roads from where sequential experience of lighting may be experienced, the susceptibility of receptors is likely to be lower than from within areas where the baseline contains no or limited existing lighting.

In relation to the other key component in determining significance of effect, the magnitude of change, reference to 'loss of important features' and 'composition of the view' are not readily discernible or relevant at night and, on this basis, a distinct set of criteria to explain the magnitude of change at night, as a consequence of the appearance of aviation lights, is set out in Table 1.7 below.

Table 1.7 Magnitude of Change Criteria for Night-time Visual Effects

Magnitude of change	Magnitude of change definition
High	Addition of aviation and marine navigation lighting results in large scale of change/large intrusion to the existing night-time baseline conditions/darkness in the view, due to a full and/ or close-range view of visible aviation lighting and/ or a high degree of contrast/ low degree of integration with level of baseline lighting in the view. Results in obtrusive light which compromises or diminishes the view of the night sky.
Medium	Addition of aviation lighting results in moderate scale of change/moderate intrusion to the existing night-time baseline conditions/ darkness in the view, due to partial and/ or middle-distance view of visible aviation lighting and/ or moderate level of contrast/ integration with level of baseline lighting in the view. Results in light that may partially compromise or diminish the view of the night sky, but which is not considered obtrusive.
Low	Addition of aviation and marine navigation lighting results in small scale of change/minor intrusion to the existing night-time baseline conditions/ darkness in the view, due to limited and/ or distant view of aviation lighting and/ or low degree of contrast/ high degree of integration with level of baseline lighting in the view. Results in light that does not compromise or diminish the view of the night sky, nor is it considered obtrusive.
Negligible	Addition of aviation and marine navigation lighting results in a largely indiscernible change/negligible intrusion to the existing night-time baseline conditions/ darkness in the view, due to glimpsed view of lighting and/ or slight degree of contrast/ very high degree of integration with level of baseline lighting in the view. Results in light that does not compromise or diminish the view of the night sky, nor is it considered obtrusive.

The significance of effects of aviation and marine navigation lighting is assessed through a combination of the sensitivity of the visual receptor and the magnitude of change that would result from the visible aviation lighting, taking into account the considerations described above, and informed by the matrix in Table 1.6, which gives an understanding of the threshold at which significant effects may arise.

A significant effect occurs where the aviation and marine navigation lighting would provide a defining influence on a view or visual receptor. A not significant effect would occur where the effect of the aviation and marine navigation lighting is not material, and the baseline characteristics of the view or visual receptor continue to provide the definitive influence. In this instance the aviation lighting may have an influence, but this influence would not be definitive.

In determining significance, particular attention is paid to the potential for 'Obtrusive Light' i.e. whether the lighting impedes a particular view of the night sky; creates sky glow, glare or light intrusion (ILP, 2011) in a prominent, incongruous or intrusive way.

1.10. Assessing Cumulative Seascape, Landscape and Visual effects

1.10.1. Approach to Additional or Combined Cumulative Effects

The Cumulative Effects Assessment (CEA) takes into account the impact associated with the Proposed Development together with other relevant plans, projects and activities. Cumulative effects are therefore the additional or combined effect of the Proposed Development in combination with the effects from a number of different projects, on the same receptor or resource.

GLVIA3 (Landscape Institute and IEMA 2013, p120) defines cumulative landscape and visual effects as those that *'result from additional changes to the landscape and visual amenity caused by the proposal in conjunction with other developments (associated with or separate to it), or actions that occurred in the past, present or are likely to occur in the foreseeable future.'*

NatureScot's guidance, Assessing the Cumulative Impact of Onshore Wind Energy Developments (NatureScot 2021) is widely used across the UK to inform the specific assessment of the cumulative effects of windfarms. Both GLVIA3 and NatureScot's guidance provide the basis for the methodology for the cumulative SLVIA undertaken in the SLVIA. The NatureScot (2021) guidance defines:

- *"Cumulative effects as the additional changes caused by a Proposed Development in conjunction with other similar developments or as the combined effect of a set of developments taken together (NatureScot, 2012: p4);*
- *Cumulative landscape effects are those effects that 'can impact on either the physical fabric or character of the landscape, or any special values attached to it' (NatureScot, 2021, p10); and*
- *Cumulative visual effects are those effects that can be caused by combined visibility, which occurs where the observer is able to see two or more developments from one viewpoint and / or sequential effects which occur when the observer has to move to another viewpoint to see different developments" (NatureScot, 2021, p11).*

In accordance with NatureScot guidance and GLVIA3 (para 7.13), existing/operational projects are included in the SLVIA baseline and described as part of the baseline conditions, including the extent to which these have altered character and views, and affected sensitivity to windfarm development.

In line with NatureScot guidance and GLVIA3, cumulative effects are assessed in this SLVIA as the additional changes caused by the Proposed Development in conjunction with other similar developments. The CEA set out in this section of the SLVIA assesses only the additional seascape, landscape and visual effects of the Proposed Development, in addition to the baseline conditions set out in Section 5.5. The CEA considers how the Proposed Development may result in additional cumulative seascape effects over and above those already identified, in conjunction with other plans/projects, such as through potential design discordance or the proliferation of multiple developments affecting particular characteristics or new geographic areas, and ultimately if character changes occur as a result of multiple developments becoming a prevailing characteristic of the seascape or view.

1.10.2. Scope of Cumulative Assessment

The cumulative wind farm plan (Figure 5.19) shows other relevant onshore and offshore wind farm projects are operational, consented or subject of a valid planning application within the SLVIA Study Area. A preliminary assessment of the plans, projects and activities within the SLVIA Study Area has been undertaken and is presented in the Chapter 5 (Table 5.25), listing the cumulative wind energy developments that are considered further in the CEA. Each project or plan has been considered on a case by case basis for screening in or out of the SLVIA based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

The CEA considers the effects of the addition of the Proposed Development to the projects and plans scoped into the CEA as identified in Chapter 5, focusing on those projects with which the Proposed Development may contribute to significant effects, including both onshore wind energy development and extending to the Neart na Gaoithe and Inch Cape offshore wind farms in the outer Firth of Forth (Figure 5.19).

Scoping stage sites are not considered in the CEA. This is in line with best practice in cumulative SLVIA and based on guidance (NatureScot, 2021), which recommends cumulative assessment goes only as far as assessing projects where an application has been lodged. Current guidance supports the approach of assessing projects with planning consent, such that schemes that are at the pre-planning or scoping stage are not generally considered in the assessment of cumulative effects, because of uncertainty about what will actually occur, that is, is not ‘reasonably foreseeable’. While guidance also recognises that occasionally it may be appropriate to include proposals which are in the early stages of development in an assessment, it is considered that the scoping stage developments shown on Figure 5.19 not require further assessment in the CEA as there will be no likely significant cumulative arising.

1.10.3. Cumulative Visual Effects

Cumulative visual effects consist of combined and sequential effects:

- **Combined visibility** - occurs where the observer is able to see two or more developments from one viewpoint. Combined visibility may either be where several developments are within the observer’s main angle of view at the same time, or, where the observer has to turn to see the various developments. The cumulative visual effect of the Proposed Development may be significant, or not significant, depending on factors influencing the cumulative magnitude of change, such as the degree of integration and consistency of image with other developments in combined views; and its position relative to other developments and the landscape context in successive views.
- **Sequential visibility** - occurs when the observer has to move to another viewpoint to see different developments. Sequential effects are assessed along regularly used routes such as major roads, railway lines and footpaths. The occurrence of sequential effects range from ‘frequently sequential’ (the features appear regularly and with short time lapses between, depending on speed of travel and distance between the viewpoints) to ‘occasionally sequential’ (long time lapses between appearances, because the observer is moving slowly and/or there are large distances between the viewpoints). The cumulative visual effect is more likely to be significant when frequently sequential.

1.10.4. Cumulative Seascape/ Landscape Effects

Cumulative development within a particular area may build up to create different types of seascape/landscape effect. The significance of the cumulative seascape/ landscape effects of the addition of the Proposed Development will be assessed as follows.

If the Proposed Development forms a separate isolated feature from other developments within the seascape/landscape, too infrequent and of insufficient significance to be perceived as a characteristic of the area, then the cumulative seascape/ landscape effect of the Proposed Development is unlikely to be significant.

If the addition of the Proposed Development results in offshore windfarms and/or energy generation/ transmission developments forming a key characteristic of the seascape/landscape, exerting sufficient presence as to establish or increase the extent of a ‘seascape/landscape with windfarms’; then the cumulative seascape/ landscape effect of the proposal may be significant or not significant, depending on the sensitivity of the receptor and magnitude of the change.

If the addition of the Proposed Development results in offshore windfarms forming the prevailing characteristic of the seascape/ landscape, seeming to define the seascape/ landscape as a ‘windfarm seascape/ landscape character type’ then the cumulative seascape/ landscape effect of the Proposed Development is likely to be significant.

1.10.5. Assessing cumulative seascape, landscape and visual effects

Cumulative Sensitivity of Landscape and Visual Receptors

In evaluating cumulative sensitivity in the cumulative SLVIA (section 5.10 of Chapter 5), the sensitivity to change of seascape, landscape and visual receptors are retained from the main assessment in sections 15.8 – 15.9.

Cumulative Magnitude of Change

The cumulative magnitude of change is an expression of the degree to which seascape, landscape and visual receptors will be changed by the addition of the Proposed Development cumulatively. The cumulative magnitude of change is assessed according to a number of criteria, described below.

- The location, position and visual relationship of the Proposed Development: Depending on the viewpoint/viewing angle from the coast, the Proposed Development may be viewed adjacent to other developments on the skyline, covering a wider lateral spread; they may form one grouping or could be viewed separately on the skyline (separated by space on the skyline); or could be viewed with one project being 'behind' the other project. The overall magnitude of change will vary depending on this visual relationship at different viewpoints and is likely to be higher when two projects are viewed adjacent to each other over a wider lateral spread; and lower when one project is viewed behind the other project.
- The location of the Proposed Development in relation to other developments: If the Proposed Development is seen in a part of the view or setting to a landscape receptor that is not affected by other development, this will generally increase the cumulative magnitude of change as it will extend influence into an area that is currently unaffected by development. Conversely, if the Proposed Development is seen in the context of other developments, the cumulative magnitude of change may be lower as development is not being extended to otherwise undeveloped parts of the outlook or setting. This is particularly true where the scale and layout of the proposal is similar to that of the other developments as where there is a high level of integration and cohesion with an existing site the various developments may appear as a single site.
- The extent of the developed skyline: the proportion (or horizontal angle) of the view that is affected by the combined lateral spread of the Proposed Development and other projects on the horizon. If the lateral spread/horizontal angle of the Proposed Development will add notably to the developed horizon in a view, the cumulative magnitude of change will tend to be higher.
- The number and scale of developments seen simultaneously or sequentially: Generally, the greater the number of clearly separate developments that are visible, the higher the cumulative magnitude of change will be. The addition of the Proposed Development to a view or seascape/ landscape where a number of smaller developments are apparent will usually have a higher cumulative magnitude of change than one or two large developments as this can lead to the impression of a less co-ordinated or strategic approach.
- The scale comparison between developments: If the Proposed Development is of a similar scale to other visible developments, particularly those seen in closest proximity to it, the cumulative magnitude of change will generally be lower as it will have more integration with the other sites and will be less apparent as an addition to the cumulative situation.
- The consistency of image of the proposal in relation to other developments: The cumulative magnitude of change of the Proposed Developments is likely to be lower if its turbine height, arrangement, layout design and visual appearance/aesthetics are broadly similar to other developments in the seascape, as they are more likely to appear as relatively simple and logical components of the seascape.
- The context in which the developments are seen: If projects are seen in a similar seascape/ landscape context, the cumulative magnitude of change is likely to be lower due to visual integration and cohesion between the sites. If projects are seen in a variety of different settings, this can lead to a perception that development is unplanned and uncoordinated, affecting a wide range of landscape character and blurring the distinction between them.

The magnitude of change of the Proposed Development as assessed in the project alone assessment: Where the Proposed Development is assessed to have a negligible or low magnitude of change on a view or seascape/landscape receptor, there is more likely to be a low cumulative effect.

Definitions of cumulative magnitude of change are applied in order that the process of assessment is made clear. These are:

- High - where the magnitude of change arising from the Proposed Development will result in a high cumulative change, loss or addition to the seascape/landscape receptor or view;
- Medium - where the magnitude of change arising from the Proposed Development will result in a medium change, loss or addition to the seascape/landscape receptor or view;

- Low - where the magnitude of change arising from the Proposed Development will result in a low change, loss or addition to the seascape/landscape receptor or view; and
- Negligible - where the magnitude of change arising from the Proposed Development will result in a negligible incremental change, loss or addition to the seascape/landscape receptor or view.

There may also be intermediate levels of cumulative magnitude of change - medium-high and medium-low - where the change falls between two of the definitions.

Significance of Cumulative Effects

The objective of the cumulative assessment is to determine whether any effects that the construction and operation of the offshore infrastructure will have on seascape, landscape and visual receptors, when seen or perceived cumulatively with the construction and operation of the other projects, will be significant or not significant. Significant cumulative seascape, landscape and visual effects arise where the addition of the Proposed Development, leads to offshore windfarms becoming a prevailing seascape, landscape or visual characteristic of a receptor that is sensitive to such change. Cumulative seascape/ landscape effects may evolve as follows:

A small scale, single development will often be perceived as a new or ‘one-off’ landscape feature or landmark within the seascape. Except at a local site level, it usually cannot change the overall existing seascape character, or become a new characteristic element of a landscape/seascape;

With the addition of further development, it can become a characteristic element of the landscape/ seascape, as they appear as elements or components that are repeated. Providing there was sufficient ‘space’ or undeveloped landscape/seascape between each development, or the overlapping of several developments is not too dense; they would appear as a series of developments within the landscape/seascape and would not necessarily become the dominant or defining characteristic of the seascape nor have significant cumulative effects; and

The next stage would be to consider larger scale developments and/or an increase in the number of developments within an area that either overlap or coalesce and/or ‘join-up’ along the skyline. The effect is to create a landscape/seascape where the offshore windfarm and/ or energy generation/ transmission element is a prevailing characteristic of the landscape/ seascape. The result would be to materially change the existing seascape/landscape character and resulting in a significant cumulative effect. A landscape/seascape characterised by offshore windfarm or energy generation/ transmission development may already exist as part of the baseline seascape context.

Less extensive, but nevertheless significant cumulative seascape, landscape and visual effects may also arise as a result of the addition of the Proposed Development where it results in a seascape, landscape or view becoming defined by the presence of more than one offshore windfarm or similar/large scale development, so that other patterns and components are no longer definitive, or where the proposal contrasts with the scale or design of an existing or development.

Higher levels of cumulative effect may arise when projects are clearly visible together in views, however provided that the projects are designed to achieve a high level of visual integration, with few notable visual differences between developments, these effects may not necessarily be significant. In particular, the effects of an extension to an existing development are often less likely to be significant, where the effect is concentrated, providing that the design of the developments are compatible and that the overall capacity of the seascape is not exceeded.

The capacity of the seascape/ landscape or view may be assessed as being exceeded where the seascape, landscape and visual receptor becomes defined by a particular type of development, or if the Proposed Development extends across seascape/landscape character areas or clear visual/topographic thresholds in a view.

More substantial cumulative effects may result from developments that have some geographical separation, but remain highly inter-visible, potentially resulting in extending effects into new areas, such as an increased presence of development on a skyline, or the creation of multiple, separate offshore windfarm defined seascape/landscapes.

1.11. Visual Representations

1.11.1. Overview

Zones of Theoretical Visibility (ZTVs) and visualisations (wirelines or wirelines and photomontages) are graphical images produced to assist and illustrate the SLVIA and the cumulative assessment. The methodology used for viewpoint photography and photomontages has been produced in accordance with the NatureScot guidance on Visual Representation of Wind Farms, Version 2.2 (2017), the Guidelines for Landscape and Visual Impact Assessment, Third Edition (GLVIA 3) (Landscape Institute and IEMA, 2013) and the Landscape Institute Technical Guidance Note on Visual Representation of Development Proposals (2019).

ZTVs and visual representations are produced on the assumption that the Proposed Development wind turbines are modelled relative to Highest Astronomical Tide (HAT) sea level at its maximum blade tip height (280 m).

1.11.2. Zone of theoretical visibility (ZTV)

The ZTVs in Figures 5.8 to Figure 5.18 have been calculated using computer software to generate a ZTV of the Proposed Development, to demonstrate the theoretical extent of visibility from any point in the study area.

A 3D computer model has been developed of the existing landscape and key reference using digital terrain data as follows:

- Ordnance Survey Terrain 50: Used to produce the main or standard ZTV plot and wirelines, these tiles provide a digital record of the existing landform of Great Britain, or Digital Terrain Model (DTM) at 10m elevation intervals based on 50m grid squares and models representing the specified geometry and position of the offshore elements. The computer model will include the entire study area and takes account of the effects caused by atmospheric refraction and the Earth's curvature.; and
- Ordnance Survey Terrain 5: Used to produce more detailed ZTV plots where required to assess particular effects, such as along the coastline, or within a detailed part of the study area.

The resulting ZTV plots have been overlaid on Ordnance Survey mapping at an appropriate scale and presented as figures using desktop publishing or graphic design software. Cumulative ZTV plots based on the intervisibility of the Proposed Development and other relevant developments within the Study Area have also been produced.

There are limitations in this theoretical production, and these should be considered in the interpretation and use of the ZTV as follows:

- Where the ZTV has been calculated using Ordnance Survey Terrain 50 or Terrain 5 digital terrain data, this will not account for the screening effects of vegetation or built form unless added in the form of OS Vectormap data or digitally added and stated on the figure.
- The 50 km radius ZTVs are based on a combination of OS Terrain 5 Digital Terrain Model (DTM) and OS Terrain 50 m DTM. A ZTV (Figure 5.9) has also been produced at an enlarged A1 scale.
- The ZTVs are based on theoretical visibility from 2 m above ground level.
- The Blade Tip ZTV does not indicate the decrease in visibility that occurs with increased distance from the array area. The nature of what is visible from 3 km away will differ markedly from what is visible from 10 km away, although both are indicated on the Blade Tip ZTV as having the same level of visibility.
- There is a wide range of variation within the visibility shown on the ZTV, for example, an area shown on the blade tip ZTV as having visibility of the Proposed Development may gain views of the smallest extremity of its blade tip, or of the whole wind turbine. This can make a considerable difference in the effects of the Proposed Development on that area.

These limitations mean that while the ZTV is used as a starting point in the assessment, providing an indication of where the Proposed Development will be theoretically visible and tending to present a worst-case or over-estimate the actual visibility. The information drawn from the ZTV is checked by field survey observation.

1.11.3. Methodology for baseline photography

Once a view has been selected, the location is visited, confirmed, and assessed with the aid of a wireline or similar visualisation in the field. A photographic record is taken to record the view and the details of the viewpoint location and associated data are recorded to assist in the production of visualisations and to validate their accuracy.

The following photographic information is recorded:

- date, time, weather conditions and visual range;
- GPS recorded 12 figure grid reference accurate to ~5-10 m;
- GPS recorded Above Ordnance Datum (AOD) height data;
- use of a fixed 50 mm focal length lens is confirmed;
- horizontal field of view (in degrees); and
- bearing to Target Site.

The photographs used to produce the photomontages were taken at the times of day and locations agreed with the consultees using Canon EOS 5D and 6D Digital SLR cameras, with a fixed lens and a full-frame (35 mm negative size) complementary metal oxide semiconductor (CMOS) sensor. The photographs were taken on a tripod with a pano-head at a height of approximately 1.5 m above ground.

In preparing photomontages for the SLVIA, photographs have been taken in favourable weather conditions during periods of ‘good’, ‘very good’ or ‘excellent’ visibility conditions - seeking to represent a maximum visibility scenario when the Proposed Development may be most visible.

1.11.4. Methodology for production of visualisations

Photomontages have been produced in accordance with NatureScot Visual Representation of Windfarms Guidance (NatureScot, 2017) and Landscape Institute (2019) Technical Guidance Note (TGN) 06/19 Visual Representation of Development Proposals.

A photomontage is a visualisation which superimposes an image of a Proposed Development upon a photograph or series of photographs. Photomontage is a widespread and popular visualisation technique, which allows changes in views and visual amenity to be illustrated and assessed, within known views of the ‘real’ landscape.

To create the baseline panorama, the frames are individually cylindrically projected and then digitally joined to create a fully cylindrically projected panorama using Adobe Photoshop or PTGui software. This process avoids the wide-angle effect that will result should these frames be arranged in a perspective projection, whereby the image is not faceted to allow for the cylindrical nature of the full 360-degree view but appears essentially as a flat plane.

Tonal alterations are made using Adobe software to create an even range of tones across the photographs once joined.

The baseline photographs and cumulative wireline visualisations shown for each viewpoint cover a 90-degree field of view (or in some cases, up to 360-degree), which accords with NatureScot guidance. These are cylindrically projected images and should be viewed flat at a comfortable arm’s length.

The photographs are also joined to create planar projection panoramas using PTGui software. These are used in the creation of the 53.5 degree field of view photomontages.

Wireline representations that illustrate the Proposed Development and set within a computer-generated image of the landform are used in the assessment to predict theoretical appearance of the Proposed Development. These are produced with Resoft WindFarm software and are based on OS Terrain 5 DTM. There are limitations in the accuracy of digital terrain model (DTM) data so that landform may not be picked up precisely and may result in wind turbines being more or less visible than is shown, however, the use of OS Terrain 5 minimises these limitations. Where descriptions within the assessment identify the numbers of wind turbines visible this refers to the illustrations generated and therefore the reality may differ to a degree from these impressions.

Daytime visualisations and wirelines show a wind turbine model which represents the maximum development scenario of the Proposed Development in the array area and allow the potential proportions of the wind turbine to be appreciated from the visualisations.

Fully rendered photomontages have been produced for the agreed viewpoints using Resoft WindFarm software, to provide a photorealistic image of the appearance of the Proposed Development. In the daytime photomontages modelled representations are combined with the baseline view photographs to create a photorealistic rendered photomontage image of the development.

'Panoramic photomontages' are produced in the SLVIA with a 53.5° HFoV, based on relevant guidance (NatureScot, 2017) and due to their suitability to encompass the horizontal spread of the Proposed Development and show the turbines at a representative scale and distance. In some views, two adjacent 53.5° photomontages will be required to capture the horizontal spread of the Proposed Development.

The 53.5 degree field of view wirelines and photomontages are prepared using a planar projected image and should also be viewed flat at a comfortable arm's length. These images are each printed on paper 841 x 297mm (half A1) which provides for a relatively large-scale image.

In the wirelines, the Proposed Development is shown with the wind turbine facing the viewer directly, with the full rotor diameter visible at its tallest extent. In the photomontages, the rotors are shown with a random appearance facing the viewer directly.

Rendering of the Proposed Development in the photomontages is as photorealistic as possible to the conditions shown in each viewpoint photograph. There may be some variation in the appearance and visibility of the Proposed Development between the viewpoints, as they are rendered to suit the conditions shown in each of the different viewpoint photographs, which have some unavoidable degree of variation in terms of lighting and weather conditions. The key requirement is that the Proposed Development needs to be rendered with sufficient contrast against the skyline backdrop to illustrate their maximum visibility scenario in each image. Photomontages have been prepared to depict how the Proposed Development will appear to illustrate the worst-case. The full suite of viewpoint photomontages should be viewed to gain an impression of the likely visual effects of the Proposed Development.

1.11.5. Night-time visualisations

The visual effect of the Proposed Development at night has been assessed in Chapter 5, informed by the night-time photomontage visualisations produced from representative viewpoints, to visually represent aviation and marine navigation lighting at night. Photomontages showing aviation lighting at 2,000 cd are provided to support the assessment.

Night-time visualisations have been produced using a combination of using Resoft's WindFarm software's aviation module software for positioning of the lights, 3D modelling software that can simulate lighting conditions, referencing existing lighting imagery/atmospheric conditions from the baseline photographs and professional judgement using photoshop.

The appearance of the lights in the night-time photomontages emulates how lights appear in the other parts of the baseline photographs. A light shown in a photograph tends to have a slight 'halo' (or bokeh) around it due to the way a camera lens renders out-of-focus points of light. This is not the way lights are seen in reality, as they tend to much more defined as point sources. However, the proposed lighting has been shown in this way for consistency with the lights in the baseline photographs.

1.11.6. Information on limitations of visualisations

The photographs and other graphic material such as wirelines and photomontages used in this assessment are for illustrative purposes only and, whilst useful tools in the assessment, are not considered to be completely representative of what has been apparent to the human eye. The assessments are carried out from observations in the field and therefore may include elements that are not visible in the photographs. Limitations of photomontages are set out further below.

The photomontage visualisations of the offshore elements of the Proposed Development (and any wind farm proposal) have a number of limitations when using them to form a judgement on visual impact. These include the following:

- a visualisation can never show exactly what the offshore elements of the Proposed Development will look like in reality due to factors such as: different lighting, weather and seasonal conditions which vary through time and the resolution of the image;
- the images provided give a reasonable impression of the scale of the wind turbines and the distance to the wind turbines but can never be 100% accurate;
- a static image cannot convey turbine movement, or flicker or reflection from the sun on the turbine blades as they move;
- the viewpoints illustrated are representative of views in the area, but cannot represent visibility at all locations;
- to form the best impression of the impacts of the Proposed Development proposal these images are best viewed at the viewpoint location shown;
- the images must be printed and viewed at the correct size (260mm by 820mm);
- images should be held flat at a comfortable arm’s length. If viewing these images on a wall or board at an exhibition, stand at arm’s length from the image presented to gain the best impression;
- it is preferable to view printed images rather than view images on screen. Images on screen should be viewed using a normal PC screen with the image enlarged to the full screen height to give a realistic impression; and
- there are practical limitations to shooting viewpoint photographs only in good to excellent visibility and at particular times of day. The photographs shown in the visualisations show the most favourable weather conditions available during photographic survey work.

1.11.7. Technical Methodology – Visualisations

In accordance with the requirements of Landscape Institute (2019) Technical Guidance Note 06/19, Table 1.8 sets out the technical information for the preparation of the visual representations contained in Figures 5.21 - 5.46.

Table 1.8: Technical Methodology - Visualisations

Category	Details
Photography	
Visualisation type	Type 4 – where survey of viewpoint locations is not required
Camera location	Established via hand-held Garmin GPS
Level of accuracy of location	1-3m (depending on satellites)
Camera	Canon EOS 5D Mark II and Canon EOS 6D Digital SLR. Full-frame (35mm negative size) CMOS sensor.
Lens	50mm fixed f1.4 lens
Tripod	Set to approximately 1.5m. Nodal Ninja panoramic head with Adjust Leveller. Nodal Ninja panoramic head set to take photographs at 20 degree increments
Photography process	Camera used on fully manual settings. Photographs taken in RAW image format. Bracketed exposures are taken for each view and those depicting the clearest images are selected to prepare the panoramic image
Preparation of panoramic photographs	PTGUI v12.8 is used to join and cylindrically project the images. Adobe Photoshop 2021 used to correct tonal alterations and create an even range of exposure across the photographs so that the individual photographs are not apparent. Planar panoramic images are prepared using Resoft Windfarm software or Hugin Panorma Stitcher

Category	Details
3D Model/Visualisation	
Topographic height data	Ordnance Survey Terrain 5 (5m resolution). Ordnance Survey Terrain 50 (50m resolution)
Use of coordinates in software	Coordinates are brought in from the surveyed GPS coordinates. Positions checked using aerial photography.
Markers for horizontal alignment	Existing offshore wind turbines and their known coordinates.
Markers for vertical alignment	Existing offshore wind turbines and their known coordinates.
Rendering software	Resoft Windfarm v.5.2.5.3 (Wind turbines in wirelines and photomontages). Sketchup or AutoCAD Map 3D 2018 (OSPs, Met Mast and jacket foundations). Autodesk 3ds Max 2018. Visual Nature Studio V 3.10.
Limitations	
Terrain data	There may therefore be local, small-scale landform that is not reflected in the data and subsequently the visualisation but may alter the real visibility of the Proposed Development, either by screening theoretical visibility or revealing parts of the Proposed Development that are not theoretically visible.
Movement	Static images are unable to capture the movement within the view or of the wind turbines.

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Contents

Tables

1 Introduction

1 This Technical Appendix summarises the results and analysis of two years of boat-based survey work undertaken at the Forthwind development site. Location of the proposed turbine and coverage of the survey work are illustrated in Figure 1.

2 Boat-based Survey Work

2.1 Survey method

2 Boat-based surveys designed by Ecofish Ltd, were conducted to characterise the Forthwind survey area over a two-year period from March 2015 – February 2017.

3 A survey area of 40.8 km^2 was defined and eight parallel transects placed within, running approximately perpendicular to the coast (Figure 1). Note that in year 2 four of the transects were extended by a kilometre closer to shore. This was felt to be more representative of the coastal distribution of a number of the focal species including the ducks and divers.

4 The survey team comprised two European Seabirds at Sea (ESAS) accredited surveyors, taking it in turns either to count birds or to scribe the data observed, thus preventing observer fatigue. Bird detection was primarily undertaken with the naked eye, with binoculars used as required.

5 The survey methodology followed the visual line transect survey methodology prescribed in COWRIE guidelines as updated by Camphuysen *et al.* (2004) and Maclean *et al.* (2009).

6 For each transect all bird species were recorded within a 300 m long 90^0 arc from the bow of the vessel. The search area was viewed either from the port or starboard side of the vessel, dependent upon climatic conditions, such as sun glare or rain direction.

7 Detections of birds sitting on the water were recorded in five distance bands respective to the position of the surveyor, namely 0-50 m, 50-100 m, 100-200 m, 200-300 m and >300 m (out with the transect).

8 Surveys of flying birds along each transect were undertaken at 1-minute intervals (Snapshots). Flying bird observations were also recorded out with the snapshots and allocated into five distinct height bands, namely 0-5 m, 5-20 m, 20-100 m, 100-200 m and >200 m.

9 Ornithological target species included all swans, geese, ducks, divers, grebes, shearwaters, petrels, gannets, cormorants, herons, birds of prey, waders, skuas, gulls, terns and auks. All other species were also recorded (e.g., passerines).

10 In most months, there were two surveys. There were no surveys during January 2017. Appendix 6A.1 shows the survey dates and lengths of transect covered on each survey; note, the shorter transect coverage in some months due to enforced exclusion zones around some oil rigs that were present in the area (Figure 1).

2.2 Survey analysis

11 Density and abundance were estimated using a conventional distance sampling analysis in the software DISTANCE 7.3 (Thomas *et al.* 2010). Data from all 8 transects were used to ensure sufficient sample sizes for modelling the detection function. Also noting that the transects closest to the development area were affected by the exclusion zones.

12 Enough survey data were available to model seabirds, but for other species including ducks and divers, there was only enough observations to model red-throated diver and eider. Detection functions could not be modelled for other target species including common scoter, velvet scoter, long-tailed duck and red-breasted merganser as there were too few observations.

13 For sitting birds, a species-specific detection function was fitted to the distance data associated with each observation by pooling the monthly data over each year. Data were truncated at 300 m or 500 m depending on the fit of the detection function model. Robust models (Buckland *et al.* 2001) consisting of a key function and series expansion were explored for fitting the detection functions, and the best model was chosen on the basis of the lowest Akaike Information Criterion (AIC).

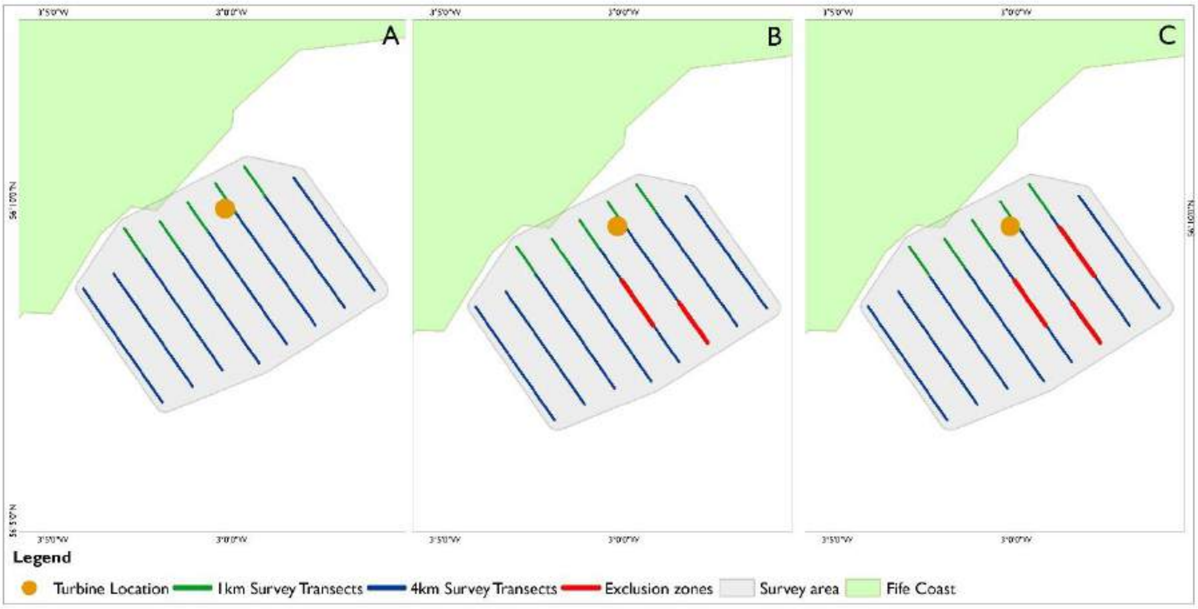
14 Data for flying birds were treated as a standard trip transect of width 300 m and the detection function modelled with a uniform key function. Only observations that were recorded during snapshot surveys were used.

15 Due to small sample sizes for most species/month combinations, mean group size over the year of data was used to estimate the abundance of birds.

16 For both sitting and flying birds, estimates were post stratified to derive density and abundance estimates for each month and year.

17 Variance was estimated empirically for all species using the delta method (Buckland *et al.* 2001). Where sample sizes allowed, non-parametric bootstrapping confidence intervals, using resamples (999) of transects within each month, were also estimated for flying birds.

Figure 1. Survey area and designed transects at Forthwind. Original transects (blue) were extended (green) in year 2 (A). Survey coverage was disrupted during year 1 (B) and year 2 (C) due to exclusion zones (red) being put in place around rigs.

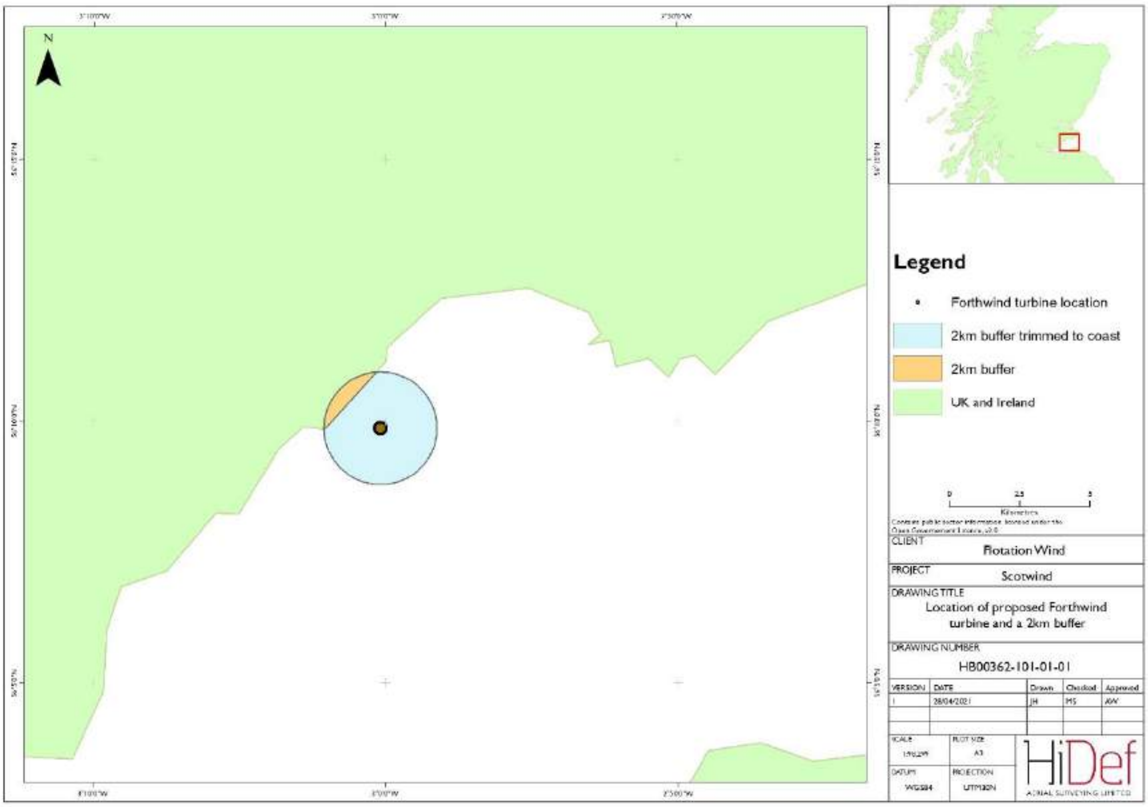


3 Results

18 The full survey observations for year 1 (March 2015 – February 2016) and year 2 (March 2016 – February 2017) of the boat-based survey work are given in Appendix 6A.2, Table 14 and Table 15. The surveys recorded a high diversity of species, with more than 40 species recorded each year.

19 The results for each species are summarised in a series of tables. These present the density estimates (calculated across the survey area) for those species at risk of collision and the abundance estimates of all birds (sitting and flying) in the impact zone for those species at risk of displacement. The impact zone is defined as the turbine itself and a precautionary 2 km buffer around it as illustrated in Figure 2.

Figure 2. Location map of the proposed Forthwind turbine and a 2 km buffer representing the impact zone (blue) used for displacement analysis



3.1 Gannet

Table 1. Density and abundance estimates of gannet at Forthwind

Gannet	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)	Abundance estimate (n) of all birds in impact zone
Mar-15	2.58	0.64	58
Apr-15	3.99	1.14	79
May-15	1.41	0.50	26
Jun-15	1.58	0.47	45
Jul-15	0.72	0.33	20
Aug-15	1.56	0.54	52
Sep-15	1.19	0.31	34
Oct-15	1.65	0.56	38
Nov-15	0.18	0.12	2
Dec-15	0.00	0.00	1
Jan-16	0.00	0.00	0
Feb-16	0.09	0.09	1
Mar-16	0.67	0.24	29
Apr-16	0.14	0.09	9
May-16	0.66	0.19	48
Jun-16	0.07	0.05	4
Jul-16	0.39	0.13	13
Aug-16	0.25	0.09	7
Sep-16	0.18	0.11	13
Oct-16	0.11	0.08	2
Nov-16	0.04	0.04	4
Dec-16	0.00	0.00	0
Feb-17	0.00	0.00	0

3.2 Kittiwake

Table 2. Density and abundance estimates of kittiwake at Forthwind

Kittiwake	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)	Abundance estimate (n) of all birds in impact zone
Mar-15	0.55	0.20	19
Apr-15	0.36	0.15	8
May-15	0.30	0.12	8
Jun-15	1.15	0.30	66
Jul-15	0.07	0.07	1
Aug-15	0.07	0.07	5
Sep-15	0.40	0.17	24
Oct-15	0.47	0.19	8
Nov-15	0.20	0.10	12
Dec-15	0.70	0.27	31
Jan-16	1.21	0.31	42
Feb-16	0.25	0.12	15
Mar-16	0.18	0.07	30
Apr-16	0.05	0.05	21
May-16	0.05	0.03	19
Jun-16	0.08	0.06	21
Jul-16	0.05	0.04	2
Aug-16	0.13	0.05	13
Sep-16	0.05	0.04	16
Oct-16	0.11	0.05	6
Nov-16	0.00	0.00	12
Dec-16	0.00	0.00	4
Feb-17	0.00	0.00	4

3.3 Herring gull

Table 3. Density estimates of herring gull at Forthwind

Herring gull	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)
Mar-15	0.34	0.16
Apr-15	0.45	0.19
May-15	0.28	0.11
Jun-15	0.62	0.14
Jul-15	0.12	0.08
Aug-15	0.13	0.09
Sep-15	0.06	0.01
Oct-15	0.19	0.11
Nov-15	0.24	0.11
Dec-15	0.48	0.17
Jan-16	1.13	0.34
Feb-16	0.59	0.19
Mar-16	0.17	0.09
Apr-16	0.06	0.06
May-16	0.09	0.04
Jun-16	0.20	0.06
Jul-16	0.00	0.00
Aug-16	0.06	0.04
Sep-16	0.03	0.03
Oct-16	0.06	0.04
Nov-16	0.33	0.16
Dec-16	0.09	0.05
Feb-17	0.15	0.07

3.4 Lesser black-backed gull

Table 4. Density estimates of lesser black-backed gull at Forthwind

Lesser black-backed gull	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)
Mar-15	0.05	0.05
Apr-15	0.00	0.00
May-15	0.00	0.00
Jun-15	0.10	0.07
Jul-15	0.00	0.00
Aug-15	0.29	0.11
Sep-15	0.00	0.00
Oct-15	0.00	0.00
Nov-15	0.00	0.00
Dec-15	0.00	0.00
Jan-16	0.00	0.00
Feb-16	0.00	0.00
Mar-16	0.00	0.00
Apr-16	0.00	0.00
May-16	0.12	0.09
Jun-16	0.12	0.09
Jul-16	0.12	0.08
Aug-16	0.06	0.06
Sep-16	0.00	0.00
Oct-16	0.00	0.00
Nov-16	0.00	0.00
Dec-16	0.00	0.00
Feb-17	0.00	0.00

3.5 Guillemot and Razorbill

Table 5. Abundance estimates of guillemot at Forthwind

Guillemot	Abundance estimate (n) of all birds in impact zone
Mar-15	146
Apr-15	207
May-15	95
Jun-15	589
Jul-15	115
Aug-15	170
Sep-15	510
Oct-15	279
Nov-15	63
Dec-15	81
Jan-16	231
Feb-16	169
Mar-16	126
Apr-16	212
May-16	216
Jun-16	106
Jul-16	245
Aug-16	122
Sep-16	223
Oct-16	272
Nov-16	291
Dec-16	45
Feb-17	139

Table 6. Abundance estimates of razorbill at Forthwind

Razorbill	Abundance estimate (n) of all birds in impact zone
Mar-15	52
Apr-15	21
May-15	3
Jun-15	85
Jul-15	0
Aug-15	0
Sep-15	22
Oct-15	5
Nov-15	0
Dec-15	4
Jan-16	88
Feb-16	82
Mar-16	67
Apr-16	29
May-16	23
Jun-16	21
Jul-16	0
Aug-16	2
Sep-16	7
Oct-16	23
Nov-16	111
Dec-16	50
Feb-17	74

3.6 Puffin and European shag

Table 7. Abundance estimates of puffin at Forthwind

Puffin	Abundance estimate (n) of all birds in impact zone
Mar-15	37
Apr-15	24
May-15	32
Jun-15	81
Jul-15	18
Aug-15	0
Sep-15	6
Oct-15	0
Nov-15	0
Dec-15	0
Jan-16	0
Feb-16	1
Mar-16	10
Apr-16	55
May-16	34
Jun-16	23
Jul-16	5
Aug-16	1
Sep-16	6
Oct-16	2
Nov-16	0
Dec-16	2
Feb-17	0

Table 8. Abundance estimates of European shag at Forthwind

European shag	Abundance estimate (n) of all birds in impact zone
Mar-15	5
Apr-15	11
May-15	4
Jun-15	9
Jul-15	1
Aug-15	11
Sep-15	5
Oct-15	7
Nov-15	10
Dec-15	46
Jan-16	0
Feb-16	17
Mar-16	9
Apr-16	17
May-16	8
Jun-16	0
Jul-16	4
Aug-16	6
Sep-16	4
Oct-16	12
Nov-16	21
Dec-16	24
Feb-17	13

3.7 Black-headed and Common gull

Table 9. Density estimates of black-headed gull at Forthwind

Black-headed gull	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)
Mar-15	0.00	0.00
Apr-15	0.00	0.00
May-15	0.00	0.00
Jun-15	0.09	0.09
Jul-15	0.00	0.00
Aug-15	0.20	0.14
Sep-15	0.10	0.10
Oct-15	0.20	0.20
Nov-15	1.27	0.48
Dec-15	1.43	0.43
Jan-16	0.10	0.10
Feb-16	0.10	0.10
Mar-16	0.02	0.02
Apr-16	0.00	0.00
May-16	0.00	0.00
Jun-16	0.00	0.00
Jul-16	0.00	0.00
Aug-16	0.00	0.00
Sep-16	0.02	0.02
Oct-16	0.08	0.04
Nov-16	0.28	0.08
Dec-16	0.03	0.03
Feb-17	0.05	0.05

Table 10. Density estimates of common gull at Forthwind

Common gull	Density estimate of flying birds in survey area (n/km²)	Standard deviation of density (n/km²)
Mar-15	0.06	0.06
Apr-15	0.00	0.00
May-15	0.00	0.00
Jun-15	0.00	0.00
Jul-15	0.06	0.06
Aug-15	0.00	0.00
Sep-15	0.13	0.09
Oct-15	0.32	0.12
Nov-15	0.88	0.25
Dec-15	0.86	0.33
Jan-16	0.24	0.11
Feb-16	0.06	0.06
Mar-16	0.00	0.00
Apr-16	0.11	0.07
May-16	0.07	0.03
Jun-16	0.00	0.00
Jul-16	0.00	0.00
Aug-16	0.00	0.00
Sep-16	0.03	0.03
Oct-16	0.17	0.06
Nov-16	0.23	0.12
Dec-16	0.03	0.03
Feb-17	0.11	0.05

3.8 Eider and Red-throated diver

Table 11. Abundance estimates of eider at Forthwind

Eider	Abundance estimate (n) of all birds in impact zone
Mar-15	7
Apr-15	4
May-15	0
Jun-15	0
Jul-15	0
Aug-15	5
Sep-15	2
Oct-15	0
Nov-15	9
Dec-15	16
Jan-16	8
Feb-16	14
Mar-16	107
Apr-16	23
May-16	14
Jun-16	0
Jul-16	23
Aug-16	42
Sep-16	30
Oct-16	17
Nov-16	18
Dec-16	18
Feb-17	137

Table 12. Abundance estimates of red-throated diver at Forthwind

Red-throated diver	Abundance estimate (n) of all birds in impact zone
Mar-15	1
Apr-15	0
May-15	0
Jun-15	0
Jul-15	0
Aug-15	0
Sep-15	1
Oct-15	0
Nov-15	4
Dec-15	3
Jan-16	0
Feb-16	1
Mar-16	3
Apr-16	0
May-16	1
Jun-16	0
Jul-16	0
Aug-16	0
Sep-16	1
Oct-16	1
Nov-16	6
Dec-16	4
Feb-17	3

4 Discussion and Conclusions

20 In both years, guillemot was the most abundant species and was present in all months.

21 The results of the boat-based survey work as analysed and reported in this Technical Appendix can be used in the impact modelling required for the Proposed Development. This includes collision risk modelling for gannet, kittiwake, herring gull, lesser black-backed gull, black-headed gull and common gull where the mean monthly densities are calculated across the two years of survey work as presented in Technical Appendix 6C.

22 Displacement analysis is also undertaken for gannet, kittiwake, guillemot, razorbill, puffin and European shag where the mean seasonal peaks of birds in the impact zone (Figure 2) are calculated from the tables in Section 3 and presented in Technical Appendix 6D.

23 As noted in Section 2.2, detection functions could not be modelled for any seaduck or diver species except red-throated diver and eider. For red-throated diver and eider only year 2 data (March 2016 – February 2017) have been considered. This was when the transects were extended 1 km towards shore and may be more representative of the coastal distribution of these species. Eider were much more abundant in year 2 and red-throated diver were slightly more abundant.

24 Potential displacement of seaduck and diver species from the impact zone (Figure 2) is further discussed in Technical Appendix 6D.

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6 Appendix 6A.1 – Summary of Survey Work

Table 13: Summary of surveys and length (km) of each transect covered within the survey area at the Forthwind. Transects with exclusion zones are highlighted in pale pink and blue and purple.

Year	Date	T1	T2	T3	T4	T5	T6	T7	T8
1	26/03/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	27/03/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	16/04/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	28/04/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	08/05/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	15/05/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	04/06/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	09/06/2015	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
1	19/07/2015	4.00	4.00	4.00	4.00	2.48	4.00	4.00	4.00
1	22/07/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	07/08/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	19/08/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	09/09/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	25/09/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	08/10/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	27/10/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	05/11/2015	4.00	4.00	4.00	4.00	2.48	2.52	4.00	4.00
1	22/11/2015	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	03/12/2015	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	14/12/2015	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	14/01/2016	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	27/01/2016	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	17/02/2016	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
1	18/02/2016	4.00	4.00	4.00	4.00	4.00	2.52	4.00	4.00
2	21/03/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	29/03/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	22/04/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	07/05/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	17/05/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	14/05/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	08/06/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	09/06/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	27/07/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	29/07/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	15/08/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	30/08/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	13/09/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	30/09/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00

2	10/10/2016	4.00	4.00	5.01	5.02	3.5	3.54	5.01	4.00
2	21/10/2016	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	10/11/2016	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	24/11/2016	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	05/12/2016	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	15/12/2016	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	27/02/2017	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00
2	28/02/2017	4.00	4.00	5.01	5.02	3.5	3.54	3.31	4.00

Appendix 6A.2 – Survey observations

Table 14: Year 1 (March 2015 – February 2016) species observations recorded during the boat-based surveys at Forthwind.

	Transect number								
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Grand Total**
Arctic Skua		1							1
Black-headed Gull	39	27	28	21	24	7	8	18	172
Black-throated Diver		1	1				1	1	4
Common Gull	28	18	12	27	13	16	14	32	160
Common Scoter	2	2	1	1			1		7
Common Tern	2	2	5	1	1	5	2	1	19
Cormorant	5	3	3	3	2	5	3	3	27
Curlew		1			1			1	3
Eider	34	18	10	7	10	7		8	94
Fulmar	10	7	3	8	2	4	13	2	49
Gannet	135	139	125	92	92	104	114	114	915
Goldeneye		1			1				2
Great Black-backed Gull	21	25	20	21	10	15	13	22	147
Great Northern Diver	2			2		1		2	7
Great Skua							1	1	2
Greenshank			1						1
Grey Heron			1						1
Guillemot	222	251	260	235	243	210	293	328	2042
Guillemot / Razorbill		2	1	5		1	1		10
Herring Gull	55	77	39	64	44	39	48	63	429
House Martin					1				1
Kittiwake	85	59	60	80	55	36	67	84	526
Lapland Bunting	1								1
Lesser Black-backed Gull	14	6	5	5	10	8	5	4	57
Little Auk	22	16	34	15	23	1	5	3	119
Long Tailed Duck		1	2		1				4
Magpie	1				1		2	1	5
Manx Shearwater	1		1	1	1	1			5
Meadow Pipit	12	5	4	12	3	2	2	12	52
Pied Wagtail		1							1
Pink-footed Goose				3		1	2	1	7
Puffin	36	32	35	38	34	24	36	26	261
Razorbill	24	33	32	44	41	27	41	46	288
Red-breasted Merganser			1						1
Redshank		1							1
Red-throated Diver	2	7	5		2	3	1	2	22
Reed Warbler		1							1
Ringed Plover	1								1

Sandwich Tern					3	4	1		8
Shag	62	47	28	14	20	22	9	22	224
Siskin								1	1
Skylark				2				1	3
Snow Bunting	1								1
Sparrowhawk	3								3
Storm Petrel	1								1
Swallow	3	3	1	1	1	3	1		13
Teal	1								1
Tufted Duck		1							1
Velvet Scoter			3	10	2	5		9	29
Whooper Swan	1								1
Grand Total	**955**	**918**	**878**	**860**	**812**	**694**	**801**	**937**	**6855**

Table 15: Year 2 (March 2016 – February 2017) species observations recorded during the boat-based surveys at Forthwind. Transects "E" denote the 1km extension on the original.

	Transect												
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**3E**	**4E**	**5E**	**7E**	**Grand Total**
Black-headed Gull	18	26	38	32	19	19	23	12	1		1		189
Black-necked Grebe			1										1
Brent Goose						1							1
Common Gull	26	27	22	32	20	12	18	14	2		3	2	178
Common Scoter	4		1	3			4	6	2				20
Common Tern	7	2	3	7	2	1	2	1					25
Cormorant	7	2	2	8	10	10	5	5		1		1	51
Curlew				1		1							2
Eider	25	6	4	13	3	17	7	5		3	1	3	87
Fulmar	4	3	1	2	3	1	1	4					19
Gannet	92	80	95	99	73	48	55	77					619
Great Black-backed Gull	23	17	24	24	16	24	10	11	1	2			152
Great Northern Diver			1	1	2		1	1				1	7
Greenshank		1	1										2
Guillemot	174	203	247	249	180	170	268	299				1	1791
Guillemot / Razorbill	1							1					2
Herring Gull	42	46	58	70	53	42	52	66	2	1	1		433
Kestrel						1							1
Kittiwake	53	47	70	59	51	23	21	30					354
Lesser Black-backed Gull	7	6	5	9	1	3	6	9					46
Little Auk								1					1
Little Grebe								1					1
Long Tailed Duck	2	1	2	3	3	8	12	3	1	1		5	41
Magpie				1									1

Manx Shearwater	2		1				1	1					5
Meadow Pipit	1	4	2	7	16	18	11	8					67
Mediterranean Gull			1	1									2
Oystercatcher					1								1
Pink-footed Goose		1		1									2
Puffin	25	19	21	25	20	2	18	20					150
Razorbill	25	31	49	46	31	23	34	40		1		1	281
Red-breasted Merganser		1	1										2
Red-throated Diver	7	2	9	7	6	3	3	1				1	39
Ruff			1										1
Sand Martin					1		1						2
Sandwich Tern	5	3	1	4	3	5	4	3					28
Scaup							2						2
Shag	40	14	25	33	21	18	22	12	1	3		2	191
Shelduck	1												1
Skylark	3		1										4
Swallow	1	1	2	1		1	2	4					12
Velvet Scoter			6	6	5	3	10	9	5			3	47
Whooper Swan	1												1
Wigeon			1										1
Grand Total	**596**	**543**	**696**	**744**	**540**	**454**	**593**	**644**	**15**	**12**	**6**	**20**	**4863**

Forthwind: Offshore Ornithology
6B Technical Appendix - Apportioning

Authorisations

Responsibility	Name	Signature	Date
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Issue	Date	Status / Changes
1	12/11/2021	First draft for client
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Contents

1 Connectivity in the Breeding Season

1.1 Introduction

1 During the breeding season, seabirds are central-placed foragers going out to forage at sea from their nest sites on coastal cliffs or islands. Most of the birds recorded at sea during the breeding season will be breeding adults associated with a breeding colony.

2 This Technical Appendix addresses the following species recorded at the Proposed Development, identified as breeding season interests, see Table 6.4 of Chapter 6 of the Environmental Statement (ES), Offshore Ornithology:

Gannet	*Morus bassanus*
Kittiwake	*Rissa tridactyla*
Herring gull	*Larus argentatus*
Lesser black-backed gull	*Larus fuscus*
Guillemot	*Uria aalge*
Razorbill	*Alca torda*
Puffin	*Fratercula arctica*
European shag	*Phalacrocorax aristotelis*

4 The foraging range for each species is presented in Table 1 below, based on the mean max foraging distance plus one standard deviation (SD) given in Woodward *et al.* (2019) (Table 1).

Table 1. Species and foraging ranges as per Woodward et al. (2019)

Species	Mean Max (km)	1 SD (km)
Gannet	315.2	194.2
Kittiwake	156.1	144.5
Herring gull	58.8	26.8
Lesser black-backed gull	127.0	109.0
Guillemot	73.2	80.5
Razorbill	88.7	75.9
Puffin	137.1	128.3
European shag	13.2	10.5

5 This information is used to check which breeding seabird colonies are within foraging range of the Proposed Development. The colonies that have been considered are all Special Protection Areas (SPAs), in this regard there is 'connectivity' between each SPA and the Proposed Development. This process provides a 'long-list' of SPAs to be considered for each species as set out in Tables 2-7 below.

6 In this regard, for lesser black-backed gull and for European shag there is only the Forth Islands SPA within foraging range, so these species are not included in the long-lists in Section 1.2 but are further addressed in Section 2.

1.2 SPA long-lists for each species

7 The SPA long-lists for each species are presented in the tables below. This includes the distance between SPA and the proposed development, as well as the most recent population counts to be used in apportioning, as further discussed in Section 2.2.

1.2.1 Gannet

Table 2. SPA long-list for gannet

Gannet SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Fair Isle	420	860	2020
Forth Islands	9	150,518	2014
Flamborough & Filey Coast	293	26,784	2017
Noss	498	27,530	2019
Sule Skerry and Sule Stack	453	18,130	2013/2018
Troup, Pennan and Lions Heads (SSSI feature)	254	9,650	2019

1.2.2 Kittiwake

Table 3. SPA long-list for kittiwake

Kittiwake SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Buchan Ness to Collieston Coast	168	22,590	2019
Farne Islands	106	8,804	2019
Flamborough & Filey Coast	293	91,008	2017
Forth Islands	9	6,822	2018/2021
Fowlsheugh	111	28,078	2018
St Abbs Head to Fast Castle	50	10,402	2016-2019
Troup, Pennan and Lions Heads	254	21,232	2017

1.2.3 Herring gull

Table 4. SPA long-list for herring gull

Herring gull SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Forth Islands	9	7,230	2019-2021
St Abbs Head to Fast Castle	50	612	2016-2020

1.2.4 Guillemot

Table 5. SPA long-list for guillemot

Guillemot SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Farne Islands	106	64,042	2019
Forth Islands	9	20,755	2018-2021
Fowlsheugh	111	69,828	2018
St Abbs Head to Fast Castle	50	45,827	2016-2018

1.2.5 Razorbill

Table 6. SPA long-list for razorbill

Razorbill SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Forth Islands	9	5,209	2017-2019
Fowlsheugh	111	14,063	2018
St Abbs Head to Fast Castle	50	2,931	2016-2018

1.2.6 Puffin

Table 7. SPA long-list for puffin

Gannet SPAs	Distance to Forthwind (km)	Count of adults (individuals)	Year of count
Farne Islands	106	87,504	2019
Forth Islands	9	78,406	2017-2020

2 Apportioning in the Breeding Season

2.1 Introduction

8 Once connectivity and the SPA long-lists have been established for each species then apportioning can be used to determine the proportional weightings between each SPA within foraging range. Apportioning follows the guidance issued by NatureScot (2018) and the calculated weightings are used to determine the numbers of birds / estimates of impacts to be assigned to each SPA.

2.2 Method

9 Apportioning during the breeding season focuses on the key SPA breeding populations of concern. The seabird populations used in the calculation are summarised for each species in **Error! Reference source not found.**-7, obtained from the Seabird Monitoring Programme database.

10 In line with the guidance, apportioning is based on numbers of individuals at each colony for a defined baseline (NatureScot, 2018). Counts must be comparable across sites so that if there is a significant gap between the counts at different sites then an earlier baseline should be used. At Forthwind it was possible to use most recent counts for all species.

11 The apportioning calculation is a weighting based on population size, distance between the Proposed Development and the SPAs within foraging range, and area of sea included in the foraging range (NatureScot, 2018). The apportioning calculation has been coded by HiDef into the R programming language and a copy of the code can be provided upon request.

12 Distances were measured on a precautionary basis from nearest boundary of each SPA to nearest boundary of the Proposed Development. To be biologically meaningful, these are the ‘at sea’ distances i.e., the actual distance the bird flies across water between the breeding site and the Proposed Development.

13 Outputs from the apportioning calculations for each species are provided in Section 2.3. It is suggested that this information may be helpful in identifying those SPAs with ‘likely significant effect’ which will need to be addressed in Habitats Regulations Appraisal (HRA) for the project, although that is ultimately a judgement for Marine Scotland and their advisers.

14 The suggested SPA breeding seabird colonies for the HRA short-list are presented in Table 14 in Section 2.4. This HRA short-list informs the assessment for these interests as set out in Section 6.7.3.4 and Table 6.6 of ES Chapter 6, Offshore Ornithology.

2.3 Results

2.3.1 Gannet

Table 8. Gannet SPA apportioning

Gannet SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	15,0518	9	1.420	1189.779	1
Fair Isle	860	420	1.108	0.002	0
Noss	27,530	498	1.080	0.054	0
Sule Skerry and Sule Stack	18,130	453	1.137	0.045	0
Troup, Pennan and Lion`s Heads (SSSI)	9,650	254	1.215	0.082	0
Flamborough & Filey Coast	26,784	293	1.450	0.204	0

2.3.2 Kittiwake

Table 9. Kittiwake SPA apportioning

Kittiwake SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	6,822	9	1.634	13.726	0.902
St Abb`s Head to Fast Castle	10,402	50	1.664	0.691	0.045
Fowlsheugh	28,078	111	1.490	0.339	0.022
Flamborough & Filey Coast	91,008	293	1.692	0.179	0.012
Farne Islands	8,804	106	1.633	0.128	0.008
Buchan Ness to Collieston Coast	22,590	168	1.388	0.111	0.007
Troup, Pennan and Lion`s Heads	21,232	254	1.363	0.045	0.003

2.3.3 Herring gull

Table 10. Herring gull SPA apportioning

Herring gull SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	7,230	9	3.131	18.345	0.998
St Abb`s Head to Fast Castle	612	50	1.883	0.030	0.002

2.3.4 Lesser black-backed gull

15 Forth Islands SPA is the only site within foraging range of lesser black-backed gull, therefore for this species all breeding season impacts are apportioned to this SPA.

2.3.5 Guillemot

Table 11. Guillemot SPA apportioning

Guillemot SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	20,755	9	2.603	10.663	0.919
St Abb`s Head to Fast Castle	45,827	50	2.139	0.627	0.054
Farne Islands	64,042	106	1.758	0.160	0.014
Fowlsheugh	69,828	111	1.656	0.150	0.013

2.3.6 Razorbill

Table 12. Razorbill SPA apportioning

Razorbill SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	5,209	9	2.495	17.061	0.973
St Abb`s Head to Fast Castle	2,931	50	2.144	0.267	0.015
Fowlsheugh	14,063	111	1.673	0.203	0.012

2.3.7 Puffin

Table 13. Razorbill SPA apportioning

Puffin SPA	SPA Count	Distance (km)	1/proportion foraging range as sea	Resulting weight	Proportional weight
Forth Islands	78,406	9	1.733	33.360	0.992
Farne Islands	87,504	106	1.697	0.263	0.008

2.3.8 European shag

16 Forth Islands SPA is the only site within foraging range of European shag, therefore for this species all breeding season impacts are apportioned to this SPA.

2.4 Conclusions

17 This apportioning provides an overview of those SPA seabird breeding colonies where a higher level of impact is likely to be considered against the site. Impacts during the breeding season are modelled for the Proposed Development in the supporting technical appendices on collision risk and displacement and will be apportioned between the different breeding colonies, as identified, based on the weightings for each species reported in Tables 8-13.

18 Apportioning outputs can be used to help identify a 'short-list' of breeding seabird SPA for consideration in the impact assessment (Table 14.). These are the SPAs where apportioning would suggest 'likely significant effect' although that is ultimately a judgement for Marine Scotland and their advisers.

19 Table 14 presents most recent SPA counts from the Seabird Monitoring Programme database. These are the populations against which to consider the apportioned impacts, as presented in Section 6.7.3.4 of ES Chapter 6, Offshore Ornithology.

Table 14. Short-list of SPA breeding populations for assessment

Species	SPA	Most recent count	Count unit*	Year
Gannet	Forth Islands	75,259	AOS	2014
Kittiwake	Forth Islands	3,411	AON	2018 - 2021
Herring gull	Forth Islands	3,615	AON/AOT	2019 - 2021
Lesser black-backed gull	Forth Islands	1,801	AON/AOT	2018 - 2021
Guillemot	Forth Islands	20,755	IND	2018 - 2021
Razorbill	Forth Islands	5,038	AOS/IND	2017 - 2019
Puffin	Forth Islands	39,206	AOB/IND	2017 - 2020
European shag	Forth Islands	441	AON	2018 - 2021

* Count Units: AOS – apparently occupied sites, AON – apparently occupied nests, AOT – apparently occupied territory, IND – individuals

3 References

NatureScot. (2018). *Interim Guidance on apportioning impacts from marine renewable developments to breeding seabird populations in SPAs.*

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Forthwind: Offshore Ornithology 6C Technical Appendix - Collision Risk Modelling

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Document History

Issue	Date	Status / Changes
1	12/11/2021	First draft for client, based on stochastic CRM
2	28/03/2021	Second draft for client, based on Band (2012) spreadsheets

Contents

Tables

1 Introduction

1 Collision risk is a possible impact from offshore wind farm development whereby birds may be injured or killed by an encounter or collision with turbines or rotor blades. Band (2012) provides a consistent and quantitative method for offshore collision risk, estimating the likelihood that a bird entering the 'risk window', the sweep of the turbine blades, could be struck. The model assumes a strike equates to mortality.

2 As such the calculation assumes that birds do not take avoiding action; this is factored in subsequently by applying an agreed avoidance rate. The avoidance rate accounts for changes in bird behaviour to avoid being struck, whether this is by avoiding the wind farm completely (macro-avoidance) or altering their flight path in proximity to the turbine blades (meso and micro-avoidance). While there are limitations to collision risk modelling (CRM), it does provide a standard approach to estimating relative risk to the seabird species of concern.

3 Furness *et al.* (2013) consider the sensitivities of key seabird species to collision risk, and these are the species recorded at Forthwind that may be subject to this impact:

- Gannet (*Morus bassanus*)
- Kittiwake (*Rissa tridactyla*)
- Herring gull (*Larus argentatus*)
- Lesser black-backed gull (*Larus fuscus*)
- Black-headed gull (*Chroicocephalus ridibundus*)
- Common gull (*Larus canus*)

4 This appendix presents the input parameters and outputs for CRM using the Band (2012) spreadsheets. Input parameters are discussed and presented in Section 2, and the outputs for each species are presented in Section 3. Monthly input densities of flying birds are discussed in Section 2.2.5 and presented in Appendix 6C.1. The spreadsheets themselves are provided alongside as part of the overall application.

5 The CRM outputs presented in Section 3 provide a quantification of collision risk impact for each species for consideration in ES chapter 6 on Offshore Ornithology.

2 Methods

2.1 Band (2012) spreadsheets

6 The Band (2012) spreadsheets are a deterministic version of the CRM, modelled in Excel using macros and cell-to-cell calculations. The overall approach to CRM is described in Band (2012) and summarised as follows:

> **Step 1.** Assemble data on the number of flights which, in the absence of birds being displaced or taking other avoiding action, or being attracted to the windfarm, are potentially at risk from windfarm turbines.

Step 2. Use this flight activity data to estimate the potential number of bird transits through the rotors of the Forthwind turbine.

Step 3. Calculate the probability of collision during a single bird rotor transit.

Step 4. Multiply these to yield the potential collision mortality rate for the bird species in question, allowing for the proportion of time that turbines are not operational, assuming current bird use of the site and that no avoiding action is taken.

Step 5. Allow for the proportion of birds likely to avoid the turbine, either because they have been displaced around it or because they take evasive action; and allow for any attraction.

Stage 6. Express the uncertainty surrounding such a collision risk estimate.

7 The spreadsheets undertake the calculations for Steps 2-5 using the following input parameters.

2.2 Input parameters

8 The input parameters used in the CRM for Forthwind are detailed below. These include details on the turbine scenario, turbine operation, seabird biometric information, mean densities for each species recorded during boat-based survey work, model option and avoidance rates.

2.2.1 Turbine scenario

9 The maximum parameters for the proposed single 20 MW turbine at Forthwind are presented in Table 1.

Table 1. Forthwind turbine parameter values

Parameters	Single turbine (20 MW)
Latitude (degrees)	56.2
Windfarm width (km)	0.3
Tidal offset (m)	3
No. turbines	1
No. blades	3
Rotor radius (m)	127.5
Air gap (m)	25
Max. blade width (m)	5.8
Upper blade height (m)	280
Rotation speed (rpm)	9.9
Pitch (degrees)	2
Mean wind speed	n/a

2.2.2 Turbine operation

10 The turbine is assumed to be operational 95% of the time to allow for downtime due to wind speed (either too low or too high for effective turbine operation) and maintenance activities (either scheduled or unscheduled).

2.2.3 Seabird parameters

CRM uses agreed seabird parameters taken from Pennycuick (1997), Alerstam *et al.* (2007) and Furness *et al.* (2018). According to general practice, gliding flight has been used for gannet and flapping flight for all other species.

Table 2. Seabird biometric and behavioural input parameters for CRM

Species	Body length (m)	Wingspan (m)	Flight speed (m/sec)	Nocturnal activity	Flight type (flapping or gliding)
Gannet	0.935	1.73	13.1	0.08	Gliding
Kittiwake	0.39	1.08	7.26	0.33	Flapping
Herring gull	0.595	1.44	12.8	0.50	Flapping
Lesser black-backed gull	0.58	1.43	12.8	0.50	Flapping
Black-headed gull	0.355	1.05	8.9	0.50	Flapping
Common gull	0.41	1.02	13.4	0.50	Flapping

2.2.4 Seabird flight heights

11 Seabird flight heights were recorded during the boat-based survey work carried out for Forthwind. The flight heights were collected monthly for two years with birds identified as flying in one of 5 bands; Band 1: 0-5 m, Band 2: 5-20 m, Band 3: 20-100 m, Band 4: 100-200 m and Band 5: > 200 m. The proportion of birds considered to be at collision risk height were those in bands 3, 4 and 5, flying at heights from 20 m to >200 m. This range of flight heights does not correspond to the turbine specifications (25-280 m), so that using these data would lead to an over-estimation of potential collision risk.

12 In preference, the generic flight height data presented in Johnston *et al.* (2014) have been used. These data also derive from boat-based surveys, pooled from 32 sites in the North, Baltic and Irish Seas and from predominantly coastal areas. The data were collected monthly over 15 years between 1998 and 2012, providing a larger pool of information from which to derive flight heights compared to a single site. The data were modelled to produce a continuous flight height distribution in one metre bands, from 0-300 m. The flight height of a single bird is estimated by the observer with uncertainty, and this modelling approach takes the uncertainty in individual flight height estimates into account. This improves the accuracy of the estimated flight height distribution when compared with individual birds categorised into height bands.

2.2.5 Seabird monthly densities

13 For collision risk modelling the input data required are monthly means of the densities of flying seabirds. The densities are calculated as the monthly means across the two years of survey work and presented in Appendix 6C.1 to this report. Standard deviations were calculated and have also been presented, however, it is not possible to utilise this information when undertaking CRM using the deterministic Band (2012) spreadsheets.

2.2.6 Model option

14 Following guidance from the statutory nature conservation bodies (SNCB, 2014), gannet and kittiwake were modelled using the basic CRM model option 2 with generic flight height data as discussed in Section 2.2.4 above. Herring gull, lesser black-backed gull, black-headed gull and common gull were modelled using the extended CRM model option 3 with the generic flight height data.

2.2.7 Avoidance rates

15 The SNCBs provided advice on CRM avoidance rates in response to the Cook *et al.* (2014) report (SNCB, 2014). These rates have been adopted for use in assessment as presented in Table 3 below, except for gannet where a more precautionary 98% avoidance rate has been used following advice from RSPB.

Table 3. Avoidance rates used for each species in the CRM

Species	**SNCB advice**	
	Option 2	**Option 3**
Gannet	0.98	-
Kittiwake	0.989	-
Herring gull	-	0.99
Lesser black-backed gull	-	0.989
Black-headed gull	-	0.989
Common gull	-	0.989

3 Results

16 The CRM mortality estimates are presented by season, based on the breeding seasons defined in NatureScot (2020) and the non-breeding seasons defined in Furness (2015).

3.1 Gannet

17 For gannet, seasonal collision mortalities are presented in Table 4; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 4. Gannet collision mortalities (numbers of birds) for model option 2

Gannet collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
Seasonal mortality	1	0	n/a	0

3.2 Kittiwake

18 For kittiwake, seasonal collision mortalities are presented in Table 5; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 5. Kittiwake collision mortalities (numbers of birds) for model option 2

Kittiwake collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid Apr - Aug	Aug - Dec	n/a	Jan - Apr
Seasonal mortality	0	0	n/a	0

3.3 Herring gull

19 For herring gull, seasonal collision mortalities are presented in Table 6; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 6. Herring gull collision mortalities (numbers of birds) for model option 3

Herring gull collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Aug	n/a	Sep-Feb	n/a
Seasonal mortality	0	n/a	0	n/a

3.4 Lesser black-backed gull

20 For lesser black-backed gull, seasonal collision mortalities are presented in Table 7; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 7. Lesser black-backed gull collision mortalities (numbers of birds) for model option 3

Lesser black-backed gull collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jul	Aug-Oct	Nov-Feb	Mar-Apr
Seasonal mortality	0	0	0	0

3.5 Black-headed gull

21 For black-headed gull, non-breeding season collision mortalities are presented in Table 8; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 8. Black-headed gull seasonal collision mortalities (numbers of birds) for model option 3

Black-headed gull collision mortalities	NatureScot Non-breeding season
	Sep - Mar
Seasonal mortality	0

3.6 Common gull

22 For common gull, non-breeding season collision mortalities are presented in Table 9; sum of the monthly CRM outputs presented in Appendix 6C.1. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 9. Common gull seasonal collision mortalities (numbers of birds) for model option 3

Common gull collision mortalities	NatureScot non-breeding season
	Sep - Mar
Seasonal mortality	0

4 Discussion and Conclusions

23 For all species, except gannet, the seasonal collision risk mortalities are zero. This is not surprising given that Forthwind is a single turbine located relatively close to shore. For all species the input densities are low, and especially for black-headed gull and common gull.

24 For gannet and kittiwake, collision risk and displacement are modelled separately and then the impacts are summed to be considered in combination as a ‘worst-case’. This is done in section 6.7.3.4 of ES chapter 6 on Offshore Ornithology.

25 For all species impacts are considered against the identified SPA reference populations, see section 6.7.3.4 of ES chapter 6.

5 References

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6 Appendix 6C.1 – Monthly mean input densities and collision risk outputs

6.1 Gannet

Table 10. Gannet monthly mean input flying bird densities and CRM option 2 mortality estimates

Gannet	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	0.00	0.04	1.63	2.07	1.04	0.83	0.55	0.90	0.69	0.88	0.11	0.00
Input densities standard deviation	0.00	4.04	0.66	1.14	0.51	0.47	0.34	0.54	0.32	0.56	0.12	0.00
CRM option 2 mortality estimates	0	0	0	1	0	0	0	0	0	0	0	0

6.2 Kittiwake

Table 11. Kittiwake monthly mean input flying bird densities and CRM option 2 mortality estimates

Kittiwake	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	1.21	0.13	0.36	0.21	0.18	0.62	0.06	0.10	0.23	0.29	0.10	0.35
Input densities standard deviation	0.31	0.12	0.21	0.15	0.12	0.30	0.07	0.08	0.17	0.19	0.10	0.27
CRM option 2 mortality estimates	0	0	0	0	0	0	0	0	0	0	0	0

6.3 Herring gull

Table 12. Herring gull monthly mean input flying bird densities and CRM option 3 mortality estimates

Herring gull	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	1.13	0.37	0.26	0.26	0.19	0.41	0.06	0.10	0.05	0.13	0.29	0.29
Input densities standard deviation	0.34	0.20	0.17	0.19	0.11	0.15	0.08	0.09	0.02	0.11	0.16	0.17
CRM option 3 mortality estimates	0	0	0	0	0	0	0	0	0	0	0	0

6.4 Lesser black-backed gull

Table 13. Lesser black-backed gull monthly mean input flying bird densities and CRM option 3 mortality estimates

Lesser black-backed gull	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	0.00	0.00	0.03	0.00	0.06	0.11	0.06	0.17	0.00	0.00	0.00	0.00
Input densities standard deviation	0.00	0.00	0.05	0.00	0.06	0.09	0.06	0.12	0.00	0.00	0.00	0.00
CRM option 3 mortality estimates	0	0	0	0	0	0	0	0	0	0	0	0

6.5 Black-headed gull

Table 14. Black-headed gull monthly mean input flying bird densities and CRM option 3 mortality estimates

Black-headed gull	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	0.10	0.08	0.01	0.00	0.00	0.05	0.00	0.10	0.06	0.14	0.78	0.73
Input densities standard deviation	0.10	0.10	0.02	0.00	0.00	0.09	0.00	0.14	0.10	0.20	0.48	0.43
CRM option 3 mortality estimates	0	0	0	0	0	0	0	0	0	0	0	0

6.6 Common gull

Table 15. Common gull monthly mean input flying bird densities and CRM option 3 mortality estimates

Common gull	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly input densities (n/km^2)	0.24	0.09	0.03	0.06	0.04	0.00	0.03	0.00	0.08	0.25	0.56	0.45
Input densities standard deviation	0.11	0.61	0.06	0.04	0.24	0.00	0.06	0.00	0.09	0.13	0.26	0.33
CRM option 3 mortality estimates	0	0	0	0	0	0	0	0	0	0	0	0

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩	used in overall collision risk sheet
🟨	used in migrant collision risk sheet
🟧	used in single transit collision risk sheet or extended model
🟪	used in available hours sheet
⬜	used in large array correction sheet
🟥	not used in calculation but stated for reference

Bird data	**Units**	**Value**	**Data sources**
Species name		**Black-headed gull**	
Bird length	m	0.36	
Wingspan	m	1.05	
Flight speed	m/sec	8.9	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

Data sources

Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0.1	0.075	0.01	0	0	0.045	0	0.1	0.06	0.14	0.775	0.73
Proportion at rotor height	%	35.1%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data														
Migration passages	birds		0	0	0	4000	2000	0	0	0	2000	4000	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

Windfarm data	**Units**	**Value**	**Data sources**
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

Turbine data	**Units**	**Value**	**Data sources**											
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

Avoidance rates used in presenting results		**Data sources (if applicable)**
	100.00%	
	98.90%	SNCB 2014
	100.00%	
	100.00%	

COLLISION RISK ASSESSMENT

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:																
Species		Black-headed gull														
Flight speed	m/sec	8.9														
Nocturnal activity factor (1-5)		3														
Nocturnal activity (% of daytime)		50%														
Windfarm data:																
Latitude	degrees	56.2														
Number of turbines		1														
Rotor radius	m	127.5														
Minimum height of rotor	m	152.5														
Total rotor frontal area	sq m	51071														
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**	
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%	
Stage A - flight activity																
Daytime areal bird density	birds/sq km		0.1	0.075	0.01	0	0	0.045	0	0.1	0.06	0.14	0.775	0.73		
Proportion at rotor height	%	35.1%														
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218		
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526		
Flux factor			315	226	36	0	0	180	0	389	213	480	2409	2253		
Option 1 -Basic model - Stages B, C and D															**per annum**	
Potential bird transits through rotors			110	79	12	0	0	63	0	137	75	168	846	791	**2282**	
Collision risk for single rotor transit	(from sheet 3)	4.8%														
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**5**	**4**	**1**	**0**	**0**	**3**	**0**	**6**	**3**	**8**	**39**	**36**	**105**	
Option 2-Basic model using proportion from flight distribution			**1**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**7**	**6**	**19**	
Option 3-Extended model using flight height distribution		Black-headed gull														
Proportion at rotor height	(from sheet 4)	6.3%														
Potential bird transits through rotors	Flux integral	0.0240	8	5	1	0	0	4	0	9	5	12	58	54	**156**	
Collisions assuming no avoidance	Collision integral	0.00062	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**4**	
Average collision risk for single rotor transit		2.6%														
Stage E - applying avoidance rates																
Using which of above options?	**Option 3**	0.00%	0	0	0	0	0	0	0	0	0	0	1	1	**4**	
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	SNCB 2014
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

COLLISION RISK ASSESSMENT

Sheet 3 - probability of collision for single bird transit through rotor

🟩	**All input data must be entered on Sheet 1, not here**
🟧	**However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦	Calculated outputs
🟨	Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	k-headed gull	
BirdLength	0.36	m
Wingspan	1.05	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	8.9	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.34	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.35	7.26	0.404	6.96	0.387
0.10	0.79	0.67	3.95	0.220	3.63	0.202
0.15	0.88	0.45	2.94	0.163	2.58	0.144
0.20	0.96	0.34	2.42	0.135	2.03	0.113
0.25	1.00	0.27	2.12	0.118	1.71	0.095
0.30	0.98	0.22	1.83	0.102	1.43	0.080
0.35	0.92	0.19	1.57	0.087	1.19	0.066
0.40	0.85	0.17	1.36	0.075	1.01	0.056
0.45	0.80	0.15	1.21	0.067	0.89	0.049
0.50	0.75	0.13	1.09	0.061	0.79	0.044
0.55	0.70	0.12	0.99	0.055	0.71	0.039
0.60	0.64	0.11	0.90	0.050	0.64	0.036
0.65	0.58	0.10	0.82	0.046	0.59	0.033
0.70	0.52	0.10	0.75	0.042	0.54	0.030
0.75	0.47	0.09	0.69	0.039	0.50	0.028
0.80	0.41	0.08	0.64	0.035	0.47	0.026
0.85	0.37	0.08	0.60	0.033	0.45	0.025
0.90	0.30	0.07	0.55	0.030	0.42	0.024
0.95	0.24	0.07	0.50	0.028	0.41	0.023
1.00	0.00	0.07	0.36	0.020	0.36	0.020

Overall p(collision) integrated over disk

		Upwind	**5.4%**	**Downwind**	**4.2%**
Proportion	upwind: downwind				
50%	50%	**Average**	**4.8%**	(copied to sheet 1)	

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	k-headed gull	0.450	0.800
BirdLength	0.36	0.500	0.750
Wingspan	1.05	0.550	0.700
Bird speed	8.9	0.600	0.640
Flight type	flapping	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down	
0.404	0.387	
0.220	0.202	
0.163	0.144	
0.135	0.113	
0.118	0.095	
0.102	0.080	
0.087	0.066	
0.075	0.056	
0.067	0.049	
0.061	0.044	
0.055	0.039	
0.050	0.036	
0.046	0.033	
0.042	0.030	
0.039	0.028	
0.035	0.026	
0.033	0.025	
0.030	0.024	
0.028	0.023	
0.020	0.020	
5.44%	**4.23%**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **4.83%**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

Flight height distribution
Black-headed gull

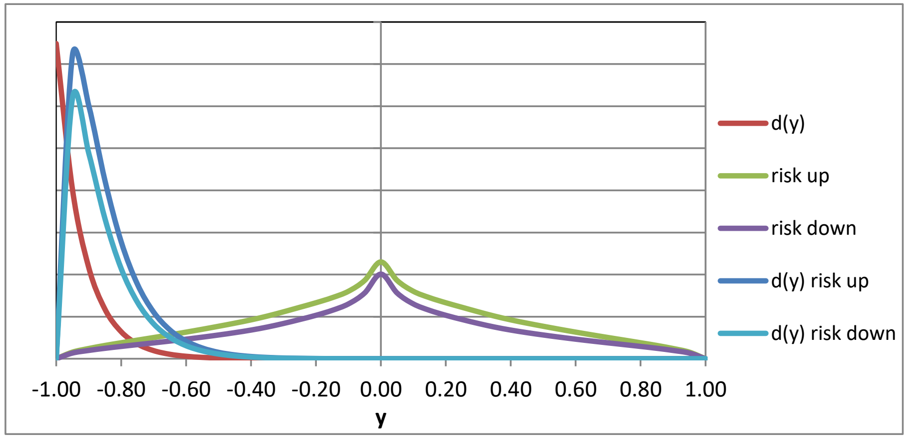
y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	0.7488	0.000	0.000	0.0000	0.0000
-0.95	0.4024	0.016	0.013	0.0063	0.0054
-0.90	0.2171	0.024	0.020	0.0053	0.0043

xinc	**yinc**
0.05	0.05

x and y increments used in results below
(though set fixed at 0.05 for diagram)

-0.85	0.1177	0.031	0.025	0.0037	0.0029
-0.80	0.0642	0.038	0.029	0.0024	0.0019
-0.75	0.0351	0.044	0.033	0.0016	0.0012
-0.70	0.0193	0.050	0.038	0.0010	0.0007
-0.65	0.0106	0.057	0.042	0.0006	0.0004
-0.60	0.0058	0.063	0.046	0.0004	0.0003
-0.55	0.0032	0.070	0.051	0.0002	0.0002
-0.50	0.0017	0.077	0.056	0.0001	0.0001
-0.45	0.0009	0.084	0.062	0.0001	0.0001
-0.40	0.0005	0.092	0.068	0.0000	0.0000
-0.35	0.0003	0.101	0.075	0.0000	0.0000
-0.30	0.0001	0.111	0.084	0.0000	0.0000
-0.25	0.0001	0.122	0.093	0.0000	0.0000
-0.20	0.0000	0.133	0.103	0.0000	0.0000
-0.15	0.0000	0.145	0.115	0.0000	0.0000
-0.10	0.0000	0.160	0.130	0.0000	0.0000
-0.05	0.0000	0.186	0.156	0.0000	0.0000
0.00	0.0000	0.230	0.201	0.0000	0.0000
0.05	0.0000	0.186	0.156	0.0000	0.0000
0.10	0.0000	0.160	0.130	0.0000	0.0000
0.15	0.0000	0.145	0.115	0.0000	0.0000
0.20	0.0000	0.133	0.103	0.0000	0.0000
0.25	0.0000	0.122	0.093	0.0000	0.0000
0.30	0.0000	0.111	0.084	0.0000	0.0000
0.35	0.0000	0.101	0.075	0.0000	0.0000
0.40	0.0000	0.092	0.068	0.0000	0.0000
0.45	0.0000	0.084	0.062	0.0000	0.0000
0.50	0.0000	0.077	0.056	0.0000	0.0000
0.55	0.0000	0.070	0.051	0.0000	0.0000
0.60	0.0000	0.063	0.046	0.0000	0.0000
0.65	0.0000	0.057	0.042	0.0000	0.0000
0.70	0.0000	0.050	0.038	0.0000	0.0000
0.75	0.0000	0.044	0.033	0.0000	0.0000
0.80	0.0000	0.038	0.029	0.0000	0.0000
0.85	0.0000	0.031	0.025	0.0000	0.0000
0.90	0.0000	0.024	0.020	0.0000	0.0000
0.95	0.0000	0.016	0.013	0.0000	0.0000
1.00	0.0000	0.000	0.000	0.0000	0.0000

Q'_{2R} from flight distribution			6.27%	
Compare with Q_{2R} input data			35.1%	
Flux integral			0.0240	
Collision integral	**(up)**	**0.0007**	**(down)**	**0.0006**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)			**0.0006**	
Compare with Q'_{2R} * p from Option 2		0.00341		0.00265
		20.3%		21.0%



FLIGHT HEIGHT DISTRIBUTIONS

D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Black-headed gull	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.094763	0.23317	0.08571	0.51408	0
1	0.085736	0.15457	0.0785	0.23184	0.03
2	0.077569	0.10506	0.07175	0.11113	0.03
3	0.070182	0.07335	0.06526	0.0542	0.03
4	0.063499	0.05355	0.05987	0.0274	0.03
5	0.057455	0.03936	0.05499	0.01441	0.03
6	0.051988	0.02885	0.05095	0.00782	0.03
7	0.047043	0.02168	0.0468	0.00439	0.03
8	0.04257	0.01673	0.04263	0.00257	0.03
9	0.038525	0.01316	0.03907	0.00155	0.03
10	0.034866	0.01077	0.0359	0.00098	0.03
11	0.031557	0.00936	0.03293	0.00065	0.005
12	0.028563	0.00871	0.02997	0.00045	0.005
13	0.025856	0.00854	0.02747	0.00033	0.005
14	0.023407	0.00877	0.02505	0.00025	0.005
15	0.021192	0.00937	0.02305	0.00019	0.005
16	0.019188	0.01009	0.02118	0.00016	0.005
17	0.017375	0.01088	0.01929	0.00013	0.005
18	0.015735	0.01151	0.01765	0.00012	0.005
19	0.014251	0.01175	0.01587	0.0001	0.005
20	0.012909	0.01167	0.01398	0.00009	0.005
21	0.011694	0.01137	0.01247	0.00009	0.005
22	0.010594	0.01079	0.01115	0.00009	0.005
23	0.009599	0.01008	0.00999	0.00008	0.005
24	0.008699	0.00924	0.00895	0.00008	0.005
25	0.007884	0.00842	0.00801	0.00008	0.005
26	0.007146	0.00757	0.0071	0.00007	0.005
27	0.006478	0.00664	0.00631	0.00007	0.005
28	0.005873	0.00578	0.00565	0.00007	0.005
29	0.005325	0.00502	0.00496	0.00007	0.005
30	0.004829	0.00429	0.00444	0.00007	0.005
31	0.00438	0.00352	0.00391	0.00007	0.005
32	0.003973	0.00296	0.00345	0.00007	0.005
33	0.003604	0.00242	0.00305	0.00007	0.005
34	0.00327	0.00202	0.00271	0.00006	0.005
35	0.002967	0.00165	0.00238	0.00006	0.005
36	0.002693	0.00137	0.00213	0.00006	0.005
37	0.002444	0.00109	0.00185	0.00005	0.005
38	0.002219	0.00088	0.00164	0.00005	0.005
39	0.002014	0.00069	0.00145	0.00005	0.005
40	0.001829	0.00054	0.00128	0.00004	0.005
41	0.001661	0.00041	0.00113	0.00004	0.005
42	0.001508	0.00032	0.00101	0.00004	0.005
43	0.00137	0.00025	0.00092	0.00003	0.005
44	0.001245	0.00019	0.00081	0.00003	0.005
45	0.001131	0.00014	0.00071	0.00003	0.005
46	0.001028	0.00011	0.00063	0.00003	0.005
47	0.000934	0.00009	0.00055	0.00003	0.005
48	0.000849	0.00007	0.00048	0.00003	0.005
49	0.000772	0.00005	0.00042	0.00003	0.005
50	0.000701	0.00004	0.00038	0.00003	0.005

51	0.000638	0.00003	0.00033	0.00003	0.005
52	0.00058	0.00002	0.0003	0.00003	0.005
53	0.000527	0.00002	0.00026	0.00003	0.005
54	0.00048	0.00002	0.00023	0.00003	0.005
55	0.000436	0.00001	0.00021	0.00003	0.005
56	0.000397	0.00001	0.00018	0.00003	0.005
57	0.000361	0.00001	0.00016	0.00003	0.005
58	0.000328	0.00001	0.00015	0.00003	0.005
59	0.000299	0.00001	0.00013	0.00003	0.005
60	0.000272	0.00001	0.00012	0.00003	0.005
61	0.000247	0	0.0001	0.00003	0.005
62	0.000225	0	0.00009	0.00002	0.005
63	0.000205	0	0.00008	0.00002	0.005
64	0.000186	0	0.00007	0.00002	0.005
65	0.00017	0	0.00007	0.00002	0.005
66	0.000154	0	0.00006	0.00001	0.005
67	0.000141	0	0.00005	0.00001	0.005
68	0.000128	0	0.00005	0.00001	0.005
69	0.000116	0	0.00004	0.00001	0.005
70	0.000106	0	0.00004	0.00001	0.005
71	9.65E-05	0	0.00003	0.00001	0.005
72	8.79E-05	0	0.00003	0	0.005
73	8.00E-05	0	0.00003	0	0.005
74	7.28E-05	0	0.00003	0	0.005
75	6.63E-05	0	0.00002	0	0.005
76	6.03E-05	0	0.00002	0	0.005
77	5.49E-05	0	0.00002	0	0.005
78	5.00E-05	0.00001	0.00002	0	0.005
79	4.55E-05	0.00001	0.00002	0	0.005
80	4.14E-05	0.00001	0.00002	0	0.005
81	3.77E-05	0.00001	0.00002	0	0.005
82	3.43E-05	0.00001	0.00002	0	0.005
83	3.12E-05	0.00001	0.00002	0	0.005
84	2.84E-05	0.00002	0.00002	0	0.005
85	2.58E-05	0.00002	0.00002	0	0.005
86	2.35E-05	0.00003	0.00002	0	0.005
87	2.13E-05	0.00003	0.00002	0	0.005
88	1.94E-05	0.00004	0.00002	0	0.005
89	1.76E-05	0.00004	0.00002	0	0.005
90	1.60E-05	0.00005	0.00002	0	0.005
91	1.46E-05	0.00006	0.00002	0	0.005
92	1.32E-05	0.00007	0.00002	0	0.005
93	1.20E-05	0.00009	0.00002	0	0.005
94	1.09E-05	0.0001	0.00002	0	0.005
95	9.93E-06	0.00012	0.00002	0	0.005
96	9.01E-06	0.00014	0.00002	0	0.005
97	8.18E-06	0.00016	0.00002	0	0.005
98	7.42E-06	0.00018	0.00002	0	0.005
99	6.74E-06	0.0002	0.00001	0	0.005
100	6.11E-06	0.00021	0.00002	0	0.005
101	5.54E-06	0.00022	0.00002	0	0.005
102	5.02E-06	0.00022	0.00002	0	0.005
103	4.55E-06	0.00022	0.00002	0	0.005
104	4.12E-06	0.00021	0.00002	0	0.005
105	3.73E-06	0.0002	0.00001	0	0.005
106	3.38E-06	0.00019	0.00001	0	0.005
107	3.06E-06	0.00017	0.00002	0	0.005
108	2.77E-06	0.00014	0.00002	0	0.005
109	2.50E-06	0.00012	0.00002	0	0.005

110	2.26E-06	0.0001	0.00002	0	0.005
111	2.04E-06	0.00009	0.00002	0	0.005
112	1.84E-06	0.00007	0.00002	0	0.005
113	1.66E-06	0.00006	0.00001	0	0.005
114	1.50E-06	0.00005	0.00001	0	0.005
115	1.35E-06	0.00004	0.00001	0	0.005
116	1.22E-06	0.00003	0.00001	0	0.005
117	1.10E-06	0.00002	0.00001	0	0.005
118	9.90E-07	0.00001	0.00001	0	0.005
119	8.91E-07	0.00001	0.00001	0	0.005
120	8.01E-07	0.00001	0.00001	0	0.005
121	7.20E-07	0	0.00001	0	0.005
122	6.47E-07	0	0.00001	0	0.005
123	5.80E-07	0	0.00001	0	0.005
124	5.21E-07	0	0.00001	0	0.005
125	4.67E-07	0	0.00001	0	0.005
126	4.18E-07	0	0.00001	0	0.005
127	3.74E-07	0	0.00001	0	0.005
128	3.35E-07	0	0.00001	0	0.005
129	2.99E-07	0	0.00001	0	0.005
130	2.68E-07	0	0.00001	0	0.005
131	2.39E-07	0	0.00001	0	0.005
132	2.13E-07	0	0.00001	0	0.005
133	1.90E-07	0	0.00001	0	0.005
134	1.69E-07	0	0.00001	0	0.005
135	1.50E-07	0	0.00001	0	0.005
136	1.34E-07	0	0.00001	0	0.005
137	1.19E-07	0	0.00001	0	0.005
138	1.05E-07	0	0.00001	0	0.005
139	9.34E-08	0	0.00001	0	0.005
140	8.28E-08	0	0	0	0.005
141	7.32E-08	0	0	0	0.005
142	6.47E-08	0	0	0	0.005
143	5.72E-08	0	0	0	0.005
144	5.04E-08	0	0	0	0.005
145	4.44E-08	0	0	0	0.005
146	3.91E-08	0	0	0	0.005
147	3.44E-08	0	0	0	0.005
148	3.02E-08	0	0	0	0.005
149	2.65E-08	0	0	0	0.005
150	2.32E-08	0	0	0	0.005
151	2.03E-08	0	0	0	0
152	1.78E-08	0	0	0	0
153	1.55E-08	0	0	0	0
154	1.35E-08	0	0	0	0
155	1.18E-08	0	0	0	0
156	1.03E-08		0.95947		
157	8.91E-09				
158	7.73E-09				
159	6.69E-09				
160	5.79E-09				
161	5.00E-09				
162	4.32E-09				
163	3.72E-09				
164	3.20E-09				
165	2.74E-09				
166	2.35E-09				
167	2.01E-09				
168	1.72E-09				

169	1.47E-09
170	1.25E-09
171	1.06E-09
172	9.03E-10
173	7.66E-10
174	6.48E-10
175	5.47E-10
176	4.61E-10
177	3.88E-10
178	3.26E-10
179	2.73E-10
180	2.28E-10
181	1.91E-10
182	1.59E-10
183	1.32E-10
184	1.10E-10
185	9.07E-11
186	7.50E-11
187	6.18E-11
188	5.09E-11
189	4.18E-11
190	3.42E-11
191	2.80E-11
192	2.28E-11
193	1.85E-11
194	1.50E-11
195	1.22E-11
196	9.84E-12
197	7.93E-12
198	6.37E-12
199	5.11E-12
200	4.08E-12
201	3.26E-12
202	2.59E-12
203	2.06E-12
204	1.63E-12
205	1.28E-12
206	1.01E-12
207	7.92E-13
208	6.20E-13
209	4.84E-13
210	3.76E-13
211	2.92E-13
212	2.26E-13
213	1.74E-13
214	1.34E-13
215	1.03E-13
216	7.83E-14
217	5.97E-14
218	4.53E-14
219	3.43E-14
220	2.58E-14
221	1.94E-14
222	1.46E-14
223	1.09E-14
224	8.09E-15
225	6.00E-15
226	4.44E-15
227	3.27E-15

228	2.40E-15
229	1.75E-15
230	1.28E-15
231	9.27E-16
232	6.71E-16
233	4.83E-16
234	3.47E-16
235	2.48E-16
236	1.77E-16
237	1.25E-16
238	8.86E-17
239	6.23E-17
240	4.37E-17
241	3.05E-17
242	2.12E-17
243	1.47E-17
244	1.01E-17
245	6.96E-18
246	4.76E-18
247	3.24E-18
248	2.19E-18
249	1.48E-18
250	9.94E-19
251	6.65E-19
252	4.43E-19
253	2.93E-19
254	1.94E-19
255	1.27E-19
256	8.30E-20
257	5.40E-20
258	3.49E-20
259	2.25E-20
260	1.44E-20
261	9.20E-21
262	5.84E-21
263	3.69E-21
264	2.32E-21
265	1.45E-21
266	9.00E-22
267	5.57E-22
268	3.43E-22
269	2.10E-22
270	1.28E-22
271	7.73E-23
272	4.66E-23
273	2.79E-23
274	1.66E-23
275	9.84E-24
276	5.80E-24
277	3.39E-24
278	1.98E-24
279	1.14E-24
280	6.58E-25
281	3.77E-25
282	2.14E-25
283	1.21E-25
284	6.81E-26
285	3.80E-26
286	2.11E-26

287	1.16E-26
288	6.39E-27
289	3.48E-27
290	1.88E-27
291	1.01E-27
292	5.42E-28
293	2.88E-28
294	1.52E-28
295	7.96E-29
296	4.14E-29
297	2.14E-29
298	1.10E-29
299	5.62E-30

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩 from Sheet 1 - input data
🟪 from Sheet 6 - available hours
🟧 from Sheet 3 - single transit collision risk
🟨 from survey data
🟦 calculated field

Bird details:		
Species		Black-headed gull
Flight speed	m/sec	8.9
Flight type		flapping
Windfarm data:		
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	4000	2000	0	0	0	2000	4000	0	0	**12000**
Migrant flux density	birds/ km		0	0	0	500	250	0	0	0	250	500	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	100	50	0	0	0	50	100	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	75	38	0	0	0	38	75	0	0	**225**
Collision risk for single rotor transit	(from sheet 3)	4.8%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**3**	**2**	**0**	**0**	**0**	**2**	**3**	**0**	**0**	**10**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	6.3%													
Potential bird transits through rotors	Flux integral	0.0240	0	0	0	2	1	0	0	0	1	2	0	0	**7**
Collisions assuming no avoidance	Collision integral	0.00062	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Average collision risk for single rotor transit		2.6%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	3	2	0	0	0	2	3	0	0	**10**
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Monthly available daylight hours	236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1
Monthly available nocturnal hours	507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9
Monthly available total hours	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT

Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of turbines	1			
Rotor radius	127.5			
Width of windfarm	0.3			
Average proportion of time operational	0.95			
Collision risk from single rotor transit	0.048			
Assumed number of turbine rows	1.0			
Avoidance rate	100.00%	98.90%	100.00%	100.00%
Collision risk for single bird passage, before correction	0.00000	0.00034	0.00000	0.00000
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Number of rows (optional)	
(if this is left blank, number is assumed to be sqrt(T)	
Number of turbines in each row	

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩	used in overall collision risk sheet	🟪	used in available hours sheet
🟨	used in migrant collision risk sheet	⬜	used in large array correction sheet
🟧	used in single transit collision risk sheet or extended model	🟥	not used in calculation but stated for reference

Bird data	**Units**	**Value**	**Data sources**
Species name		**Common gull**	
Bird length	m	0.41	
Wingspan	m	1.20	
Flight speed	m/sec	13.4	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

Data sources

Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0.24	0.085	0.03	0.055	0.035	0	0.03	0	0.08	0.245	0.555	0.445
Proportion at rotor height	%	35.1%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Migration passages	birds		0	0	0	4000	2000	0	0	0	2000	4000	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

Windfarm data	**Units**	**Value**	**Data sources**
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

Turbine data	**Units**	**Value**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5												
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

Data sources

Avoidance rates used in presenting results		**Data sources (if applicable)**
	100.00%	
	98.90%	SNCB 2014
	100.00%	
	100.00%	

COLLISION RISK ASSESSMENT

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:																
Species		Common gull														
Flight speed	m/sec	13.4														
Nocturnal activity factor (1-5)		3														
Nocturnal activity (% of daytime)		50%														
Windfarm data:																
Latitude	degrees	56.2														
Number of turbines		1														
Rotor radius	m	127.5														
Minimum height of rotor	m	152.5														
Total rotor frontal area	sq m	51071														
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**	
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%	
Stage A - flight activity																
Daytime areal bird density	birds/sq km		0.24	0.085	0.03	0.055	0.035	0	0.03	0	0.08	0.245	0.555	0.445		
Proportion at rotor height	%	35.1%														
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218		
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526		
Flux factor			1137	385	161	304	211	0	184	0	427	1265	2598	2068		
Option 1 -Basic model - Stages B, C and D															**per annum**	
Potential bird transits through rotors			399	135	56	107	74	0	65	0	150	444	912	726	**3068**	
Collision risk for single rotor transit	(from sheet 3)	4.4%														
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**17**	**6**	**2**	**4**	**3**	**0**	**3**	**0**	**6**	**19**	**38**	**31**	**129**	
Option 2-Basic model using proportion from flight distribution			**6**	**2**	**1**	**2**	**1**	**0**	**1**	**0**	**2**	**6**	**13**	**10**	**43**	
Option 3-Extended model using flight height distribution		Common gull														
Proportion at rotor height	(from sheet 4)	11.7%														
Potential bird transits through rotors	Flux integral	0.0526	60	20	8	16	11	0	10	0	22	66	137	109	**459**	
Collisions assuming no avoidance	Collision integral	0.00118	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3**	**2**	**10**	
Average collision risk for single rotor transit		2.2%														
Stage E - applying avoidance rates																
Using which of above options?	**Option 3**	0.00%	1	0	0	0	0	0	0	0	0	1	3	2	**10**	
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	SNCB 2014
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

COLLISION RISK ASSESSMENT
Sheet 3 - probability of collision for single bird transit through rotor

🟩 **All input data must be entered on Sheet 1, not here**
🟧 **However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦 Calculated outputs
🟨 Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	Common gull	
BirdLength	0.41	m
Wingspan	1.20	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	13.4	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.34	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	2.03	11.16	0.412	10.86	0.401
0.10	0.79	1.01	6.02	0.222	5.70	0.211
0.15	0.88	0.68	4.44	0.164	4.08	0.151
0.20	0.96	0.51	3.62	0.134	3.23	0.119
0.25	1.00	0.41	3.04	0.112	2.63	0.097
0.30	0.98	0.34	2.53	0.093	2.13	0.079
0.35	0.92	0.29	2.14	0.079	1.77	0.065
0.40	0.85	0.25	1.83	0.068	1.49	0.055
0.45	0.80	0.23	1.62	0.060	1.29	0.048
0.50	0.75	0.20	1.44	0.053	1.14	0.042
0.55	0.70	0.18	1.30	0.048	1.02	0.038
0.60	0.64	0.17	1.17	0.043	0.91	0.034
0.65	0.58	0.16	1.05	0.039	0.82	0.030
0.70	0.52	0.14	0.95	0.035	0.74	0.027
0.75	0.47	0.14	0.87	0.032	0.68	0.025
0.80	0.41	0.13	0.79	0.029	0.63	0.023
0.85	0.37	0.12	0.74	0.027	0.59	0.022
0.90	0.30	0.11	0.67	0.025	0.55	0.020
0.95	0.24	0.11	0.61	0.022	0.51	0.019
1.00	0.00	0.10	0.41	0.015	0.41	0.015

Overall p(collision) integrated over disk

		Upwind	**4.8%**	**Downwind**	**4.0%**
Proportion	upwind: downwind				
50%	50%	**Average**	**4.4%**	(copied to sheet 1)	

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	Common gull	0.450	0.800
BirdLength	0.41	0.500	0.750
Wingspan	1.20	0.550	0.700
Bird speed	13.4	0.600	0.640
Flight type	flapping	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down	
0.412	0.401	
0.222	0.211	
0.164	0.151	
0.134	0.119	
0.112	0.097	
0.093	0.079	
0.079	0.065	
0.068	0.055	
0.060	0.048	
0.053	0.042	
0.048	0.038	
0.043	0.034	
0.039	0.030	
0.035	0.027	
0.032	0.025	
0.029	0.023	
0.027	0.022	
0.025	0.020	
0.022	0.019	
0.015	0.015	
4.83%	**4.02%**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **4.42%**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

Flight height distribution

Common gull

y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	1.1082	0.000	0.000	0.0000	0.0000
-0.95	0.6847	0.012	0.011	0.0085	0.0075
-0.90	0.4233	0.019	0.016	0.0082	0.0070

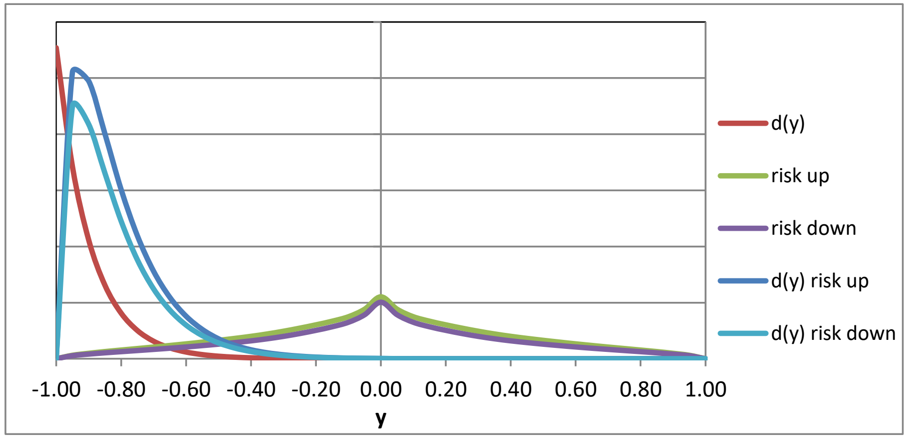
xinc	**yinc**
0.05	0.05

x and y increments used in results below

(though set fixed at 0.05 for diagram)

-0.85	0.2619	0.026	0.021	0.0067	0.0055
-0.80	0.1623	0.031	0.025	0.0050	0.0041
-0.75	0.1006	0.036	0.029	0.0037	0.0029
-0.70	0.0623	0.042	0.033	0.0026	0.0021
-0.65	0.0386	0.047	0.037	0.0018	0.0014
-0.60	0.0238	0.053	0.042	0.0013	0.0010
-0.55	0.0147	0.059	0.047	0.0009	0.0007
-0.50	0.0090	0.066	0.052	0.0006	0.0005
-0.45	0.0055	0.072	0.058	0.0004	0.0003
-0.40	0.0033	0.080	0.064	0.0003	0.0002
-0.35	0.0020	0.088	0.071	0.0002	0.0001
-0.30	0.0012	0.098	0.080	0.0001	0.0001
-0.25	0.0007	0.109	0.090	0.0001	0.0001
-0.20	0.0004	0.121	0.101	0.0000	0.0000
-0.15	0.0002	0.134	0.114	0.0000	0.0000
-0.10	0.0001	0.150	0.130	0.0000	0.0000
-0.05	0.0001	0.177	0.157	0.0000	0.0000
0.00	0.0000	0.221	0.201	0.0000	0.0000
0.05	0.0000	0.177	0.157	0.0000	0.0000
0.10	0.0000	0.150	0.130	0.0000	0.0000
0.15	0.0000	0.134	0.114	0.0000	0.0000
0.20	0.0000	0.121	0.101	0.0000	0.0000
0.25	0.0000	0.109	0.090	0.0000	0.0000
0.30	0.0000	0.098	0.080	0.0000	0.0000
0.35	0.0000	0.088	0.071	0.0000	0.0000
0.40	0.0000	0.080	0.064	0.0000	0.0000
0.45	0.0000	0.072	0.058	0.0000	0.0000
0.50	0.0000	0.066	0.052	0.0000	0.0000
0.55	0.0000	0.059	0.047	0.0000	0.0000
0.60	0.0000	0.053	0.042	0.0000	0.0000
0.65	0.0000	0.047	0.037	0.0000	0.0000
0.70	0.0000	0.042	0.033	0.0000	0.0000
0.75	0.0000	0.036	0.029	0.0000	0.0000
0.80	0.0000	0.031	0.025	0.0000	0.0000
0.85	0.0000	0.026	0.021	0.0000	0.0000
0.90	0.0000	0.019	0.016	0.0000	0.0000
0.95	0.0000	0.012	0.011	0.0000	0.0000
1.00	0.0000	0.000	0.000	0.0000	0.0000

Q'$_{2R}$ from flight distribution			11.74%	
Compare with Q$_{2R}$ input data			35.1%	
Flux integral			0.0526	
Collision integral	**(up)**	**0.0013**	**(down)**	**0.0011**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)			**0.0012**	
Compare with Q'$_{2R}$ * p from Option 2		0.00567		0.00472
		22.7%		22.7%



FLIGHT HEIGHT DISTRIBUTIONS
D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Common gull	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.073359	0.23317	0.08571	0.51408	0
1	0.067961	0.15457	0.0785	0.23184	0.03
2	0.062961	0.10506	0.07175	0.11113	0.03
3	0.058328	0.07335	0.06526	0.0542	0.03
4	0.054037	0.05355	0.05987	0.0274	0.03
5	0.050063	0.03936	0.05499	0.01441	0.03
6	0.046381	0.02885	0.05095	0.00782	0.03
7	0.04297	0.02168	0.0468	0.00439	0.03
8	0.039811	0.01673	0.04263	0.00257	0.03
9	0.036885	0.01316	0.03907	0.00155	0.03
10	0.034174	0.01077	0.0359	0.00098	0.03
11	0.031664	0.00936	0.03293	0.00065	0.005
12	0.029338	0.00871	0.02997	0.00045	0.005
13	0.027184	0.00854	0.02747	0.00033	0.005
14	0.025189	0.00877	0.02505	0.00025	0.005
15	0.023341	0.00937	0.02305	0.00019	0.005
16	0.021629	0.01009	0.02118	0.00016	0.005
17	0.020043	0.01088	0.01929	0.00013	0.005
18	0.018574	0.01151	0.01765	0.00012	0.005
19	0.017213	0.01175	0.01587	0.0001	0.005
20	0.015953	0.01167	0.01398	0.00009	0.005
21	0.014785	0.01137	0.01247	0.00009	0.005
22	0.013703	0.01079	0.01115	0.00009	0.005
23	0.012701	0.01008	0.00999	0.00008	0.005
24	0.011772	0.00924	0.00895	0.00008	0.005
25	0.010912	0.00842	0.00801	0.00008	0.005
26	0.010115	0.00757	0.0071	0.00007	0.005
27	0.009376	0.00664	0.00631	0.00007	0.005
28	0.008692	0.00578	0.00565	0.00007	0.005
29	0.008058	0.00502	0.00496	0.00007	0.005
30	0.007471	0.00429	0.00444	0.00007	0.005
31	0.006926	0.00352	0.00391	0.00007	0.005
32	0.006422	0.00296	0.00345	0.00007	0.005
33	0.005954	0.00242	0.00305	0.00007	0.005
34	0.005521	0.00202	0.00271	0.00006	0.005
35	0.005119	0.00165	0.00238	0.00006	0.005
36	0.004747	0.00137	0.00213	0.00006	0.005
37	0.004402	0.00109	0.00185	0.00005	0.005
38	0.004082	0.00088	0.00164	0.00005	0.005
39	0.003786	0.00069	0.00145	0.00005	0.005
40	0.003511	0.00054	0.00128	0.00004	0.005
41	0.003256	0.00041	0.00113	0.00004	0.005
42	0.00302	0.00032	0.00101	0.00004	0.005
43	0.002801	0.00025	0.00092	0.00003	0.005
44	0.002598	0.00019	0.00081	0.00003	0.005
45	0.00241	0.00014	0.00071	0.00003	0.005
46	0.002235	0.00011	0.00063	0.00003	0.005
47	0.002073	0.00009	0.00055	0.00003	0.005
48	0.001923	0.00007	0.00048	0.00003	0.005
49	0.001784	0.00005	0.00042	0.00003	0.005
50	0.001655	0.00004	0.00038	0.00003	0.005

51	0.001535	0.00003	0.00033	0.00003	0.005
52	0.001424	0.00002	0.0003	0.00003	0.005
53	0.001321	0.00002	0.00026	0.00003	0.005
54	0.001225	0.00002	0.00023	0.00003	0.005
55	0.001137	0.00001	0.00021	0.00003	0.005
56	0.001055	0.00001	0.00018	0.00003	0.005
57	0.000978	0.00001	0.00016	0.00003	0.005
58	0.000908	0.00001	0.00015	0.00003	0.005
59	0.000842	0.00001	0.00013	0.00003	0.005
60	0.000781	0.00001	0.00012	0.00003	0.005
61	0.000725	0	0.0001	0.00003	0.005
62	0.000672	0	0.00009	0.00002	0.005
63	0.000624	0	0.00008	0.00002	0.005
64	0.000579	0	0.00007	0.00002	0.005
65	0.000537	0	0.00007	0.00002	0.005
66	0.000498	0	0.00006	0.00001	0.005
67	0.000462	0	0.00005	0.00001	0.005
68	0.000428	0	0.00005	0.00001	0.005
69	0.000397	0	0.00004	0.00001	0.005
70	0.000369	0	0.00004	0.00001	0.005
71	0.000342	0	0.00003	0.00001	0.005
72	0.000317	0	0.00003	0	0.005
73	0.000294	0	0.00003	0	0.005
74	0.000273	0	0.00003	0	0.005
75	0.000253	0	0.00002	0	0.005
76	0.000234	0	0.00002	0	0.005
77	0.000217	0	0.00002	0	0.005
78	0.000202	0.00001	0.00002	0	0.005
79	0.000187	0.00001	0.00002	0	0.005
80	0.000173	0.00001	0.00002	0	0.005
81	0.000161	0.00001	0.00002	0	0.005
82	0.000149	0.00001	0.00002	0	0.005
83	0.000138	0.00001	0.00002	0	0.005
84	0.000128	0.00002	0.00002	0	0.005
85	0.000118	0.00002	0.00002	0	0.005
86	0.00011	0.00003	0.00002	0	0.005
87	0.000102	0.00003	0.00002	0	0.005
88	9.42E-05	0.00004	0.00002	0	0.005
89	8.72E-05	0.00004	0.00002	0	0.005
90	8.08E-05	0.00005	0.00002	0	0.005
91	7.48E-05	0.00006	0.00002	0	0.005
92	6.93E-05	0.00007	0.00002	0	0.005
93	6.41E-05	0.00009	0.00002	0	0.005
94	5.94E-05	0.0001	0.00002	0	0.005
95	5.49E-05	0.00012	0.00002	0	0.005
96	5.08E-05	0.00014	0.00002	0	0.005
97	4.70E-05	0.00016	0.00002	0	0.005
98	4.35E-05	0.00018	0.00002	0	0.005
99	4.02E-05	0.0002	0.00001	0	0.005
100	3.72E-05	0.00021	0.00002	0	0.005
101	3.44E-05	0.00022	0.00002	0	0.005
102	3.18E-05	0.00022	0.00002	0	0.005
103	2.94E-05	0.00022	0.00002	0	0.005
104	2.72E-05	0.00021	0.00002	0	0.005
105	2.51E-05	0.0002	0.00001	0	0.005
106	2.32E-05	0.00019	0.00001	0	0.005
107	2.14E-05	0.00017	0.00002	0	0.005
108	1.98E-05	0.00014	0.00002	0	0.005
109	1.82E-05	0.00012	0.00002	0	0.005

110	1.68E-05	0.0001	0.00002	0	0.005
111	1.55E-05	0.00009	0.00002	0	0.005
112	1.43E-05	0.00007	0.00002	0	0.005
113	1.32E-05	0.00006	0.00001	0	0.005
114	1.22E-05	0.00005	0.00001	0	0.005
115	1.12E-05	0.00004	0.00001	0	0.005
116	1.03E-05	0.00003	0.00001	0	0.005
117	9.52E-06	0.00002	0.00001	0	0.005
118	8.77E-06	0.00001	0.00001	0	0.005
119	8.07E-06	0.00001	0.00001	0	0.005
120	7.43E-06	0.00001	0.00001	0	0.005
121	6.84E-06	0	0.00001	0	0.005
122	6.29E-06	0	0.00001	0	0.005
123	5.78E-06	0	0.00001	0	0.005
124	5.31E-06	0	0.00001	0	0.005
125	4.88E-06	0	0.00001	0	0.005
126	4.48E-06	0	0.00001	0	0.005
127	4.11E-06	0	0.00001	0	0.005
128	3.78E-06	0	0.00001	0	0.005
129	3.46E-06	0	0.00001	0	0.005
130	3.18E-06	0	0.00001	0	0.005
131	2.91E-06	0	0.00001	0	0.005
132	2.67E-06	0	0.00001	0	0.005
133	2.44E-06	0	0.00001	0	0.005
134	2.24E-06	0	0.00001	0	0.005
135	2.05E-06	0	0.00001	0	0.005
136	1.87E-06	0	0.00001	0	0.005
137	1.71E-06	0	0.00001	0	0.005
138	1.56E-06	0	0.00001	0	0.005
139	1.43E-06	0	0.00001	0	0.005
140	1.30E-06	0	0	0	0.005
141	1.19E-06	0	0	0	0.005
142	1.09E-06	0	0	0	0.005
143	9.90E-07	0	0	0	0.005
144	9.02E-07	0	0	0	0.005
145	8.21E-07	0	0	0	0.005
146	7.47E-07	0	0	0	0.005
147	6.80E-07	0	0	0	0.005
148	6.18E-07	0	0	0	0.005
149	5.62E-07	0	0	0	0.005
150	5.10E-07	0	0	0	0.005
151	4.63E-07	0	0	0	0
152	4.20E-07	0	0	0	0
153	3.81E-07	0	0	0	0
154	3.45E-07	0	0	0	0
155	3.12E-07	0	0	0	0
156	2.82E-07		0.95947		
157	2.55E-07				
158	2.31E-07				
159	2.08E-07				
160	1.88E-07				
161	1.70E-07				
162	1.53E-07				
163	1.38E-07				
164	1.24E-07				
165	1.11E-07				
166	1.00E-07				
167	8.97E-08				
168	8.05E-08				

169	7.21E-08
170	6.46E-08
171	5.78E-08
172	5.17E-08
173	4.62E-08
174	4.12E-08
175	3.68E-08
176	3.28E-08
177	2.92E-08
178	2.60E-08
179	2.31E-08
180	2.05E-08
181	1.82E-08
182	1.61E-08
183	1.43E-08
184	1.26E-08
185	1.11E-08
186	9.83E-09
187	8.67E-09
188	7.64E-09
189	6.72E-09
190	5.91E-09
191	5.19E-09
192	4.55E-09
193	3.99E-09
194	3.49E-09
195	3.05E-09
196	2.66E-09
197	2.32E-09
198	2.02E-09
199	1.76E-09
200	1.53E-09
201	1.33E-09
202	1.15E-09
203	9.98E-10
204	8.63E-10
205	7.46E-10
206	6.43E-10
207	5.54E-10
208	4.77E-10
209	4.10E-10
210	3.52E-10
211	3.01E-10
212	2.58E-10
213	2.20E-10
214	1.88E-10
215	1.60E-10
216	1.36E-10
217	1.16E-10
218	9.83E-11
219	8.33E-11
220	7.05E-11
221	5.95E-11
222	5.02E-11
223	4.23E-11
224	3.55E-11
225	2.98E-11
226	2.50E-11
227	2.09E-11

228	1.75E-11
229	1.46E-11
230	1.21E-11
231	1.01E-11
232	8.37E-12
233	6.93E-12
234	5.73E-12
235	4.73E-12
236	3.90E-12
237	3.20E-12
238	2.63E-12
239	2.16E-12
240	1.76E-12
241	1.44E-12
242	1.17E-12
243	9.54E-13
244	7.75E-13
245	6.28E-13
246	5.08E-13
247	4.10E-13
248	3.30E-13
249	2.65E-13
250	2.13E-13
251	1.70E-13
252	1.36E-13
253	1.09E-13
254	8.63E-14
255	6.85E-14
256	5.43E-14
257	4.29E-14
258	3.39E-14
259	2.66E-14
260	2.09E-14
261	1.64E-14
262	1.28E-14
263	1.00E-14
264	7.78E-15
265	6.04E-15
266	4.68E-15
267	3.61E-15
268	2.79E-15
269	2.14E-15
270	1.64E-15
271	1.26E-15
272	9.61E-16
273	7.32E-16
274	5.56E-16
275	4.21E-16
276	3.18E-16
277	2.40E-16
278	1.80E-16
279	1.35E-16
280	1.01E-16
281	7.55E-17
282	5.62E-17
283	4.17E-17
284	3.08E-17
285	2.28E-17
286	1.68E-17

287	1.23E-17
288	9.00E-18
289	6.57E-18
290	4.78E-18
291	3.47E-18
292	2.51E-18
293	1.81E-18
294	1.30E-18
295	9.34E-19
296	6.68E-19
297	4.76E-19
298	3.38E-19
299	2.40E-19

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Bird details:															
Species		Common gull													
Flight speed	m/sec	13.4													
Flight type		flapping													
Windfarm data:															
Number of turbines		1													
Rotor radius	m	127.5													
Minimum height of rotor	m	152.5													
Total rotor frontal area	sq m	51071													
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	4000	2000	0	0	0	2000	4000	0	0	**12000**
Migrant flux density	birds/ km		0	0	0	500	250	0	0	0	250	500	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	100	50	0	0	0	50	100	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	75	38	0	0	0	38	75	0	0	**225**
Collision risk for single rotor transit	(from sheet 3)	4.4%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**3**	**2**	**0**	**0**	**0**	**2**	**3**	**0**	**0**	**9**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	11.7%													
Potential bird transits through rotors	Flux integral	0.0526	0	0	0	5	3	0	0	0	3	5	0	0	**16**
Collisions assuming no avoidance	Collision integral	0.00118	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Average collision risk for single rotor transit		2.2%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	3	2	0	0	0	2	3	0	0	**9**
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

Monthly available daylight hours

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1

Monthly available nocturnal hours

507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9

Monthly available total hours

744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT
Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of turbines	1
Rotor radius	127.5
Width of windfarm	0.3
Average proportion of time operational	0.95
Collision risk from single rotor transit	0.044
Assumed number of turbine rows	1.0

Number of rows (optional)	
(if this is left blank, number is assumed to be sqrt(T)	
Number of turbines in each row	

Avoidance rate	100.00%	98.90%	100.00%	100.00%
Collision risk for single bird passage, before correction	0.00000	0.00031	0.00000	0.00000
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩	used in overall collision risk sheet
🟨	used in migrant collision risk sheet
🟧	used in single transit collision risk sheet or extended model
🟪	used in available hours sheet
🟨	used in large array correction sheet
🟥	not used in calculation but stated for reference

Bird data	**Units**	**Value**	**Data sources**
Species name		**Gannet**	
Bird length	m	0.94	
Wingspan	m	1.72	
Flight speed	m/sec	14.9	
Nocturnal activity factor (1-5)		1	
Flight type, flapping or gliding		gliding	

Data sources

Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0	0.0436	1.6265	2.068	1.0379	0.826	0.553	0.9045	0.6854	0.8809	0.1081	0
Proportion at rotor height	%	38.0%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data														
Migration passages	birds		0	0	0	4000	2000	0	0	0	2000	4000	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

Windfarm data	**Units**	**Value**	**Data sources**
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

Turbine data	**Units**	**Value**	**Data sources**											
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

Avoidance rates used in presenting results		**Data sources (if applicable)**
	98.70%	
	98.90%	SNCB (Option 2)
	99.10%	
	98.00%	

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:		
Species		Gannet
Flight speed	m/sec	14.9
Nocturnal activity factor (1-5)		1
Nocturnal activity (% of daytime)		0%
Windfarm data:		
Latitude	degrees	56.2
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average	
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%	
Stage A - flight activity																
Daytime areal bird density	birds/sq km		0	0.0436	1.6265	2.068	1.03793	0.825975	0.552985	0.904485	0.68541	0.880895	0.108117	0		
Proportion at rotor height	%	38.0%														
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218		
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526		
Flux factor			0	125	6386	9442	5640	4672	3134	4556	2834	3073	289	0		
Option 1 -Basic model - Stages B, C and D															**per annum**	
Potential bird transits through rotors			0	47	2427	3588	2143	1775	1191	1731	1077	1168	110	0	**15258**	
Collision risk for single rotor transit	(from sheet 3)	5.9%														
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**3**	**136**	**202**	**120**	**100**	**67**	**97**	**60**	**66**	**6**	**0**	**857**	
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**19**	**29**	**17**	**14**	**9**	**14**	**9**	**9**	**1**	**0**	**121**	
Option 3-Extended model using flight height distribution		Gannet														
Proportion at rotor height	(from sheet 4)	5.4%														
Potential bird transits through rotors	Flux integral	0.0194	0	2	124	183	109	91	61	88	55	60	6	0	**778**	
Collisions assuming no avoidance	Collision integral	#VALUE!	**######**	**######**	**######**	**######**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	
Average collision risk for single rotor transit		#VALUE!														
Stage E - applying avoidance rates																
Using which of above options?	**Option 2**	0.00%	0	0	19	29	17	14	9	14	9	9	1	0	**121**	
Collisions assuming avoidance rate	birds per month or year	98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**2**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	SNCB (Option 2)
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
		98.00%	0	0	0	1	0	0	0	0	0	0	0	0	**2**	
Collisions after applying large array correction		98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**2**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
		98.00%	0	0	0	1	0	0	0	0	0	0	0	0	**2**	

COLLISION RISK ASSESSMENT
Sheet 3 - probability of collision for single bird transit through rotor

🟩	**All input data must be entered on Sheet 1, not here**
🟧	**However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦	Calculated outputs
🟨	Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	Gannet	
BirdLength	0.94	m
Wingspan	1.72	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	14.9	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.54	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	**Upwind:** collide length	**Upwind:** p(collision)	**Downwind:** collide length	**Downwind:** p(collision)
0.00				1.000		1.000
0.05	0.73	2.25	12.16	0.404	11.86	0.394
0.10	0.79	1.13	6.56	0.218	6.24	0.207
0.15	0.88	0.75	4.83	0.161	4.48	0.149
0.20	0.96	0.56	3.95	0.131	3.56	0.118
0.25	1.00	0.45	3.75	0.125	3.35	0.111
0.30	0.98	0.38	3.27	0.109	2.87	0.095
0.35	0.92	0.32	2.84	0.094	2.47	0.082
0.40	0.85	0.28	2.50	0.083	2.15	0.071
0.45	0.80	0.25	2.26	0.075	1.93	0.064
0.50	0.75	0.23	2.07	0.069	1.76	0.059
0.55	0.70	0.20	1.91	0.063	1.62	0.054
0.60	0.64	0.19	1.76	0.059	1.50	0.050
0.65	0.58	0.17	1.64	0.054	1.40	0.047
0.70	0.52	0.16	1.53	0.051	1.32	0.044
0.75	0.47	0.15	1.44	0.048	1.25	0.042
0.80	0.41	0.14	1.35	0.045	1.19	0.039
0.85	0.37	0.13	1.29	0.043	1.14	0.038
0.90	0.30	0.13	1.21	0.040	1.09	0.036
0.95	0.24	0.12	1.15	0.038	1.05	0.035
1.00	0.00	0.11	0.94	0.031	0.94	0.031

Overall p(collision) integrated over disk

Upwind	**6.3%**	**Downwind**	**5.6%**	
Proportion upwind: downwind				
50%	50%	**Average**	**5.9%**	(copied to sheet 1)

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	Gannet	0.450	0.800
BirdLength	0.94	0.500	0.750
Wingspan	1.72	0.550	0.700
Bird speed	14.9	0.600	0.640
Flight type	gliding	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down
0.406	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
0.109	#VALUE!
#VALUE!	#VALUE!
#VALUE!	0.071
#VALUE!	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
#VALUE!	0.050
#VALUE!	#VALUE!
0.051	#VALUE!
0.048	#VALUE!
0.045	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
#VALUE!	#VALUE!
0.031	#VALUE!

#VALUE!	**#VALUE!**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **#VALUE!**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

Flight height distribution

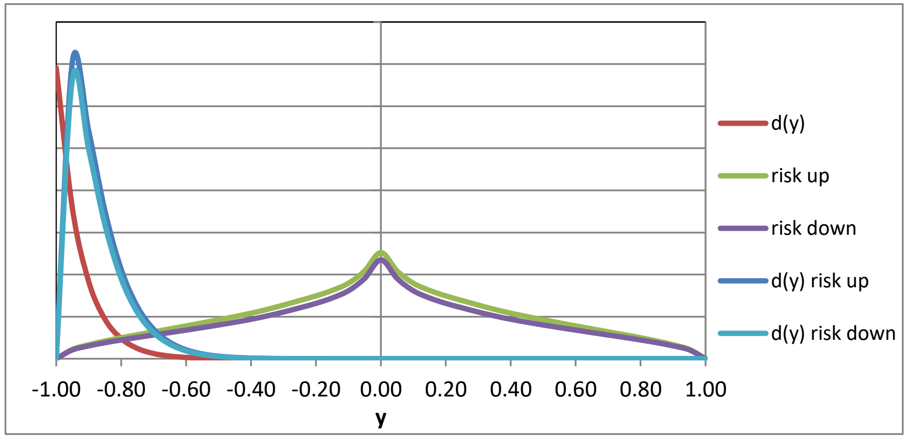
Gannet

y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	0.6910	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.95	0.3567	#VALUE!	0.021	#VALUE!	0.0075
-0.90	0.1835	#VALUE!	0.030	#VALUE!	0.0056

xinc	**yinc**	
0.05	0.05	x and y increments used in results below
		(though set fixed at 0.05 for diagram)

-0.85	0.0941	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.80	0.0481	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.75	0.0244	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.70	0.0123	0.064	#VALUE!	0.0008	#VALUE!
-0.65	0.0062	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.60	0.0031	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.55	0.0015	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.50	0.0007	0.093	0.080	0.0001	0.0001
-0.45	0.0004	0.100	#VALUE!	0.0000	#VALUE!
-0.40	0.0002	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.35	0.0001	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.30	0.0000	0.127	#VALUE!	0.0000	#VALUE!
-0.25	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.20	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.15	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
-0.10	0.0000	0.177	#VALUE!	0.0000	#VALUE!
-0.05	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.00	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.05	0.0000	#VALUE!	0.184	#VALUE!	0.0000
0.10	0.0000	0.177	0.159	0.0000	0.0000
0.15	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.20	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.25	0.0000	0.138	#VALUE!	0.0000	#VALUE!
0.30	0.0000	0.127	#VALUE!	0.0000	#VALUE!
0.35	0.0000	#VALUE!	0.102	#VALUE!	0.0000
0.40	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.45	0.0000	0.100	#VALUE!	0.0000	#VALUE!
0.50	0.0000	#VALUE!	0.080	#VALUE!	0.0000
0.55	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.60	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.65	0.0000	0.071	#VALUE!	0.0000	#VALUE!
0.70	0.0000	0.064	0.056	0.0000	0.0000
0.75	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.80	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.85	0.0000	0.042	#VALUE!	0.0000	#VALUE!
0.90	0.0000	#VALUE!	0.030	#VALUE!	0.0000
0.95	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!
1.00	0.0000	#VALUE!	#VALUE!	#VALUE!	#VALUE!

Q'_{2R} from flight distribution			5.38%	
Compare with Q_{2R} input data			38.0%	
Flux integral			0.0194	
Collision integral	**(up)**	**#VALUE!**	**(down)**	**0.0007**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)			**#VALUE!**	
Compare with Q'_{2R} * p from Option 2		#VALUE!		#VALUE!
		#VALUE!		#VALUE!



FLIGHT HEIGHT DISTRIBUTIONS

D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Gannet	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.098314	0.23317	0.08571	0.51408	0
1	0.088657	0.15457	0.0785	0.23184	0.03
2	0.079948	0.10506	0.07175	0.11113	0.03
3	0.072095	0.07335	0.06526	0.0542	0.03
4	0.065013	0.05355	0.05987	0.0274	0.03
5	0.058626	0.03936	0.05499	0.01441	0.03
6	0.052867	0.02885	0.05095	0.00782	0.03
7	0.047673	0.02168	0.0468	0.00439	0.03
8	0.04299	0.01673	0.04263	0.00257	0.03
9	0.038766	0.01316	0.03907	0.00155	0.03
10	0.034957	0.01077	0.0359	0.00098	0.03
11	0.031522	0.00936	0.03293	0.00065	0.005
12	0.028425	0.00871	0.02997	0.00045	0.005
13	0.025631	0.00854	0.02747	0.00033	0.005
14	0.023112	0.00877	0.02505	0.00025	0.005
15	0.020841	0.00937	0.02305	0.00019	0.005
16	0.018792	0.01009	0.02118	0.00016	0.005
17	0.016944	0.01088	0.01929	0.00013	0.005
18	0.015278	0.01151	0.01765	0.00012	0.005
19	0.013775	0.01175	0.01587	0.0001	0.005
20	0.01242	0.01167	0.01398	0.00009	0.005
21	0.011199	0.01137	0.01247	0.00009	0.005
22	0.010097	0.01079	0.01115	0.00009	0.005
23	0.009103	0.01008	0.00999	0.00008	0.005
24	0.008207	0.00924	0.00895	0.00008	0.005
25	0.007398	0.00842	0.00801	0.00008	0.005
26	0.00667	0.00757	0.0071	0.00007	0.005
27	0.006013	0.00664	0.00631	0.00007	0.005
28	0.00542	0.00578	0.00565	0.00007	0.005
29	0.004886	0.00502	0.00496	0.00007	0.005
30	0.004404	0.00429	0.00444	0.00007	0.005
31	0.003969	0.00352	0.00391	0.00007	0.005
32	0.003577	0.00296	0.00345	0.00007	0.005
33	0.003224	0.00242	0.00305	0.00007	0.005
34	0.002906	0.00202	0.00271	0.00006	0.005
35	0.002618	0.00165	0.00238	0.00006	0.005
36	0.002359	0.00137	0.00213	0.00006	0.005
37	0.002126	0.00109	0.00185	0.00005	0.005
38	0.001915	0.00088	0.00164	0.00005	0.005
39	0.001726	0.00069	0.00145	0.00005	0.005
40	0.001555	0.00054	0.00128	0.00004	0.005
41	0.0014	0.00041	0.00113	0.00004	0.005
42	0.001261	0.00032	0.00101	0.00004	0.005
43	0.001136	0.00025	0.00092	0.00003	0.005
44	0.001023	0.00019	0.00081	0.00003	0.005
45	0.000921	0.00014	0.00071	0.00003	0.005
46	0.00083	0.00011	0.00063	0.00003	0.005
47	0.000747	0.00009	0.00055	0.00003	0.005
48	0.000673	0.00007	0.00048	0.00003	0.005
49	0.000605	0.00005	0.00042	0.00003	0.005
50	0.000545	0.00004	0.00038	0.00003	0.005

51	0.00049	0.00003	0.00033	0.00003	0.005
52	0.000441	0.00002	0.0003	0.00003	0.005
53	0.000397	0.00002	0.00026	0.00003	0.005
54	0.000357	0.00002	0.00023	0.00003	0.005
55	0.000321	0.00001	0.00021	0.00003	0.005
56	0.000289	0.00001	0.00018	0.00003	0.005
57	0.00026	0.00001	0.00016	0.00003	0.005
58	0.000234	0.00001	0.00015	0.00003	0.005
59	0.00021	0.00001	0.00013	0.00003	0.005
60	0.000189	0.00001	0.00012	0.00003	0.005
61	0.00017	0	0.0001	0.00003	0.005
62	0.000153	0	0.00009	0.00002	0.005
63	0.000137	0	0.00008	0.00002	0.005
64	0.000123	0	0.00007	0.00002	0.005
65	0.000111	0	0.00007	0.00002	0.005
66	9.94E-05	0	0.00006	0.00001	0.005
67	8.92E-05	0	0.00005	0.00001	0.005
68	8.01E-05	0	0.00005	0.00001	0.005
69	7.19E-05	0	0.00004	0.00001	0.005
70	6.45E-05	0	0.00004	0.00001	0.005
71	5.79E-05	0	0.00003	0.00001	0.005
72	5.19E-05	0	0.00003	0	0.005
73	4.66E-05	0	0.00003	0	0.005
74	4.17E-05	0	0.00003	0	0.005
75	3.74E-05	0	0.00002	0	0.005
76	3.35E-05	0	0.00002	0	0.005
77	0.00003	0	0.00002	0	0.005
78	2.69E-05	0.00001	0.00002	0	0.005
79	2.41E-05	0.00001	0.00002	0	0.005
80	2.16E-05	0.00001	0.00002	0	0.005
81	1.93E-05	0.00001	0.00002	0	0.005
82	1.73E-05	0.00001	0.00002	0	0.005
83	1.55E-05	0.00001	0.00002	0	0.005
84	1.38E-05	0.00002	0.00002	0	0.005
85	1.24E-05	0.00002	0.00002	0	0.005
86	0.000011	0.00003	0.00002	0	0.005
87	9.87E-06	0.00003	0.00002	0	0.005
88	8.82E-06	0.00004	0.00002	0	0.005
89	7.87E-06	0.00004	0.00002	0	0.005
90	7.03E-06	0.00005	0.00002	0	0.005
91	6.27E-06	0.00006	0.00002	0	0.005
92	5.59E-06	0.00007	0.00002	0	0.005
93	4.99E-06	0.00009	0.00002	0	0.005
94	4.45E-06	0.0001	0.00002	0	0.005
95	3.96E-06	0.00012	0.00002	0	0.005
96	3.53E-06	0.00014	0.00002	0	0.005
97	3.14E-06	0.00016	0.00002	0	0.005
98	2.8E-06	0.00018	0.00002	0	0.005
99	2.49E-06	0.0002	0.00001	0	0.005
100	2.21E-06	0.00021	0.00002	0	0.005
101	1.97E-06	0.00022	0.00002	0	0.005
102	1.75E-06	0.00022	0.00002	0	0.005
103	1.55E-06	0.00022	0.00002	0	0.005
104	1.38E-06	0.00021	0.00002	0	0.005
105	1.22E-06	0.0002	0.00001	0	0.005
106	1.09E-06	0.00019	0.00001	0	0.005
107	9.63E-07	0.00017	0.00002	0	0.005
108	8.53E-07	0.00014	0.00002	0	0.005
109	7.56E-07	0.00012	0.00002	0	0.005

110	6.69E-07	0.0001	0.00002	0	0.005
111	5.92E-07	0.00009	0.00002	0	0.005
112	5.24E-07	0.00007	0.00002	0	0.005
113	4.63E-07	0.00006	0.00001	0	0.005
114	4.09E-07	0.00005	0.00001	0	0.005
115	3.61E-07	0.00004	0.00001	0	0.005
116	3.19E-07	0.00003	0.00001	0	0.005
117	2.81E-07	0.00002	0.00001	0	0.005
118	2.48E-07	0.00001	0.00001	0	0.005
119	2.19E-07	0.00001	0.00001	0	0.005
120	1.93E-07	0.00001	0.00001	0	0.005
121	1.7E-07	0	0.00001	0	0.005
122	1.49E-07	0	0.00001	0	0.005
123	1.31E-07	0	0.00001	0	0.005
124	1.15E-07	0	0.00001	0	0.005
125	1.01E-07	0	0.00001	0	0.005
126	8.87E-08	0	0.00001	0	0.005
127	7.78E-08	0	0.00001	0	0.005
128	6.82E-08	0	0.00001	0	0.005
129	5.97E-08	0	0.00001	0	0.005
130	5.23E-08	0	0.00001	0	0.005
131	4.57E-08	0	0.00001	0	0.005
132	4E-08	0	0.00001	0	0.005
133	3.49E-08	0	0.00001	0	0.005
134	3.05E-08	0	0.00001	0	0.005
135	2.66E-08	0	0.00001	0	0.005
136	2.32E-08	0	0.00001	0	0.005
137	2.02E-08	0	0.00001	0	0.005
138	1.75E-08	0	0.00001	0	0.005
139	1.53E-08	0	0.00001	0	0.005
140	1.33E-08	0	0	0	0.005
141	1.15E-08	0	0	0	0.005
142	9.98E-09	0	0	0	0.005
143	8.65E-09	0	0	0	0.005
144	7.49E-09	0	0	0	0.005
145	6.49E-09	0	0	0	0.005
146	5.61E-09	0	0	0	0.005
147	4.84E-09	0	0	0	0.005
148	4.18E-09	0	0	0	0.005
149	3.61E-09	0	0	0	0.005
150	3.11E-09	0	0	0	0.005
151	2.67E-09	0	0	0	0
152	2.3E-09	0	0	0	0
153	1.98E-09	0	0	0	0
154	1.7E-09	0	0	0	0
155	1.46E-09	0	0	0	0
156	1.25E-09				
157	1.07E-09				
158	9.12E-10				
159	7.8E-10				
160	6.65E-10				
161	5.67E-10				
162	4.83E-10				
163	4.11E-10				
164	3.49E-10				
165	2.96E-10				
166	2.51E-10				
167	2.13E-10				
168	1.8E-10				

169	1.52E-10
170	1.29E-10
171	1.08E-10
172	9.13E-11
173	7.68E-11
174	6.46E-11
175	5.42E-11
176	4.54E-11
177	3.8E-11
178	3.18E-11
179	2.66E-11
180	2.21E-11
181	1.84E-11
182	1.53E-11
183	1.27E-11
184	1.06E-11
185	8.76E-12
186	7.25E-12
187	5.99E-12
188	4.94E-12
189	4.07E-12
190	3.35E-12
191	2.75E-12
192	2.26E-12
193	1.85E-12
194	1.51E-12
195	1.24E-12
196	1.01E-12
197	8.22E-13
198	6.68E-13
199	5.42E-13
200	4.4E-13
201	3.56E-13
202	2.87E-13
203	2.32E-13
204	1.87E-13
205	1.5E-13
206	1.21E-13
207	9.66E-14
208	7.73E-14
209	6.17E-14
210	4.92E-14
211	3.92E-14
212	3.11E-14
213	2.47E-14
214	1.95E-14
215	1.54E-14
216	1.22E-14
217	9.58E-15
218	7.53E-15
219	5.9E-15
220	4.62E-15
221	3.61E-15
222	2.82E-15
223	2.19E-15
224	1.7E-15
225	1.32E-15
226	1.02E-15
227	7.89E-16

228	6.08E-16
229	4.67E-16
230	3.59E-16
231	2.75E-16
232	2.1E-16
233	1.6E-16
234	1.22E-16
235	9.24E-17
236	7E-17
237	5.29E-17
238	3.99E-17
239	3.01E-17
240	2.26E-17
241	1.69E-17
242	1.26E-17
243	9.42E-18
244	7.01E-18
245	5.2E-18
246	3.85E-18
247	2.85E-18
248	2.1E-18
249	1.54E-18
250	1.13E-18
251	8.28E-19
252	6.04E-19
253	4.4E-19
254	3.19E-19
255	2.31E-19
256	1.67E-19
257	1.2E-19
258	8.65E-20
259	6.2E-20
260	4.43E-20
261	3.16E-20
262	2.25E-20
263	1.59E-20
264	1.13E-20
265	7.95E-21
266	5.59E-21
267	3.92E-21
268	2.74E-21
269	1.91E-21
270	1.33E-21
271	9.22E-22
272	6.38E-22
273	4.4E-22
274	3.02E-22
275	2.07E-22
276	1.42E-22
277	9.64E-23
278	6.55E-23
279	4.44E-23
280	2.99E-23
281	2.02E-23
282	1.35E-23
283	9.05E-24
284	6.03E-24
285	4.01E-24
286	2.66E-24

287	1.75E-24
288	1.15E-24
289	7.57E-25
290	4.95E-25
291	3.23E-25
292	2.1E-25
293	1.36E-25
294	8.76E-26
295	5.64E-26
296	3.61E-26
297	2.31E-26
298	1.47E-26
299	9.31E-27

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩 from Sheet 1 - input data
🟪 from Sheet 6 - available hours
🟧 from Sheet 3 - single transit collision risk
🟨 from survey data
🟦 calculated field

Bird details:		
Species		Gannet
Flight speed	m/sec	14.9
Flight type		gliding
Windfarm data:		
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	4000	2000	0	0	0	2000	4000	0	0	**12000**
Migrant flux density	birds/ km		0	0	0	500	250	0	0	0	250	500	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	100	50	0	0	0	50	100	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	75	38	0	0	0	38	75	0	0	**225**
Collision risk for single rotor transit	(from sheet 3)	5.9%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**4**	**2**	**0**	**0**	**0**	**2**	**4**	**0**	**0**	**13**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	5.4%													
Potential bird transits through rotors	Flux integral	0.0194	0	0	0	2	1	0	0	0	1	2	0	0	**6**
Collisions assuming no avoidance	Collision integral	#VALUE!	**#######**	**#######**	**######**	**######**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**
Average collision risk for single rotor transit		#VALUE!													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	4	2	0	0	0	2	4	0	0	**13**
Collisions assuming avoidance rate	birds per month or year	98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

Monthly available daylight hours

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1

Monthly available nocturnal hours

507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9

Monthly available total hours

744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT
Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of turbines	1			
Rotor radius	127.5			
Width of windfarm	0.3			
Average proportion of time operational	0.95			
Collision risk from single rotor transit	0.059			
Assumed number of turbine rows	1.0			
Avoidance rate	98.70%	98.90%	99.10%	98.00%
Collision risk for single bird passage, before correction	0.00049	0.00041	0.00034	0.00075
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Number of rows (optional)	
(if this is left blank, number is assumed to be sqrt(T)	
Number of turbines in each row	

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩 used in overall collision risk sheet
🟨 used in migrant collision risk sheet
🟧 used in single transit collision risk sheet or extended model
🟦 used in available hours sheet
⬜ used in large array correction sheet
🟥 not used in calculation but stated for reference

	Units	Value	Data sources
Bird data			
Species name		**Herring gull**	
Bird length	m	0.60	
Wingspan	m	1.44	
Flight speed	m/sec	12.8	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

	Units	Value	Data sources											
Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		1.13	0.37	0.255	0.255	0.185	0.41	0.06	0.095	0.045	0.125	0.285	0.285
Proportion at rotor height	%	2.0%												
Proportion of flights upwind	%	50.0%												

	Units	Value	Data sources											
Birds on migration data														
Migration passages	birds		0	0	0	0	0	0	0	0	0	0	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

	Units	Value	Data sources
Windfarm data			
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

	Units	Value	Data sources											
Turbine data														
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

			Data sources (if applicable)
Avoidance rates used in presenting results	99.00%	SNCB 2014	
	100.00%		
	100.00%		
	100.00%		

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:		
Species		Herring gull
Flight speed	m/sec	12.8
Nocturnal activity factor (1-5)		3
Nocturnal activity (% of daytime)		50%
Windfarm data:		
Latitude	degrees	56.2
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**	
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%	
Stage A - flight activity																
Daytime areal bird density	birds/sq km		1.13	0.37	0.255	0.255	0.185	0.41	0.06	0.095	0.045	0.125	0.285	0.285		
Proportion at rotor height	%	2.0%														
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218		
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526		
Flux factor			5112	1602	1305	1347	1067	2358	352	532	229	616	1274	1265		
Option 1 -Basic model - Stages B, C and D															**per annum**	
Potential bird transits through rotors			102	32	26	27	21	47	7	11	5	12	25	25	**341**	
Collision risk for single rotor transit	(from sheet 3)	5.2%														
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**5**	**2**	**1**	**1**	**1**	**2**	**0**	**1**	**0**	**1**	**1**	**1**	**17**	
Option 2-Basic model using proportion from flight distribution			**50**	**16**	**13**	**13**	**11**	**23**	**3**	**5**	**2**	**6**	**13**	**12**	**168**	
Option 3-Extended model using flight height distribution		Herring gull														
Proportion at rotor height	(from sheet 4)	19.9%														
Potential bird transits through rotors	Flux integral	0.1030	527	165	134	139	110	243	36	55	24	63	131	130	**1757**	
Collisions assuming no avoidance	Collision integral	0.00327	**16**	**5**	**4**	**4**	**3**	**7**	**1**	**2**	**1**	**2**	**4**	**4**	**53**	
Average collision risk for single rotor transit		3.2%														
Stage E - applying avoidance rates																
Using which of above options?	**Option 3**	0.00%	16	5	4	4	3	7	1	2	1	2	4	4	**53**	
Collisions assuming avoidance rate	birds per month or year	99.00%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
Collisions after applying large array correction		99.00%	0	0	0	0	0	0	0	0	0	0	0	0	**1**	SNCB 2014
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

COLLISION RISK ASSESSMENT

Sheet 3 - probability of collision for single bird transit through rotor

🟩	**All input data must be entered on Sheet 1, not here**
🟧	**However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦	Calculated outputs
🟨	Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	Herring gull	
BirdLength	0.60	m
Wingspan	1.44	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	12.8	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.42	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.94	11.13	0.430	10.84	0.419
0.10	0.79	0.97	5.99	0.232	5.67	0.219
0.15	0.88	0.65	4.40	0.170	4.04	0.156
0.20	0.96	0.48	3.59	0.139	3.20	0.124
0.25	1.00	0.39	3.05	0.118	2.64	0.102
0.30	0.98	0.32	2.63	0.102	2.24	0.086
0.35	0.92	0.28	2.26	0.087	1.89	0.073
0.40	0.85	0.24	1.96	0.076	1.62	0.063
0.45	0.80	0.22	1.76	0.068	1.44	0.056
0.50	0.75	0.19	1.59	0.062	1.29	0.050
0.55	0.70	0.18	1.46	0.056	1.17	0.045
0.60	0.64	0.16	1.33	0.051	1.07	0.041
0.65	0.58	0.15	1.22	0.047	0.98	0.038
0.70	0.52	0.14	1.12	0.043	0.91	0.035
0.75	0.47	0.13	1.05	0.040	0.86	0.033
0.80	0.41	0.12	0.97	0.038	0.80	0.031
0.85	0.37	0.11	0.92	0.036	0.77	0.030
0.90	0.30	0.11	0.85	0.033	0.73	0.028
0.95	0.24	0.10	0.79	0.031	0.69	0.027
1.00	0.00	0.10	0.60	0.023	0.60	0.023

Overall p(collision) integrated over disk

Upwind	**5.6%**	**Downwind**	**4.8%**

Proportion	upwind: downwind
50%	50%

Average **5.2%** (copied to sheet 1)

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	Herring gull	0.450	0.800
BirdLength	0.60	0.500	0.750
Wingspan	1.44	0.550	0.700
Bird speed	12.8	0.600	0.640
Flight type	flapping	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down	
0.430	0.419	
0.232	0.219	
0.170	0.156	
0.139	0.124	
0.118	0.102	
0.102	0.086	
0.087	0.073	
0.076	0.063	
0.068	0.056	
0.062	0.050	
0.056	0.045	
0.051	0.041	
0.047	0.038	
0.043	0.035	
0.040	0.033	
0.038	0.031	
0.036	0.030	
0.033	0.028	
0.031	0.027	
0.023	0.023	
5.64%	**4.80%**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **5.22%**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

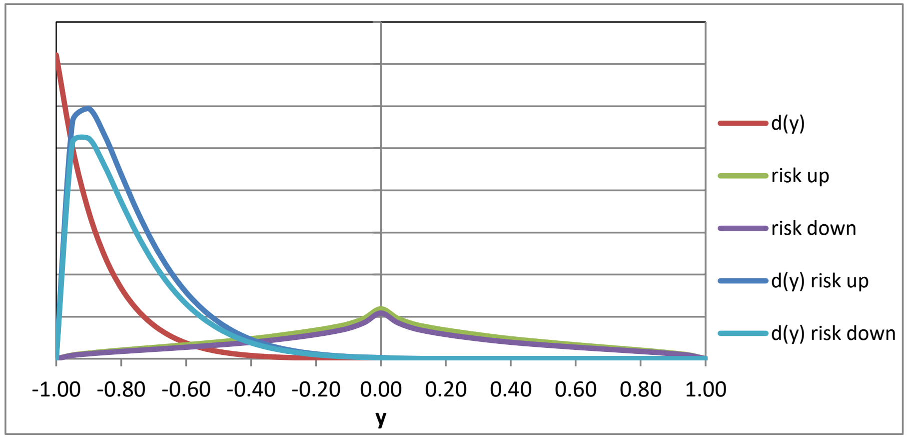
Flight height distribution
Herring gull

y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	1.4434	0.000	0.000	0.0000	0.0000
-0.95	1.0052	0.017	0.016	0.0176	0.0160
-0.90	0.6988	0.027	0.023	0.0186	0.0164

xinc	**yinc**	
0.05	0.05	x and y increments used in results below (though set fixed at 0.05 for diagram)

-0.85	0.4850	0.034	0.029	0.0165	0.0143
-0.80	0.3360	0.041	0.035	0.0137	0.0117
-0.75	0.2320	0.047	0.040	0.0109	0.0092
-0.70	0.1597	0.053	0.045	0.0085	0.0071
-0.65	0.1095	0.060	0.049	0.0065	0.0054
-0.60	0.0746	0.066	0.055	0.0049	0.0041
-0.55	0.0506	0.073	0.060	0.0037	0.0030
-0.50	0.0341	0.080	0.066	0.0027	0.0022
-0.45	0.0228	0.087	0.072	0.0020	0.0016
-0.40	0.0151	0.095	0.078	0.0014	0.0012
-0.35	0.0099	0.104	0.086	0.0010	0.0008
-0.30	0.0064	0.114	0.095	0.0007	0.0006
-0.25	0.0041	0.124	0.104	0.0005	0.0004
-0.20	0.0026	0.136	0.115	0.0004	0.0003
-0.15	0.0016	0.149	0.128	0.0002	0.0002
-0.10	0.0010	0.165	0.144	0.0002	0.0001
-0.05	0.0006	0.193	0.172	0.0001	0.0001
0.00	0.0004	0.237	0.217	0.0001	0.0001
0.05	0.0002	0.193	0.172	0.0000	0.0000
0.10	0.0001	0.165	0.144	0.0000	0.0000
0.15	0.0001	0.149	0.128	0.0000	0.0000
0.20	0.0000	0.136	0.115	0.0000	0.0000
0.25	0.0000	0.124	0.104	0.0000	0.0000
0.30	0.0000	0.114	0.095	0.0000	0.0000
0.35	0.0000	0.104	0.086	0.0000	0.0000
0.40	0.0000	0.095	0.078	0.0000	0.0000
0.45	0.0000	0.087	0.072	0.0000	0.0000
0.50	0.0000	0.080	0.066	0.0000	0.0000
0.55	0.0000	0.073	0.060	0.0000	0.0000
0.60	0.0000	0.066	0.055	0.0000	0.0000
0.65	0.0000	0.060	0.049	0.0000	0.0000
0.70	0.0000	0.053	0.045	0.0000	0.0000
0.75	0.0000	0.047	0.040	0.0000	0.0000
0.80	0.0000	0.041	0.035	0.0000	0.0000
0.85	0.0000	0.034	0.029	0.0000	0.0000
0.90	0.0000	0.027	0.023	0.0000	0.0000
0.95	0.0000	0.017	0.016	0.0000	0.0000
1.00	0.0000	0.000	0.000	0.0000	0.0000

Q'_{2R} from flight distribution			19.86%	
Compare with Q_{2R} input data			2.0%	
Flux integral			0.1030	
Collision integral	**(up)**	**0.0035**	**(down)**	**0.0030**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)			**0.0033**	
Compare with Q'_{2R} * p from Option 2		0.01120		0.00953
		31.4%		31.7%



FLIGHT HEIGHT DISTRIBUTIONS

D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Herring gull	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.055193	0.23317	0.08571	0.51408	0
1	0.05216	0.15457	0.0785	0.23184	0.03
2	0.049294	0.10506	0.07175	0.11113	0.03
3	0.046585	0.07335	0.06526	0.0542	0.03
4	0.044026	0.05355	0.05987	0.0274	0.03
5	0.041606	0.03936	0.05499	0.01441	0.03
6	0.03932	0.02885	0.05095	0.00782	0.03
7	0.037159	0.02168	0.0468	0.00439	0.03
8	0.035117	0.01673	0.04263	0.00257	0.03
9	0.033187	0.01316	0.03907	0.00155	0.03
10	0.031363	0.01077	0.0359	0.00098	0.03
11	0.029639	0.00936	0.03293	0.00065	0.005
12	0.028009	0.00871	0.02997	0.00045	0.005
13	0.02647	0.00854	0.02747	0.00033	0.005
14	0.025014	0.00877	0.02505	0.00025	0.005
15	0.023639	0.00937	0.02305	0.00019	0.005
16	0.022339	0.01009	0.02118	0.00016	0.005
17	0.02111	0.01088	0.01929	0.00013	0.005
18	0.019949	0.01151	0.01765	0.00012	0.005
19	0.018851	0.01175	0.01587	0.0001	0.005
20	0.017814	0.01167	0.01398	0.00009	0.005
21	0.016833	0.01137	0.01247	0.00009	0.005
22	0.015906	0.01079	0.01115	0.00009	0.005
23	0.01503	0.01008	0.00999	0.00008	0.005
24	0.014202	0.00924	0.00895	0.00008	0.005
25	0.01342	0.00842	0.00801	0.00008	0.005
26	0.01268	0.00757	0.0071	0.00007	0.005
27	0.011981	0.00664	0.00631	0.00007	0.005
28	0.01132	0.00578	0.00565	0.00007	0.005
29	0.010696	0.00502	0.00496	0.00007	0.005
30	0.010106	0.00429	0.00444	0.00007	0.005
31	0.009548	0.00352	0.00391	0.00007	0.005
32	0.00902	0.00296	0.00345	0.00007	0.005
33	0.008522	0.00242	0.00305	0.00007	0.005
34	0.008051	0.00202	0.00271	0.00006	0.005
35	0.007605	0.00165	0.00238	0.00006	0.005
36	0.007184	0.00137	0.00213	0.00006	0.005
37	0.006787	0.00109	0.00185	0.00005	0.005
38	0.00641	0.00088	0.00164	0.00005	0.005
39	0.006055	0.00069	0.00145	0.00005	0.005
40	0.005719	0.00054	0.00128	0.00004	0.005
41	0.005402	0.00041	0.00113	0.00004	0.005
42	0.005102	0.00032	0.00101	0.00004	0.005
43	0.004818	0.00025	0.00092	0.00003	0.005
44	0.00455	0.00019	0.00081	0.00003	0.005
45	0.004296	0.00014	0.00071	0.00003	0.005
46	0.004057	0.00011	0.00063	0.00003	0.005
47	0.003831	0.00009	0.00055	0.00003	0.005
48	0.003617	0.00007	0.00048	0.00003	0.005
49	0.003415	0.00005	0.00042	0.00003	0.005
50	0.003224	0.00004	0.00038	0.00003	0.005

51	0.003043	0.00003	0.00033	0.00003	0.005
52	0.002873	0.00002	0.0003	0.00003	0.005
53	0.002711	0.00002	0.00026	0.00003	0.005
54	0.002559	0.00002	0.00023	0.00003	0.005
55	0.002415	0.00001	0.00021	0.00003	0.005
56	0.002279	0.00001	0.00018	0.00003	0.005
57	0.002151	0.00001	0.00016	0.00003	0.005
58	0.002029	0.00001	0.00015	0.00003	0.005
59	0.001914	0.00001	0.00013	0.00003	0.005
60	0.001806	0.00001	0.00012	0.00003	0.005
61	0.001704	0	0.0001	0.00003	0.005
62	0.001607	0	0.00009	0.00002	0.005
63	0.001516	0	0.00008	0.00002	0.005
64	0.001429	0	0.00007	0.00002	0.005
65	0.001348	0	0.00007	0.00002	0.005
66	0.001271	0	0.00006	0.00001	0.005
67	0.001198	0	0.00005	0.00001	0.005
68	0.001129	0	0.00005	0.00001	0.005
69	0.001065	0	0.00004	0.00001	0.005
70	0.001003	0	0.00004	0.00001	0.005
71	0.000946	0	0.00003	0.00001	0.005
72	0.000891	0	0.00003	0	0.005
73	0.000839	0	0.00003	0	0.005
74	0.000791	0	0.00003	0	0.005
75	0.000745	0	0.00002	0	0.005
76	0.000701	0	0.00002	0	0.005
77	0.000661	0	0.00002	0	0.005
78	0.000622	0.00001	0.00002	0	0.005
79	0.000585	0.00001	0.00002	0	0.005
80	0.000551	0.00001	0.00002	0	0.005
81	0.000519	0.00001	0.00002	0	0.005
82	0.000488	0.00001	0.00002	0	0.005
83	0.000459	0.00001	0.00002	0	0.005
84	0.000432	0.00002	0.00002	0	0.005
85	0.000406	0.00002	0.00002	0	0.005
86	0.000382	0.00003	0.00002	0	0.005
87	0.000359	0.00003	0.00002	0	0.005
88	0.000338	0.00004	0.00002	0	0.005
89	0.000317	0.00004	0.00002	0	0.005
90	0.000298	0.00005	0.00002	0	0.005
91	0.00028	0.00006	0.00002	0	0.005
92	0.000263	0.00007	0.00002	0	0.005
93	0.000247	0.00009	0.00002	0	0.005
94	0.000232	0.0001	0.00002	0	0.005
95	0.000218	0.00012	0.00002	0	0.005
96	0.000205	0.00014	0.00002	0	0.005
97	0.000192	0.00016	0.00002	0	0.005
98	0.00018	0.00018	0.00002	0	0.005
99	0.000169	0.0002	0.00001	0	0.005
100	0.000159	0.00021	0.00002	0	0.005
101	0.000149	0.00022	0.00002	0	0.005
102	0.000139	0.00022	0.00002	0	0.005
103	0.000131	0.00022	0.00002	0	0.005
104	0.000122	0.00021	0.00002	0	0.005
105	0.000115	0.0002	0.00001	0	0.005
106	0.000107	0.00019	0.00001	0	0.005
107	0.000101	0.00017	0.00002	0	0.005
108	9.41E-05	0.00014	0.00002	0	0.005
109	0.000088	0.00012	0.00002	0	0.005

110	8.24E-05	0.0001	0.00002	0	0.005
111	0.000077	0.00009	0.00002	0	0.005
112	0.000072	0.00007	0.00002	0	0.005
113	6.73E-05	0.00006	0.00001	0	0.005
114	6.29E-05	0.00005	0.00001	0	0.005
115	5.88E-05	0.00004	0.00001	0	0.005
116	5.49E-05	0.00003	0.00001	0	0.005
117	5.13E-05	0.00002	0.00001	0	0.005
118	4.79E-05	0.00001	0.00001	0	0.005
119	4.47E-05	0.00001	0.00001	0	0.005
120	4.17E-05	0.00001	0.00001	0	0.005
121	3.88E-05	0	0.00001	0	0.005
122	3.62E-05	0	0.00001	0	0.005
123	3.38E-05	0	0.00001	0	0.005
124	3.14E-05	0	0.00001	0	0.005
125	2.93E-05	0	0.00001	0	0.005
126	2.73E-05	0	0.00001	0	0.005
127	2.54E-05	0	0.00001	0	0.005
128	2.36E-05	0	0.00001	0	0.005
129	0.000022	0	0.00001	0	0.005
130	2.04E-05	0	0.00001	0	0.005
131	0.000019	0	0.00001	0	0.005
132	1.76E-05	0	0.00001	0	0.005
133	1.64E-05	0	0.00001	0	0.005
134	1.52E-05	0	0.00001	0	0.005
135	1.41E-05	0	0.00001	0	0.005
136	1.31E-05	0	0.00001	0	0.005
137	1.21E-05	0	0.00001	0	0.005
138	1.12E-05	0	0.00001	0	0.005
139	1.04E-05	0	0.00001	0	0.005
140	9.63E-06	0	0	0	0.005
141	8.91E-06	0	0	0	0.005
142	8.25E-06	0	0	0	0.005
143	7.63E-06	0	0	0	0.005
144	7.05E-06	0	0	0	0.005
145	6.51E-06	0	0	0	0.005
146	6.01E-06	0	0	0	0.005
147	5.55E-06	0	0	0	0.005
148	5.12E-06	0	0	0	0.005
149	4.72E-06	0	0	0	0.005
150	4.35E-06	0	0	0	0.005
151	4.01E-06	0	0	0	0
152	3.69E-06	0	0	0	0
153	3.4E-06	0	0	0	0
154	3.13E-06	0	0	0	0
155	2.87E-06	0	0	0	0
156	2.64E-06				
157	2.43E-06				
158	2.23E-06				
159	2.04E-06				
160	1.87E-06				
161	1.72E-06				
162	1.57E-06				
163	1.44E-06				
164	1.32E-06				
165	1.2E-06				
166	1.1E-06				
167	0.000001				
168	9.17E-07				

169	8.36E-07
170	7.62E-07
171	6.94E-07
172	6.32E-07
173	5.75E-07
174	5.23E-07
175	4.75E-07
176	4.31E-07
177	3.91E-07
178	3.55E-07
179	3.22E-07
180	2.91E-07
181	2.64E-07
182	2.38E-07
183	2.15E-07
184	1.94E-07
185	1.75E-07
186	1.58E-07
187	1.42E-07
188	1.28E-07
189	1.15E-07
190	1.04E-07
191	9.32E-08
192	8.36E-08
193	7.5E-08
194	6.72E-08
195	6.01E-08
196	5.38E-08
197	4.81E-08
198	4.29E-08
199	3.83E-08
200	3.42E-08
201	3.04E-08
202	2.71E-08
203	2.41E-08
204	2.14E-08
205	1.9E-08
206	1.68E-08
207	1.49E-08
208	1.32E-08
209	1.17E-08
210	1.03E-08
211	9.11E-09
212	8.03E-09
213	7.07E-09
214	6.23E-09
215	5.47E-09
216	4.81E-09
217	4.22E-09
218	3.7E-09
219	3.24E-09
220	2.83E-09
221	2.48E-09
222	2.16E-09
223	1.88E-09
224	1.64E-09
225	1.43E-09
226	1.24E-09
227	1.08E-09

228	9.35E-10
229	8.1E-10
230	7.01E-10
231	6.06E-10
232	5.23E-10
233	4.51E-10
234	3.89E-10
235	3.34E-10
236	2.87E-10
237	2.47E-10
238	2.11E-10
239	1.81E-10
240	1.55E-10
241	1.32E-10
242	1.13E-10
243	9.61E-11
244	8.18E-11
245	6.95E-11
246	5.9E-11
247	5E-11
248	4.23E-11
249	3.58E-11
250	3.02E-11
251	2.55E-11
252	2.14E-11
253	1.8E-11
254	1.51E-11
255	1.27E-11
256	1.06E-11
257	8.89E-12
258	7.42E-12
259	6.19E-12
260	5.15E-12
261	4.28E-12
262	3.56E-12
263	2.95E-12
264	2.44E-12
265	2.02E-12
266	1.66E-12
267	1.37E-12
268	1.13E-12
269	9.27E-13
270	7.6E-13
271	6.23E-13
272	5.09E-13
273	4.16E-13
274	3.39E-13
275	2.76E-13
276	2.24E-13
277	1.82E-13
278	1.47E-13
279	1.19E-13
280	9.6E-14
281	7.73E-14
282	6.22E-14
283	4.99E-14
284	4E-14
285	3.2E-14
286	2.56E-14

287	2.04E-14
288	1.62E-14
289	1.29E-14
290	1.02E-14
291	8.11E-15
292	6.41E-15
293	5.06E-15
294	3.98E-15
295	3.13E-15
296	2.46E-15
297	1.92E-15
298	1.5E-15
299	1.17E-15

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:															
Species		Herring gull													
Flight speed	m/sec	12.8													
Flight type		flapping													
Windfarm data:															
Number of turbines		1													
Rotor radius	m	127.5													
Minimum height of rotor	m	152.5													
Total rotor frontal area	sq m	51071													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	0	0	0	0	0	0	0	0	0	**0**
Migrant flux density	birds/ km		0	0	0	0	0	0	0	0	0	0	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	0	0	0	0	0	0	0	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collision risk for single rotor transit	(from sheet 3)	5.2%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	19.9%													
Potential bird transits through rotors	Flux integral	0.1030	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions assuming no avoidance	Collision integral	0.00327	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Average collision risk for single rotor transit		3.2%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions assuming avoidance rate	birds per month or year	99.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		99.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

Monthly available daylight hours

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1

Monthly available nocturnal hours

507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9

Monthly available total hours

744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT
Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of rows (optional)	
(if this is left blank, number is assumed to be sqrt(T)	
Number of turbines in each row	

Number of turbines	1			
Rotor radius	127.5			
Width of windfarm	0.3			
Average proportion of time operational	0.95			
Collision risk from single rotor transit	0.052			
Assumed number of turbine rows	1.0			
Avoidance rate	99.00%	100.00%	100.00%	100.00%
Collision risk for single bird passage, before correction	0.00033	0.00000	0.00000	0.00000
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩	used in overall collision risk sheet
🟩	used in migrant collision risk sheet
🟧	used in single transit collision risk sheet or extended model
🟪	used in available hours sheet
🟨	used in large array correction sheet
🟥	not used in calculation but stated for reference

Bird data	**Units**	**Value**	**Data sources**
Species name		**Kittiwake**	
Bird length	m	0.39	
Wingspan	m	1.08	
Flight speed	m/sec	12.8	
Nocturnal activity factor (1-5)		2	
Flight type, flapping or gliding		flapping	

Data sources

Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		1.2086	0.1272	0.3649	0.2083	0.1779	0.6157	0.0589	0.0991	0.2271	0.2882	0.0979	0.3499
Proportion at rotor height	%	42.0%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data														
Migration passages	birds		0	0	0	4000	2000	0	0	0	2000	4000	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

Windfarm data	**Units**	**Value**	**Data sources**
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

Turbine data	**Units**	**Value**	**Data sources**											
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

Avoidance rates used in presenting results			**Data sources (if applicable)**
	98.70%		
	98.90%	SNCB 2014	
	99.10%		
	100.00%		

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:															
Species		Kittiwake													
Flight speed	m/sec	12.8													
Nocturnal activity factor (1-5)		2													
Nocturnal activity (% of daytime)		25%													
Windfarm data:															
Latitude	degrees	56.2													
Number of turbines		1													
Rotor radius	m	127.5													
Minimum height of rotor	m	152.5													
Total rotor frontal area	sq m	51071													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															
Daytime areal bird density	birds/sq km		1.2086	0.12722	0.3649	0.2082685	0.177934	0.615746	0.058903	0.099133	0.227099	0.288175	0.09785	0.34986	
Proportion at rotor height	%	42.0%													
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218	
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526	
Flux factor			4053	432	1550	959	928	3267	316	492	982	1142	331	1129	
Option 1 -Basic model - Stages B, C and D															**per annum**
Potential bird transits through rotors			1702	181	651	403	390	1372	133	207	413	480	139	474	**6544**
Collision risk for single rotor transit	(from sheet 3)	4.4%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**71**	**8**	**27**	**17**	**16**	**57**	**6**	**9**	**17**	**20**	**6**	**20**	**273**
Option 2-Basic model using proportion from flight distribution			**12**	**1**	**4**	**3**	**3**	**9**	**1**	**1**	**3**	**3**	**1**	**3**	**45**
Option 3-Extended model using flight height distribution		Kittiwake													
Proportion at rotor height	(from sheet 4)	6.9%													
Potential bird transits through rotors	Flux integral	0.0262	106	11	41	25	24	86	8	13	26	30	9	30	**408**
Collisions assuming no avoidance	Collision integral	0.00056	**2**	**0**	**1**	**1**	**0**	**2**	**0**	**0**	**1**	**1**	**0**	**1**	**8**
Average collision risk for single rotor transit		2.1%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 2**	0.00%	12	1	4	3	3	9	1	1	3	3	1	3	45
Collisions assuming avoidance rate	birds per month or year	98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**1**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**1**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0** SNCB 2014
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 3 - probability of collision for single bird transit through rotor

🟩	**All input data must be entered on Sheet 1, not here**
🟧	**However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦	Calculated outputs
🟨	Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	Kittiwake	
BirdLength	0.39	m
Wingspan	1.08	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	12.8	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.36	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.94	10.43	0.404	10.14	0.392
0.10	0.79	0.97	5.64	0.218	5.32	0.206
0.15	0.88	0.65	4.17	0.161	3.81	0.147
0.20	0.96	0.48	3.41	0.132	3.02	0.117
0.25	1.00	0.39	2.87	0.111	2.46	0.095
0.30	0.98	0.32	2.42	0.094	2.03	0.078
0.35	0.92	0.28	2.05	0.079	1.68	0.065
0.40	0.85	0.24	1.75	0.068	1.41	0.055
0.45	0.80	0.22	1.55	0.060	1.23	0.047
0.50	0.75	0.19	1.38	0.054	1.08	0.042
0.55	0.70	0.18	1.25	0.048	0.96	0.037
0.60	0.64	0.16	1.12	0.043	0.86	0.033
0.65	0.58	0.15	1.01	0.039	0.77	0.030
0.70	0.52	0.14	0.91	0.035	0.70	0.027
0.75	0.47	0.13	0.84	0.032	0.65	0.025
0.80	0.41	0.12	0.76	0.029	0.59	0.023
0.85	0.37	0.11	0.71	0.027	0.56	0.022
0.90	0.30	0.11	0.64	0.025	0.52	0.020
0.95	0.24	0.10	0.58	0.022	0.48	0.019
1.00	0.00	0.10	0.39	0.015	0.39	0.015

Overall p(collision) integrated over disk

Upwind **4.8%** **Downwind** **4.0%**

Proportion	upwind: downwind
50%	50%

Average **4.4%** (copied to sheet 1)

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	Kittiwake	0.450	0.800
BirdLength	0.39	0.500	0.750
Wingspan	1.08	0.550	0.700
Bird speed	12.8	0.600	0.640
Flight type	flapping	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down	
0.404	0.392	
0.218	0.206	
0.161	0.147	
0.132	0.117	
0.111	0.095	
0.094	0.078	
0.079	0.065	
0.068	0.055	
0.060	0.047	
0.054	0.042	
0.048	0.037	
0.043	0.033	
0.039	0.030	
0.035	0.027	
0.032	0.025	
0.029	0.023	
0.027	0.022	
0.025	0.020	
0.022	0.019	
0.015	0.015	
4.82%	**3.97%**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **4.40%**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

Flight height distribution
Kittiwake

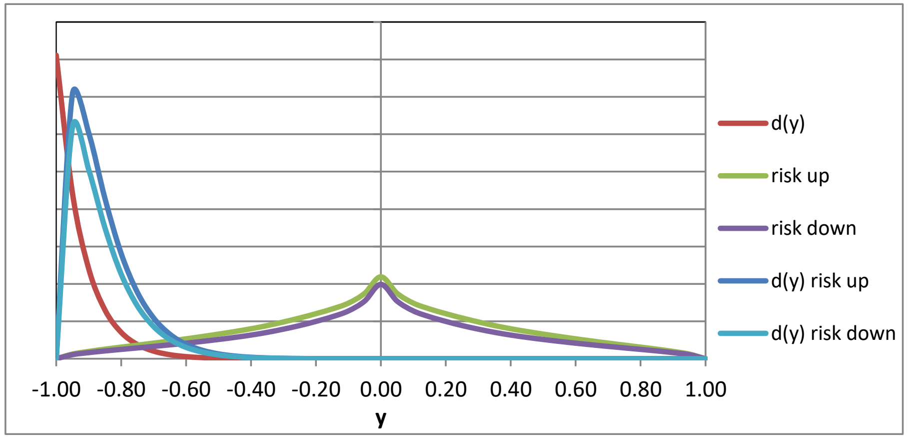
y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	0.8114	0.000	0.000	0.0000	0.0000
-0.95	0.4427	0.012	0.011	0.0055	0.0048
-0.90	0.2407	0.020	0.016	0.0047	0.0039

xinc	**yinc**
0.05	0.05

x and y increments used in results below
(though set fixed at 0.05 for diagram)

-0.85	0.1305	0.026	0.021	0.0033	0.0027
-0.80	0.0706	0.031	0.025	0.0022	0.0018
-0.75	0.0379	0.036	0.029	0.0014	0.0011
-0.70	0.0203	0.042	0.033	0.0008	0.0007
-0.65	0.0108	0.047	0.037	0.0005	0.0004
-0.60	0.0057	0.053	0.042	0.0003	0.0002
-0.55	0.0030	0.059	0.046	0.0002	0.0001
-0.50	0.0015	0.066	0.051	0.0001	0.0001
-0.45	0.0008	0.073	0.057	0.0001	0.0000
-0.40	0.0004	0.080	0.063	0.0000	0.0000
-0.35	0.0002	0.089	0.071	0.0000	0.0000
-0.30	0.0001	0.098	0.079	0.0000	0.0000
-0.25	0.0000	0.109	0.089	0.0000	0.0000
-0.20	0.0000	0.120	0.100	0.0000	0.0000
-0.15	0.0000	0.133	0.112	0.0000	0.0000
-0.10	0.0000	0.149	0.128	0.0000	0.0000
-0.05	0.0000	0.175	0.154	0.0000	0.0000
0.00	0.0000	0.219	0.199	0.0000	0.0000
0.05	0.0000	0.175	0.154	0.0000	0.0000
0.10	0.0000	0.149	0.128	0.0000	0.0000
0.15	0.0000	0.133	0.112	0.0000	0.0000
0.20	0.0000	0.120	0.100	0.0000	0.0000
0.25	0.0000	0.109	0.089	0.0000	0.0000
0.30	0.0000	0.098	0.079	0.0000	0.0000
0.35	0.0000	0.089	0.071	0.0000	0.0000
0.40	0.0000	0.080	0.063	0.0000	0.0000
0.45	0.0000	0.073	0.057	0.0000	0.0000
0.50	0.0000	0.066	0.051	0.0000	0.0000
0.55	0.0000	0.059	0.046	0.0000	0.0000
0.60	0.0000	0.053	0.042	0.0000	0.0000
0.65	0.0000	0.047	0.037	0.0000	0.0000
0.70	0.0000	0.042	0.033	0.0000	0.0000
0.75	0.0000	0.036	0.029	0.0000	0.0000
0.80	0.0000	0.031	0.025	0.0000	0.0000
0.85	0.0000	0.026	0.021	0.0000	0.0000
0.90	0.0000	0.020	0.016	0.0000	0.0000
0.95	0.0000	0.012	0.011	0.0000	0.0000
1.00	0.0000	0.000	0.000	0.0000	0.0000

Q'$_{2R}$ from flight distribution		6.85%		
Compare with Q$_{2R}$ input data		42.0%		
Flux integral		0.0262		
Collision integral	**(up)**	**0.0006**	**(down)**	**0.0005**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)		**0.0006**		
Compare with Q'$_{2R}$ * p from Option 2		0.00330		0.00272
		18.5%		18.6%



FLIGHT HEIGHT DISTRIBUTIONS
D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Kittiwake	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.090443	0.23317	0.08571	0.51408	0
1	0.082273	0.15457	0.0785	0.23184	0.03
2	0.074841	0.10506	0.07175	0.11113	0.03
3	0.06808	0.07335	0.06526	0.0542	0.03
4	0.061929	0.05355	0.05987	0.0274	0.03
5	0.056334	0.03936	0.05499	0.01441	0.03
6	0.051245	0.02885	0.05095	0.00782	0.03
7	0.046615	0.02168	0.0468	0.00439	0.03
8	0.042403	0.01673	0.04263	0.00257	0.03
9	0.038572	0.01316	0.03907	0.00155	0.03
10	0.035086	0.01077	0.0359	0.00098	0.03
11	0.031916	0.00936	0.03293	0.00065	0.005
12	0.029031	0.00871	0.02997	0.00045	0.005
13	0.026407	0.00854	0.02747	0.00033	0.005
14	0.02402	0.00877	0.02505	0.00025	0.005
15	0.021849	0.00937	0.02305	0.00019	0.005
16	0.019873	0.01009	0.02118	0.00016	0.005
17	0.018076	0.01088	0.01929	0.00013	0.005
18	0.016441	0.01151	0.01765	0.00012	0.005
19	0.014954	0.01175	0.01587	0.0001	0.005
20	0.013601	0.01167	0.01398	0.00009	0.005
21	0.01237	0.01137	0.01247	0.00009	0.005
22	0.011251	0.01079	0.01115	0.00009	0.005
23	0.010232	0.01008	0.00999	0.00008	0.005
24	0.009305	0.00924	0.00895	0.00008	0.005
25	0.008462	0.00842	0.00801	0.00008	0.005
26	0.007696	0.00757	0.0071	0.00007	0.005
27	0.006998	0.00664	0.00631	0.00007	0.005
28	0.006364	0.00578	0.00565	0.00007	0.005
29	0.005786	0.00502	0.00496	0.00007	0.005
30	0.005261	0.00429	0.00444	0.00007	0.005
31	0.004784	0.00352	0.00391	0.00007	0.005
32	0.004349	0.00296	0.00345	0.00007	0.005
33	0.003954	0.00242	0.00305	0.00007	0.005
34	0.003595	0.00202	0.00271	0.00006	0.005
35	0.003268	0.00165	0.00238	0.00006	0.005
36	0.00297	0.00137	0.00213	0.00006	0.005
37	0.0027	0.00109	0.00185	0.00005	0.005
38	0.002454	0.00088	0.00164	0.00005	0.005
39	0.00223	0.00069	0.00145	0.00005	0.005
40	0.002027	0.00054	0.00128	0.00004	0.005
41	0.001842	0.00041	0.00113	0.00004	0.005
42	0.001674	0.00032	0.00101	0.00004	0.005
43	0.001521	0.00025	0.00092	0.00003	0.005
44	0.001382	0.00019	0.00081	0.00003	0.005
45	0.001255	0.00014	0.00071	0.00003	0.005
46	0.00114	0.00011	0.00063	0.00003	0.005
47	0.001036	0.00009	0.00055	0.00003	0.005
48	0.00094	0.00007	0.00048	0.00003	0.005
49	0.000854	0.00005	0.00042	0.00003	0.005
50	0.000776	0.00004	0.00038	0.00003	0.005

51	0.000704	0.00003	0.00033	0.00003	0.005
52	0.000639	0.00002	0.0003	0.00003	0.005
53	0.00058	0.00002	0.00026	0.00003	0.005
54	0.000527	0.00002	0.00023	0.00003	0.005
55	0.000478	0.00001	0.00021	0.00003	0.005
56	0.000434	0.00001	0.00018	0.00003	0.005
57	0.000394	0.00001	0.00016	0.00003	0.005
58	0.000357	0.00001	0.00015	0.00003	0.005
59	0.000324	0.00001	0.00013	0.00003	0.005
60	0.000294	0.00001	0.00012	0.00003	0.005
61	0.000266	0	0.0001	0.00003	0.005
62	0.000241	0	0.00009	0.00002	0.005
63	0.000219	0	0.00008	0.00002	0.005
64	0.000198	0	0.00007	0.00002	0.005
65	0.00018	0	0.00007	0.00002	0.005
66	0.000163	0	0.00006	0.00001	0.005
67	0.000148	0	0.00005	0.00001	0.005
68	0.000134	0	0.00005	0.00001	0.005
69	0.000121	0	0.00004	0.00001	0.005
70	0.00011	0	0.00004	0.00001	0.005
71	9.93E-05	0	0.00003	0.00001	0.005
72	8.98E-05	0	0.00003	0	0.005
73	8.13E-05	0	0.00003	0	0.005
74	7.36E-05	0	0.00003	0	0.005
75	6.65E-05	0	0.00002	0	0.005
76	6.02E-05	0	0.00002	0	0.005
77	5.44E-05	0	0.00002	0	0.005
78	4.92E-05	0.00001	0.00002	0	0.005
79	4.44E-05	0.00001	0.00002	0	0.005
80	4.02E-05	0.00001	0.00002	0	0.005
81	3.63E-05	0.00001	0.00002	0	0.005
82	3.28E-05	0.00001	0.00002	0	0.005
83	2.96E-05	0.00001	0.00002	0	0.005
84	2.67E-05	0.00002	0.00002	0	0.005
85	2.41E-05	0.00002	0.00002	0	0.005
86	2.17E-05	0.00003	0.00002	0	0.005
87	1.96E-05	0.00003	0.00002	0	0.005
88	1.77E-05	0.00004	0.00002	0	0.005
89	1.59E-05	0.00004	0.00002	0	0.005
90	1.43E-05	0.00005	0.00002	0	0.005
91	1.29E-05	0.00006	0.00002	0	0.005
92	1.16E-05	0.00007	0.00002	0	0.005
93	1.05E-05	0.00009	0.00002	0	0.005
94	9.43E-06	0.0001	0.00002	0	0.005
95	8.48E-06	0.00012	0.00002	0	0.005
96	7.63E-06	0.00014	0.00002	0	0.005
97	6.86E-06	0.00016	0.00002	0	0.005
98	6.16E-06	0.00018	0.00002	0	0.005
99	5.54E-06	0.0002	0.00001	0	0.005
100	4.97E-06	0.00021	0.00002	0	0.005
101	4.46E-06	0.00022	0.00002	0	0.005
102	0.000004	0.00022	0.00002	0	0.005
103	3.59E-06	0.00022	0.00002	0	0.005
104	3.22E-06	0.00021	0.00002	0	0.005
105	2.89E-06	0.0002	0.00001	0	0.005
106	2.59E-06	0.00019	0.00001	0	0.005
107	2.32E-06	0.00017	0.00002	0	0.005
108	2.07E-06	0.00014	0.00002	0	0.005
109	1.85E-06	0.00012	0.00002	0	0.005

110	1.66E-06	0.0001	0.00002	0	0.005
111	1.48E-06	0.00009	0.00002	0	0.005
112	1.32E-06	0.00007	0.00002	0	0.005
113	1.18E-06	0.00006	0.00001	0	0.005
114	1.06E-06	0.00005	0.00001	0	0.005
115	9.42E-07	0.00004	0.00001	0	0.005
116	8.4E-07	0.00003	0.00001	0	0.005
117	7.49E-07	0.00002	0.00001	0	0.005
118	6.67E-07	0.00001	0.00001	0	0.005
119	5.94E-07	0.00001	0.00001	0	0.005
120	5.29E-07	0.00001	0.00001	0	0.005
121	4.7E-07	0	0.00001	0	0.005
122	4.18E-07	0	0.00001	0	0.005
123	3.71E-07	0	0.00001	0	0.005
124	3.3E-07	0	0.00001	0	0.005
125	2.93E-07	0	0.00001	0	0.005
126	2.6E-07	0	0.00001	0	0.005
127	2.3E-07	0	0.00001	0	0.005
128	2.04E-07	0	0.00001	0	0.005
129	1.81E-07	0	0.00001	0	0.005
130	1.6E-07	0	0.00001	0	0.005
131	1.41E-07	0	0.00001	0	0.005
132	1.25E-07	0	0.00001	0	0.005
133	1.1E-07	0	0.00001	0	0.005
134	9.73E-08	0	0.00001	0	0.005
135	8.58E-08	0	0.00001	0	0.005
136	7.56E-08	0	0.00001	0	0.005
137	6.66E-08	0	0.00001	0	0.005
138	5.86E-08	0	0.00001	0	0.005
139	5.16E-08	0	0.00001	0	0.005
140	4.53E-08	0	0	0	0.005
141	3.98E-08	0	0	0	0.005
142	3.5E-08	0	0	0	0.005
143	3.07E-08	0	0	0	0.005
144	2.69E-08	0	0	0	0.005
145	2.35E-08	0	0	0	0.005
146	2.06E-08	0	0	0	0.005
147	1.8E-08	0	0	0	0.005
148	1.57E-08	0	0	0	0.005
149	1.37E-08	0	0	0	0.005
150	1.2E-08	0	0	0	0.005
151	1.04E-08	0	0	0	0
152	9.09E-09	0	0	0	0
153	7.91E-09	0	0	0	0
154	6.87E-09	0	0	0	0
155	5.97E-09	0	0	0	0
156	5.18E-09		0.95947		
157	4.49E-09				
158	3.89E-09				
159	3.37E-09				
160	2.91E-09				
161	2.51E-09				
162	2.17E-09				
163	1.87E-09				
164	1.61E-09				
165	1.39E-09				
166	1.19E-09				
167	1.02E-09				
168	8.78E-10				

169	7.53E-10
170	6.44E-10
171	5.51E-10
172	4.71E-10
173	4.02E-10
174	3.43E-10
175	2.92E-10
176	2.48E-10
177	2.11E-10
178	1.79E-10
179	1.52E-10
180	1.28E-10
181	1.09E-10
182	9.17E-11
183	7.74E-11
184	6.52E-11
185	5.49E-11
186	4.61E-11
187	3.87E-11
188	3.25E-11
189	2.72E-11
190	2.27E-11
191	1.9E-11
192	1.58E-11
193	1.32E-11
194	1.1E-11
195	9.12E-12
196	7.57E-12
197	6.27E-12
198	5.19E-12
199	4.28E-12
200	3.53E-12
201	2.91E-12
202	2.4E-12
203	1.97E-12
204	1.61E-12
205	1.32E-12
206	1.08E-12
207	8.82E-13
208	7.19E-13
209	5.85E-13
210	4.75E-13
211	3.86E-13
212	3.12E-13
213	2.53E-13
214	2.04E-13
215	1.64E-13
216	1.32E-13
217	1.06E-13
218	8.52E-14
219	6.82E-14
220	5.45E-14
221	4.35E-14
222	3.46E-14
223	2.75E-14
224	2.18E-14
225	1.73E-14
226	1.37E-14
227	1.08E-14

228	8.51E-15
229	6.69E-15
230	5.25E-15
231	4.11E-15
232	3.22E-15
233	2.51E-15
234	1.95E-15
235	1.52E-15
236	1.18E-15
237	9.12E-16
238	7.05E-16
239	5.43E-16
240	4.18E-16
241	3.21E-16
242	2.46E-16
243	1.88E-16
244	1.44E-16
245	1.09E-16
246	8.3E-17
247	6.29E-17
248	4.76E-17
249	3.59E-17
250	2.71E-17
251	2.03E-17
252	1.52E-17
253	1.14E-17
254	8.51E-18
255	6.34E-18
256	4.71E-18
257	3.49E-18
258	2.58E-18
259	1.9E-18
260	1.4E-18
261	1.03E-18
262	7.53E-19
263	5.5E-19
264	4.01E-19
265	2.91E-19
266	2.11E-19
267	1.53E-19
268	1.1E-19
269	7.92E-20
270	5.69E-20
271	4.07E-20
272	2.91E-20
273	2.07E-20
274	1.47E-20
275	1.04E-20
276	7.35E-21
277	5.17E-21
278	3.63E-21
279	2.55E-21
280	1.78E-21
281	1.24E-21
282	8.61E-22
283	5.96E-22
284	4.12E-22
285	2.84E-22
286	1.95E-22

287	1.33E-22
288	9.1E-23
289	6.19E-23
290	4.2E-23
291	2.84E-23
292	1.92E-23
293	1.29E-23
294	8.65E-24
295	5.78E-24
296	3.85E-24
297	2.56E-24
298	1.69E-24
299	1.12E-24

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:		
Species		Kittiwake
Flight speed	m/sec	12.8
Flight type		flapping
Windfarm data:		
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	4000	2000	0	0	0	2000	4000	0	0	**12000**
Migrant flux density	birds/ km		0	0	0	500	250	0	0	0	250	500	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	100	50	0	0	0	50	100	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	75	38	0	0	0	38	75	0	0	**225**
Collision risk for single rotor transit	(from sheet 3)	4.4%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**3**	**2**	**0**	**0**	**0**	**2**	**3**	**0**	**0**	**9**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	6.9%													
Potential bird transits through rotors	Flux integral	0.0262	0	0	0	3	1	0	0	0	1	3	0	0	**8**
Collisions assuming no avoidance	Collision integral	0.00056	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Average collision risk for single rotor transit		2.1%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	3	2	0	0	0	2	3	0	0	**9**
Collisions assuming avoidance rate	birds per month or year	98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		98.70%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		99.10%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

Monthly available daylight hours

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1

Monthly available nocturnal hours

507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9

Monthly available total hours

744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT
Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of turbines	1
Rotor radius	127.5
Width of windfarm	0.3
Average proportion of time operational	0.95
Collision risk from single rotor transit	0.044
Assumed number of turbine rows	1.0

Number of rows (optional)	
(if this is left blank, number is assumed to be sqrt(T)	
Number of turbines in each row	

Avoidance rate	98.70%	98.90%	99.10%	100.00%
Collision risk for single bird passage, before correction	0.00036	0.00031	0.00025	0.00000
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

🟩	used in overall collision risk sheet	🟪	used in available hours sheet
🟩	used in migrant collision risk sheet	🟨	used in large array correction sheet
🟧	used in single transit collision risk sheet or extended model	🟥	not used in calculation but stated for reference

Bird data	**Units**	**Value**	**Data sources**
Species name		**Lesser black-backed gull**	
Bird length	m	0.58	
Wingspan	m	1.42	
Flight speed	m/sec	12.8	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

Data sources

Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0.1	0.075	0.01	0	0	0.045	0	0.1	0.06	0.14	0.775	0.73
Proportion at rotor height	%	35.1%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data														
Migration passages	birds		0	0	0	4000	2000	0	0	0	2000	4000	0	0
Width of migration corridor	km	8												
Proportion at rotor height	%	75%												
Proportion of flights upwind	%	50.0%												

Windfarm data	**Units**	**Value**	**Data sources**
Name of windfarm site		**Cierco Forthwind**	
Latitude	degrees	56.20	
Number of turbines		1	
Width of windfarm	km	0.3	
Tidal offset	m	3	

Turbine data	**Units**	**Value**	**Data sources**											
Turbine model		**20MW turbine**												
No of blades		3												
Rotation speed	rpm	9.9												
Rotor radius	m	127.5												
Hub height	m	152.5	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Max blade width	m	5.800												
Pitch	degrees	2												

Avoidance rates used in presenting results			**Data sources (if applicable)**
	100.00%		
	98.90%	SNCB 2014	
	100.00%		
	100.00%		

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

🟩	from Sheet 1 - input data
🟪	from Sheet 6 - available hours
🟧	from Sheet 3 - single transit collision risk
🟨	from survey data
🟦	calculated field

Bird details:		
Species		Lesser black-backed gull
Flight speed	m/sec	12.8
Nocturnal activity factor (1-5)		3
Nocturnal activity (% of daytime)		50%
Windfarm data:		
Latitude	degrees	56.2
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**year average**	
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%	
Stage A - flight activity																
Daytime areal bird density	birds/sq km		0.1	0.075	0.01	0	0	0.045	0	0.1	0.06	0.14	0.775	0.73		
Proportion at rotor height	%	35.1%														
Total daylight hours per month	hrs		236	266	365	425	506	526	528	469	385	325	249	218		
Total night hours per month	hrs		508	406	379	295	238	194	216	275	335	419	471	526		
Flux factor			452	325	51	0	0	259	0	560	306	690	3465	3241		
Option 1 -Basic model - Stages B, C and D															**per annum**	
Potential bird transits through rotors			159	114	18	0	0	91	0	196	107	242	1216	1137	**3282**	
Collision risk for single rotor transit	(from sheet 3)	5.1%														
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**8**	**6**	**1**	**0**	**0**	**4**	**0**	**10**	**5**	**12**	**59**	**56**	**160**	
Option 2-Basic model using proportion from flight distribution			**4**	**3**	**0**	**0**	**0**	**2**	**0**	**5**	**2**	**6**	**28**	**26**	**76**	
Option 3-Extended model using flight height distribution		Lesser black-backed gull														
Proportion at rotor height	(from sheet 4)	16.7%														
Potential bird transits through rotors	Flux integral	0.0818	37	27	4	0	0	21	0	46	25	56	283	265	**764**	
Collisions assuming no avoidance	Collision integral	0.00249	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**2**	**8**	**8**	**22**	
Average collision risk for single rotor transit		3.0%														
Stage E - applying avoidance rates																
Using which of above options?	**Option 3**	0.00%	1	1	0	0	0	1	0	1	1	2	8	8	**22**	
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	SNCB 2014
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

COLLISION RISK ASSESSMENT

Sheet 3 - probability of collision for single bird transit through rotor

🟩	**All input data must be entered on Sheet 1, not here**
🟧	**However the blade profile (orange) may be revised here to match the actual turbine blades used**
🟦	Calculated outputs
🟨	Main output copied to sheet 1

NoBlades	3	
MaxChord	5.80	m
Pitch (degrees)	2	
Species name	k-backed gull	
BirdLength	0.58	m
Wingspan	1.42	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	12.8	m/sec
Rotor Radius	127.5	m
Rotation Speed	9.9	rpm
Rotation Period	6.06	sec
Bird aspect ratio: β	0.41	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.94	11.09	0.429	10.80	0.418
0.10	0.79	0.97	5.97	0.231	5.65	0.218
0.15	0.88	0.65	4.39	0.170	4.03	0.156
0.20	0.96	0.48	3.58	0.138	3.19	0.123
0.25	1.00	0.39	3.03	0.117	2.62	0.101
0.30	0.98	0.32	2.61	0.101	2.22	0.086
0.35	0.92	0.28	2.24	0.087	1.87	0.072
0.40	0.85	0.24	1.94	0.075	1.60	0.062
0.45	0.80	0.22	1.74	0.067	1.42	0.055
0.50	0.75	0.19	1.57	0.061	1.27	0.049
0.55	0.70	0.18	1.44	0.056	1.15	0.045
0.60	0.64	0.16	1.31	0.051	1.05	0.041
0.65	0.58	0.15	1.20	0.046	0.96	0.037
0.70	0.52	0.14	1.10	0.043	0.89	0.034
0.75	0.47	0.13	1.03	0.040	0.84	0.032
0.80	0.41	0.12	0.95	0.037	0.78	0.030
0.85	0.37	0.11	0.90	0.035	0.75	0.029
0.90	0.30	0.11	0.83	0.032	0.71	0.027
0.95	0.24	0.10	0.77	0.030	0.67	0.026
1.00	0.00	0.10	0.58	0.022	0.58	0.022

Overall p(collision) integrated over disk

Upwind	**5.6%**	**Downwind**	**4.7%**

Proportion	upwind: downwind
50%	50%

Average **5.1%** (copied to sheet 1)

INPUTS		Npoints	21
		r/R	c/C
NoBlades	3	0	0.690
Radius	127.5	0.050	0.730
Rotation speed	9.9	0.100	0.790
MaxChord	5.8	0.150	0.880
Pitch	2	0.200	0.960
Hub height	152.5	0.250	1.000
Tidal offset	3	0.300	0.980
		0.350	0.920
		0.400	0.850
Species name	:k-backed gull	0.450	0.800
BirdLength	0.58	0.500	0.750
Wingspan	1.42	0.550	0.700
Bird speed	12.8	0.600	0.640
Flight type	flapping	0.650	0.580
		0.700	0.520
		0.750	0.470
		0.800	0.410
		0.850	0.370
		0.900	0.300
		0.950	0.240
		1.000	0.000

BASIC MODEL

p(r) up	p(r) down	
0.429	0.418	
0.231	0.218	
0.170	0.156	
0.138	0.123	
0.117	0.101	
0.101	0.086	
0.087	0.072	
0.075	0.062	
0.067	0.055	
0.061	0.049	
0.056	0.045	
0.051	0.041	
0.046	0.037	
0.043	0.034	
0.040	0.032	
0.037	0.030	
0.035	0.029	
0.032	0.027	
0.030	0.026	
0.022	0.022	
5.56%	**4.72%**	Average collision risks for flight through disk
50%	50%	Proportions upwind/downwind flight

Average **5.14%**

EXTENDED MODEL USING FLIGHT HEIGHT DISTRIBUTION

Flight height distribution

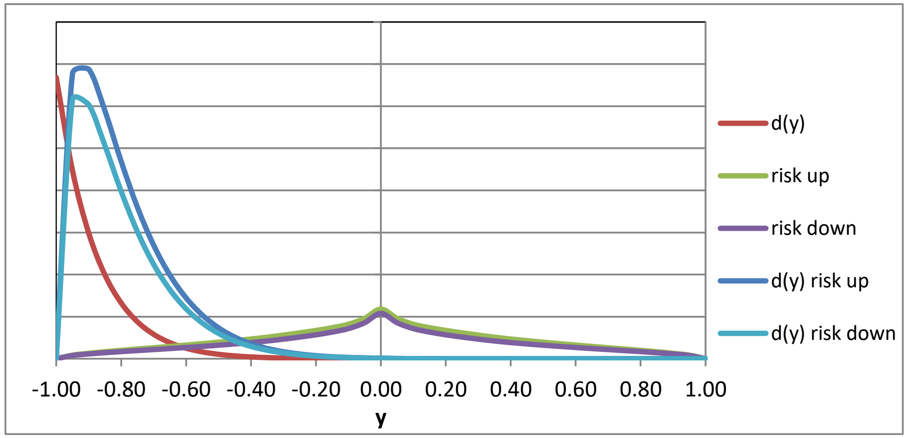
Lesser black-backed gull

y	**d(y)**	risk up	risk down	d(y) risk up	d(y) risk down
-1.00	1.3376	0.000	0.000	0.0000	0.0000
-0.95	0.8947	0.017	0.015	0.0152	0.0138
-0.90	0.5974	0.026	0.023	0.0155	0.0136

xinc	**yinc**	
0.05	0.05	x and y increments used in results below
		(though set fixed at 0.05 for diagram)

-0.85	0.3982	0.033	0.029	0.0133	0.0114
-0.80	0.2650	0.040	0.034	0.0106	0.0089
-0.75	0.1757	0.046	0.039	0.0081	0.0068
-0.70	0.1162	0.052	0.043	0.0061	0.0050
-0.65	0.0765	0.059	0.048	0.0045	0.0037
-0.60	0.0500	0.065	0.053	0.0032	0.0027
-0.55	0.0326	0.072	0.059	0.0023	0.0019
-0.50	0.0210	0.079	0.064	0.0017	0.0014
-0.45	0.0135	0.086	0.070	0.0012	0.0009
-0.40	0.0086	0.094	0.077	0.0008	0.0007
-0.35	0.0054	0.102	0.084	0.0005	0.0005
-0.30	0.0033	0.112	0.093	0.0004	0.0003
-0.25	0.0020	0.123	0.103	0.0003	0.0002
-0.20	0.0012	0.134	0.114	0.0002	0.0001
-0.15	0.0007	0.147	0.127	0.0001	0.0001
-0.10	0.0004	0.164	0.143	0.0001	0.0001
-0.05	0.0002	0.192	0.171	0.0000	0.0000
0.00	0.0001	0.236	0.215	0.0000	0.0000
0.05	0.0001	0.192	0.171	0.0000	0.0000
0.10	0.0000	0.164	0.143	0.0000	0.0000
0.15	0.0000	0.147	0.127	0.0000	0.0000
0.20	0.0000	0.134	0.114	0.0000	0.0000
0.25	0.0000	0.123	0.103	0.0000	0.0000
0.30	0.0000	0.112	0.093	0.0000	0.0000
0.35	0.0000	0.102	0.084	0.0000	0.0000
0.40	0.0000	0.094	0.077	0.0000	0.0000
0.45	0.0000	0.086	0.070	0.0000	0.0000
0.50	0.0000	0.079	0.064	0.0000	0.0000
0.55	0.0000	0.072	0.059	0.0000	0.0000
0.60	0.0000	0.065	0.053	0.0000	0.0000
0.65	0.0000	0.059	0.048	0.0000	0.0000
0.70	0.0000	0.052	0.043	0.0000	0.0000
0.75	0.0000	0.046	0.039	0.0000	0.0000
0.80	0.0000	0.040	0.034	0.0000	0.0000
0.85	0.0000	0.033	0.029	0.0000	0.0000
0.90	0.0000	0.026	0.023	0.0000	0.0000
0.95	0.0000	0.017	0.015	0.0000	0.0000
1.00	0.0000	0.000	0.000	0.0000	0.0000

Q'$_{2R}$ from flight distribution			16.66%	
Compare with Q_{2R} input data			35.1%	
Flux integral			0.0818	
Collision integral	**(up)**	**0.0027**	**(down)**	**0.0023**
Proportions upwind/downwind flight		50.0%		50.0%
Collision integral (average)			**0.0025**	
Compare with Q'$_{2R}$ * p from Option 2		0.00927		0.00786
		28.8%		29.2%



FLIGHT HEIGHT DISTRIBUTIONS

D(Y) is relative frequency per m of height

1

Ensure birddata for current collision assessment is pasted into column B!

Current bird:	Lesser black-backe	Gannet	Kittiwake	Fulmar	Uniform
No of points	300	155	150	155	155
height Y above sea (m)	D(Y)	D(Y)	D(Y)	D(Y)	D(Y)
0	0.061137	0.23317	0.08571	0.51408	0
1	0.05741	0.15457	0.0785	0.23184	0.03
2	0.05391	0.10506	0.07175	0.11113	0.03
3	0.050623	0.07335	0.06526	0.0542	0.03
4	0.047537	0.05355	0.05987	0.0274	0.03
5	0.044639	0.03936	0.05499	0.01441	0.03
6	0.041917	0.02885	0.05095	0.00782	0.03
7	0.039361	0.02168	0.0468	0.00439	0.03
8	0.036961	0.01673	0.04263	0.00257	0.03
9	0.034708	0.01316	0.03907	0.00155	0.03
10	0.032592	0.01077	0.0359	0.00098	0.03
11	0.030604	0.00936	0.03293	0.00065	0.005
12	0.028738	0.00871	0.02997	0.00045	0.005
13	0.026985	0.00854	0.02747	0.00033	0.005
14	0.02534	0.00877	0.02505	0.00025	0.005
15	0.023794	0.00937	0.02305	0.00019	0.005
16	0.022343	0.01009	0.02118	0.00016	0.005
17	0.02098	0.01088	0.01929	0.00013	0.005
18	0.0197	0.01151	0.01765	0.00012	0.005
19	0.018498	0.01175	0.01587	0.0001	0.005
20	0.017369	0.01167	0.01398	0.00009	0.005
21	0.016309	0.01137	0.01247	0.00009	0.005
22	0.015313	0.01079	0.01115	0.00009	0.005
23	0.014378	0.01008	0.00999	0.00008	0.005
24	0.0135	0.00924	0.00895	0.00008	0.005
25	0.012676	0.00842	0.00801	0.00008	0.005
26	0.011901	0.00757	0.0071	0.00007	0.005
27	0.011174	0.00664	0.00631	0.00007	0.005
28	0.010491	0.00578	0.00565	0.00007	0.005
29	0.009849	0.00502	0.00496	0.00007	0.005
30	0.009247	0.00429	0.00444	0.00007	0.005
31	0.008681	0.00352	0.00391	0.00007	0.005
32	0.00815	0.00296	0.00345	0.00007	0.005
33	0.007651	0.00242	0.00305	0.00007	0.005
34	0.007182	0.00202	0.00271	0.00006	0.005
35	0.006742	0.00165	0.00238	0.00006	0.005
36	0.006329	0.00137	0.00213	0.00006	0.005
37	0.005941	0.00109	0.00185	0.00005	0.005
38	0.005576	0.00088	0.00164	0.00005	0.005
39	0.005234	0.00069	0.00145	0.00005	0.005
40	0.004912	0.00054	0.00128	0.00004	0.005
41	0.00461	0.00041	0.00113	0.00004	0.005
42	0.004327	0.00032	0.00101	0.00004	0.005
43	0.00406	0.00025	0.00092	0.00003	0.005
44	0.00381	0.00019	0.00081	0.00003	0.005
45	0.003575	0.00014	0.00071	0.00003	0.005
46	0.003355	0.00011	0.00063	0.00003	0.005
47	0.003148	0.00009	0.00055	0.00003	0.005
48	0.002953	0.00007	0.00048	0.00003	0.005
49	0.002771	0.00005	0.00042	0.00003	0.005
50	0.002599	0.00004	0.00038	0.00003	0.005

51	0.002438	0.00003	0.00033	0.00003	0.005
52	0.002287	0.00002	0.0003	0.00003	0.005
53	0.002145	0.00002	0.00026	0.00003	0.005
54	0.002012	0.00002	0.00023	0.00003	0.005
55	0.001887	0.00001	0.00021	0.00003	0.005
56	0.001769	0.00001	0.00018	0.00003	0.005
57	0.001659	0.00001	0.00016	0.00003	0.005
58	0.001555	0.00001	0.00015	0.00003	0.005
59	0.001458	0.00001	0.00013	0.00003	0.005
60	0.001367	0.00001	0.00012	0.00003	0.005
61	0.001281	0	0.0001	0.00003	0.005
62	0.001201	0	0.00009	0.00002	0.005
63	0.001125	0	0.00008	0.00002	0.005
64	0.001055	0	0.00007	0.00002	0.005
65	0.000988	0	0.00007	0.00002	0.005
66	0.000926	0	0.00006	0.00001	0.005
67	0.000867	0	0.00005	0.00001	0.005
68	0.000812	0	0.00005	0.00001	0.005
69	0.000761	0	0.00004	0.00001	0.005
70	0.000713	0	0.00004	0.00001	0.005
71	0.000667	0	0.00003	0.00001	0.005
72	0.000625	0	0.00003	0	0.005
73	0.000585	0	0.00003	0	0.005
74	0.000547	0	0.00003	0	0.005
75	0.000512	0	0.00002	0	0.005
76	0.000479	0	0.00002	0	0.005
77	0.000448	0	0.00002	0	0.005
78	0.00042	0.00001	0.00002	0	0.005
79	0.000392	0.00001	0.00002	0	0.005
80	0.000367	0.00001	0.00002	0	0.005
81	0.000343	0.00001	0.00002	0	0.005
82	0.000321	0.00001	0.00002	0	0.005
83	0.0003	0.00001	0.00002	0	0.005
84	0.00028	0.00002	0.00002	0	0.005
85	0.000262	0.00002	0.00002	0	0.005
86	0.000245	0.00003	0.00002	0	0.005
87	0.000229	0.00003	0.00002	0	0.005
88	0.000213	0.00004	0.00002	0	0.005
89	0.000199	0.00004	0.00002	0	0.005
90	0.000186	0.00005	0.00002	0	0.005
91	0.000174	0.00006	0.00002	0	0.005
92	0.000162	0.00007	0.00002	0	0.005
93	0.000151	0.00009	0.00002	0	0.005
94	0.000141	0.0001	0.00002	0	0.005
95	0.000132	0.00012	0.00002	0	0.005
96	0.000123	0.00014	0.00002	0	0.005
97	0.000114	0.00016	0.00002	0	0.005
98	0.000107	0.00018	0.00002	0	0.005
99	9.93E-05	0.0002	0.00001	0	0.005
100	9.25E-05	0.00021	0.00002	0	0.005
101	8.62E-05	0.00022	0.00002	0	0.005
102	8.02E-05	0.00022	0.00002	0	0.005
103	7.47E-05	0.00022	0.00002	0	0.005
104	6.95E-05	0.00021	0.00002	0	0.005
105	6.47E-05	0.0002	0.00001	0	0.005
106	6.01E-05	0.00019	0.00001	0	0.005
107	5.59E-05	0.00017	0.00002	0	0.005
108	5.20E-05	0.00014	0.00002	0	0.005
109	4.83E-05	0.00012	0.00002	0	0.005

110	4.49E-05	0.0001	0.00002	0	0.005
111	4.17E-05	0.00009	0.00002	0	0.005
112	3.87E-05	0.00007	0.00002	0	0.005
113	3.59E-05	0.00006	0.00001	0	0.005
114	3.33E-05	0.00005	0.00001	0	0.005
115	3.09E-05	0.00004	0.00001	0	0.005
116	2.87E-05	0.00003	0.00001	0	0.005
117	2.66E-05	0.00002	0.00001	0	0.005
118	2.46E-05	0.00001	0.00001	0	0.005
119	2.28E-05	0.00001	0.00001	0	0.005
120	2.11E-05	0.00001	0.00001	0	0.005
121	1.96E-05	0	0.00001	0	0.005
122	1.81E-05	0	0.00001	0	0.005
123	1.68E-05	0	0.00001	0	0.005
124	1.55E-05	0	0.00001	0	0.005
125	1.43E-05	0	0.00001	0	0.005
126	1.32E-05	0	0.00001	0	0.005
127	1.22E-05	0	0.00001	0	0.005
128	1.13E-05	0	0.00001	0	0.005
129	1.04E-05	0	0.00001	0	0.005
130	9.61E-06	0	0.00001	0	0.005
131	8.86E-06	0	0.00001	0	0.005
132	8.17E-06	0	0.00001	0	0.005
133	7.53E-06	0	0.00001	0	0.005
134	6.93E-06	0	0.00001	0	0.005
135	6.38E-06	0	0.00001	0	0.005
136	5.87E-06	0	0.00001	0	0.005
137	5.40E-06	0	0.00001	0	0.005
138	4.97E-06	0	0.00001	0	0.005
139	4.57E-06	0	0.00001	0	0.005
140	4.19E-06	0	0	0	0.005
141	3.85E-06	0	0	0	0.005
142	3.53E-06	0	0	0	0.005
143	3.24E-06	0	0	0	0.005
144	2.97E-06	0	0	0	0.005
145	2.72E-06	0	0	0	0.005
146	2.49E-06	0	0	0	0.005
147	2.28E-06	0	0	0	0.005
148	2.09E-06	0	0	0	0.005
149	1.91E-06	0	0	0	0.005
150	1.74E-06	0	0	0	0.005
151	1.59E-06	0	0	0	0
152	1.45E-06	0	0	0	0
153	1.33E-06	0	0	0	0
154	1.21E-06	0	0	0	0
155	1.10E-06	0	0	0	0
156	1.00E-06		0.95947		
157	9.13E-07				
158	8.31E-07				
159	7.55E-07				
160	6.86E-07				
161	6.23E-07				
162	5.65E-07				
163	5.13E-07				
164	4.65E-07				
165	4.21E-07				
166	3.81E-07				
167	3.44E-07				
168	3.11E-07				

169	2.81E-07
170	2.54E-07
171	2.29E-07
172	2.06E-07
173	1.86E-07
174	1.67E-07
175	1.50E-07
176	1.35E-07
177	1.21E-07
178	1.09E-07
179	9.75E-08
180	8.74E-08
181	7.82E-08
182	6.99E-08
183	6.25E-08
184	5.58E-08
185	4.98E-08
186	4.44E-08
187	3.95E-08
188	3.52E-08
189	3.13E-08
190	2.78E-08
191	2.47E-08
192	2.19E-08
193	1.94E-08
194	1.72E-08
195	1.52E-08
196	1.34E-08
197	1.18E-08
198	1.04E-08
199	9.20E-09
200	8.10E-09
201	7.12E-09
202	6.25E-09
203	5.49E-09
204	4.81E-09
205	4.21E-09
206	3.69E-09
207	3.22E-09
208	2.81E-09
209	2.45E-09
210	2.14E-09
211	1.86E-09
212	1.62E-09
213	1.40E-09
214	1.22E-09
215	1.06E-09
216	9.14E-10
217	7.90E-10
218	6.82E-10
219	5.88E-10
220	5.07E-10
221	4.36E-10
222	3.75E-10
223	3.22E-10
224	2.76E-10
225	2.36E-10
226	2.02E-10
227	1.73E-10

228	1.47E-10
229	1.25E-10
230	1.07E-10
231	9.07E-11
232	7.70E-11
233	6.52E-11
234	5.52E-11
235	4.67E-11
236	3.94E-11
237	3.32E-11
238	2.80E-11
239	2.35E-11
240	1.97E-11
241	1.65E-11
242	1.39E-11
243	1.16E-11
244	9.67E-12
245	8.06E-12
246	6.71E-12
247	5.57E-12
248	4.63E-12
249	3.83E-12
250	3.17E-12
251	2.62E-12
252	2.16E-12
253	1.78E-12
254	1.46E-12
255	1.20E-12
256	9.84E-13
257	8.05E-13
258	6.58E-13
259	5.37E-13
260	4.37E-13
261	3.55E-13
262	2.88E-13
263	2.34E-13
264	1.89E-13
265	1.53E-13
266	1.23E-13
267	9.90E-14
268	7.95E-14
269	6.38E-14
270	5.10E-14
271	4.08E-14
272	3.25E-14
273	2.59E-14
274	2.06E-14
275	1.63E-14
276	1.29E-14
277	1.02E-14
278	8.06E-15
279	6.35E-15
280	4.99E-15
281	3.91E-15
282	3.06E-15
283	2.39E-15
284	1.87E-15
285	1.45E-15
286	1.13E-15

287	8.74E-16
288	6.76E-16
289	5.22E-16
290	4.02E-16
291	3.09E-16
292	2.37E-16
293	1.82E-16
294	1.39E-16
295	1.06E-16
296	8.04E-17
297	6.11E-17
298	4.63E-17
299	3.50E-17

COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!
other than to choose option for final tables

🟩 from Sheet 1 - input data
🟪 from Sheet 6 - available hours
🟧 from Sheet 3 - single transit collision risk
🟨 from survey data
🟦 calculated field

Bird details:		
Species		Lesser black-backed gull
Flight speed	m/sec	12.8
Flight type		flapping
Windfarm data:		
Number of turbines		1
Rotor radius	m	127.5
Minimum height of rotor	m	152.5
Total rotor frontal area	sq m	51071

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Proportion of time operational	%		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95.0%
Stage A - flight activity															**per annum**
Migration passages			0	0	0	4000	2000	0	0	0	2000	4000	0	0	**12000**
Migrant flux density	birds/ km		0	0	0	500	250	0	0	0	250	500	0	0	
Proportion at rotor height	%	75%													
Flux factor			0	0	0	100	50	0	0	0	50	100	0	0	
Option 1 -Basic model - Stages B, C and D															
Potential bird transits through rotors			0	0	0	75	38	0	0	0	38	75	0	0	**225**
Collision risk for single rotor transit	(from sheet 3)	5.1%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**4**	**2**	**0**	**0**	**0**	**2**	**4**	**0**	**0**	**11**
Option 2-Basic model using proportion from flight distribution			**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**2**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	16.7%													
Potential bird transits through rotors	Flux integral	0.0818	0	0	0	8	4	0	0	0	4	8	0	0	**25**
Collisions assuming no avoidance	Collision integral	0.00249	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Average collision risk for single rotor transit		3.0%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	0	0	4	2	0	0	0	2	4	0	0	**11**
Collisions assuming avoidance rate	birds per month or year	100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Collisions after applying large array correction		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		98.90%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		100.00%	0	0	0	0	0	0	0	0	0	0	0	0	**0**

COLLISION RISK ASSESSMENT
Sheet 4 - Daylight and night hours

Latitude = 56.20 **central latitude of the proposal, copied from the input data shoet: do not enter here**

Taken from Forsythe *et al.* (1995) A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

	P	Daylength	
1	-0.40270065	7.00823905	01-Jan
2	-0.401298	7.0318512	02-Jan
3	-0.39976204	7.05761237	03-Jan
4	-0.39809354	7.08548554	04-Jan
5	-0.3962933	7.11543129	05-Jan
6	-0.39436222	7.14740794	06-Jan
7	-0.39230124	7.18137185	07-Jan
8	-0.39011137	7.21727756	08-Jan
9	-0.38779368	7.25507805	09-Jan
10	-0.38534929	7.29472491	10-Jan
11	-0.38277939	7.33616858	11-Jan
12	-0.38008522	7.37935855	12-Jan
13	-0.37726806	7.42424355	13-Jan
14	-0.37432927	7.47077176	14-Jan
15	-0.37127023	7.51889096	15-Jan
16	-0.36809238	7.56854875	16-Jan
17	-0.3647972	7.61969267	17-Jan
18	-0.36138623	7.67227042	18-Jan
19	-0.35786103	7.72622991	19-Jan
20	-0.35422322	7.78151951	20-Jan
21	-0.35047443	7.83808807	21-Jan
22	-0.34661635	7.89588511	22-Jan
23	-0.34265069	7.95486088	23-Jan
24	-0.3385792	8.01496646	24-Jan
25	-0.33440365	8.07615386	25-Jan
26	-0.33012585	8.13837608	26-Jan
27	-0.32574763	8.20158717	27-Jan
28	-0.32127083	8.26574229	28-Jan
29	-0.31669733	8.33079775	29-Jan
30	-0.31202903	8.39671107	30-Jan
31	-0.30726784	8.46344096	31-Jan

Monthly available daylight hours

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
236.5	266.3	365.5	425.0	505.8	526.5	527.6	468.9	384.9	324.7	249.0	218.1

Monthly available nocturnal hours

507.5	405.7	378.5	295.0	238.2	193.5	216.4	275.1	335.1	419.3	471.0	525.9

Monthly available total hours

744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0

these data are copied automatically to the 'overall collision risk' sheet

32	-0.30241569	8.53094741	01-Feb
33	-0.29747453	8.59919166	02-Feb
34	-0.29244631	8.66813623	03-Feb
35	-0.287333	8.73774489	04-Feb
36	-0.28213658	8.80798273	05-Feb
37	-0.27685905	8.8788161	06-Feb
38	-0.2715024	8.9502126	07-Feb
39	-0.26606864	9.0221411	08-Feb
40	-0.26055978	9.09457171	09-Feb
41	-0.25497782	9.16747575	10-Feb
42	-0.2493248	9.24082575	11-Feb
43	-0.24360272	9.3145954	12-Feb
44	-0.23781361	9.38875955	13-Feb
45	-0.23195948	9.46329416	14-Feb
46	-0.22604236	9.53817631	15-Feb
47	-0.22006426	9.61338411	16-Feb
48	-0.2140272	9.68889673	17-Feb
49	-0.20793318	9.76469432	18-Feb
50	-0.20178421	9.84075801	19-Feb
51	-0.1955823	9.91706986	20-Feb
52	-0.18932943	9.99361285	21-Feb
53	-0.18302761	10.0703708	22-Feb
54	-0.17667882	10.1473284	23-Feb
55	-0.17028503	10.2244711	24-Feb
56	-0.16384821	10.3017851	25-Feb
57	-0.15737034	10.3792575	26-Feb
58	-0.15085336	10.4568759	27-Feb
59	-0.14429922	10.5346287	28-Feb
60	-0.13770986	10.6125048	01-Mar
61	-0.13108722	10.6904939	02-Mar
62	-0.12443321	10.7685861	03-Mar
63	-0.11774975	10.8467721	04-Mar
64	-0.11103874	10.9250433	05-Mar
65	-0.10430209	11.0033912	06-Mar
66	-0.09754167	11.0818081	07-Mar
67	-0.09075937	11.1602866	08-Mar
68	-0.08395705	11.2388196	09-Mar
69	-0.07713657	11.3174006	10-Mar
70	-0.07029979	11.3960232	11-Mar
71	-0.06344855	11.4746815	12-Mar
72	-0.05658468	11.5533697	13-Mar

73	-0.04971001	11.6320825	14-Mar
74	-0.04282635	11.7108146	15-Mar
75	-0.03593551	11.789561	16-Mar
76	-0.0290393	11.868317	17-Mar
77	-0.0221395	11.9470778	18-Mar
78	-0.01523789	12.0258391	19-Mar
79	-0.00833627	12.1045963	20-Mar
80	-0.00143638	12.1833452	21-Mar
81	0.00546	12.2620815	22-Mar
82	0.01235111	12.340801	23-Mar
83	0.01923522	12.4194994	24-Mar
84	0.02611058	12.4981727	25-Mar
85	0.03297546	12.5768165	26-Mar
86	0.03982812	12.6554265	27-Mar
87	0.04666685	12.7339983	28-Mar
88	0.05348993	12.8125275	29-Mar
89	0.06029565	12.8910094	30-Mar
90	0.0670823	12.9694394	31-Mar
91	0.07384819	13.0478123	01-Apr
92	0.08059162	13.1261232	02-Apr
93	0.0873109	13.2043666	03-Apr
94	0.09400434	13.282537	04-Apr
95	0.10067027	13.3606285	05-Apr
96	0.10730701	13.4386348	06-Apr
97	0.11391289	13.5165496	07-Apr
98	0.12048624	13.594366	08-Apr
99	0.1270254	13.6720767	09-Apr
100	0.13352871	13.7496743	10-Apr
101	0.13999452	13.8271507	11-Apr
102	0.14642118	13.9044974	12-Apr
103	0.15280703	13.9817055	13-Apr
104	0.15915045	14.0587656	14-Apr
105	0.16544978	14.1356677	15-Apr
106	0.1717034	14.2124014	16-Apr
107	0.17790967	14.2889555	17-Apr
108	0.18406697	14.3653184	18-Apr
109	0.19017367	14.4414777	19-Apr
110	0.19622816	14.5174204	20-Apr
111	0.20222883	14.593133	21-Apr
112	0.20817406	14.6686009	22-Apr
113	0.21406226	14.7438091	23-Apr

114	0.21989182	14.8187417	24-Apr
115	0.22566115	14.8933819	25-Apr
116	0.23136867	14.9677122	26-Apr
117	0.23701279	15.0417143	27-Apr
118	0.24259193	15.1153688	28-Apr
119	0.24810454	15.1886555	29-Apr
120	0.25354904	15.2615535	30-Apr
121	0.25892389	15.3340405	01-May
122	0.26422754	15.4060935	02-May
123	0.26945846	15.4776884	03-May
124	0.27461511	15.5488002	04-May
125	0.27969598	15.6194028	05-May
126	0.28469956	15.6894689	06-May
127	0.28962435	15.7589702	07-May
128	0.29446888	15.8278774	08-May
129	0.29923167	15.89616	09-May
130	0.30391126	15.9637864	10-May
131	0.3085062	16.0307239	11-May
132	0.31301507	16.0969387	12-May
133	0.31743645	16.1623958	13-May
134	0.32176895	16.2270593	14-May
135	0.32601117	16.2908919	15-May
136	0.33016177	16.3538554	16-May
137	0.33421939	16.4159107	17-May
138	0.33818272	16.4770174	18-May
139	0.34205044	16.5371341	19-May
140	0.34582129	16.5962188	20-May
141	0.34949401	16.6542282	21-May
142	0.35306735	16.7111185	22-May
143	0.35654012	16.7668448	23-May
144	0.35991113	16.8213618	24-May
145	0.36317923	16.8746233	25-May
146	0.36634329	16.9265829	26-May
147	0.36940222	16.9771935	27-May
148	0.37235495	17.0264078	28-May
149	0.37520045	17.0741782	29-May
150	0.37793771	17.1204573	30-May
151	0.38056577	17.1651975	31-May
152	0.38308369	17.2083515	01-Jun
153	0.38549057	17.2498724	02-Jun
154	0.38778556	17.2897137	03-Jun

155	0.38996783	17.3278299	04-Jun
156	0.39203659	17.3641761	05-Jun
157	0.3939911	17.3987085	06-Jun
158	0.39583065	17.4313845	07-Jun
159	0.39755459	17.4621632	08-Jun
160	0.39916227	17.491005	09-Jun
161	0.40065314	17.5178721	10-Jun
162	0.40202664	17.5427289	11-Jun
163	0.40328229	17.5655419	12-Jun
164	0.40441964	17.5862797	13-Jun
165	0.40543829	17.6049136	14-Jun
166	0.40633788	17.6214176	15-Jun
167	0.4071181	17.6357684	16-Jun
168	0.40777869	17.6479456	17-Jun
169	0.40831943	17.657932	18-Jun
170	0.40874015	17.6657134	19-Jun
171	0.40904072	17.671279	20-Jun
172	0.40922108	17.6746211	21-Jun
173	0.4092812	17.6757355	22-Jun
174	0.4092211	17.6746213	23-Jun
175	0.40904084	17.671281	24-Jun
176	0.40874054	17.6657206	25-Jun
177	0.40832036	17.6579492	26-Jun
178	0.40778052	17.6479794	27-Jun
179	0.40712127	17.6358268	28-Jun
180	0.40634292	17.6215101	29-Jun
181	0.40544581	17.6050514	30-Jun
182	0.40443034	17.5864751	01-Jul
183	0.40329695	17.5658087	02-Jul
184	0.40204613	17.5430823	03-Jul
185	0.40067839	17.5183282	04-Jul
186	0.39919432	17.4915812	05-Jul
187	0.39759452	17.462878	06-Jul
188	0.39587965	17.4322572	07-Jul
189	0.39405041	17.3997593	08-Jul
190	0.39210753	17.3654261	09-Jul
191	0.39005178	17.3293008	10-Jul
192	0.38788398	17.2914278	11-Jul
193	0.38560497	17.2518525	12-Jul
194	0.38321564	17.2106209	13-Jul
195	0.38071691	17.1677799	14-Jul

196	0.37810974	17.1233766	15-Jul
197	0.3753951	17.0774586	16-Jul
198	0.37257403	17.0300735	17-Jul
199	0.36964755	16.9812689	18-Jul
200	0.36661677	16.9310923	19-Jul
201	0.36348277	16.879591	20-Jul
202	0.3602467	16.8268119	21-Jul
203	0.35690971	16.7728014	22-Jul
204	0.35347299	16.7176052	23-Jul
205	0.34993776	16.6612687	24-Jul
206	0.34630523	16.6038361	25-Jul
207	0.34257668	16.5453512	26-Jul
208	0.33875337	16.4858567	27-Jul
209	0.33483659	16.4253943	28-Jul
210	0.33082767	16.364005	29-Jul
211	0.32672793	16.3017285	30-Jul
212	0.32253873	16.2386037	31-Jul
213	0.31826142	16.1746683	01-Aug
214	0.31389739	16.109959	02-Aug
215	0.30944804	16.0445111	03-Aug
216	0.30491476	15.9783593	04-Aug
217	0.30029898	15.9115366	05-Aug
218	0.29560213	15.8440754	06-Aug
219	0.29082566	15.7760067	07-Aug
220	0.28597101	15.7073604	08-Aug
221	0.28103965	15.6381653	09-Aug
222	0.27603305	15.5684493	10-Aug
223	0.27095268	15.4982389	11-Aug
224	0.26580003	15.4275598	12-Aug
225	0.2605766	15.3564365	13-Aug
226	0.25528389	15.2848926	14-Aug
227	0.24992339	15.2129507	15-Aug
228	0.24449663	15.1406323	16-Aug
229	0.23900512	15.067958	17-Aug
230	0.23345037	14.9949477	18-Aug
231	0.22783392	14.9216199	19-Aug
232	0.22215729	14.8479928	20-Aug
233	0.21642201	14.7740833	21-Aug
234	0.21062962	14.6999078	22-Aug
235	0.20478166	14.6254817	23-Aug
236	0.19887966	14.5508197	24-Aug

237	0.19292518	14.4759357	25-Aug
238	0.18691976	14.4008432	26-Aug
239	0.18086495	14.3255545	27-Aug
240	0.1747623	14.2500817	28-Aug
241	0.16861336	14.1744361	29-Aug
242	0.16241969	14.0986283	30-Aug
243	0.15618284	14.0226686	31-Aug
244	0.14990438	13.9465663	01-Sep
245	0.14358587	13.8703308	02-Sep
246	0.13722886	13.7939704	03-Sep
247	0.13083494	13.7174933	04-Sep
248	0.12440566	13.6409071	05-Sep
249	0.1179426	13.5642192	06-Sep
250	0.11144733	13.4874362	07-Sep
251	0.10492143	13.4105648	08-Sep
252	0.09836647	13.333611	09-Sep
253	0.09178404	13.2565807	10-Sep
254	0.08517572	13.1794793	11-Sep
255	0.0785431	13.102312	12-Sep
256	0.07188777	13.025084	13-Sep
257	0.06521134	12.9477999	14-Sep
258	0.05851539	12.8704643	15-Sep
259	0.05180153	12.7930815	16-Sep
260	0.04507137	12.7156557	17-Sep
261	0.03832653	12.6381911	18-Sep
262	0.03156862	12.5606916	19-Sep
263	0.02479926	12.483161	20-Sep
264	0.01802009	12.4056031	21-Sep
265	0.01123273	12.3280217	22-Sep
266	0.00443883	12.2504204	23-Sep
267	-0.00235997	12.172803	24-Sep
268	-0.009162	12.0951732	25-Sep
269	-0.01596562	12.0175347	26-Sep
270	-0.02276916	11.9398914	27-Sep
271	-0.02957093	11.8622471	28-Sep
272	-0.03636926	11.7846059	29-Sep
273	-0.04316247	11.706972	30-Sep
274	-0.04994884	11.6293495	01-Oct
275	-0.05672668	11.5517429	02-Oct
276	-0.06349427	11.4741571	03-Oct
277	-0.07024988	11.3965967	04-Oct

278	-0.0769918	11.319067	05-Oct
279	-0.08371826	11.2415734	06-Oct
280	-0.09042753	11.1641217	07-Oct
281	-0.09711784	11.0867178	08-Oct
282	-0.10378742	11.0093682	09-Oct
283	-0.1104345	10.9320796	10-Oct
284	-0.11705728	10.8548592	11-Oct
285	-0.12365397	10.7777146	12-Oct
286	-0.13022275	10.700654	13-Oct
287	-0.13676182	10.6236859	14-Oct
288	-0.14326933	10.5468193	15-Oct
289	-0.14974346	10.470064	16-Oct
290	-0.15618235	10.3934302	17-Oct
291	-0.16258415	10.3169286	18-Oct
292	-0.16894698	10.2405708	19-Oct
293	-0.17526898	10.1643689	20-Oct
294	-0.18154825	10.0883357	21-Oct
295	-0.18778291	10.012485	22-Oct
296	-0.19397104	9.93683097	23-Oct
297	-0.20011074	9.86138886	24-Oct
298	-0.20620008	9.78617466	25-Oct
299	-0.21223714	9.71120525	26-Oct
300	-0.21821998	9.63649841	27-Oct
301	-0.22414667	9.56207286	28-Oct
302	-0.23001525	9.48794829	29-Oct
303	-0.23582378	9.41414537	30-Oct
304	-0.24157028	9.34068582	31-Oct
305	-0.24725281	9.26759242	01-Nov
306	-0.2528694	9.19488905	02-Nov
307	-0.25841809	9.1226007	03-Nov
308	-0.26389689	9.05075351	04-Nov
309	-0.26930384	8.9793748	05-Nov
310	-0.27463698	8.90849309	06-Nov
311	-0.27989434	8.8381381	07-Nov
312	-0.28507394	8.76834081	08-Nov
313	-0.29017384	8.69913345	09-Nov
314	-0.29519206	8.63054952	10-Nov
315	-0.30012667	8.5626238	11-Nov
316	-0.30497572	8.49539232	12-Nov
317	-0.30973727	8.42889244	13-Nov
318	-0.31440941	8.36316276	14-Nov

319	-0.31899021	8.29824316	15-Nov
320	-0.3234778	8.23417479	16-Nov
321	-0.32787027	8.171	17-Nov
322	-0.33216577	8.10876236	18-Nov
323	-0.33636245	8.04750659	19-Nov
324	-0.34045848	7.98727853	20-Nov
325	-0.34445206	7.9281251	21-Nov
326	-0.34834142	7.87009421	22-Nov
327	-0.35212479	7.81323469	23-Nov
328	-0.35580045	7.75759624	24-Nov
329	-0.35936671	7.70322931	25-Nov
330	-0.3628219	7.65018501	26-Nov
331	-0.3661644	7.59851498	27-Nov
332	-0.3693926	7.54827128	28-Nov
333	-0.37250497	7.49950628	29-Nov
334	-0.37549997	7.45227247	30-Nov
335	-0.37837613	7.40662232	01-Dec
336	-0.38113204	7.36260814	02-Dec
337	-0.38376629	7.32028187	03-Dec
338	-0.38627757	7.27969491	04-Dec
339	-0.38866459	7.24089794	05-Dec
340	-0.39092611	7.2039407	06-Dec
341	-0.39306095	7.1688718	07-Dec
342	-0.39506799	7.13573851	08-Dec
343	-0.39694617	7.10458653	09-Dec
344	-0.39869448	7.07545981	10-Dec
345	-0.40031197	7.0484003	11-Dec
346	-0.40179776	7.02344776	12-Dec
347	-0.40315104	7.00063957	13-Dec
348	-0.40437104	6.9800105	14-Dec
349	-0.40545707	6.96159254	15-Dec
350	-0.40640853	6.9454147	16-Dec
351	-0.40722485	6.93150287	17-Dec
352	-0.40790556	6.91987967	18-Dec
353	-0.40845025	6.91056429	19-Dec
354	-0.40885857	6.90357238	20-Dec
355	-0.40913025	6.898916	21-Dec
356	-0.40926511	6.89660347	22-Dec
357	-0.40926301	6.8966394	23-Dec
358	-0.40912392	6.89902458	24-Dec
359	-0.40884785	6.90375605	25-Dec

360	-0.40843489	6.91082707	26-Dec	
361	-0.40788523	6.92022718	27-Dec	
362	-0.4071991	6.93194227	28-Dec	
363	-0.40637681	6.94595466	29-Dec	
364	-0.40541876	6.96224318	30-Dec	
365	-0.4043254	6.98078336	31-Dec	
		4498.78225	2044.98	2453.806
		annual	winter	summer

COLLISION RISK ASSESSMENT
Sheet 5 - Large array correction factor

Do not enter data on this sheet, unless to prescribe the number of turbine rows
All the data below is derived from Sheets 1, 2 or 3

🟩	data from Sheet 1
🟧	data from Sheet 2
🟧	data from Sheet 3
🟨	data to be entered here (optional)
🟦	calculated fields

Number of turbines	1
Rotor radius	127.5
Width of windfarm	0.3
Average proportion of time operational	0.95
Collision risk from single rotor transit	0.051
Assumed number of turbine rows	1.0

Number of rows (optional)
(if this is left blank, number is assumed to be sqrt(T)
Number of turbines in each row

Avoidance rate	100.00%	98.90%	100.00%	100.00%
Collision risk for single bird passage, before correction	0.00000	0.00036	0.00000	0.00000
Large array correction factor	**100.00%**	**100.00%**	**100.00%**	**100.00%**

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Forthwind: Offshore Ornithology 6D Technical Appendix - Displacement Analysis

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1	12/11/2021	First draft for client
2	29/03/2022	Second draft for client, updated for seaduck and diver species

Contents

Tables

1 Introduction

1 Displacement is considered by Furness *et al.* (2013) and Bradbury *et al.* (2014) to be 'a reduced number of birds occurring within or immediately adjacent to an offshore wind farm'. This happens when birds avoid the area of operational turbines and different species are more or less likely to display this behaviour, based on their biology.

2 Furness *et al.* (2013) and Bradbury *et al.* (2014) give a displacement ranking for a range of species based on susceptibility to disturbance and habitat specialisation. This gives an indication of species more likely to be displaced and the potential consequences of that displacement.

3 Table 1 displays the displacement scoring for those species either recorded at Forthwind or potentially present. Disturbance susceptibility is considered further in Sections 2.1.5 – **Error! Reference source not found.** as it influences the rates of displacement assigned to each species; a higher score equates to a higher level of potential displacement. Habitat specialisation is considered in Section 2.1.6 as it may influence the potential mortality arising from displacement. Species which are more specialized and have a higher score, such as red-throated diver, may be more severely affected by displacement impacts.

Table 1 Displacement scoring taken from Furness *et al.* (2013)

Species	Scientific name	Disturbance susceptibility	Habitat specialisation
Guillemot	*Uria aalge*	3	3
Razorbill	*Alca torda*	3	3
Puffin	*Fratecula arctica*	2	3
Gannet	*Morus bassanas*	2	1
Kittiwake	*Rissa tridactyla*	2	2
European shag	*Phalacrocorax aristotelis*	3	3
Eider	*Somateria mollissima*	3	4
Red-throated diver	*Gavia stellata*	5	4
Common scoter	*Melanitta nigra*	5	4
Velvet scoter	*Melanitta fusca*	5	3
Long-tailed duck	*Clangula hyemalis*	3	4
Red-breasted merganser	*Mergus serrator*	Not addressed	
Slavonian grebe	*Podiceps auritus*	3	4
Goldeneye	*Bucephala clangula*	4	4

2 Methods

2.1 Assessment method

4 Assessment of displacement for seabird species follows the interim advice issued by the statutory nature conservation bodies (SNCBs), promoting the use of 'displacement matrices' to give a range of displacement rates which are then considered in terms of adult mortality (SNCB, 2017). So far, seaduck and diver species have not regularly been assessed for displacement from offshore wind farm development and in the absence of alternative methods, it has been advised by Marine Scotland Science and NatureScot that displacement matrices are also adopted for these species.

2.1.1 Spatial scales

5 For the Forthwind single turbine, the impact zone defined for displacement assessment is the location of the turbine plus a 2 km buffer around it, minus the small area of land contained. This gives an impact zone of 11.5 km^2. Previous assessment (for the consented two turbine 2016 proposal) utilised a buffer of 1km around the array area; therefore, the current assessment is more precautionary.

6 Consideration was given to using a larger buffer for seaduck and diver species but as the turbine is only 1.5 km from the shore and it is the inshore waters that are of key concern, it was considered that the 2 km buffer sufficiently covers this area. It is also considered that this buffer also adequately addresses any risk of lateral displacement. In addition, review of operational monitoring data for the nearby Levenmouth turbine confirmed that use of a 2km buffer is sufficiently precautionary for seaduck and diver species. These data confirmed the presence of seaduck and divers within 500 m of the operational turbine, as discussed in Section 6.6 of this report, Appendix 6D.1.

2.1.2 Defined seasons

7 As set out in SNCB (2017), displacement matrices are required for each species in the breeding and non-breeding seasons. The breeding season for seabirds is based on NatureScot (2020) and for the non-breeding season is based on Furness (2015): the report on biologically defined minimum population scales (BDMPS), as set out in Table 2.

Table 2. Defined seasons for seabird interests

Species	Breeding season (NatureScot, 2020)	BDMPS (Furness, 2015)		
		autumn migration	non-breeding	spring migration
Guillemot	Apr - mid Aug	n/a	Aug - Feb	n/a
Razorbill	Apr - mid Aug	Aug - Oct	Nov - Dec	Jan - Mar
Puffin	Apr - mid Aug	n/a	Aug - Mar	n/a
Gannet	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
Kittiwake	mid Apr - Aug	Aug - Dec	n/a	Jan - Apr
European shag	Mar - Sep	n/a	Sep - Jan	n/a

8 Seaduck and diver species are included for assessment as wintering interests of the Outer Firth of Forth and St Andrews Bay SPA. The non-breeding season for each of these species is based on NatureScot (2020), as set out in Table 3.

Table 3. Defined seasons for seaduck and diver species

Species	Non-breeding season (NatureScot, 2020)
Eider	Sep - mid Apr
Red-throated diver	mid Sep - Apr
Common scoter	July - Apr
Velvet scoter	Sep - Apr
Long-tailed duck	mid Sep - Apr
Red-breasted merganser	mid Aug - Mar
Slavonian grebe	mid Sep - Apr
Goldeneye	Sep - mid Apr

2.1.3 Seabird population estimates

9 For the seabird species in Table 1, the mean seasonal peaks have been calculated from monthly population estimates for all birds present within the defined impact zone. These mean seasonal peak population estimates are based on the two years of boat-based survey data for each of the defined seasons for each species set out in Table 2.

10 Technical Appendix 6A sets out the monthly population estimates for each species in the impact zone from which can be derived the peak estimates for each season in each year. The mean peaks in each season are what is then used for each of the displacement matrices in Appendix 6D.2 of this report.

2.1.4 Seaduck and diver population estimates

11 ‘Worst-case’ population estimates for seaduck and diver species have been derived from review of all available data for Forthwind, as discussed in Appendix 6D.1 of this report.

2.1.5 Displacement rates

12 The ‘disturbance susceptibility’ scores outlined in SNCB guidance (SNCB, 2017) and based on Furness *et al.* (2013) and Bradbury *et al.* (2014), can be used as a proxy for displacement rates where specific empirical evidence is lacking. For example, the SNCBs advise that species with a ‘disturbance susceptibility’ score of 1 are unlikely to be displaced (or at least be displaced at very low levels) and so this score would translate to a displacement level of 10% or less. Species with a ‘disturbance susceptibility’ score of 3, where species have a moderate to high sensitivity to disturbance, would translate to a likely displacement level of between 30-70%.

13 This advice informs the displacement rates for the seabird species included in Table 4.

14 However, for the seaduck and diver species a precautionary rate of 100% displacement has been applied. This substantially over-estimates the impacts (especially for a single turbine) but has been used to demonstrate that even so, impacts are not significant.

2.1.6 Mortality rates

15 The fitness consequences of displacement on birds are two-fold; birds may require higher energetic expenditure deviating from their usual flight or foraging areas, whilst a loss of perceived and physical habitat may reduce available food resources, in turn risking some degree of potential mortality (Fox and Peterson, 2019; Fox *et al*., 2006; Masden *et al*., 2009).

16 This degree of mortality will differ depending on several factors, including the size of the wind farm, the amount of habitat lost, the distance deviated by birds in flight, the availability of suitable replacement habitat and the level of increased competition. Mortality impacts are also likely to differ between season and species, based on their morphology, foraging range, foraging rates and seasonal energetic needs such as when provisioning for chicks (Masden *et al*., 2010).

17 Bird species showing limited flexibility in habitat use will be expected to experience greater fitness consequences from displacement compared to those species that are more generalised (Furness *et al.,* 2013). Therefore, the scores of species-specific 'habitat specialization' (Table 1) can be used to provide an indication of the relative scale of mortality arising from displacement for each species. Species considered less flexible in their habitat use, are likely to be more vulnerable to displacement from favoured habitats. A high score for specialization would therefore be expected to indicate a higher level of potential mortality.

18 This advice informs the mortality rates for the seabird species included in Table 4. NatureScot have provided advice in the 2021 scoping opinion on mortality rates to use for the auk species. Rates for other species are considered in relation to the auks and informed by the scores in Table 1.

19 For the seaduck and diver species a precautionary rate of 5% mortality has been applied. Again, this will substantially over-estimate the impacts considering that the identified impact zone is not particularly important for seaduck or diver foraging (see discussion in Section 6.7.3.1 of the ES chapter) and is a very small proportion of the total available resource.

20 While Table 4 presents the mortalities taken forward for assessment, the displacement matrices in Appendix 6D.2 present the full range of possible mortalities from 0 – 100%.

Table 4. Suggested rates of displacement and resulting mortality

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Guillemot	60%	1%	1%
Razorbill	60%	1%	1%
Puffin	60%	2%	1%
Gannet	70%	1%	1%
Kittiwake	30%	1%	1%
European shag	60%	1%	1%
Eider	100%	n/a	5%
Red-throated diver	100%	n/a	5%
Common scoter	100%	n/a	5%
Velvet scoter	100%	n/a	5%
Long-tailed duck	100%	n/a	5%
Red-breasted merganser	100%	n/a	5%
Slavonian grebe	100%	n/a	5%
Goldeneye	100%	n/a	5%
Common scoter	100%	n/a	5%

3 Results

21 Displacement mortality estimates are presented for each species by season as discussed in section 2.1.2. Full displacement matrices for each species and each season are presented in Appendix 6D.2.

3.1 Guillemot

Table 5. Guillemot displacement mortalities (numbers of birds)

Guillemot displacement mortalities	**Breeding season (NatureScot)**	**BDMPS**		
		autumn migration	**non-breeding**	**spring migration**
	Apr - mid Aug	**n/a**	**Aug - Feb**	**n/a**
Seasonal mean peak	417	n/a	401	n/a
Seasonal mortality	6	n/a	2	n/a

3.2 Razorbill

Table 6. Razorbill displacement mortalities (numbers of birds)

Razorbill displacement mortalities	**Breeding season (NatureScot)**	**BDMPS**	
		migration	**non-breeding**
	Apr - mid Aug	**Aug - Oct, Jan - Mar**	**Nov - Dec**
Seasonal mean peak	57	81	58
Seasonal mortality	0	0	0

3.3 Puffin

Table 7. Puffin displacement mortalities (numbers of birds)

Puffin displacement mortalities	**Breeding season (NatureScot)**	**BDMPS**		
		autumn migration	**non-breeding**	**spring migration**
	Apr - mid Aug	**n/a**	**Aug - Mar**	**n/a**
Seasonal mean peak	68	n/a	24	n/a
Seasonal mortality	1	n/a	0	n/a

3.4 Gannet

Table 8. Gannet displacement mortalities (numbers of birds)

Gannet displacement mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
Seasonal mean peak	64	26	n/a	44
Seasonal mortality	0	0	n/a	0

3.5 Kittiwake

Table 9. Kittiwake displacement mortalities (numbers of birds)

Kittiwake displacement mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid Apr - Aug	Aug - Dec	n/a	Jan - Apr
Seasonal mean peak	44	24	n/a	36
Seasonal mortality	0	0	n/a	0

3.6 European shag

Table 10. European shag displacement mortalities (numbers of birds)

European shag displacement mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	Mar - Sep	n/a	Sep - Jan	n/a
Seasonal mean peak	14	n/a	35	n/a
Seasonal mortality	0	n/a	0	n/a

3.7 Eider

Table 11. Eider displacement mortalities (numbers of birds)

Eider displacement mortalities	Non-breeding season (NatureScot)
	Sep - mid Apr
Worst-case population estimate	1150
Worst-case mortality	58

3.8 Red-throated diver

Table 12. Red-throated diver displacement mortalities (numbers of birds)

Red-throated diver displacement mortalities	Non-breeding season (NatureScot)
	mid Sep - Apr
Worst-case population estimate	9
Worst-case mortality	0

3.9 Common scoter

Table 13. Common scoter displacement mortalities (numbers of birds)

Common scoter displacement mortalities	Non-breeding season (NatureScot)
	July - Apr
Worst-case population estimate	622
Worst-case mortality	31

3.10 Velvet scoter

Table 14. Velvet scoter displacement mortalities (numbers of birds)

Velvet scoter displacement mortalities	Non-breeding season (NatureScot)
	Sep - Apr
Worst-case population estimate	83
Worst-case mortality	5

3.11 Long-tailed duck

Table 15. Long-tailed duck displacement mortalities (numbers of birds)

Long-tailed duck displacement mortalities	Non-breeding season (NatureScot)
	mid Sep - Apr
Worst-case population estimate	58
Worst-case mortality	3

3.12 Red-breasted merganser

Table 16. Red-breasted merganser displacement mortalities (numbers of birds)

Red-breasted merganser displacement mortalities	Non-breeding season (NatureScot)
	mid Aug - Mar
Worst-case population estimate	30
Worst-case mortality	2

3.13 Slavonian grebe

Table 17. Slavonian grebe displacement mortalities (numbers of birds)

Slavonian grebe displacement mortalities	Non-breeding season (NatureScot)
	mid Sep - Apr
Worst-case population estimate	3
Worst-case mortality	0

3.14 Goldeneye

Table 18. Goldeneye displacement mortalities (numbers of birds)

Goldeneye displacement mortalities	Non-breeding season (NatureScot)
	Sep - mid Apr
Worst-case population estimate	75
Worst-case mortality	4

4 Discussion and Conclusions

22 Full displacement matrices for each species and season are presented in Appendix 6D.2.

23 Assessment is based on the displacement and mortality rates presented in Table 4.

24 Estimated displacement mortalities are considered against identified reference populations as noted below and addressed in Section 6.7.3.4 of ES Chapter 6, Offshore Ornithology.

4.1 Guillemot

25 Breeding season impacts can be apportioned between SPA seabird colonies using the weightings given in Technical Appendix 6B. For guillemot, 91.9% of birds are apportioned to Forth Islands SPA which gives a breeding season mortality of six birds against this SPA.

26 In the non-breeding season, displacement impacts are considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA. This gives a non-breeding season mortality of two birds against this SPA.

4.2 Razorbill

27 Predicted razorbill displacement mortalities are zero in the breeding and non-breeding seasons, the former to be considered against the breeding population of the Forth Islands SPA, as noted in Technical Appendix 6B, and the latter against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA.

4.3 Puffin

28 Breeding season impacts can be apportioned between SPA seabird colonies using the weightings given in Technical Appendix 6B. For puffin, 99.2% of birds are apportioned to Forth Islands SPA which gives a breeding season mortality of one bird against this SPA.

4.4 Gannet

29 Predicted gannet displacement mortalities are zero in the breeding and non-breeding seasons, to be considered against the breeding population of the Forth Islands SPA, as identified in Technical Appendix 6B. As a ‘worst case’ displacement and collision mortalities are added together, addressed in Section 6.7.3.4.1 of ES Chapter 6, Offshore Ornithology.

4.5 Kittiwake

30 Predicted kittiwake displacement mortalities are zero in the breeding and non-breeding seasons, the former to be considered against the breeding population of the Forth Islands SPA, as noted in Technical Appendix 6B, and the latter against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA. As a ‘worst case’ displacement and collision mortalities are added together, addressed in Section 6.7.3.4.2 of ES Chapter 6, Offshore Ornithology.

4.6 European shag

31 Predicted shag displacement mortalities are zero in the breeding and non-breeding seasons, the former to be considered against the breeding population of the Forth Islands SPA, as noted in Technical Appendix 6B, and the latter against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA.

4.7 Eider

32 Eider displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of 58 birds against this SPA population.

4.8 Red-throated diver

33 Red-throated diver displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: zero predicted mortalities against this SPA population, even using worst-case assumptions.

4.9 Common scoter

34 Common scoter displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of 31 birds against this SPA population.

4.10 Velvet scoter

35 Velvet scoter displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of four birds against this SPA population.

4.11 Long-tailed duck

36 Long-tailed duck displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of three birds against this SPA population.

4.12 Red-breasted merganser

37 Red-breasted merganser displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of two birds against this SPA population.

4.13 Slavonian grebe

38 Slavonian grebe displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: zero predicted mortalities against this SPA population, even using worst-case assumptions.

4.14 Goldeneye

39 Goldeneye displacement mortality in the non-breeding season is considered against the non-breeding population of the Outer Firth of Forth and St Andrews Bay SPA: a worst-case mortality of four birds against this SPA population.

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6 Appendix 6D.1 – Seaduck and diver populations

6.1 Introduction

40 The following seaduck and diver species may potentially be at risk of displacement from the Forthwind turbine:

- Red-throated diver (*Gavia stellata*)
- Eider (*Somateria mollissima*)
- Common scoter (*Melanitta nigra*)
- Velvet scoter (*Melanitta fusca*)
- Long-tailed duck (*Clangula hyemalis*)
- Red-breasted merganser (*Mergus serrator*)
- Slavonian grebe (*Podiceps auritus*)
- Goldeneye (*Bucephala clangula*)

41 The only method available for assessment of seaduck and diver displacement is very crude (SNCB, 2017). It is based on applying an assumed rate of displacement and an assumed rate of mortality to an estimated site population. It provides a general measure of risk from development rather than any kind of precise quantification. In this regard, it should be possible to take a view of the level of risk from the Project on seaduck and diver species based on a ‘worst-case’ analysis using worst-case estimates of population size (numbers of birds at risk), and worst-case assumptions on rates of displacement and rates of mortality.

42 HiDef have reviewed the range of available data which can be used to inform displacement assessment for seaduck and divers and consider that there is more than sufficient information to be able to determine worst-case population estimates for use in displacement assessment. In this regard, it is unclear as to the added value from further site-specific survey work and no obvious reason for requiring it.

6.2 Outer Firth of Forth and St Andrews Bay SPA site selection (JNCC, 2016; Lawson *et al.* 2015)

6.2.1 Visual Aerial Surveys (2001/02-2004/05)

43 Visual aerial surveys covering the extent of the Firth of Forth were conducted using a Partenavia (PN-68) or an Islander plane flown at 76 m ASL, at a speed of 185 km per hour (100 knots). Six line transect surveys were undertaken between December and February across three years (2001/02, 2003/04 and 2004/05). The survey design consisted of ~60 transects angled southwest to northeast, spaced 2 km apart. The 2001/02 surveys assigned observations to three distance bands, whilst subsequent surveys used four distance bands. Distance was recorded to 1000m on either side of the plane, providing full coverage of the site. Distance sampling was used to calculate population estimates. For the purposes of calculating population estimates, all unidentified divers were assumed to be red-throated diver.

44 The aerial survey data was used to establish both mean density surfaces and population estimates for red-throated diver, common eider, long-tailed duck, and common scoter, as given in Tables 19 and 20 below.

45 Table 19 gives the relative density bands of each species in the Forthwind turbine location; as calculated and presented in the SPA site selection document (JNCC, 2016). For application to the Forthwind assessment, the upper limit of the band is multiplied by the area of the defined 'impact zone', the location of the turbine plus a 2km buffer around it, which is an area of 11.5 km^2 (as discussed earlier in Section 2.1.1). This gives a worst-case population estimate as presented in Table 19.

Table 19. Relative density band (birds/km^2) of birds at the Forthwind turbine (JNCC, 2016) and subsequent worst-case population estimates calculated for the 'impact zone'

Species	Relative density (birds/km^2)	Worst-case population estimate
Red-throated diver (all diver sp.)	0.25 - 0.75	9
Eider	50 - 100	1150
Common scoter	2 - 5	58
Long-tailed duck	2 - 5	58

46 HiDef have also checked the mean-density surface underpinning the analysis for the SPA site selection document (JNCC, 2016). This information has been generated directly from the visual aerial surveys and acquired as GIS shapefiles from JNCC (these can be provided by HiDef upon request, or else are available directly from JNCC). The mean-density surface consists of a point estimate of density for each species within a 1km grid square. It was cropped to the area of the impact zone (the 2km buffer area) and the highest mean-density within it was then selected. This figure was then multiplied by the area of the impact zone (11.5 km^2) to give a worst-case population estimate for each species; see Table 20.

Table 20. Highest mean-density point (birds/km^2) calculated for the 'impact zone' and subsequent worst-case population estimate

Species	Highest mean-density (birds/km^2)	Worst-case population estimate
Red-throated diver (all diver sp.)	0.61	7
Eider	61.13	703
Common scoter	5.22	60
Long-tailed duck	2.62	30

6.2.2 WeBS counts (2006/7 to 2010/11)

47 Land-based WeBS counts covering the coastline of the Firth of Forth were collated for five years (2006/7 to 2010/11). Monthly WeBS core counts were conducted between November to March by land-based observers from vantage points using the 'look-see' method (Bibby *et al.*, 2000); providing complete coverage of each count sector within a four-hour period. Large flocks were estimated by dividing the birds into groups.

48 WeBS data are used in the SPA site selection document for Slavonian grebe, velvet scoter, common goldeneye and red-breasted merganser (JNCC, 2016).

49 For each shore-based count sector ('East Wemyss to River Leven West Bank' in the case of Forthwind) a peak count was identified for each of the five years, taken from the monthly surveys carried out across the winter season (Nov to March). A mean peak was then calculated for each species; the average of the five annual peaks identified. This information has been taken from the SPA site selection document and is presented in Table 21.

Table 21. Mean peak of birds in the WeBS shore-based count sector opposite Forthwind (taken from JNCC, 2016)

Species	Mean number of birds per shore-based count sector
Velvet scoter	≤ 50
Red-breasted merganser	15 - 30
Slavonian grebe	≤ 3
Goldeneye	30 - 75

6.3 Recent WeBS counts (2015/16 to 2019/20)

50 The most recent five years of WeBS data available for the 'East Wemyss to River Leven West Bank' count sector have been obtained by HiDef from the BTO. This sector covers a ~5km stretch of coastline directly opposite Forthwind.

51 WeBS core counts were conducted between November to March by land-based observers from vantage points using the 'look-see' method (Bibby *et al.*, 2000); providing complete coverage of the count sector within a four-hour period. Large flocks were estimated by dividing the birds into groups.

52 Monthly counts were collated for six winter seasons between 2015 and 2020, including:

- November to December 2015;
- November to March 2016;
- December to March 2017;
- November to March 2018;
- November to March 2019;
- January to March 2020.

53 The peak count of each winter season is presented in Table 16, alongside the overall peak of the 2015-2020 survey period. Counts considered as unrepresentative due to gaps in coverage, disturbance or weather induced effects on numbers and distribution are noted as 'poor'.

Table 22. **WeBS peak monthly counts from the East Wemyss to River Leven West Bank sector (2015 – 2020)**

Species	2015	2016	2017	2018	2019	2020	Overall peak
Red-throated diver	1	3	0	2	2	1 *	**3**
Eider	170	189	141*	149	253	170	**253**
Common scoter	12	19	196*	190	622	0	**622**
Velvet scoter	0	18	8	14	83	6	**83**
Long-tailed duck	22	12	21	20	32	0	**32**
Red-breasted merganser	17	13	18	5*	11	9	**18**
Slavonian grebe	0	0	0	0	0	0	**0**
Goldeneye	0	0	12*	0	0	8*	**12**

**Poor species coverage*

54 The rows marked in grey are those for which visual aerial survey was used in the SPA site selection document (JNCC, 2016). While the unmarked rows can be compared against the earlier WeBS data used for these species in SPA site selection, see Table 21 (JNCC, 2016).

6.4 Forthwind boat-based survey data (2015/2016 and 2016/2017)

55 The applicant has undertaken two years of boat-based survey as described, discussed and analysed in Technical Appendix 6A: year 1 (March 2015 – February 2016) and year 2 (March 2016 – February 2017). The survey area is substantially larger than the identified impact zone: 40.8 km^2 as compared to 11.5 km^2 and, even so, there were not enough sightings of seaduck and divers to be able to undertake distance sampling for any species other than red-throated diver and eider.

56 The maximum densities of red-throated diver and eider recorded during boat-based survey, and the resulting peak population estimates are presented in Table 23. Only year 2 data has been used for these species; this was when the transects were extended to cover more inshore waters and may be more representative of the species' coastal distribution (Section 4, Technical Appendix 6A, Baseline Data).

Table 23. **Highest density of birds (birds/km^2) recorded during boat-based survey and subsequent peak population estimate for the 'impact zone'**

Species	Highest density (birds/km^2)	Peak population estimate
Red-throated diver	0.54	6
Eider	11.89	137

6.5 Choice of worst-case population estimates

57 The tables of data set out above (Table 19 to Table 23) have been reviewed in order to select the worst-case population estimate for each species. These choices are presented in Table 24 and taken forward for assessment in Appendix 6D.2, generating a worst-case displacement matrix for each species.

Table 24. Worst-case population estimates for Forthwind 'impact zone'

Species	Worst-case population estimate	Source of estimate	HiDef comments
Eider	1150	SPA visual aerial surveys (Table 19)	Derived from upper limit of relative density band. Substantially 'worst-case' compared to other data.
Red-throated diver	9	SPA visual aerial surveys (Table 19)	Derived from upper limit of relative density band. Red throated diver estimates all of similar magnitude.
Common scoter	622	Recent WeBS (Table 22)	Peak count in 2019. Substantially 'worst-case' compared to other data.
Velvet scoter	83	Recent WeBS (Table 22)	Peak count in 2019. Compares to SPA WeBS mean peak of ≤ 50 birds (Table 21).
Long-tailed duck	58	SPA visual aerial surveys (Table 19)	Derived from upper limit of relative density band. Compares to peak of ~30 birds in Tables 20 and 22.
Red-breasted merganser	30	SPA WeBS (Table 21)	Compares to recent WeBS peak count of 18 birds in 2017 (Table 22).
Slavonian grebe	3	SPA WeBS (Table 21)	Zero Slavonian grebe recorded over the last five years of recent WeBS (Table 22).
Goldeneye	75	SPA WeBS (Table 21)	Poor species coverage in recent WeBS; peak count of 12 birds in 2017 (Table 22).

6.6 Levenmouth post-construction monitoring

58 Decision-making can also be informed by the operational (post-construction) monitoring data available for the Levenmouth turbine, consented 3 May 2013 and granted a 10-year extension by Marine Scotland in 2018, extending its operational lifespan up until 2029. The Levenmouth turbine, as built, is 196 m to blade tip with a rotor diameter of 171 m; in this regard, it is smaller than what is proposed at Forthwind (280 m to blade tip with a rotor diameter of 255 m). It can, however, still provide useful information in terms of considering the risk of seaduck and diver displacement.

59 Operational ornithological monitoring has been carried out at Levenmouth in 2014/15, 2015/16, 2016/17 (years 1-3) and 2017/18 (year 4). Data and monitoring reports have been made available to HiDef via a data-sharing agreement between Cierco (the Forthwind applicant) and Catapult (the Levenmouth developer). The monitoring reports will also have been submitted to Marine Scotland and NatureScot via the conditions on the Section 36 consent, although they do not appear to be publicly available.

60 The Levenmouth operational monitoring employs vantage point (VP) watches that are undertaken from a single onshore VP located at NT 36613 98260, a hundred metres or so along the coast from the turbine. The turbine itself is located in the intertidal area not far offshore but monitoring checks for the presence and flight activity of various birds within a survey area extending out to sea for a distance of 500 m from the coast. As seaduck and diver species are known to use these inshore waters it can therefore be checked whether they occur at sea within 500 m of the operational turbine.

61 It is not possible to determine actual rates of displacement from the Levenmouth data, but Table 19 below presents the total number of observations of seaduck and divers occurring at sea within 500 m of the operational turbine (taken from Table 2 of the Levenmouth Years 1-3 Operational Bird Monitoring Comparative Analysis, published May 2017).

62 The operational monitoring was spread evenly throughout the year with roughly 12 hours of observation completed each month, and a total of 144 hours of observation completed each year. The records presented in Table 25 indicate that use of a 100% displacement rate and 2 km buffer for seaduck and diver species at Forthwind is likely to be worst-case.

Table 25. Levenmouth total seaduck and diver observations within 500m of the operational turbine over years 1-3 of operational monitoring

Species	Yr 1 2014/15	Yr 2 2015/16	Yr 3 2016/17
Eider	162	119	121
Red-throated diver	5	0	2
Common scoter	8	5	1
Velvet scoter	8	7	4
Long-tailed duck	25	12	8
Red-breasted merganser	6	12	3
Slavonian grebe	0	2	2
Goldeneye	0	1	0

6.7 Further data collection

63 Given the small sample sizes for seaduck and diver obtained from the two years of boat survey (covering an area of 40.8 km^2), a further six months of site-specific survey work for the impact zone alone (11.5 km^2) would be very unlikely to generate any usable data for robust estimation of population sizes.

64 When considering the age of survey data it should be noted that there is at least a 10-year age-gap between the data used for the available site-specific survey estimates (2016/17) and that used for total population counts in the SPA (2001/02-2004/05). There seems to be little point in having up-to-date estimates of impact if the baseline used for comparison is so out-of-date. There is no available information on SPA trends for seaduck and diver species and no way of knowing whether overall numbers are increasing or declining.

65 As previously noted, any refinement of the site-specific survey estimates is unlikely to make an appreciable difference to the outcome of displacement assessment given that it's such a crude approach. Judgements on the level of risk from the Project can as well be made on the basis of a worst-case assessment and assumptions. This includes whether or not it is likely to give rise to any adverse impact on SPA site integrity for seaduck and diver species, as required under HRA.

66 Overall, there really needs to be some explanation as to how a further six months of site survey data adds any value to the assessment or decision-making for the Proposed Development.

67 Rather than requiring further pre-construction data, it would seem more beneficial to agree the proposals for post-construction monitoring, to explore the actual responses of seaduck and diver species to the operational turbine and to check the validity of the worst-case assumptions used in assessment.

68 In this regard, expectations will need to be kept realistic as to what it's possible to achieve for a single turbine: the monitoring could be used to confirm presence/absence of seaduck and divers in vicinity of the operational turbine, occurring within the 1.5 km stretch of sea between it and the coast. While this could indicate whether the assumed rate of 100% displacement is valid, it's unlikely that there will be sufficient data to determine actual rates of displacement for most of the species of concern.

69 The applicant would be happy to agree the requirements for, and approach to, any such operational (post-construction) monitoring with Marine Scotland, NatureScot and the RSPB.

7 Appendix 6D.2 – Displacement matrices

Shaded cells indicate the 'worst-case' taken forward for the seasonal assessments, as presented in Section 3 – Results.

7.1 Guillemot

Table 26. Guillemot displacement – breeding season

Guillemot Apr - mid Aug		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	1	1	2	2	4	6	8	13	21	33	42
	20%	0	1	2	3	3	4	8	13	17	25	42	67	83
	30%	0	1	3	4	5	6	13	19	25	38	63	100	125
	40%	0	2	3	5	7	8	17	25	33	50	83	133	167
	50%	0	2	4	6	8	10	21	31	42	63	104	167	208
	60%	0	3	5	8	10	13	25	38	50	75	125	200	250
	70%	0	3	6	9	12	15	29	44	58	88	146	234	292
	80%	0	3	7	10	13	17	33	50	67	100	167	267	334
	90%	0	4	8	11	15	19	38	56	75	113	188	300	375
	100%	0	4	8	13	17	21	42	63	83	125	208	334	417

Table 27. Guillemot displacement – non-breeding season

Guillemot Aug-Feb		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	1	1	2	2	4	6	8	12	20	32	40
	20%	0	1	2	2	3	4	8	12	16	24	40	64	80
	30%	0	1	2	4	5	6	12	18	24	36	60	96	120
	40%	0	2	3	5	6	8	16	24	32	48	80	128	160
	50%	0	2	4	6	8	10	20	30	40	60	100	160	200
	60%	0	2	5	7	10	12	24	36	48	72	120	192	240
	70%	0	3	6	8	11	14	28	42	56	84	140	224	280
	80%	0	3	6	10	13	16	32	48	64	96	160	256	320
	90%	0	4	7	11	14	18	36	54	72	108	180	288	360
	100%	0	4	8	12	16	20	40	60	80	120	200	320	400

7.2 Razorbill

Table 28. Razorbill displacement – breeding season

Razorbill Apr-mid Aug		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	3	5	6
	20%	0	0	0	0	0	1	1	2	2	3	6	9	11
	30%	0	0	0	1	1	1	2	3	3	5	9	14	17
	40%	0	0	0	1	1	1	2	3	5	7	11	18	23
	50%	0	0	1	1	1	1	3	4	6	9	14	23	28
	60%	0	0	1	1	1	2	3	5	7	10	17	27	34
	70%	0	0	1	1	2	2	4	6	8	12	20	32	40
	80%	0	0	1	1	2	2	5	7	9	14	23	36	46
	90%	0	1	1	2	2	3	5	8	10	15	26	41	51
	100%	0	1	1	2	2	3	6	9	11	17	28	46	57

Table 29. Razorbill displacement – non-breeding season

Razorbill Nov-Dec		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	3	5	6
	20%	0	0	0	0	0	1	1	2	2	3	6	9	12
	30%	0	0	0	1	1	1	2	3	3	5	9	14	17
	40%	0	0	0	1	1	1	2	3	5	7	12	18	23
	50%	0	0	1	1	1	1	3	4	6	9	14	23	29
	60%	0	0	1	1	1	2	3	5	7	10	17	28	35
	70%	0	0	1	1	2	2	4	6	8	12	20	32	40
	80%	0	0	1	1	2	2	5	7	9	14	23	37	46
	90%	0	1	1	2	2	3	5	8	10	16	26	41	52
	100%	0	1	1	2	2	3	6	9	12	17	29	46	58

Table 30. Razorbill displacement – migration

Razorbill Jan-Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	2	2	4	6	8
	20%	0	0	0	0	1	1	2	2	3	5	8	13	16
	30%	0	0	0	1	1	1	2	4	5	7	12	19	24
	40%	0	0	1	1	1	2	3	5	6	10	16	26	32
	50%	0	0	1	1	2	2	4	6	8	12	20	32	40
	60%	0	0	1	1	2	2	5	7	10	15	24	39	49
	70%	0	1	1	2	2	3	6	9	11	17	28	45	57
	80%	0	1	1	2	3	3	6	10	13	19	32	52	65
	90%	0	1	1	2	3	4	7	11	15	22	36	58	73
	100%	0	1	2	2	3	4	8	12	16	24	40	65	81

7.3 Puffin

Table 31. Puffin displacement – breeding season

Puffin Apr-mid Aug		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	3	5	7
	20%	0	0	0	0	1	1	1	2	3	4	7	11	14
	30%	0	0	0	1	1	1	2	3	4	6	10	16	20
	40%	0	0	1	1	1	1	3	4	5	8	14	22	27
	50%	0	0	1	1	1	2	3	5	7	10	17	27	34
	60%	0	0	1	1	2	2	4	6	8	12	20	33	41
	70%	0	0	1	1	2	2	5	7	10	14	24	38	48
	80%	0	1	1	2	2	3	5	8	11	16	27	44	54
	90%	0	1	1	2	2	3	6	9	12	18	31	49	61
	100%	0	1	1	2	3	3	7	10	14	20	34	54	68

Table 32. Puffin displacement – non-breeding season

Puffin Aug-Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	1	1	2	2
	20%	0	0	0	0	0	0	0	1	1	1	2	4	5
	30%	0	0	0	0	0	0	1	1	1	2	4	6	7
	40%	0	0	0	0	0	0	1	1	2	3	5	8	9
	50%	0	0	0	0	0	1	1	2	2	4	6	9	12
	60%	0	0	0	0	1	1	1	2	3	4	7	11	14
	70%	0	0	0	0	1	1	2	2	3	5	8	13	16
	80%	0	0	0	1	1	1	2	3	4	6	9	15	19
	90%	0	0	0	1	1	1	2	3	4	6	11	17	21
	100%	0	0	0	1	1	1	2	4	5	7	12	19	24

7.4 Gannet

Table 33. Gannet displacement – breeding season

Gannet mid Mar-Sep		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	3	5	6
	20%	0	0	0	0	1	1	1	2	3	4	6	10	13
	30%	0	0	0	1	1	1	2	3	4	6	10	15	19
	40%	0	0	1	1	1	1	3	4	5	8	13	20	25
	50%	0	0	1	1	1	2	3	5	6	10	16	25	32
	60%	0	0	1	1	2	2	4	6	8	11	19	30	38
	70%	0	0	1	1	2	2	4	7	9	13	22	36	44
	80%	0	1	1	2	2	3	5	8	10	15	25	41	51
	90%	0	1	1	2	2	3	6	9	11	17	29	46	57
	100%	0	1	1	2	3	3	6	10	13	19	32	51	64

Table 34. Gannet displacement – autumn migration

Gannet Sep-Nov		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	1	1	1	2	3
	20%	0	0	0	0	0	0	1	1	1	2	3	4	5
	30%	0	0	0	0	0	0	1	1	2	2	4	6	8
	40%	0	0	0	0	0	1	1	2	2	3	5	8	10
	50%	0	0	0	0	1	1	1	2	3	4	6	10	13
	60%	0	0	0	0	1	1	2	2	3	5	8	12	15
	70%	0	0	0	1	1	1	2	3	4	5	9	14	18
	80%	0	0	0	1	1	1	2	3	4	6	10	16	20
	90%	0	0	0	1	1	1	2	3	5	7	11	18	23
	100%	0	0	1	1	1	1	3	4	5	8	13	20	26

Table 35. Gannet displacement – spring migration

Gannet Dec-Mar		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	1	2	3	4
	20%	0	0	0	0	0	0	1	1	2	3	4	7	9
	30%	0	0	0	0	1	1	1	2	3	4	7	10	13
	40%	0	0	0	1	1	1	2	3	3	5	9	14	17
	50%	0	0	0	1	1	1	2	3	4	7	11	17	22
	60%	0	0	1	1	1	1	3	4	5	8	13	21	26
	70%	0	0	1	1	1	2	3	5	6	9	15	24	30
	80%	0	0	1	1	1	2	3	5	7	10	17	28	35
	90%	0	0	1	1	2	2	4	6	8	12	20	31	39
	100%	0	0	1	1	2	2	4	7	9	13	22	35	44

7.5 Kittiwake

Table 36. Kittiwake displacement – breeding season

Kittiwake mid Apr-Aug		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	1	2	3	4
	20%	0	0	0	0	0	0	1	1	2	3	4	7	9
	30%	0	0	0	0	1	1	1	2	3	4	7	10	13
	40%	0	0	0	1	1	1	2	3	3	5	9	14	17
	50%	0	0	0	1	1	1	2	3	4	7	11	17	22
	60%	0	0	1	1	1	1	3	4	5	8	13	21	26
	70%	0	0	1	1	1	2	3	5	6	9	15	24	30
	80%	0	0	1	1	1	2	3	5	7	10	17	28	35
	90%	0	0	1	1	2	2	4	6	8	12	20	31	39
	100%	0	0	1	1	2	2	4	7	9	13	22	35	44

Table 37. Kittiwake displacement – autumn migration

Kittiwake Aug-Dec		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	1	1	2	2
	20%	0	0	0	0	0	0	0	1	1	1	2	4	5
	30%	0	0	0	0	0	0	1	1	1	2	4	6	7
	40%	0	0	0	0	0	0	1	1	2	3	5	8	9
	50%	0	0	0	0	0	1	1	2	2	4	6	9	12
	60%	0	0	0	0	1	1	1	2	3	4	7	11	14
	70%	0	0	0	0	1	1	2	2	3	5	8	13	16
	80%	0	0	0	1	1	1	2	3	4	6	9	15	19
	90%	0	0	0	1	1	1	2	3	4	6	11	17	21
	100%	0	0	0	1	1	1	2	4	5	7	12	19	24

Table 38. Kittiwake displacement – spring migration

Kittiwake Jan-Apr		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	1	2	3	4
	20%	0	0	0	0	0	0	1	1	1	2	4	6	7
	30%	0	0	0	0	0	1	1	2	2	3	5	9	11
	40%	0	0	0	0	1	1	1	2	3	4	7	12	14
	50%	0	0	0	1	1	1	2	3	4	5	9	14	18
	60%	0	0	0	1	1	1	2	3	4	6	11	17	22
	70%	0	0	1	1	1	1	3	4	5	8	13	20	25
	80%	0	0	1	1	1	1	3	4	6	9	14	23	29
	90%	0	0	1	1	1	2	3	5	6	10	16	26	32
	100%	0	0	1	1	1	2	4	5	7	11	18	29	36

7.6 European shag

Table 39. **European shag displacement – breeding season**

European shag Mar-Sep		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	0	1	1	1
	20%	0	0	0	0	0	0	0	0	1	1	1	2	3
	30%	0	0	0	0	0	0	0	1	1	1	2	3	4
	40%	0	0	0	0	0	0	1	1	1	2	3	4	6
	50%	0	0	0	0	0	0	1	1	1	2	4	6	7
	60%	0	0	0	0	0	0	1	1	2	3	4	7	8
	70%	0	0	0	0	0	0	1	1	2	3	5	8	10
	80%	0	0	0	0	0	1	1	2	2	3	6	9	11
	90%	0	0	0	0	1	1	1	2	3	4	6	10	13
	100%	0	0	0	0	1	1	1	2	3	4	7	11	14

Table 40. European shag displacement – non-breeding season

European shag Sep-Jan		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	1	2	3	4
	20%	0	0	0	0	0	0	1	1	1	2	4	6	7
	30%	0	0	0	0	0	1	1	2	2	3	5	8	11
	40%	0	0	0	0	1	1	1	2	3	4	7	11	14
	50%	0	0	0	1	1	1	2	3	4	5	9	14	18
	60%	0	0	0	1	1	1	2	3	4	6	11	17	21
	70%	0	0	0	1	1	1	2	4	5	7	12	20	25
	80%	0	0	1	1	1	1	3	4	6	8	14	22	28
	90%	0	0	1	1	1	2	3	5	6	9	16	25	32
	100%	0	0	1	1	1	2	4	5	7	10	18	28	35

7.7 Eider

Table 41. Eider displacement – non-breeding season

Eider **Sep – mid Apr**		**Mortality Level (% of displaced birds that die)**												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	2	3	5	6	12	17	23	34	58	92	115
	20%	0	2	5	7	9	12	23	34	46	69	115	184	230
	30%	0	3	7	10	14	17	35	52	69	104	173	276	345
	40%	0	5	9	14	18	23	46	69	92	138	230	368	460
	50%	0	6	12	17	23	29	58	86	115	172	288	460	575
	60%	0	7	14	21	28	35	69	104	138	207	345	552	690
	70%	0	8	16	24	32	40	81	121	161	242	403	644	805
	80%	0	9	18	28	37	46	92	138	184	276	460	736	920
	90%	0	10	21	31	41	52	104	155	207	310	518	828	1035
	100%	0	12	23	34	46	58	115	172	230	345	575	920	1150

7.8 Red-throated diver

Table 42. Red-throated diver displacement – non-breeding season

Red-throated diver mid Sep-Apr		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	0	0	1	1
	20%	0	0	0	0	0	0	0	0	0	1	1	1	2
	30%	0	0	0	0	0	0	0	0	1	1	1	2	3
	40%	0	0	0	0	0	0	0	1	1	1	2	3	4
	50%	0	0	0	0	0	0	0	1	1	1	2	4	4
	60%	0	0	0	0	0	0	1	1	1	2	3	4	5
	70%	0	0	0	0	0	0	1	1	1	2	3	5	6
	80%	0	0	0	0	0	0	1	1	1	2	4	6	7
	90%	0	0	0	0	0	0	1	1	2	2	4	6	8
	100%	0	0	0	0	0	0	1	1	2	3	4	7	9

7.9 Common scoter

Table 43. Common scoter displacement – non-breeding season

Common scoter July - Apr		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of site population)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	2	2	3	6	9	12	19	31	50	62
	20%	0	1	2	4	5	6	12	19	25	37	62	100	124
	30%	0	2	4	6	7	9	19	28	37	56	93	149	187
	40%	0	2	5	7	10	12	25	37	50	75	124	199	249
	50%	0	3	6	9	12	16	31	47	62	93	156	249	311
	60%	0	4	7	11	15	19	37	56	75	112	187	299	373
	70%	0	4	9	13	17	22	44	65	87	131	218	348	435
	80%	0	5	10	15	20	25	50	75	100	149	249	398	498
	90%	0	6	11	17	22	28	56	84	112	168	280	448	560
	100%	0	6	12	19	25	31	62	93	124	187	311	498	622

7.10 Velvet scoter

Table 44. Velvet scoter – non-breeding season

Velvet scoter Sep - Apr		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	2	2	4	7	8
	20%	0	0	0	0	1	1	2	2	3	5	8	13	17
	30%	0	0	0	1	1	1	2	4	5	7	12	20	25
	40%	0	0	1	1	1	2	3	5	7	10	17	27	33
	50%	0	0	1	1	2	2	4	6	8	12	21	33	42
	60%	0	0	1	1	2	2	5	7	10	15	25	40	50
	70%	0	1	1	2	2	3	6	9	12	17	29	46	58
	80%	0	1	1	2	3	3	7	10	13	20	33	53	66
	90%	0	1	1	2	3	4	7	11	15	22	37	60	75
	100%	0	1	2	2	3	4	8	12	17	25	42	66	83

7.11 Long-tailed duck

Table 45. Long-tailed duck displacement – non-breeding season

Long-tailed duck mid Sep-Apr		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	1	1	2	2	3	5	6
	20%	0	1	1	1	1	1	2	2	3	4	6	10	12
	30%	0	1	1	1	1	1	2	3	4	6	9	14	18
	40%	0	1	1	1	1	2	3	4	5	7	12	19	24
	50%	0	1	1	1	2	2	3	5	6	9	15	24	29
	60%	0	1	1	2	2	2	4	6	7	11	18	28	35
	70%	0	1	1	2	2	3	5	7	9	13	21	33	41
	80%	0	1	1	2	2	3	5	7	10	14	24	38	47
	90%	0	1	2	2	3	3	6	8	11	16	27	42	53
	100%	0	1	2	2	3	3	6	9	12	18	29	47	58

7.12 Red-breasted merganser

Table 46. Red-breasted merganser displacement – non-breeding season

Red-breasted merganser mid Aug - Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	1	1	2	2	3
	20%	0	0	0	0	0	0	1	1	1	2	3	5	6
	30%	0	0	0	0	0	0	1	1	2	3	5	7	9
	40%	0	0	0	0	0	1	1	2	2	4	6	10	12
	50%	0	0	0	0	1	1	2	2	3	4	8	12	15
	60%	0	0	0	1	1	1	2	3	4	5	9	14	18
	70%	0	0	0	1	1	1	2	3	4	6	11	17	21
	80%	0	0	0	1	1	1	2	4	5	7	12	19	24
	90%	0	0	1	1	1	1	3	4	5	8	14	22	27
	100%	0	0	1	1	1	2	3	4	6	9	15	24	30

7.13 Slavonian grebe

Table 47. Slavonian grebe displacement – non-breeding season

Slavonian grebe mid Sep-Apr		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	0	0	0	0
	20%	0	0	0	0	0	0	0	0	0	0	0	0	1
	30%	0	0	0	0	0	0	0	0	0	0	0	1	1
	40%	0	0	0	0	0	0	0	0	0	0	1	1	1
	50%	0	0	0	0	0	0	0	0	0	0	1	1	2
	60%	0	0	0	0	0	0	0	0	0	1	1	1	2
	70%	0	0	0	0	0	0	0	0	0	1	1	2	2
	80%	0	0	0	0	0	0	0	0	0	1	1	2	2
	90%	0	0	0	0	0	0	0	0	1	1	1	2	3
	100%	0	0	0	0	0	0	0	0	1	1	2	2	3

7.14 Goldeneye

Table 48. Goldeneye displacement – non-breeding season

Goldeneye Sep - mid Apr		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of site population)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	2	2	4	6	8
	20%	0	0	0	0	1	1	2	2	3	4	8	12	15
	30%	0	0	0	1	1	1	2	3	5	7	11	18	23
	40%	0	0	1	1	1	2	3	4	6	9	15	24	30
	50%	0	0	1	1	2	2	4	6	8	11	19	30	38
	60%	0	0	1	1	2	2	5	7	9	14	23	36	45
	70%	0	1	1	2	2	3	5	8	11	16	26	42	53
	80%	0	1	1	2	2	3	6	9	12	18	30	48	60
	90%	0	1	1	2	3	3	7	10	14	20	34	54	68
	100%	0	1	2	2	3	4	8	11	15	22	38	60	75

FORTHWIND DEMONSTRATOR TURBINE
ORNITHOLOGY: PROPOSED ASSESSMENT METHODOLOGY

Introduction

This is a simple collation of key information required for the Forthwind ornithological impact assessment. It is supported by the spreadsheet of site population estimates – 'Forthwind breeding population estimates' which includes all Special Protection Areas (SPAs), within foraging range – and we are also hoping to submit the SPA apportioning calculations when these become available.

HiDef seek to agree the species of concern, based on the boat-based survey data, and the seasons for assessment. Once the apportioning has been done we can look to agree the short-list of SPAs for assessment and to identify the most recent population counts from the Seabird Monitoring Programme (SMP) database.

We then look to agree methodologies for collision risk modelling and displacement assessment. Although we have not yet done the impact modelling, it seems unlikely that estimates of mortality will be significant for a single turbine, so that it is unlikely population modelling will be required.

Species of Concern

We have identified species of concern based on the 2019 scoping opinion (for the previous two turbine proposal) and on two years of boat-based survey data from March 2015 to February 2017. We are supplying this data in a report ("Forthwind Ornithology – boat-based survey data report") and excel spreadsheet ("Forthwind Ornithology – distance corrected density and abundance estimates"), where distance modelling has been applied to the observations, to take account of decreasing detectability with distance from the boat.

These are the species addressed in the report and spreadsheet:

- Gannet (*Morus bassanus*),
- Kittiwake (*Rissa tridactyla*),
- Herring gull (*Larus argentatus*),
- Black-headed gull (*Chroicocephalus ridibundus*),
- Common gull (*Larus canus*),
- Guillemot (*Uria aalge*),
- Razorbill (*Alca torda*),
- Puffin (*Fratercula arctica*),
- Red-throated diver (*Gavia stellata*) and
- Eider (*Somateria mollissima*).

Species that were identified in the 2019 scoping opinion but were not recorded in great enough numbers on-site for distance modelling to be undertaken include common tern (*Sterna hirundo*), Sandwich tern (*Sterna sandvicensis*), common scoter (*Melanitta nigra*), velvet scoter (*Melanitta fusca*), long-tailed duck (*Clangula hyemalis*), red-breasted merganser (*Mergus serrator*), Slavonian grebe (*Podiceps auratus*) and goldeneye (*Bucephala clangula*). Whooper swan (*Cygnus cygnus*) and pink-footed goose (*Anser brachyrhynchus*) were not target species for the boat-based surveys and records of these species are incidental only.

Species included in the 2019 scoping opinion but are yet to be addressed in distance modelling are lesser black-backed gull (*Larus fuscus*) and European shag (*Phalacrocorax aristotelis*).

Seasons of Interest

For species which are identified as breeding interests, the following seasons of interest are taken from NatureScot guidance[i] and the biologically defined minimum population scales (BDMPS) report[ii]. It should be possible to combine the breeding and non-breeding season impacts and assign these to the relevant SPA breeding populations of concern.

Species	Breeding Season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
Gannet	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
Kittiwake	mid Apr - Aug	Aug - Dec	n/a	Jan - Apr
Herring gull	Apr - Aug	n/a	Sep - Feb	n/a
Lesser black-backed gull	mid Mar - Aug	Aug - Oct	Nov - Feb	Mar-Apr
Guillemot	Apr - mid Aug	n/a	Aug - Feb	n/a
Razorbill	Apr - mid Aug	Aug - Oct	Nov - Dec	Jan - Mar
Puffin	Apr - mid Aug	n/a	Aug - Mar	n/a
European shag	Mar - Sep	n/a	Sep - Jan	n/a

For species which are identified as non-breeding interests, the following seasons of interest are identified solely from NatureScot guidance.

Species	Non-Breeding Season (NatureScot)
Black-headed gull	Sep - Mar
Common gull	Sep - Mar
Red-throated diver	mid Sep - Apr
Eider	Sep - mid Apr

Reference Populations for each relevant Species

For breeding interests, we have yet to undertake the apportioning calculations to identify the short-list of SPAs where there is likely to be significant effect. We will supply the apportioning calculations once these are available. For apportioning we will be using the method detailed in NatureScot guidance[iii].

For breeding interests, the most recent SPA count will be used as the reference population against which both breeding and non-breeding season impacts can be assigned (we can discuss the method for doing so at any meeting with Marine Scotland and NatureScot).

For species which are identified as non-breeding interests, we will be using the SPA citation counts as the reference populations unless otherwise directed. Impacts recorded during the non-breeding season will be assigned to these reference populations.

Species	SPA	Citation count	Count unit
Black-headed gull	Outer Firth of Forth and St Andrews Bay	26,835	IND
Common gull	Outer Firth of Forth and St Andrews Bay	14,647	IND
Red-throated diver	Outer Firth of Forth and St Andrews Bay	851	IND
Eider	Outer Firth of Forth and St Andrews Bay	21,546	IND

Approach to Collision Risk Modelling

Collision risk modelling (CRM) is required for gannet, kittiwake, herring gull, black-headed gull, common gull and lesser black-backed gull. Modelling will use the default seabird parameters and approach set out for the stochastic CRM, coded in R.[iv]

For gannet and kittiwake, it is proposed that assessment is based on the 'basic' offshore Band CRM model. This will use a simple proportion of birds at collision risk height applied uniformly over the rotor, calculated from the site-specific digital aerial survey data (Option 1), and generic flight height distribution data measured at different sites around the UK (Johnstone et. al. 2014) (Option 2). For gannet and kittiwake, an avoidance rate of **0.989 (± 0.002)** for each species will be used as recommended in joint guidance from the Statutory Nature Conservation Bodies (SNCBs).[v]

If there is a recommendation to use the updated advice and avoidance rates provided by Cook (2021)[vi] then please let us know.

For herring gull, black-headed gull, common gull and lesser black-backed gull, it is proposed to use the 'extended' offshore Band CRM model with an avoidance rate of **0.989 (± 0.002)**, except herring gull where an avoidance rate of **0.990 (± 0.002)** will be applied. Distribution of flight heights will be modelled along the length of the turbine blade as recommended in guidance for which Johnstone et. al. (2014) flight height data will be used (Option 3).

Monthly mean bird densities are given for each species (except lesser black-backed gull) in the excel spreadsheet for "Forthwind Ornithology – distance corrected density and abundance estimates" (see tabs "Year 1 Fly" and "Year 2 Fly"). These are based on observations along all transects to which distance modelling has been applied. These are taken as representative of the Forthwind turbine location which is included within the survey area. No buffer is used for CRM.

Approach to Displacement Assessment

For displacement assessment we will follow the joint SNCB interim advice note (2017).[vii] Assessment is required for gannet, kittiwake, puffin, guillemot, razorbill, shag, eider and red-throated diver.

Population estimates will be presented for an impact zone comprising the single turbine and a 2km buffer, minus the small area of land encompassed by this. We have thus calculated an impact zone of 11.5km^2 – the area of sea from which birds might be displaced. We propose using this impact zone for all species, given the turbine's proximity to shore.

Population estimates will be based on the seasonal mean peaks for each species as recorded on the excel spreadsheet for "Forthwind Ornithology – distance corrected density and abundance estimates". Population estimates are calculated for the impact zone by multiplying the recorded densities (across the survey area) by 11.5km^2.

For red-throated diver and for eider the peak winter counts for year 2 are used – we feel these are more representative of the turbine location as the transects were extended 1km closer to shore during these surveys. See "RH&E Abundance Impact Area" tab on the excel spreadsheet.

For all other species the both the breeding and non-breeding seasonal mean peaks of year 1 (Mar 2015 – Feb 2016) and year 2 (Mar 2016 – Feb 2017) distance corrected data are used – see "Abundance Impact Area" tab on the excel spreadsheet. For gannet, kittiwake, puffin, guillemot, razorbill and shag we will provide separate displacement estimates for both the breeding and the non-breeding seasons. We can combine these impacts for consideration against the SPA breeding populations – method to be discussed with Marine Scotland and NatureScot.

Population estimates will be inputted into a 'displacement matrix' for each species giving a range of percentages (%) of birds displaced, and resulting mortality. We seek to agree the figures to use for this.

Approach to Population Modelling

We are not anticipating that levels of modelled mortality (CRM / displacement) will be significant, so we are not anticipating that population modelling will be required for a single turbine. We can confirm whether or not this is the case once the impact modelling has been undertaken.

Population modelling is required for the breeding birds only, as it cannot be undertaken for non-breeding interests.

If it is required, any population modelling will follow the approach set out in Natural England's guidance 'A Population Viability Analysis Modelling Tool for Seabird Species'.[viii] This constructs and runs deterministic Leslie Matrix models, programmed in R code.

Starting populations for modelling will use the most recent population counts available from the SMP database – see the supporting excel spreadsheet 'Forthwind breeding population estimates'. Where possible, site-specific demographic data will be used, otherwise data will be taken from Horswill and Robinson (2015).[ix]

Next Steps

This paper has been drawn together by Hidef so any queries about it should be directed to them: catriona.gall@hidefsurveying.co.uk. HiDef will be undertaking the impact modelling and population modelling and would welcome discussion of these elements based on the proposed methodologies above.

HiDef, 15th September 2021

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[i] NatureScot seasonality guidance: https://www.nature.scot/doc/guidance-note-seasonal-definitions-birds-scottish-marine-environment

[ii] BDMPS report: http://publications.naturalengland.org.uk/publication/6427568802627584

[iii] Nature Scot apportioning guidance: https://www.nature.scot/doc/interim-guidance-apportioning-impacts-marine-renewable-developments-breeding-seabird-populations

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[iv] Stochastic CRM available at: https://dmpstats.shinyapps.io/avian_stochcrm/

[v] SNCB guidance on CRM and avoidance rates: https://www.nature.scot/sites/default/files/2018-02/SNCB%20Position%20Note%20on%20avoidance%20rates%20for%20use%20in%20collision%20risk%20modelling.pdf

[vi] Cook, A.S.C.P. 2021. Additional analysis to inform SNCB recommendations regarding collision risk modelling. BTO Research Report 739. ISBN 978-1-912642-30-4. https://www.bto.org/sites/default/files/publications/bto_rr_739_cook_collision_risk_models_final_web.pdf

[vii] SNCB guidance on displacement: https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/Joint-SNCB-Interim-Displacement-AdviceNote-2017-web.pdf

[viii] Natural England population modelling tool: publications.naturalengland.org.uk/file/6217749003239424

[ix] Horswill, C. & Robinson, R.A. 2015. Review of Seabird Demographic Rates and Density Dependence. JNCC Report No. 552, JNCC, Peterborough, ISSN 0963-8091. https://hub.jncc.gov.uk/assets/897c2037-56d0-42c8-b828-02c0c9c12d13

Gemma Lee

From: Malcolm Fraser <Malcolm.Fraser@nature.scot>
Sent: 06 April 2022 15:48
To: Rebecca.Bamlett@gov.scot; Gayle.Holland@gov.scot; Kate.Taylor@fss.scot
Cc: Gemma Lee; Erica Knott; Helen Wade
Subject: RE: Forthwind Ornithology - 11th February Meeting Minutes

Follow Up Flag: Follow up
Flag Status: Flagged

Marine Scotland (CC Cierco) –

A meeting on ornithology issues arising from the Forthwind Scoping Opinion was held on Friday 11 February 2022, between Cierco, HiDef, Marine Scotland, and NatureScot. We subsequently received meeting minutes from Cierco on 09 March 2022.

This advice responds to the list of actions presented in those meeting minutes.

<u>Action 1: Forthwind to provide further details on the different available data sources (SPA site selection data, WeBS data, Levenmouth turbine data and existing boat-based survey data) that can be used to inform decision-making on seaduck and diver displacement impacts.</u>
This is an action for Cierco – however we recommend re-framing this action as the <u>production of a Desk Based Study</u> of all existing and planned bird survey work. This should seek to produce:

- a comprehensive review of existing data that is easy to interpret;
- demonstrates the extent of existing and planned survey areas and how these relate spatially to the current proposal;
- includes proposals for pre- and post-construction monitoring – which should be Vantage Point surveys designed in collaboration with NatureScot and Marine Scotland Science, with initial proposals submitted by ForthWind / Cierco;
- should consider the merit of novel survey methods (eg drone based);
- should consider the merit of incorporating a control site for planned surveys.

We take this opportunity to re-iterate the point that this proposal is located within an SPA, and in an area known to be used by seaduck and diver species that are particularly sensitive to disturbance. As a result clear and robust assessment and monitoring are required for this proposal.

<u>Action 2: Further consideration of lateral displacement required by Forthwind.</u>
We have no substantive comments on this action – in our view this should be included in the Desk Based Study.

<u>Action 3: HiDef to provide further explanation of distance sampling analysis and how it accounts for flushing in the derivation of density estimates.</u>
We have no substantive comments on this action – in our view this should be included in the Desk Based Study.

<u>Action 4: NatureScot to review mortality rates internally and feedback findings to Forthwind early w/c 14th February.</u>
In our view matrices of mortality rates should be produced and used as a basis for further discussion on which rates should be used in the final assessment. These matrices should have an upper value of at least 10% which would bring them in line with similar studies (Thanet extension, Norfolk Vanguard, EA 1, 2 and 3, Hornsea 3).

If all modelling shows low mortality rates then it's possible that no further work on this topic would be required.

Action 5: NatureScot to discuss internally potential for split-season survey work.
We do not support split-season survey work – this produces incomplete pictures of site usage. We request that Cierco confirm what bird surveys are currently underway, if any. We also expect a full season of wintering bird survey work starting in September 2022.

Action 6: NatureScot to confirm status of SPA Biotope reports (total available foraging habitat for seaduck and diver species within the SPA).
We confirm that these reports are not yet ready to be shared – we have still to set out how they should be interpreted.

However, we will be able to share maximum and preferred dive depths for the relevant species – which can then be cross-referenced with Cierco's benthic surveys.

Action 7: NatureScot & Marine Scotland to consider internally the requirement for a Draft HRA Screening Report prior to submission of application.
We confirm that we expect an HRA Screening Report to be presented prior to submission of application.

Action 8: NatureScot to provide guidance on HRA screening approach and any comments on presentation of the information..
The approach to HRA Screening should follow standard European Site guidance – commencing with the identification of any/ all European sites for which likely significant effects may arise from this project. For further detail please refer to guidance on our website

In our view it is not appropriate to carry out apportioning at the screening stage, this is typically carried out within the appropriate assessment stage.

Action 9: Marine Scotland to confirm whether use of the MSS apportioning tool is required for kittiwake, guillemot and razorbill at Forthwind.
This action is for Marine Scotland – we acknowledge that if these species are seen at this site it will be in low numbers. We defer to MSS as to whether the tool should be used here for the assessment of cumulative effects going forward.

We hope this advice is useful. We suggest that it might be useful for Marine Scotland and NatureScot to agree on a preferred pathway for requesting and providing advice.

All the best.

--
Malcolm Fraser (he/ him) | Area Officer - Forth | Marine Ecology Advisor
NatureScot | Silvan House, 3rd Floor East, 231 Corstorphine Road, Edinburgh, EH12 7AT | 0131 316 2629
nature.scot | @nature_scot | *Scotland's Nature Agency* | *Buidheann Nàdair na h-Alba*

From: Gemma Lee <Gemma.Lee@ciercoenergy.com>
Sent: 09 March 2022 13:15
To: Erica Knott <Erica.Knott@nature.scot>
Cc: Rebecca.Bamlett@gov.scot; Kate.Taylor@fss.scot; Gayle.Holland@gov.scot; Ewan.Edwards@gov.scot; tom.evans@gov.scot; Helen Wade <Helen.Wade@nature.scot>; Malcolm Fraser <Malcolm.Fraser@nature.scot>;

Marc Murray <marc.murray@cierco.uk>; Catriona Gall <Catriona.Gall@hidefsurveying.co.uk>
Subject: Forthwind Ornithology - 11th February Meeting Minutes

Good afternoon all,

Please see attached a copy of the meeting minutes and actions from the meeting held on 11th February to discuss the Forthwind Ornithology.
Please let me know if there are any comments.

Kind regards
Gemma Lee
Project Development Manager
M: 07510 075141

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POTENTIAL SHADOW FLICKER EFFECTS AT ASSESSED LOCATIONS

Table 1- – Potential Shadow Flicker Effects at Assessed Locations

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
Viewforth a	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**34**	**27.0**	**12.1**	**8.6**	**3.9**
	South	**3**	**34**	**26.4**	**12.1**	**8.4**	**3.9**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**34**	**27.0**	**12.1**	**8.6**	**3.9**
	South	**6**	**34**	**27.0**	**12.1**	**8.6**	**3.9**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Viewforth b	North	3	0	0	0	0	0
	East	3	36	28.8	13.8	9.22	4.4
	South	3	36	28.8	13.7	9.22	4.4
	West	3	0	0	0	0	0
West High Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**39**	**30.6**	**15.6**	**9.8**	**5.0**
	South	**3**	**39**	**30.6**	**15.5**	**9.8**	**5.0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**38**	**30.6**	**15.5**	**9.8**	**5.0**
	South	**6**	**38**	**30.6**	**15.5**	**9.8**	**5.0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lawson Lane	North	3	0	0	0	0	0
	East	3	42	32.4	17.7	10.4	5.7
	South	3	42	32.4	17.7	10.4	5.7
	West	3	0	0	0	0	0
Shore Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**44**	**33.6**	**19.5**	**10.8**	**6.2**
	South	**3**	**44**	**33.6**	**19.5**	**10.8**	**6.2**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**44**	**33.6**	**19.5**	**10.8**	**6.2**
	South	**6**	**44**	**33.6**	**19.5**	**10.8**	**6.2**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lady Wynd	North	3	0	0	0	0	0
	East	3	46	34.8	21.3	11.1	6.8
	South	3	46	34.8	21.3	11.1	6.8
	West	3	0	0	0	0	0
Rising Sun Road	North	3	0	0	0	0	0
	East	3	48	33.0	20.6	10.6	6.5
	South	3	48	33.0	20.6	10.6	6.5

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[1] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	West	3	0	0	0	0	0
Wellesley Road a	North	3	0	0	0	0	0
	East	3	48	32.4	19.8	10.4	6.3
	South	3	48	32.4	19.8	10.4	6.3
	West	3	0	0	0	0	0
Wellesley Road b	North	3	0	0	0	0	0
	East	3	93	33.6	35.9	10.8	11.5
	South	3	93	33.6	35.9	10.8	11.5
	West	3	0	0	0	0	0
Wellesley Road c	North	3	0	0	0	0	0
	East	3	87	34.8	39.9	11.1	12.8
	South	3	87	34.8	39.9	11.1	12.8
	West	3	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	49	29.4	18.8	9.4	6.0
	South	3	49	29.4	18.8	9.4	6.0
	West	3	0	0	0	0	0
Forth Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**73**	**31.8**	**32.6**	**10.2**	**10.4**
	South	**3**	**73**	**31.8**	**32.7**	**10.2**	**10.5**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**72**	**31.8**	**32.4**	**10.2**	**10.4**
	South	**6**	**72**	**31.8**	**32.4**	**10.2**	**10.4**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Randolph Wemyss Memorial Hospital	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**71**	**32.4**	**28.9**	**10.4**	**9.2**
	South	**3**	**71**	**32.4**	**28.9**	**10.4**	**9.2**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**72**	**32.4**	**29.3**	**10.4**	**9.4**
	South	**6**	**72**	**32.4**	**29.3**	**10.4**	**9.4**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Shepherds Park	North	3	0	0	0	0	0
	East	3	19	13.8	3.5	4.6	1.1
	South	3	19	13.8	3.5	4.6	1.1
	West	3	0	0	0	0	0
High Street a	North	3	-	-	-	-	-
	East	3	-	-	-	-	-
	South	3	-	-	-	-	-
	West	3	-	-	-	-	-
Main Street	**North**	**3**	-	-	-	-	-
	East	**3**	-	-	-	-	-
	South	**3**	-	-	-	-	-
	West	**3**	-	-	-	-	-
	North	**6**	-	-	-	-	-
	East	**6**	-	-	-	-	-
	South	**6**	-	-	-	-	-
	West	**6**	-	-	-	-	-

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
South Grove	North	3	-	-	-	-	-
	East	3	-	-	-	-	-
	South	3	-	-	-	-	-
	West	3	-	-	-	-	-
High Street b	North	3	-	-	-	-	-
	East	3	-	-	-	-	-
	South	3	-	-	-	-	-
	West	3	-	-	-	-	-
Swan Court	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**51**	**29.4**	**20.4**	**9.4**	**6.5**
	South	**3**	**51**	**29.4**	**20.4**	**9.4**	**6.5**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**51**	**29.4**	**19.9**	**9.4**	**6.4**
	South	**6**	**51**	**29.4**	**20.0**	**9.4**	**6.4**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**49**	**28.8**	**19.5**	**9.2**	**6.2**
	South	**9**	**49**	**28.8**	**19.5**	**9.2**	**6.2**
	West	**9**	**0**	**0**	**0**	**0**	**0**
	North	**12**	**0**	**0**	**0**	**0**	**0**
	East	**12**	**49**	**28.8**	**19.0**	**9.2**	**6.1**
	South	**12**	**49**	**28.8**	**19.0**	**9.2**	**6.1**
	West	**12**	**0**	**0**	**0**	**0**	**0**
	North	**15**	**0**	**0**	**0**	**0**	**0**
	East	**15**	**48**	**28.8**	**18.5**	**9.2**	**5.9**
	South	**15**	**48**	**28.8**	**18.5**	**9.2**	**5.9**
	West	**15**	**0**	**0**	**0**	**0**	**0**
	North	**18**	**0**	**0**	**0**	**0**	**0**
	East	**18**	**47**	**28.8**	**18.1**	**9.2**	**5.8**
	South	**18**	**47**	**28.8**	**18.1**	**9.2**	**5.8**
	West	**18**	**0**	**0**	**0**	**0**	**0**
	North	**21**	**0**	**0**	**0**	**0**	**0**
	East	**21**	**46**	**28.8**	**17.6**	**9.2**	**5.6**
	South	**21**	**46**	**28.8**	**17.6**	**9.2**	**5.6**
	West	**21**	**0**	**0**	**0**	**0**	**0**
	North	**24**	**0**	**0**	**0**	**0**	**0**
	East	**24**	**45**	**28.2**	**17.2**	**9.0**	**5.5**
	South	**24**	**45**	**28.8**	**17.2**	**9.2**	**5.5**
	West	**24**	**0**	**0**	**0**	**0**	**0**
	North	**27**	**0**	**0**	**0**	**0**	**0**
	East	**27**	**45**	**28.2**	**16.9**	**9.0**	**5.4**
	South	**27**	**45**	**28.2**	**17.0**	**9.0**	**5.4**
	West	**27**	**0**	**0**	**0**	**0**	**0**
	North	**30**	**0**	**0**	**0**	**0**	**0**
	East	**30**	**43**	**28.2**	**16.4**	**9.0**	**5.2**
	South	**30**	**43**	**28.2**	**16.5**	**9.0**	**5.3**
	West	**30**	**0**	**0**	**0**	**0**	**0**
	North	**33**	**0**	**0**	**0**	**0**	**0**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	East	33	43	27.6	15.8	8.8	5.1
	South	33	43	27.6	15.9	8.8	5.1
	West	33	0	0	0	0	0
	North	36	0	0	0	0	0
	East	36	41	27.0	15.2	8.6	4.9
	South	36	41	27.0	15.2	8.6	4.9
	West	36	0	0	0	0	0
	North	39	0	0	0	0	0
	East	39	41	27.0	14.6	8.6	4.8
	South	39	41	27.0	14.6	8.6	4.8
	West	39	0	0	0	0	0
Lady Wynd b	North	3	0	0	0	0	0
	East	3	48	34.2	20.9	10.9	6.7
	South	3	48	34.2	20.9	10.9	6.7
	West	3	0	0	0	0	0
Bethune Way	North	3	0	0	0	0	0
	East	3	46	34.2	20.2	10.9	6.5
	South	3	46	34.2	20.1	10.9	6.4
	West	3	0	0	0	0	0
Denbeath Primary School	North	3	0	0	0	0	0
	East	3	68	30.6	26.2	9.8	8.4
	South	3	68	30.6	26.2	9.8	8.4
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	70	30.6	26.5	9.8	8.5
	South	6	70	30.6	26.5	9.8	8.5
	West	6	0	0	0	0	0
Anderson Lane	North	3	0	0	0	0	0
	East	3	43	32.4	18.0	10.4	5.8
	South	3	43	32.4	18.0	10.4	5.8
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	42	32.4	18.0	10.4	5.8
	South	6	42	32.4	17.9	10.4	5.7
	West	6	0	0	0	0	0
	North	9	0	0	0	0	0
	East	9	42	32.4	18.0	10.4	5.8
	South	9	42	32.4	18.0	10.4	5.8
	West	9	0	0	0	0	0
	North	12	0	0	0	0	0
	East	12	42	32.4	18.0	10.4	5.8
	South	12	42	32.4	18.0	10.4	5.8
	West	12	0	0	0	0	0
Den Walk a	North	3	0	0	0	0	0
	East	3	46	28.2	16.6	9.0	5.3
	South	3	46	28.2	16.5	9.0	5.3
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	46	28.2	16.8	9.0	5.4

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	South	6	46	28.2	16.8	9.0	5.4
	West	6	0	0	0	0	0
Omar Crescent	North	3	0	0	0	0	0
	East	3	46	29.4	17.1	9.4	5.5
	South	3	46	29.4	17.1	9.4	5.5
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	44	29.4	17.1	9.4	5.5
	South	6	44	29.4	17.1	9.4	5.5
	West	6	0	0	0	0	0
Den Walk b	North	3	0	0	0	0	0
	East	3	52	28.2	18.9	9.0	6.0
	South	3	52	28.2	18.9	9.0	6.0
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	53	28.2	19.0	9.0	6.1
	South	6	53	28.2	19.0	9.0	6.1
	West	6	0	0	0	0	0
Braehead Gardens	North	3	0	0	0	0	0
	East	3	42	31.8	17.7	10.2	5.7
	South	3	42	31.8	17.7	10.2	5.7
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	42	31.8	17.8	10.2	5.7
	South	6	42	31.8	17.7	10.2	5.7
	West	6	0	0	0	0	0
	North	9	0	0	0	0	0
	East	9	42	31.8	17.8	10.2	5.7
	South	9	42	31.8	17.7	10.2	5.7
	West	9	0	0	0	0	0
	North	12	0	0	0	0	0
	East	12	44	31.8	17.9	10.2	5.7
	South	12	44	31.8	17.9	10.2	5.7
	West	12	0	0	0	0	0
	North	15	0	0	0	0	0
	East	15	43	31.8	17.9	10.2	5.7
	South	15	4	31.8	17.8	10.2	5.7
	West	15	0	0	0	0	0
Clyde Street	North	3	0	0	0	0	0
	East	3	71	31.2	31.2	10.0	10.0
	South	3	71	31.2	31.2	10.0	10.0
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	71	31.2	30.9	10.0	9.9
	South	6	71	31.2	30.9	10.0	9.9
	West	6	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	79	33.0	35.6	10.6	11.4
	South	3	79	33.0	35.6	10.6	11.4

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**79**	**33.0**	**35.5**	**10.6**	**11.4**
	South	**6**	**79**	**33.0**	**35.5**	**10.6**	**11.4**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Ward Street	North	3	0	0	0	0	0
	East	3	87	31.2	34.2	10.0	10.9
	South	3	87	31.2	34.2	10.0	10.9
	West	3	0	0	0	0	0
Wellesley Road e	North	3	0	0	0	0	0
	East	3	59	33.0	25.1	10.6	8.0
	South	3	59	33.0	25.1	10.6	8.0
	West	3	0	0	0	0	0
Swan View	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**51**	**29.4**	**20.4**	**9.4**	**6.5**
	South	**3**	**51**	**29.4**	**20.4**	**9.4**	**6.5**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**51**	**29.4**	**19.9**	**9.4**	**6.4**
	South	**6**	**51**	**29.4**	**20.0**	**9.4**	**6.4**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**51**	**29.4**	**19.9**	**9.4**	**6.4**
	South	**9**	**51**	**29.4**	**20.0**	**9.4**	**6.4**
	West	**9**	**0**	**0**	**0**	**0**	**0**
***Properties highlighted in bold are regarded as multi-storey receptors.**							

Table 2 – Summarised Shadow Flicker Effects from ~~all~~ Development Turbine~~s~~

Name	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[2]
Viewforth a	34	27.0	12.2	8.6	3.9
Viewforth b	36	28.8	13.8	9.2	4.4
West High Street	**39**	**33.6**	**15.8**	**10.6**	**5.1**
Lawson Lane	42	32.4	17.8	10.4	5.7
Shore Street	44	33.6	19.7	10.6	6.3
Lady Wynd a	46	34.8	21.3	11.1	6.8
Rising Sun Road	48	33.0	20.6	10.6	6.6
Wellesley Road a	48	32.4	19.8	10.4	6.3
Wellesley Road b	93	33.6	35.9	10.6	11.5
Wellesley Road c	87	34.8	39.9	11.1	12.8
Wellesley Road d	49	28.8	18.8	9.2	6.0
Forth Street	**73**	**31.8**	**32.9**	**10.2**	**10.5**
Randolph Wemyss Memorial Hospital	**73**	**32.4**	**29.6**	**10.4**	**9.5**
Shepherds Park	19	13.8	3.5	4.4	1.1
High Street a	-	-	-	-	-
Main Street	**-**	**-**	**-**	**-**	**-**
South Grove	-	-	-	-	-
High Street b	-	-	-	-	-
Swan Court	51	29.4	21.2	9.4	6.8
Lady Wynd b	48	34.2	20.9	6.3	6.7
Bethune Way	46	34.2	20.2	6.5	6.5
Denbeath Primary School	**70**	**30.6**	**26.8**	**9.8**	**8.6**
Anderson Lane	**43**	**33.0**	**18.7**	**10.6**	**6.0**
Den Walk a	**46**	**28.2**	**17.0**	**9.0**	**5.4**
Omar Crescent	**46**	**29.4**	**17.4**	**9.4**	**5.6**
Den Walk b	**53**	**28.2**	**19.2**	**9.0**	**6.1**
Braehead Gardens	**44**	**32.4**	**18.8**	**10.4**	**6.0**
Clyde Street	**71**	**31.2**	**31.4**	**10.0**	**10.0**
Wellesley Road e	**79**	**33.0**	**35.9**	**10.6**	**11.5**
Ward Street	87	31.2	24.2	10.0	7.7
Wellesley Road f	59	33.0	25.1	10.6	8.0
Swan View	**51**	**29.4**	**20.6**	**9.4**	**6.6**

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[2] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at:

***Properties highlighted in bold are regarded as multi-storey dwellings.**

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https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

POTENTIAL CUMULATIVE SHADOW FLICKER EFFECTS AT ASSESSED LOCATIONS

Table 1 – Potential Cumulative Shadow Flicker Effects at Assessed Locations

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
Viewforth a	**North**	**3**	**48**	**31.8**	**19.8**	**10.2**	**6.3**
	East	**3**	**82**	**31.8**	**32.0**	**10.2**	**10.2**
	South	**3**	**34**	**26.4**	**12.1**	**8.6**	**3.9**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**48**	**31.8**	**19.7**	**10.3**	**6.3**
	East	**6**	**82**	**31.8**	**31.9**	**10.2**	**10.2**
	South	**6**	**34**	**26.4**	**12.1**	**8.6**	**3.8**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Viewforth b	North	3	71	34.2	31.3	10.9	10.0
	East	3	107	34.2	45.1	10.9	14.4
	South	3	36	28.8	13.7	9.2	4.4
	West	3	0	0	0	0	0
West High Street	**North**	**3**	**89**	**37.8**	**48.9**	**12.1**	**15.6**
	East	**3**	**128**	**37.8**	**64.6**	**12.1**	**20.7**
	South	**3**	**39**	**30.6**	**15.5**	**9.8**	**5.0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**89**	**37.8**	**49.2**	**12.1**	**15.7**
	East	**6**	**127**	**37.8**	**64.8**	**12.1**	**20.7**
	South	**6**	**38**	**30.6**	**15.5**	**9.8**	**5.0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lawson Lane	North	3	107	45.6	69.2	14.6	22.1
	East	3	149	46.2	87.2	14.8	27.9
	South	3	42	32.4	17.7	10.4	5.7
	West	3	0	0	0	0	0
Shore Street	**North**	**3**	**109**	**52.2**	**82.9**	**16.7**	**26.5**
	East	**3**	**153**	**52.8**	**102.7**	**16.9**	**32.9**
	South	**3**	**44**	**33.6**	**19.1**	**10.8**	**6.1**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**109**	**52.2**	**83.4**	**16.7**	**26.7**
	East	**6**	**153**	**52.8**	**103.1**	**16.9**	**33.0**
	South	**6**	**44**	**33.6**	**19.5**	**10.8**	**6.2**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lady Wynd a	North	3	125	62.4	107.3	20.0	34.3
	East	3	171	62.4	129.1	20.0	41.3
	South	3	46	34.8	21.3	11.1	6.8
	West	3	0	0	0	0	0
Rising Sun Road	North	3	76	60.0	60.4	19.2	19.3
	East	3	124	60.6	81.3	19.4	26.0
	South	3	48	33.0	20.6	10.6	6.6

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[1] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
	West	3	0	0	0	0	0
Wellesley Road a	North	3	0	0	0	0	0
	East	3	130	63.6	87.9	20.4	28.1
	South	3	130	63.6	87.7	20.4	28.1
	West	3	0	0	0	0	0
Wellesley Road b	North	3	0	0	0	0	0
	East	3	151	73.2	119.1	23.4	38.1
	South	3	151	73.2	119.2	23.4	38.1
	West	3	0	0	0	0	0
Wellesley Road c	North	3	0	0	0	0	0
	East	3	147	111.6	218.0	35.7	69.8
	South	3	148	111.6	218.6	35.7	70.0
	West	3	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	57	70.8	52.0	22.7	16.6
	South	3	57	71.4	52.2	22.9	16.7
	West	3	0	0	0	0	0
Forth Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**97**	**94.2**	**123.4**	**30.1**	**39.5**
	South	**3**	**97**	**94.2**	**123.8**	**30.1**	**39.6**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**97**	**93.6**	**121.5**	**30.0**	**38.9**
	South	**6**	**97**	**93.6**	**121.9**	**30.0**	**39.0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Randolph Wemyss Memorial Hospital	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**129**	**66.6**	**98.3**	**21.3**	**31.5**
	South	**3**	**129**	**66.6**	**98.3**	**21.3**	**31.5**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**130**	**66.6**	**99.1**	**21.3**	**31.7**
	South	**6**	**130**	**66.6**	**99.1**	**21.3**	**31.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Shepherds Park	North	3	0	0	0	0	0
	East	3	19	13.8	3.5	4.4	1.1
	South	3	41	48.0	22.4	15.4	7.2
	West	3	41	34.2	19.0	10.9	6.1
High Street a	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	29	23.4	8.9	7.5	2.8
	West	3	29	23.4	8.9	7.5	2.8
Main Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**0**	**0**	**0**	**0**	**0**
	South	**3**	**49**	**32.4**	**22.0**	**10.4**	**7.0**
	West	**3**	**49**	**32.4**	**22.0**	**10.4**	**7.0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**0**	**0**	**0**	**0**	**0**
	South	**6**	**47**	**32.4**	**20.8**	**10.4**	**6.7**
	West	**6**	**47**	**32.4**	**20.8**	**10.4**	**6.7**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
South Grove	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	49	31.2	21.0	10.0	6.7
	West	3	49	31.2	21.0	10,0	6.7
High Street b	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	31	20.4	8.1	6.5	2.6
	West	3	31	20.4	8.1	6.5	2.6
Swan Court	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**61**	**73.8**	**58.7**	**23.6**	**18.8**
	South	**3**	**61**	**73.8**	**59.0**	**23.6**	**18.8**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**59**	**72.6**	**56.1**	**23.2**	**18.0**
	South	**6**	**59**	**72.6**	**56.3**	**23.2**	**18.0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**57**	**71.4**	**53.5**	**22.9**	**17.1**
	South	**9**	**57**	**71.4**	**53.7**	**22.9**	**17.2**
	West	**9**	**0**	**0**	**0**	**0**	**0**
	North	**12**	**0**	**0**	**0**	**0**	**0**
	East	**12**	**53**	**70.2**	**50.8**	**22.5**	**16.3**
	South	**12**	**55**	**70.2**	**51.0**	**22.5**	**16.3**
	West	**12**	**0**	**0**	**0**	**0**	**0**
	North	**15**	**0**	**0**	**0**	**0**	**0**
	East	**15**	**51**	**69.0**	**48.0**	**22.1**	**15.4**
	South	**15**	**51**	**69.0**	**48.2**	**22.1**	**15.4**
	West	**15**	**0**	**0**	**0**	**0**	**0**
	North	**18**	**0**	**0**	**0**	**0**	**0**
	East	**18**	**49**	**67.8**	**45.4**	**21.7**	**14.5**
	South	**18**	**49**	**67.8**	**45.5**	**21.7**	**14.6**
	West	**18**	**0**	**0**	**0**	**0**	**0**
	North	**21**	**0**	**0**	**0**	**0**	**0**
	East	**21**	**47**	**66.0**	**42.6**	**21.1**	**13.6**
	South	**21**	**47**	**66.6**	**42.8**	**21.3**	**13.7**
	West	**21**	**0**	**0**	**0**	**0**	**0**
	North	**24**	**0**	**0**	**0**	**0**	**0**
	East	**24**	**45**	**64.8**	**40.0**	**20.7**	**12.8**
	South	**24**	**45**	**64.8**	**40.1**	**20.7**	**12.8**
	West	**24**	**0**	**0**	**0**	**0**	**0**
	North	**27**	**0**	**0**	**0**	**0**	**0**
	East	**27**	**45**	**63.6**	**37.4**	**20.4**	**12.0**
	South	**27**	**45**	**63.6**	**37.5**	**20.4**	**12.0**
	West	**27**	**0**	**0**	**0**	**0**	**0**
	North	**30**	**0**	**0**	**0**	**0**	**0**
	East	**30**	**43**	**63.6**	**35.0**	**20.4**	**11.2**
	South	**30**	**43**	**63.6**	**35.1**	**20.4**	**11.2**
	West	**30**	**0**	**0**	**0**	**0**	**0**
	North	**33**	**0**	**0**	**0**	**0**	**0**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
	East	**33**	**43**	**61.8**	**32.0**	**19.8**	**10.2**
	South	**33**	**43**	**61.8**	**32.1**	**19.8**	**10.3**
	West	**33**	**0**	**0**	**0**	**0**	**0**
	North	**36**	**0**	**0**	**0**	**0**	**0**
	East	**36**	**41**	**58.2**	**28.7**	**18.6**	**9.2**
	South	**36**	**41**	**58.8**	**28.8**	**19.8**	**9.2**
	West	**36**	**0**	**0**	**0**	**0**	**0**
	North	**39**	**0**	**0**	**0**	**0**	**0**
	East	**39**	**41**	**54.6**	**25.4**	**17.5**	**8.1**
	South	**39**	**41**	**55.2**	**25.5**	**17.7**	**8.2**
	West	**39**	**0**	**0**	**0**	**0**	**0**
Lady Wynd b	North	3	126	60.0	102.3	19.2	32.7
	East	3	174	60.0	123.6	19.2	39.6
	South	3	48	34.2	20.9	10.9	6.7
	West	3	0	0	0	0	0
Bethune Way	North	3	111	55.2	89.3	17.7	28.6
	East	3	157	55.2	109.8	17.7	35.1
	South	3	46	34.2	20.1	10.9	6.4
	West	3	0	0	0	0	0
Denbeath Primary School	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**112**	**55.2**	**72.8**	**17.7**	**23.3**
	South	**3**	**112**	**54.6**	**72.8**	**17.5**	**23.3**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**112**	**55.2**	**73.4**	**17.7**	**23.5**
	South	**6**	**112**	**55.2**	**73.4**	**17.7**	**23.5**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Anderson Lane	**North**	**3**	**112**	**46.8**	**71.9**	**15.0**	**23.0**
	East	**3**	**155**	**47.4**	**90.1**	**15.2**	**28.8**
	South	**3**	**43**	**32.4**	**18.0**	**10.4**	**5.8**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**113**	**46.8**	**71.6**	**15.0**	**22.9**
	East	**6**	**155**	**47.4**	**89.8**	**15.2**	**28.7**
	South	**6**	**42**	**32.4**	**17.9**	**10.4**	**5.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**114**	**46.8**	**71.1**	**15.0**	**22.8**
	East	**9**	**156**	**47.4**	**89.4**	**15.2**	**28.6**
	South	**9**	**42**	**32.4**	**18.0**	**10.4**	**5.8**
	West	**9**	**0**	**0**	**0**	**0**	**0**
	North	**12**	**115**	**46.8**	**70.6**	**15.0**	**22.6**
	East	**12**	**157**	**46.8**	**88.9**	**15.0**	**28.5**
	South	**12**	**42**	**32.4**	**18.0**	**10.4**	**5.8**
	West	**12**	**0**	**0**	**0**	**0**	**0**
Den Walk a	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**103**	**42.6**	**47.8**	**13.6**	**15.3**
	South	**3**	**102**	**42.6**	**47.6**	**13.6**	**15.2**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**102**	**42.6**	**48.1**	**13.6**	**15.4**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
	South	6	102	42.6	48.0	13.6	15.4
	West	6	0	0	0	0	0
Omar Crescent	North	3	0	0	0	0	0
	East	3	106	46.2	53.3	14.8	17.1
	South	3	106	46.2	53.2	14.8	17.0
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	103	46.2	53.3	14.8	17.1
	South	6	103	46.2	53.1	14.8	17.0
	West	6	0	0	0	0	0
Den Walk b	North	3	0	0	0	0	0
	East	3	94	54.6	54.4	17.5	17.4
	South	3	94	54.6	54.3	17.5	17.4
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	95	55.2	54.9	17.7	17.6
	South	6	95	55.2	54.8	17.7	17.4
	West	6	0	0	0	0	0
Braehead Gardens	North	3	83	48.0	51.4	15.4	16.5
	East	3	125	48.0	69.3	15.4	22.2
	South	3	42	34.8	17.7	11.1	5.7
	West	3	0	0	0	0	0
	North	6	82	48.0	50.9	15.4	16.3
	East	6	124	48.0	68.8	15.4	22.0
	South	6	42	34.8	17.7	11.1	5.7
	West	6	0	0	0	0	0
	North	9	81	48.0	50.3	15.4	16.1
	East	9	134	48.0	68.3	15.4	21.9
	South	9	42	34.8	17.7	11.1	5.7
	West	9	0	0	0	0	0
	North	12	80	48.0	49.8	15.4	15.9
	East	12	123	48.0	67.9	15.4	21.7
	South	12	42	34.8	17.9	11.1	5.8
	West	12	0	0	0	0	0
	North	15	81	48.0	49.5	15.4	15.8
	East	15	124	48.0	67.5	15.4	21.6
	South	15	43	34.8	17.8	11.1	5.7
	West	15	0	0	0	0	0
Clyde Street	North	3	0	0	0	0	0
	East	3	91	88.8	110.0	28.4	35.2
	South	3	91	88.8	110.3	28.4	35.3
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	91	88.2	107.9	28.2	34.6
	South	6	91	88.2	108.3	28.2	34.7
	West	6	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	115	98.4	150.9	31.5	48.3
	South	3	115	98.4	151.2	31.5	48.4

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[1]
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**113**	**98.4**	**148.9**	**31.5**	**47.6**
	South	**6**	**113**	**98.4**	**149.3**	**31.5**	**47.8**
	West	**6**	**0**	**0**	**0**	0	**0**
Ward Street	North	3	0	0	0	0	0
	East	3	123	55.8	86.3	17.9	27.6
	South	3	123	55.8	86.4	17.9	27.6
	West	3	0	0	0	0	0
Wellesley Road e	North	3	0	0	0	0	0
	East	3	142	69.0	107.0	22.1	34.2
	South	3	142	68.4	106.9	21.9	34.2
	West	3	0	0	0	0	0
Swan View	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**61**	**73.8**	**58.7**	**23.6**	**18.8**
	South	**3**	**61**	**73.8**	**59.0**	**23.6**	**18.9**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**59**	**72.6**	**56.1**	**23.2**	**18.0**
	South	**6**	**59**	**72.6**	**56.3**	**23.2**	**18.0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**57**	**71.4**	**53.5**	**22.8**	**17.1**
	South	**9**	**57**	**71.4**	**53.7**	**22.8**	**17.2**
	West	**9**	**0**	**0**	**0**	**0**	**0**
***Properties highlighted in bold are regarded as multi-storey dwellings.**							

Table 2 – Summarised Cumulative Shadow Flicker Effects from all Turbines

Name	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[2]
Viewforth a	83	31.8	32.5	10.2	10.4
Viewforth b	107	34.2	45.1	10.9	14.4
West High Street	**128**	**37.8**	**65.5**	**12.1**	**21.0**
Lawson Lane	149	46.2	87.2	14.8	27.9
Shore Street	153	46.2	104.2	14.8	33.3
Lady Wynd a	171	62.4	129.1	20.0	41.3
Rising Sun Road	124	60.6	81.4	19.4	26.0
Wellesley Road a	130	33.6	87.9	10.8	28.1
Wellesley Road b	151	73.2	119.3	22.0	38.2
Wellesley Road c	148	111.6	218.6	35.7	70.0
Wellesley Road d	57	71.4	52.3	22.8	16.7
Forth Street	**97**	**94.2**	**124.3**	**30.1**	**39.8**
Randolph Wemyss Memorial Hospital	**131**	**67.2**	**100.7**	**20.2**	**32.2**
Shepherds Park	41	48.6	22.5	15.6	7.2
High Street a	29	23.4	9.0	7.5	2.9
Main Street	**49**	**33.0**	**22.2**	**10.6**	**7.1**
South Grove	49	31.2	21.0	10.0	6.7
High Street b	31	20.4	8.1	6.1	2.6
Swan Court	61	75.6	60.0	24.2	19.2
Lady Wynd b	**174**	60.0	123.6	19.2	37.1
Bethune Way	157	55.2	109.8	17.7	35.1
Denbeath Primary School	114	**55.2**	**74.7**	**17.7**	**23.9**
Anderson Lane	158	**48.6**	**93.8**	**15.6**	**30.0**
Den Walk a	103	**43.2**	**48.9**	**13.8**	**15.6**
Omar Crescent	106	**46.8**	**54.4**	**15.0**	**17.4**
Den Walk b	**95**	**55.8**	**55.7**	**17.9**	**17.8**
Braehead Gardens	**131**	**49.8**	**74.0**	**15.9**	**23.7**
Clyde Street	**91**	**88.8**	**110.6**	**26.6**	**35.4**
Wellesley Road e	**115**	**98.4**	**152.0**	**31.5**	**48.6**
Ward Street	123	55.8	86.4	27.6	27.6
Wellesley Road f	142	69.0	107.1	34.3	34.3
Swan View	**61**	**74.4**	**59.4**	**19.0**	**19.0**

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[2] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at:

***Properties highlighted in bold are regarded as multi-storey dwellings.**

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https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

POTENTIAL SHADOW FLICKER EFFECTS FROM THE LEVENMOUTH DEMONSTRATION TURBINE.

Table 1 – Potential Shadow Flicker Effects from the Levenmouth Demonstration Turbine.

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
Viewforth a	**North**	**3**	**48**	**31.8**	**19.8**	**10.2**	**6.3**
	East	**3**	**48**	**31.8**	**19.9**	**10.2**	**6.4**
	South	**3**	**0**	**0**	**0**	**0**	**0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**48**	**31.8**	**19.7**	**10.2**	**6.3**
	East	**6**	**48**	**31.8**	**19.8**	**10.2**	**6.3**
	South	**6**	**0**	**0**	**0**	**0**	**0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Viewforth b	North	3	71	34.2	31.3	10.9	10.0
	East	3	71	34.2	31.3	10.9	10.0
	South	3	0	0	0	0	0
	West	3	**0**	**0**	**0**	0	**0**
West High Street	**North**	**3**	**89**	**37.8**	**48.9**	**12.1**	**15.6**
	East	**3**	**89**	**37.8**	**49.0**	**12.1**	**15.7**
	South	**3**	**0**	**0**	**0**	**0**	**0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**89**	**37.8**	**49.2**	**12.1**	**15.7**
	East	**6**	**89**	**37.8**	**49.3**	**12.1**	**15.8**
	South	**6**	**0**	**0**	**0**	**0**	**0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lawson Lane	North	3	107	45.6	69.2	13.7	22.1
	East	3	107	46.2	69.4	14.6	22.2
	South	3	0	0	0	0	0
	West	3	**0**	**0**	**0**	0	**0**
Shore Street	**North**	**3**	**109**	**52.2**	**82.9**	**16.7**	**26.5**
	East	**3**	**109**	**52.8**	**83.2**	**16.9**	**26.6**
	South	**3**	**0**	**0**	**0**	**0**	**0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**109**	**52.2**	**83.4**	**16.7**	**26.7**
	East	**6**	**109**	**52.8**	**83.6**	**16.9**	**26.8**
	South	**6**	**0**	**0**	**0**	**0**	**0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Lady Wynd a	North	3	125	62.4	107.3	20.0	34.3
	East	3	125	62.4	107.8	20.0	34.5
	South	3	0	0	0	0	0
	West	3	0	0	0	0	0
Rising Sun Road	North	3	76	60.0	60.4	19.2	19.3
	East	3	76	60.1	60.8	19.2	19.5
	South	3	0	0	0	0	0

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[1] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	West	3	0	0	0	0	0
Wellesley Road a	North	3	0	0	0	0	0
	East	3	82	63.6	68.0	20.4	21.8
	South	3	82	63.6	67.8	20.4	21.7
	West	3	0	0	0	0	0
Wellesley Road b	North	3	0	0	0	0	0
	East	3	135	73.2	115.6	23.4	37.0
	South	3	135	73.2	115.7	23.4	37.0
	West	3	0	0	0	0	0
Wellesley Road c	North	3	0	0	0	0	0
	East	3	147	87.0	181.2	27.8	58.0
	South	3	148	87.0	181.9	27.8	58.2
	West	3	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	57	43.2	33.2	13.8	10.6
	South	3	57	43.2	33.4	13.8	10.7
	West	3	0	0	0	0	0
Forth Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**97**	**64.2**	**90.8**	**20.5**	**29.1**
	South	**3**	**97**	**64.2**	**91.1**	**20.5**	**29.2**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**97**	**64.2**	**89.2**	**20.5**	**28.6**
	South	**6**	**97**	**64.2**	**89.5**	**20.5**	**28.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Randolph Wemyss Memorial Hospital	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**103**	**66.6**	**85.4**	**21.3**	**27.3**
	South	**3**	**103**	**66.6**	**85.4**	**21.3**	**27.3**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**105**	**66.6**	**86.5**	**21.3**	**27.7**
	South	**6**	**105**	**66.6**	**86.5**	**21.3**	**27.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Shepherds Park	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	41	34.2	18.9	10.9	6.0
	West	3	41	34.2	19.0	10.9	6.0
High Street a	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	29	23.4	8.9	7.5	2.8
	West	3	29	23,4	8.9	7.5	2.8
Main Street	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**0**	**0**	**0**	**0**	**0**
	South	**3**	**49**	**32.4**	**22.0**	**10.4**	**7.0**
	West	**3**	**49**	**32.4**	**22.0**	**10.4**	**7.0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**0**	**0**	**0**	**0**	**0**
	South	**6**	**47**	**32.4**	**20.8**	**10.4**	**6.7**
	West	**6**	**47**	**32.4**	**20.8**	**10.4**	**6.7**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
South Grove	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	49	31.2	21.0	10.0	6.7
	West	3	49	31.2	21.0	10.0	6.7
High Street b	North	3	0	0	0	0	0
	East	3	0	0	0	0	0
	South	3	31	20.4	8.1	6.5	2.6
	West	3	31	20.4	8.1	6.5	2.6
Swan Court	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**61**	**46.8**	**38.3**	**15.0**	**12.3**
	South	**3**	**61**	**46.8**	**38.5**	**15.0**	**12.3**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**59**	**45.6**	**36.2**	**14.6**	**11.6**
	South	**6**	**59**	**45.6**	**36.4**	**14.6**	**11.6**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**57**	**44.4**	**34.0**	**14.2**	**10.9**
	South	**9**	**57**	**44.4**	**34.2**	**14.2**	**11.0**
	West	**9**	**0**	**0**	**0**	**0**	**0**
	North	**12**	**0**	**0**	**0**	**0**	**0**
	East	**12**	**53**	**43.2**	**31.8**	**13.8**	**10.2**
	South	**12**	**55**	**43.2**	**31.9**	**13.8**	**10.2**
	West	**12**	**0**	**0**	**0**	**0**	**0**
	North	**15**	**0**	**0**	**0**	**0**	**0**
	East	**15**	**51**	**41.4**	**29.5**	**13.2**	**9.4**
	South	**15**	**51**	**42.0**	**29.6**	**13.4**	**9.5**
	West	**15**	**0**	**0**	**0**	**0**	**0**
	North	**18**	**0**	**0**	**0**	**0**	**0**
	East	**18**	**49**	**40.2**	**27.4**	**12.9**	**8.8**
	South	**18**	**49**	**40.2**	**27.4**	**12.9**	**8.8**
	West	**18**	**0**	**0**	**0**	**0**	**0**
	North	**21**	**0**	**0**	**0**	**0**	**0**
	East	**21**	**47**	**38.4**	**25.0**	**12.3**	**8.0**
	South	**21**	**47**	**38.4**	**25.1**	**12.3**	**8.0**
	West	**21**	**0**	**0**	**0**	**0**	**0**
	North	**24**	**0**	**0**	**0**	**0**	**0**
	East	**24**	**45**	**36.6**	**22.8**	**11.7**	**7.3**
	South	**24**	**45**	**36.6**	**22.9**	**11.7**	**7.3**
	West	**24**	**0**	**0**	**0**	**0**	**0**
	North	**27**	**0**	**0**	**0**	**0**	**0**
	East	**27**	**41**	**36.6**	**20.5**	**11.7**	**6.6**
	South	**27**	**42**	**36.0**	**20.5**	**11.5**	**6.6**
	West	**27**	**0**	**0**	**0**	**0**	**0**
	North	**30**	**0**	**0**	**0**	**0**	**0**
	East	**30**	**39**	**36.0**	**18.6**	**11.5**	**6.0**
	South	**30**	**39**	**36.0**	**18.6**	**11.5**	**6.0**
	West	**30**	**0**	**0**	**0**	**0**	**0**
	North	**33**	**0**	**0**	**0**	**0**	**0**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	East	**33**	**37**	**34.2**	**16.2**	**10.9**	**5.2**
	South	**33**	**37**	**34.2**	**16.3**	**10.9**	**5.3**
	West	**33**	**0**	**0**	**0**	**0**	**0**
	North	**36**	**0**	**0**	**0**	**0**	**0**
	East	**36**	**33**	**31.2**	**13.5**	**10.0**	**4.3**
	South	**36**	**33**	**31.2**	**13.6**	**10.0**	**4.4**
	West	**36**	**0**	**0**	**0**	**0**	**0**
	North	**39**	**0**	**0**	**0**	**0**	**0**
	East	**39**	**29**	**28.2**	**10.8**	**9.0**	**3.5**
	South	**39**	**29**	**28.2**	**10.9**	**9.0**	**3.5**
	West	**39**	**0**	**0**	**0**	**0**	**0**
Lady Wynd b	North	3	126	60.0	102.3	19.2	32.7
	East	3	126	60.0	102.7	19.2	32.9
	South	3	0	0	0	0	0
	West	3	0	0	0	0	0
Bethune Way	North	3	111	55.2	89.3	17.7	28.6
	East	3	111	55.2	89.6	17.7	28.7
	South	3	0	0	0	0	0
	West	3	0	0	0	0	0
Denbeath Primary School	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**91**	**55.2**	**61.5**	**17.7**	**19.7**
	South	**3**	**91**	**54.6**	**61.5**	**17.5**	**19.7**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**92**	**55.2**	**62.2**	**17.7**	**19.9**
	South	**6**	**92**	**55.2**	**62.2**	**17.7**	**19.9**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Anderson Lane	**North**	**3**	**112**	**46.8**	**71.9**	**15.0**	**23.0**
	East	**3**	**112**	**47.4**	**72.1**	**15.2**	**23.1**
	South	**3**	**0**	**0**	**0**	**0**	**0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**113**	**46.8**	**71.6**	**15.0**	**22.9**
	East	**6**	**113**	**47.4**	**71.8**	**15.2**	**23.0**
	South	**6**	**0**	**0**	**0**	**0**	**0**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**114**	**46.8**	**71.1**	**15.0**	**22.8**
	East	**9**	**114**	**47.4**	**71.4**	**15.2**	**22.7**
	South	**9**	**0**	**0**	**0**	**0**	**0**
	West	**9**	**0**	**0**	**0**	**0**	**0**
	North	**12**	**115**	**46.8**	**70.6**	**15.0**	**22.6**
	East	**12**	**115**	**46.8**	**70.9**	**15.0**	**22.7**
	South	**12**	**0**	**0**	**0**	**0**	**0**
	West	**12**	**0**	**0**	**0**	**0**	**0**
Den Walk a	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**57**	**42.6**	**31.2**	**13.6**	**10.0**
	South	**3**	**56**	**42.6**	**31.1**	**13.6**	**10.0**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**56**	**42.6**	**31.3**	**13.6**	**10.0**

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	South	6	56	42.6	31.3	13.6	10.0
	West	6	0	0	0	0	0
Omar Crescent	North	3	0	0	0	0	0
	East	3	60	46.2	36.2	14.8	11.6
	South	3	60	46.2	36.1	14.8	11.5
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	59	46.2	36.2	14.8	11.6
	South	6	59	46.2	36.0	14.8	11.5
	West	6	0	0	0	0	0
Den Walk b	North	3	0	0	0	0	0
	East	3	62	43.2	35.5	13.8	11.4
	South	3	62	43.2	35.5	13.8	11.4
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	64	43.2	35.9	13.8	11.5
	South	6	64	43.2	35.8	13.8	11.5
	West	6	0	0	0	0	0
Braehead Gardens	North	3	83	48.0	51.4	15.4	16.4
	East	3	83	48.0	51.6	15.4	16.5
	South	3	0	0	0	0	0
	West	3	0	0	0	0	0
	North	6	82	48.0	50.9	15.4	16.3
	East	6	82	48.0	51.1	15.4	16.4
	South	6	0	0	0	0	0
	West	6	0	0	0	0	0
	North	9	81	48.0	50.3	15.4	16.1
	East	9	81	48.0	50.5	15.4	16.2
	South	9	0	0	0	0	0
	West	9	0	0	0	0	0
	North	12	80	48.0	49.8	15.4	15.9
	East	12	80	48.0	50.0	15.4	16.0
	South	12	0	0	0	0	0
	West	12	0	0	0	0	0
	North	15	81	48.0	49.5	15.4	15.8
	East	15	81	48.0	49.7	15.4	15.9
	South	15	0	0	0	0	0
	West	15	0	0	0	0	0
Clyde Street	North	3	0	0	0	0	0
	East	3	91	59.4	78.8	19.0	25.2
	South	3	91	60.0	79.1	19.2	25.3
	West	3	0	0	0	0	0
	North	6	0	0	0	0	0
	East	6	91	60.0	77.0	19.2	24.6
	South	6	91	60.0	77.3	19.2	24.7
	West	6	0	0	0	0	0
Wellesley Road d	North	3	0	0	0	0	0
	East	3	115	69.0	116.0	22.1	37.1
	South	3	115	69.0	116.3	22.1	37.2

Name	Window Orientation	Window Height	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Year	Likely Hours per Annum[1]
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**113**	**69.0**	**114.2**	**22.1**	**36.5**
	South	**6**	**113**	**69.0**	**114.6**	**22.1**	**36.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
Ward Street	North	3	0	0	0	0	0
	East	3	123	55.8	86.3	17.9	27.6
	South	3	123	55.8	86.4	17.9	27.6
	West	3	0	0	0	0	0
Wellesley Road e	North	3	0	0	0	0	0
	East	3	91	69.0	82.0	22.1	26.2
	South	3	91	68.4	81.8	21.9	26.2
	West	3	0	0	0	0	0
Swan View	**North**	**3**	**0**	**0**	**0**	**0**	**0**
	East	**3**	**61**	**46.8**	**38.3**	**15.0**	**12.3**
	South	**3**	**61**	**46.8**	**38.5**	**15.0**	**12.3**
	West	**3**	**0**	**0**	**0**	**0**	**0**
	North	**6**	**0**	**0**	**0**	**0**	**0**
	East	**6**	**59**	**45.6**	**36.2**	**14.6**	**11.6**
	South	**6**	**59**	**45.6**	**36.4**	**14.6**	**11.7**
	West	**6**	**0**	**0**	**0**	**0**	**0**
	North	**9**	**0**	**0**	**0**	**0**	**0**
	East	**9**	**59**	**45.6**	**36.3**	**14.6**	**11.6**
	South	**9**	**59**	**45.6**	**36.5**	**14.6**	**11.7**
	West	**9**	**0**	**0**	**0**	**0**	**0**
***Properties highlighted in bold are regarded as multi-storey dwellings.**							

Table 2 – Summarised Cumulative Shadow Flicker Effects from the Levenmouth Demonstration Turbine.

Name	Days per Year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Minutes per Day	Likely Hours per Annum[2]
Viewforth a	**49**	**31.8**	**20.3**	**10.2**	**6.5**
Viewforth b	71	34.2	31.3	10.9	10.0
West High Street	**89**	**37.8**	**49.7**	**12.1**	**15.9**
Lawson Lane	107	46.2	69.4	13.9	22.2
Shore Street	**109**	**52.8**	**84.5**	**16.9**	**27.0**
Lady Wynd a	125	62.4	107.8	20.0	34.4
Rising Sun Road	76	60.6	60.8	19.4	12.2
Wellesley Road a	82	63.6	68.1	20.4	21.8
Wellesley Road b	135	73.2	115.8	23.4	37.1
Wellesley Road c	148	87.0	181.9	27.8	58.2
Wellesley Road d	57	43.2	33.4	13.8	10.7
Forth Street	**97**	**64.8**	**91.4**	**20.7**	**29.2**
Randolph Wemyss Memorial Hospital	**106**	**67.2**	**88.1**	**21.5**	**28.2**
Shepherds Park	41	34.2	19.1	10.9	6.1
High Street a	29	23.4	9.0	7.5	2.9
Main Street	**49**	**33.0**	**22.2**	**10.6**	**7.1**
South Grove	49	31.2	21.0	10.0	6.7
High Street b	31	20.4	8.1	6.5	2.6
Swan Court	**61**	**46.8**	**38.8**	**15.0**	**12.4**
Lady Wynd b	126	60.0	102.7	19.2	32.9
Bethune Way	111	55.2	89.6	17.7	28.7
Denbeath Primary School	**94**	**55.2**	**63.6**	**17.7**	**20.4**
Anderson Lane	**115**	**48.6**	**75.1**	**15.6**	**24.0**
Den Walk a	**57**	**43.2**	**32.0**	**13.8**	**10.2**
Omar Crescent	**60**	**46.8**	**37.0**	**14.0**	**11.9**
Den Walk b	**64**	**43.8**	**36.5**	**14.0**	**11.7**
Braehead Gardens	**87**	**49.8**	**55.2**	**15.9**	**17.7**
Clyde Street	**91**	**60.0**	**79.2**	**19.2**	**25.3**
Wellesley Road e	**115**	**69.6**	**117.0**	**22.3**	**37.4**
Ward Street	123	55.8	86.4	17.9	27.6
Wellesley Road f	91	69.0	82.0	22.1	26.2
Swan View	**61**	**46.8**	**38.7**	**15.0**	**12.4**

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[2] Bright sunshine of 32% based on data from Kirkcaldy where an annual average of 1,425.6 sunshine hours was measured, and where daylight hours are assumed to be half of all hours throughout the year. Available at:

***Properties highlighted in bold are regarded as multi-storey dwellings.**

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https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvz0r35b (Accessed 16/02/2022).

Forthwind Demonstration Project

Navigational Risk Assessment

Prepared by	Anatec Limited
Presented to	Cierco Energy
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Revision Number	Date	Summary of Change
00	26th November 2021	Initial Draft
01	25th March 2022	Updated following Cierco Energy review
02	15th April 2022	Updated following further consultation

Table of Contents

Table of Figures

Table of Tables

Glossary of Terms

Term	Definition
Allision	The act of striking or collision of a moving vessel against a stationary object.
Automatic Identification System (AIS)	A system by which vessels automatically broadcast their identity, key statistics including location, destination, length, speed and current status, e.g., under power. Most commercial vessels and United Kingdom (UK)/European Union (EU) fishing vessels over 15 m length are required to carry AIS.
Baseline	The existing conditions as represented by the latest available data which is used as a benchmark for making comparisons to assess the risk of hazards.
Cable burial risk assessment	Risk assessment to determine suitable burial depths for cables, based upon effects such as anchor strike, fishing gear interaction and seabed mobility.
Cause	An event or activity that may create a hazard.
Collision	The act or process of one moving object striking another moving object.
Cumulative effect	Additional changes caused by a development in conjunction with other similar developments or as a combined effect of a set of developments.
Cumulative Effect Assessment (CEA)	Assessment of risk as a result of the incremental change caused by other past, present and reasonably foreseeable human activities and natural processes together with a development.
Environmental Impact Assessment (EIA)	The process of evaluating the potential effects of the Proposed Development over and above the baseline.
Environmental Statement (ES)	The written output presenting the full findings of the Environmental Impact Assessment (EIA).
European Union (EU)	The political and economic union of 27 European member states.
Formal Safety Assessment (FSA)	A structured and systematic process for assessing the risks and costs (if applicable) associated with shipping activity.
Future case	The assessment of risk based on the predicted growth in future shipping densities and traffic types as well as foreseeable changes in the marine environment.
Geographical Information System (GIS)	A system that captures, stores, analyses, manages and presents data linked to location. It links spatial information to a digital database.
Hazard	A potential to threaten human life, health, property or the environment.
International Maritime Organization (IMO) routeing measure	Predetermined shipping routes and areas established by the IMO to improve the safety of shipping at sea.
Main commercial route	Defined transit route (mean position) of commercial vessels identified within the specified routeing study area.
Marine aggregate	Marine dredged sand and/or gravel.
Marine Guidance Note (MGN)	A system of guidance notes issued by the Maritime and Coastguard Agency (MCA) which provide significant advice relating to the improvement of the safety of shipping at sea, and to prevent or minimise pollution from shipping.

Term	Definition
Mitigation measure	A means of controlling a single element of risk, usually expressed as embedded (standard or good practice measures already utilised or in place) or additional (in addition to embedded controls for reducing risk to As Low as Reasonably Practicable (ALARP)).
Navigational Risk Assessment (NRA)	A document which assesses the overall risk to shipping and navigation of a proposed Offshore Renewable Energy Installation (OREI) based on Formal Safety Assessment (FSA).
Offshore Renewable Energy Installation (OREI)	As defined by Marine Guidance Note (MGN) 654 (MCA, 2021). For the purposes of this chapter an OREI refers to offshore WTGs and associated infrastructure such as the Meteorological Mast (Met Mast).
Radio Detection and Ranging (Radar)	An object-detection system which uses radio waves to determine the range, altitude, direction or speed of objects.
Regular operator	A commercial operator whose vessel(s) are observed to transit through a particular region on a regular basis.
Risk	The combination of the frequency of occurrence and the severity of consequence of a hazard.
Routeing study area	An eight nautical mile (nm) buffer of the two structures of the Proposed Development. This study area has been used to identify main commercial routes and provide geographical boundaries to the collision and allision risk modelling.
Safety zone	A statutory marine zone demarcated for the purposes of safety around a possibly hazardous installation or works/construction area.
Scoping Opinion	A report presenting the written opinion of Marine Scotland – Licensing Operations Team (MS-LOT) to the scope and level of detail of information to be provided in the Environmental Impact Assessment (EIA) Report for a development.
Scoping Report	A report presenting the findings of an initial stage in the Environmental Impact Assessment (EIA) process.
Sensitivity	A term applied to specific users, combining judgements of the susceptibility of the user to the specific type of charge or development proposed and the value associated to that user.
Stakeholder	A person or organisation with a specific interest (commercial, professional or personal) in a particular issue.
The Applicant	Forthwind Ltd.
Traffic study area	An approximately 15 nautical mile (nm) wide segment of the Firth of Forth between Kinghorn and North Berwick. This study area has been used to characterise the vessel traffic baseline.
Unique vessel	An individual vessel identified on any particular calendar day using Maritime Mobile Service Identities (MMSI), irrespective of how many tracks were recorded for that vessel on that day. This prevents overcounting of vessels.
User(s)	A risk sufferer(s).
Vessel Traffic Service (VTS)	A service implemented by a competent authority designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the vessel traffic and to respond to traffic situations developing in the VTS area.

Abbreviations Table

AIS	Definition
ALARP	Automatic Identification System
ALB	All Weather Lifeboats
CA	Cruising Association
CBA	Cost Benefit Analysis
CHIRP	Confidential Human Factors Incident Reporting Programme
COLREGs	International Regulations for Preventing Collisions at Sea
CRO	Coastguard Rescue Officer
CRT	Coastguard Rescue Team
DfT	Department for Transport
EIA	Environmental Impact Assessment
ERCOP	Emergency Response Co-operation Plan
ES	Environmental Statement
FSA	Formal Safety Assessment
GT	Gross Tonnage
HAT	Highest Astronomical Tide
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ILB	Inshore Lifeboat
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
ITOPF	International Tanker Owners Pollution Federation
JRCC	Joint Rescue Coordination Centre
km	Kilometre
LOA	Length Overall
LPG	Liquid Petroleum Gas
MAIB	Marine Accident Investigation Branch
MCA	Maritime and Coastguard Agency
MECP	Marine Environment Protection Committee
MEHRAS	Marine Environmental High Risk Areas
MGN	Marine Guidance Note
MHWS	Mean High Water Springs
MMSI	Mobile Maritime Service Identity
MRCC	Maritime Rescue Coordination Centre
MS-LOT	Marine Scotland – Licensing Operating Team

AIS	Definition
NLB	Northern Lighthouse Board
NRA	Navigational Risk Assessment
OREI	Offshore Renewable Energy Installation
PINS	Planning Inspectorate
PLA	Port of London Authority
PLL	Potential Loss of Life
POB	People on Board
QHSE	Quality, Health, Safety and Environment
RADAR	Radio Detection and Ranging
REZ	Renewable Energy Zone
RNLI	Royal National Lifeboat Institution
RYA	Royal Yachting Association
SAR	Search and Rescue
SFF	Scottish Fishing Federation
SOLAS	International Convention for the Safety of Life at Sea
SONAR	Sound Navigation and Ranging
TCE	The Crown Estate
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
VHF	Very High Frequency
VTS	Vessel Traffic Service
WTG	Wind Turbine Generator

1 Introduction

1.1 Background

1. Anatec was commissioned by Cierco Energy to undertake a Navigational Risk Assessment (NRA) on behalf of Forthwind Ltd. (hereafter referred to as ‘the Applicant’) for the proposed Forthwind Demonstration Project (hereby referred to as the ‘Proposed Development’). The NRA presents information on the Proposed Development relative to the existing and estimated future navigational activity and forms the technical appendix to Chapter 13 of the Environmental Statement (ES).

1.2 Navigational Risk Assessment

2. An Environmental Impact Assessment (EIA) is a process which identifies the environmental risks of a proposed development, both negative and positive. An important element/requirement of the EIA for offshore projects is the NRA. Following the relevant Maritime and Coastguard Agency (MCA) guidance, the NRA includes:

- Outline of methodology applied in the NRA;
- Summary of consultation undertaken with shipping and navigation stakeholders to date;
- Lessons learnt from previous offshore developments;
- Summary of the Proposed Development relevant to shipping and navigation;
- Baseline characterisation of the existing environment;
- Discussions of potential risks on navigation, communication and position fixing equipment;
- Future case vessel traffic characterisation;
- Collision and allision risk modelling;
- Hazard identification;
- Formal Safety Assessment (FSA);
- Outline of embedded and additional mitigation measures; and
- Outline of through life safety management features.

3. The NRA screens the potential hazards to determine which should be taken forward to the FSA undertaken in Section 15. Potential hazards are considered for the construction, operational and decommissioning phases.

2 Guidance and Legislation

2.1 Legislation and Policy

4. As part of the EIA Directive (2011/92/EU, as amended by Directive 2014/52/EU) (which remains applicable following Brexit), an EIA Report is required to be undertaken to support the application for the Section 36 consent for the Project. The MCA require that, as part of the EIA Report, an NRA is undertaken to "*inform the shipping and navigation chapter of the EIA Report*" (MCA, 2021).

2.2 Primary Guidance

5. The primary guidance documents used during the assessment are the following:

- *Marine Guidance Note (MGN) 654 (Merchant and Fishing) Safety of Navigation: Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response* (MCA, 2021); and
- *Revised Guidelines for FSA for Use in the Rule-Making Process* (IMO, 2018).

6. MGN 654 highlights issues that shall be considered when assessing the risk to navigational safety from offshore renewable energy developments, proposed in United Kingdom (UK) internal waters, territorial sea or Renewable Energy Zone (REZ).

7. It is noted that MGN 654 also includes multiple annexes including *the Methodology for Assessing the Marine Navigational Safety & Emergency Response Risks of OREIs*, which the MCA require as a template for preparing NRAs. The methodology is centred on risk management and requires a submission that shows that sufficient controls are, or will be, in place for the assessed risk to be judged as broadly acceptable or tolerable with mitigation. In the NRA the base and future case levels of risk have been identified as well as the mitigation measures required to ensure the future case remains broadly acceptable or tolerable with mitigation.

8. It is noted that the MCA methodology discusses proportionality of the assessment and indicates that the requirements of a submission may be dependent upon the scale of the development being assessed.

2.3 Other Guidance

9. Other guidance documents used during the assessment include:

- *MGN 372 (Merchant and Fishing) OREI: Guidance to Mariners Operating in the Vicinity of UK OREIs* (MCA, 2008);
- *International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Recommendation O-139 on the Marking of Man-Made Offshore Structures* (IALA, 2013); and

- *The Royal Yachting Association’s (RYA) Position on Offshore Renewable Energy Developments: Paper 1 (of 4) – Wind Energy* (RYA, 2019).

3 Navigation Risk Assessment Methodology

3.1 Formal Safety Assessment Methodology

10. A shipping and navigation user can only be affected by a hazard if there is a pathway through which a hazard can be transmitted between the source activity and the user. In cases where a user is exposed to a hazard, the overall severity of consequence to the user is determined. This process incorporates a degree of subjectivity, and therefore multiple assessment criteria are considered for shipping and navigation users including:

- Baseline data and assessment;
- Expert opinion;
- Outputs of the Hazard Workshop;
- Level of stakeholder concern;
- Time and/or distance of any deviation;
- Number of transits of specific vessels and/or vessel types; and
- Lessons learnt from existing offshore developments.

11. It is noted that, with regards to commercial fishing vessels, the methodology and assessment has been applied to hazards considering commercial fishing vessels in transit (i.e., where gear is not deployed). A separate methodology and assessment have been applied in Chapter 13 to consider hazards which are directly related to commercial fishing activity (as opposed to commercial fishing vessels in transit) including hazards of a commercial nature.

3.1.1 Formal Safety Assessment Process

12. In line with standard approach to marine risk assessment, the IMO FSA process (IMO, 2018) as approved by the IMO in 2018 under Maritime Safety Committee – Marine Environment Protection Committee (MECP).2/circ.12/Rev.2 has been applied to the risk assessment within this NRA and Chapter 13.

13. The FSA process is a structured and systematic methodology based upon risk analysis and Cost Benefit Analysis (CBA) (if applicable) to reduce risks to As Low as Reasonably Practicable (ALARP). There are five basic steps within this process as illustrated by Figure 3.1 and summarised in the following list:

- **Step 1** – Identification of hazards (a list is produced of hazards prioritised by risk level specific to the problem under review);
- **Step 2** – Risk analysis (investigation of the causes and initiating events and consequences of the more important hazards identified in Step 1);
- **Step 3** – Risk control options (identification of measures to control and reduce the identified hazards);
- **Step 4** – CBA (identification and comparison of the benefit and costs associated with the risk control options identified in Step 3; and

- **Step 5** – Recommendations for decision-making (defining of recommendations based upon Steps 1 to 4).

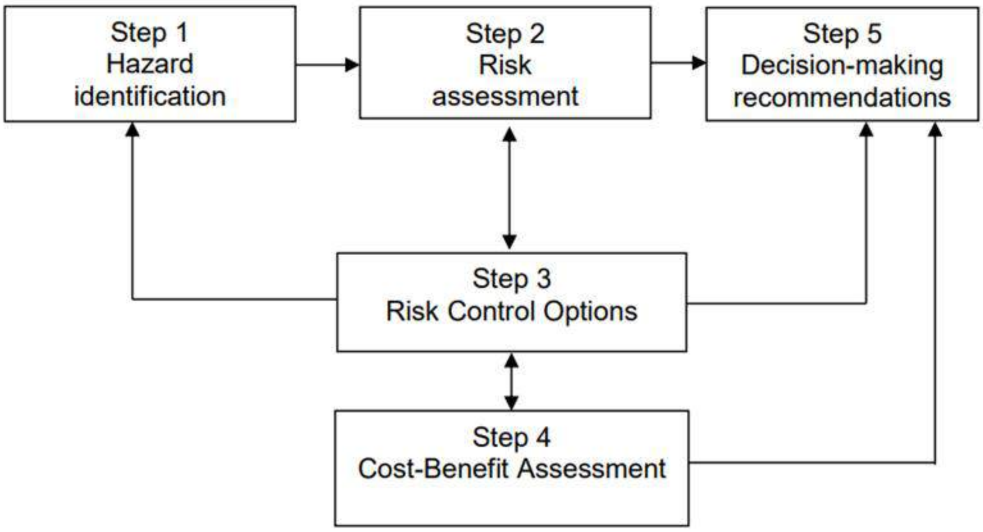


Figure 3.1 Flow Chart of the FSA Methodology (IMO, 2018)

3.1.2 Hazard Workshop Methodology

14. A standard and key tool used in the NRA process is the Hazard Workshop which ensures that all risks are identified and qualified in discussion with relevant consultees. Table 3.1 and Table 3.2 define the severity of consequence and the frequency of occurrence rankings that have been used to assess the preliminary risk within the hazard list (see Appendix B) completed based upon the outputs of the Hazard Workshop). The hazard list is a simplified version of a hazard log typically produced in offshore wind farm NRAs and reflects the scale of the Proposed Development. This is aligned with the details of NRA proportionality provided in the MCA methodology.

Table 3.1 Severity of Consequence

Rank	Description	Definition
1	Insignificant	▪ No significant harm to people.
2	Minor	▪ Injury to vessel crew. ▪ Injury to OREI installation crew. ▪ Injury on the shore.
3	Major	▪ Loss of vessel crew members (1 to 3). ▪ Loss of OREI installation or maintenance crew members (1 to 3). ▪ Fatalities on shore (1 to 3).

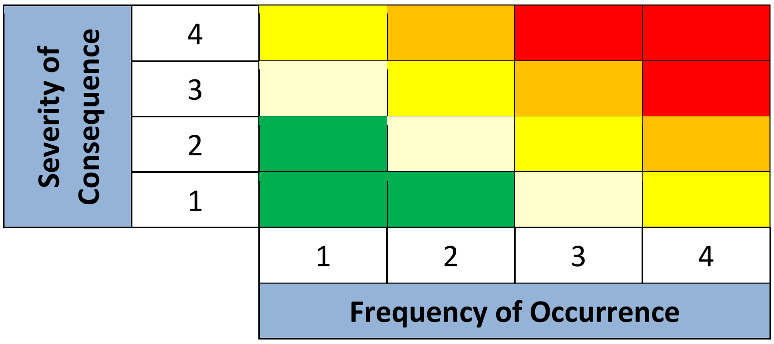
Rank	Description	Definition
4	Catastrophic	▪ Total loss of vessel crew. ▪ Total loss of OREI installation or maintenance crew. ▪ Multiple fatalities onshore.

Table 3.2 Frequency of Occurrence

Rank	Description	Definition
1	Extremely Remote	Only likely to happen in exceptional circumstances.
2	Remote	Unlikely (but not exceptional) to happen during the licence period.
3	Reasonably Probable	Likely to happen during the licence period of an OREI (nominally 20 years).
4	Frequent	Likely to happen annually or more frequently.

15. The severity of consequence and frequency of occurrence are then used to define the significance of risk via a risk/tolerability matrix approach as shown in Table 3.3.

Table 3.3 Risk/Tolerability Matrix and Risk Rankings



Severity of Consequence	4	🟨	🟧	🟥	🟥
	3	⬜	🟨	🟧	🟥
	2	🟩	⬜	🟨	🟧
	1	🟩	🟩	⬜	🟨
		1	2	3	4
		Frequency of Occurrence			

🟩	Broadly Acceptable
⬜	Tolerable with Monitoring
🟨	Tolerable with Additional Controls
🟧	Tolerable with Modifications
🟥	Unacceptable

16. Once identified, the tolerability of a hazard will be assessed to ensure it is ALARP. Additional mitigation measures may be required to further mitigate a hazard in

accordance with the ALARP principles, noting that unacceptable risks are not considered to be ALARP.

3.2 Cumulative Effects Assessment Methodology

17. All hazards identified and assessed within the FSA process should also be assessed for potential cumulative risks taking into account other cumulative developments.

18. The approach for screening in or out cumulative developments for shipping and navigation includes consideration of the following criteria:

- Project status;
- Proximity to the Proposed Development;
- Level of interaction with baseline traffic relevant to the Proposed Development;
- Level of stakeholder concern; and
- Data confidence.

19. As the Proposed Development is within the Firth of Forth, only other offshore developments within the Forth are considered relevant to the cumulative effects assessment (CEA). Offshore developments outside the Forth have not been considered given the distance from the Proposed Development and that the risk to vessel traffic movements within the Forth due to offshore developments out with the Forth will be minimal.

20. The only offshore development (operational or planned) within the Forth that is considered relevant is Energy Park Fife, a decommissioning facility located approximately 400 m south west of the Port of Methil. This development attracts the majority of the traffic passing in proximity to the Proposed Development with associated vessel numbers expected to fluctuate depending upon the decommissioning activity present. However, since this development is operational and included in the characterisation of the baseline environment, it is considered a baseline development rather than a cumulative development.

21. Since there are no cumulative developments screened in to the CEA, no assessment of cumulative risk has been undertaken in this NRA.

3.3 Assumptions

22. The shipping and navigation baseline and FSA within the NRA and Chapter 13 has been undertaken based upon the information available and responses received at the time of preparation. It was assessed based upon a conservative scenario, in particular noting that the location of the structures will not be finalised until post consent.

23. Limitations of the data sources considered are discussed in detail in Section 7.4.

4 Consultation

24. This section sets out the consultation undertaken to date of relevance to shipping and navigation for the Proposed Development. This process has considered consultation requirements and recommendations within the Annex 1 to MGN 654 (MCA, 2021).

4.1 Scoping Opinion

25. The Applicant submitted a Scoping Report to Marine Scotland – Licensing Operations Team (MS-LOT) in August 2021 with the Scoping Opinion received in return in December 2021. A summary of the key points raised is provided in Table 4.1. Responses confirming no comments at this stage were also received from the UK Chamber of Shipping and East Lothian Yacht Club.

Table 4.1 Scoping Opinion Summary

Consultee	Point Raised	Where Addressed in the NRA
MCA	An NRA will need to be submitted in accordance with MGN 654 (and MGN 372) and the MCA's methodology. The NRA should be accompanied by a detailed MGN 654 Checklist.	This document is an NRA and has been undertaken in line with MGN 654 and its annexes (see Section 2.2). The MGN 654 Checklist has been completed (see Appendix A).
	Recommend further consultation with relevant stakeholders to ensure the marine traffic data used remains relevant and identify any potential new hazards.	Dedicated consultation has been undertaken with MCA and Forth Ports (see Section 4.2) for the updated project design noting that the earlier project design considered at the Hazard Workshop represented a greater worst case for shipping and navigation.
	Do not agree that hazards to emergency response and Search and Rescue (SAR) operations should be scoped out of the risk assessment. Consideration will need to be given to the implications on SAR resources and Emergency Response Cooperation Plan (ERCoP). Attention should be paid to the level of Radio Detection and Ranging (Radar) surveillance, Automatic Identification System (AIS) and shore-based Very High Frequency (VHF).	Disruption to emergency response and SAR operations has been scoped into the FSA (see Section 15.314.2). Compliance with MGN 654, including implementation of an ERCoP and completion of a SAR checklist, is included as an embedded mitigation measure (see Section 16).
	Any application for safety zones will need to be carefully assessed and additionally supported by experience from the development and construction stages.	An application for statutory safety zones has not been included on the basis that Forth Ports – as the competent harbour authority in the area – will implement safety zones, exclusion zones or speed restrictions as deemed necessary at each phase of the Proposed Development (see Section 16).

Consultee	Point Raised	Where Addressed in the NRA
	On the understanding that shipping and navigation aspects are undertaken in accordance with MGN 654 and its annexes, along with a completed MGN 654 Checklist, the MCA is likely to be content with the approach.	This NRA has been undertaken in line with MGN 654 and its annexes (see Section 2.2). The MGN 654 Checklist has been completed (see Appendix A).
NLB	Satisfied with the content of the Scoping Report and note the proposal to engage in consultation with NLB with regard to the navigational lighting and marking of the Proposed Development.	Lighting and marking of the Proposed Development in agreement with NLB is included as an embedded mitigation measure (see Section 16).
	MGN 543, referenced in the Scoping Report, is no longer valid and has been superseded by MGN 654.	This NRA has been undertaken in line with MGN 654 and its annexes (see Section 2.2).
RYA Scotland	Content to assist with the NRA noting that consultation will be undertaken with stakeholders such as RYA Scotland.	A meeting was held with the RYA Scotland to discuss the NRA (see Section 4.2.3).
Forth Ports	The impact on Forth Ports Radar equipment and that of vessels using the Forth needs to be adequately addressed in the ES and NRA.	The prevention of use of existing aids to navigation has been scoped into the FSA (see Section 14.2) and use of marine Radar has been considered (see Section 11).

4.2 Key Stakeholder Meetings

4.2.1 Maritime and Coastguard Agency

26. A meeting was held with the MCA in November 2021 to discuss the Proposed Development, NRA methodology, baseline conditions and hazard list. During this meeting, the MCA noted that Forth Ports should be considered the primary stakeholder, followed by the MCA.

27. Additionally, during email correspondence in February 2022, the MCA confirmed that Radar and visual surveys are not required for shipping and navigation with the data sources outlined in the previous meeting sufficient.

4.2.2 Forth Ports

28. A meeting was held with Forth Ports in January 2022. During the meeting, Forth Ports confirmed that pilot boarding for Methil is not typically undertaken in proximity to the charted pilot boarding station and is typically done where the vessel has anchored within the anchorage area. An exclusion zone could be applied and the location of the anchorage and pilot boarding station reconfigured; however this will be a consideration for post consent when the final design parameters are known.

29. Forth Ports also confirmed that the development is located a sufficient distance from navigational features in the area including Energy Park Fife. However, there could be an issue for small vessels and this would be for the VTS to manage and can be revisited post consent.

4.2.3 Royal Yachting Association Scotland

30. A meeting was held with RYA Scotland in April 2022. During the meeting, RYA Scotland confirmed that the vessel traffic data collected may not be comprehensive for local recreational vessels not broadcasting on AIS but no additional data collection is requested.

31. Also, recreational vessels are unlikely to utilise the pilotage services for the Port of Methil and would not be expected to anchor in the area given water depths. Additionally, the grounding risk to recreational vessels is considered minimal with directional drilling and the water depths.

32. Additional lighting and marking may cause confusion for mariners, noting the Craigkelly transmitter has three noticeable lights at night and in suitable conditions the Inch Cape Met Mast can be seen from a far distance.

4.3 Hazard Workshop

33. A Hazard Workshop was undertaken in Aberdour on 20th October 2017 for the nine-turbine Forthwind Demonstration Array project (as proposed within the 2016 Scoping Report). The Hazard Workshop identified and discussed scenarios and prioritised them by risk level based on the findings of the original NRA. The workshop assisted with identifying additional mitigation measures and the findings and mitigation have been brought forward into the EIA Report, noting that the revised project design assessed is considered a lesser worse case for shipping and navigation than that considered in the Hazard Workshop.

34. Participant organisations were as follows:

- Northern Lighthouse Board (NLB);
- RYA Scotland;
- Forth Ports;
- Forth Yacht Clubs Association;
- Fife Fishermen’s Association; and
- Scottish Fishermen’s Federation (SFF).

35. The MCA and UK Chamber of Shipping were invited to attend the Hazard Workshop but were unable to attend.

36. The key output of the Hazard Workshop is the hazard list (see Appendix B) and is used to inform the FSA undertaken in the NRA. A summary of the key points raised is provided in Table 4.2.

Table 4.2 Hazard Workshop Summary

Consultee	Point Raised	Where Addressed in the NRA
SFF and Fife Fishermen's Association	The floating foundation option would create additional problems for fishing.	Floating foundations are no longer considered as part of the Design Envelope (see Section 6).
Forth Ports	The area marked as foul ground that intersects the development was historically a mine practice area but is no longer active.	Noted in the characterisation of the baseline environment (see Section 8.4.1).
Forth Ports	Tugs headed out of the Port of Methil are typically based in Leith and used for towing barges in and out of Methil with a variety of infrastructure as well as rigs. The frequency of such operations is very variable but re-routeing would be required, resulting in slightly longer transits.	A main commercial route between Methil and Leith was identified in the characterisation of the baseline environment (see Section 10.5.2).
SFF and Fife Fishermen's Association	There are smaller vessels in the region not carrying AIS including fishing vessels under 15 metres (m) which frequently turn off their AIS when engaged in fishing activity. Questioned whether Forth Ports could track smaller vessels using Radar.	Noted in the characterisation of the baseline environment (see Section 10.2.3). Forth Ports confirmed that small targets are difficult to track for any length of time.
Fife Fishermen's Association	Not all fishing activity is local to the region, and more inshore fishing occurs in the sheltered waters closer to the coast during the winter months with vessels coming from ports further afield such as Arbroath.	The vessel traffic data covers both summer and winter periods to ensure seasonal variation is incorporated as per MGN 654 requirements for vessel traffic surveys (see Section 7.2).
RYA Scotland	Recreational traffic in the study area is most likely headed to Port Edgar and Granton and generally consists of non-local vessels.	Noted in the characterisation of the baseline environment (see Section 10.2.5).
Forth Yacht Clubs Association	The cruising routes identified in the RYA dataset are likely to be within inshore areas and used by mariners with local knowledge and visitors less likely to be familiar with the Project are less likely to be passing in proximity to the Project.	Noted in the characterisation of the baseline environment (see Section 10.2.5).
Forth Ports	Anchor berths K1 and K2 would likely require removal although acknowledged that there are numerous other anchoring locations in the region and so this is not considered a significant issue.	Noted in the FSA (see Section 1515.2.2).
Forth Ports	Semi submersibles generally anchor within the port of Methil anchorage areas and given their anchor spread could encroach upon the Project.	Noted in the characterisation of the baseline environment (see Section 10.2.6).

Consultee	Point Raised	Where Addressed in the NRA
Forth Ports	Pilot boarding would not be notably affected by the Project since the embarking location, which is located within a small vessel anchorage area, can be moved further north away from the Project.	Noted in the FSA (see Section 1515.2.2).
SFF	Notices to Mariners are not always quickly distributed and additional sources including Kingfisher, Fishsafe and Fishfinder are noted.	Promulgation of information via Kingfisher Bulletins is included as an embedded mitigation measure (see Section 16).
Forth Yacht Clubs Association	There are a significant number of beach landings at Largo Bay and Elie where angling boats launch from, with nearshore activity generally as far as the 20 m contour.	Noted in the characterisation of the baseline environment (see Section 10.2.5).
RYA Scotland	Kite and wind surfers may be scoped out of the assessment as they do not lunch from nearby locations and are limited in the distance they can travel.	Kite and wind surfers have not been considered as users in the hazard list (see Appendix B).
NLB and Forth Ports	The Proposed Development may result in the visual impairment of vessels visiting the Port of Methil, with the harbour lights not clearly visible through the wind farm; amendments may be needed to the leading lights and this will be reviewed.	The prevention of use of existing aids to navigation has been scoped into the FSA (see Section 14.2).
Forth Ports	Impacts relating to VHF will be reviewed following installation of the Project.	Risks to navigation, communication and position fixing equipment have been scoped out of the FSA (see Section 11).

5 Lessons Learnt

37. There is considerable benefit for the Applicant in the sharing of lessons learnt within the offshore industry. The NRA and Chapter 13 include general consideration for lessons learnt and expert opinion from previous offshore developments and other sea users, capitalising upon the UK's position as a leading generator of offshore wind power.

38. Data sources for lessons learnt include the following:

- *Sharing the Wind – Recreational Boating in the Offshore Wind Strategic Areas* (RYA and Cruising Association (CA), 2004);
- *Results of the Electromagnetic Investigations* (MCA and QinetiQ, 2004);
- *Offshore Wind Farm Helicopter Search and Rescue Trials Undertaken at the North Hoyle Wind Farm* (MCA, 2005);
- *Interference to Radar Imagery from Offshore Wind Farms* (Port of London Authority (PLA), 2005);
- *Strategic Assessment of Impacts on Navigation of Shipping and Related Effects on Other Marine Activities Arising from the Development of Offshore Wind Farms in the UK REZ* (Anatec & The Crown Estate (TCE), 2012);
- *Offshore Wind and Marine Energy Health and Safety Guidelines* (RenewableUK, 2014);
- *Methil Offshore Wind Turbines Navigational Safety Risk Assessment* (TÜV SÜD PMSS, 2015); and
- *G+ Global Offshore Wind Health & Safety Organisation 2020 Incident Data Report* (G+, 2021).

6 Project Description

39. This section sets out the Project Description from a shipping and navigation perspective. An overview of the Proposed Development is presented in Figure 6.1 which indicates the proposed location of the Wind Turbine Generator (WTG) and Meteorological Mast (Met Mast), separated by approximately 625 m. A detailed overview is presented in Figure 6.2 which also includes the export and interconnector cables.

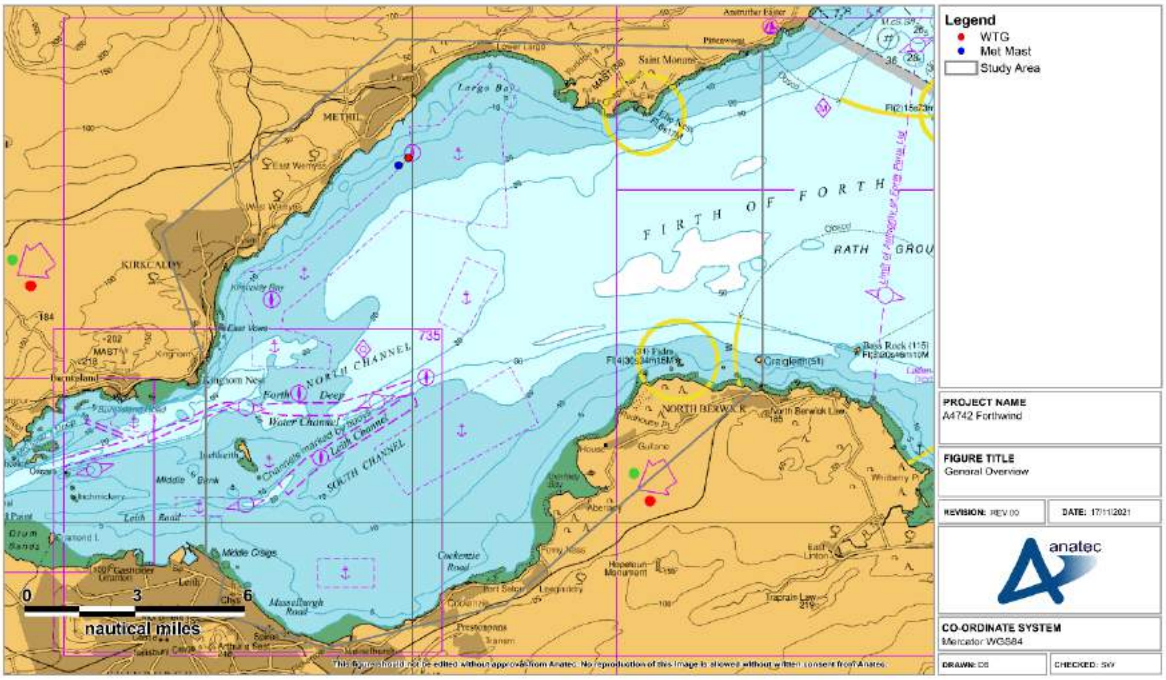


Figure 6.1 General Overview

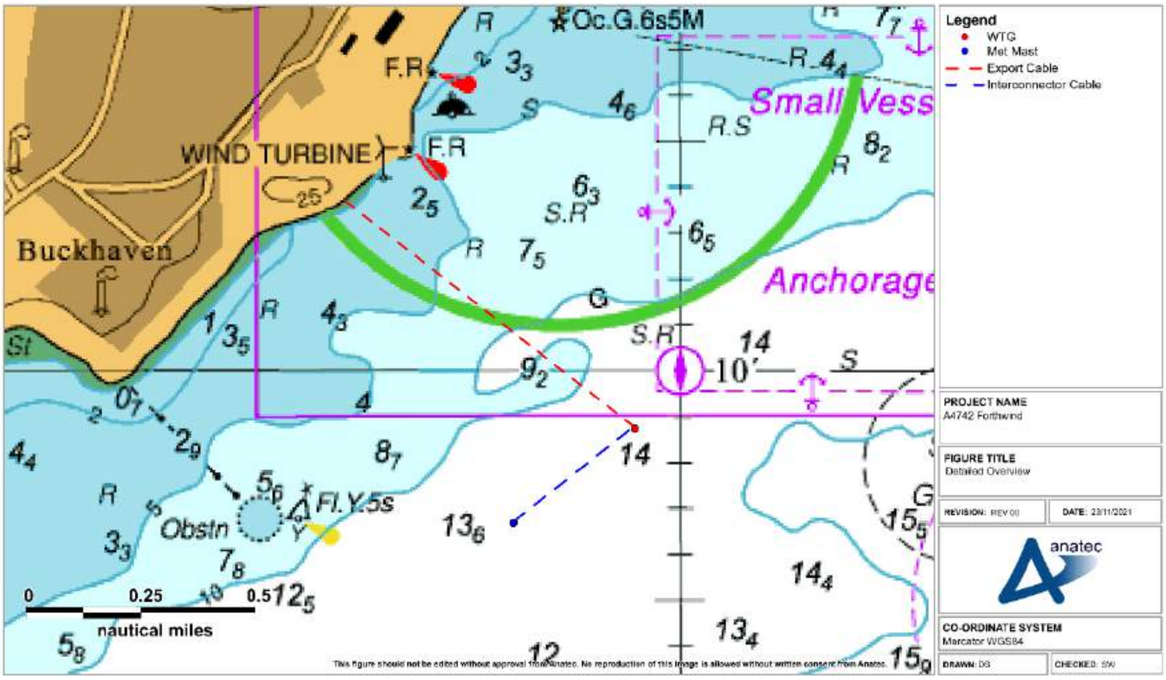


Figure 6.2 Detailed Overview

40. Charted water depths in proximity to the wind farm structures and interconnector cable are between 13 to 14 m below Chart Datum (CD) and in proximity to the export cable are between 2 and 14 m below CD.

6.1 Turbine Location

41. The WTG is located approximately 0.8 nm from the nearest point of land, within the Firth of Forth, as shown in Figure 6.2. Coordinates and information for the WTG are given in Table 6.1 and Table 6.2, respectively.

Table 6.1 WTG Coordinates

Geographical Co-ordinates (World Geodetic System 1984 (WGS84)	
Latitude	**Longitude**
56˚ 09' 52.49" N	003˚ 00' 10.65" W

Table 6.2 WTG Information

Parameter	Value
Foundation type	Monopile or jacket
Maximum foundation dimensions at sea surface	10.5 m diameter (associated with monopile)

Parameter	Value
Hub height (Highest Astronomical Tide (HAT))	152.5 m
Maximum blade tip height (above HAT)	280 m
Minimum blade tip height (above HAT)	25 m
Rotor diameter	255 m
Design life	25 years

6.2 Meteorological Mast

42. The Met Mast is located approximately 0.8 nm from the nearest point of land, as shown in Figure 6.2. Coordinates and information for the Met Mast are given in Table 6.3 and Table 6.4, respectively.

Table 6.3 Met Mast Coordinates

Geographical Co-ordinates (World Geodetic System 1984 (WGS84))	
Latitude	**Longitude**
56˚ 09' 40.16" N	003˚ 00' 39.19" W

Table 6.4 Met Mast Information

Parameter	Value
Foundation type	Monopile
Foundation dimensions at sea surface	3.9 m diameter
Height (above HAT)	160 m
Design life	25 years[1]
Worst Case Foundation/ Substructure	Monopile

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[1] The Met Mast has an operational life of five years but is anticipated to be decommissioned only at the end of the WTG's design life.

6.3 Subsea Cables

43. There will be two subsea cables installed as part of the Proposed Development:

- An export cable of approximate length 0.8 nm connecting the WTG to landfall; and
- An interconnector cable of approximate length 625 m connecting the WTG and the Met Mast.

44. Both subsea cables are expected to be buried to a depth of between 1 and 1.5 m.

6.4 Timescales and Project Vessel Movements

45. The construction phase will be undertaken over two phases – one phase for foundation installation and one for main structure installation – taking place over a two to three month period. One jack-up vessel and one lifting vessel will be on-site for each phase making minimal movements once on-site. For the subsea cables, one cable lay vessel and a possible secondary support vessel will be on-site. Following completion of the subsea cable installation, a Remotely Operated Vehicle (ROV) will be used to undertake a Post Lay Inspection and Burial (PLIB) operation.

46. The operational phase will last for 25 years, with the Met Mast anticipated to be decommissioned only at the end of the WTG’s design life. A Crew Transfer Vessel (CTV) will be used to enable maintenance activities to be undertaken when required and an ROV will be used to undertake cable inspections with an appropriate frequency.

47. The decommissioning phase is expected to be broadly similar in nature to the construction phase, although it is anticipated that the subsea cables will be left in situ.

48. Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS. Therefore, it is not anticipated that a project vessel will be involved in a collision or allision incident associated with the Proposed Development.

7 Data Sources

49. This section summarises the main data sources used to characterise the shipping and navigation baseline deemed of relevance to the Proposed Development, including considerations of any data limitations associated.

7.1 Study Area

7.1.1 Traffic Study Area

50. The study area within which the vessel traffic baseline has primarily been characterised is an approximately 15 nm wide segment of the Firth of Forth between Kinghorn and North Berwick, as shown in Figure 7.1.

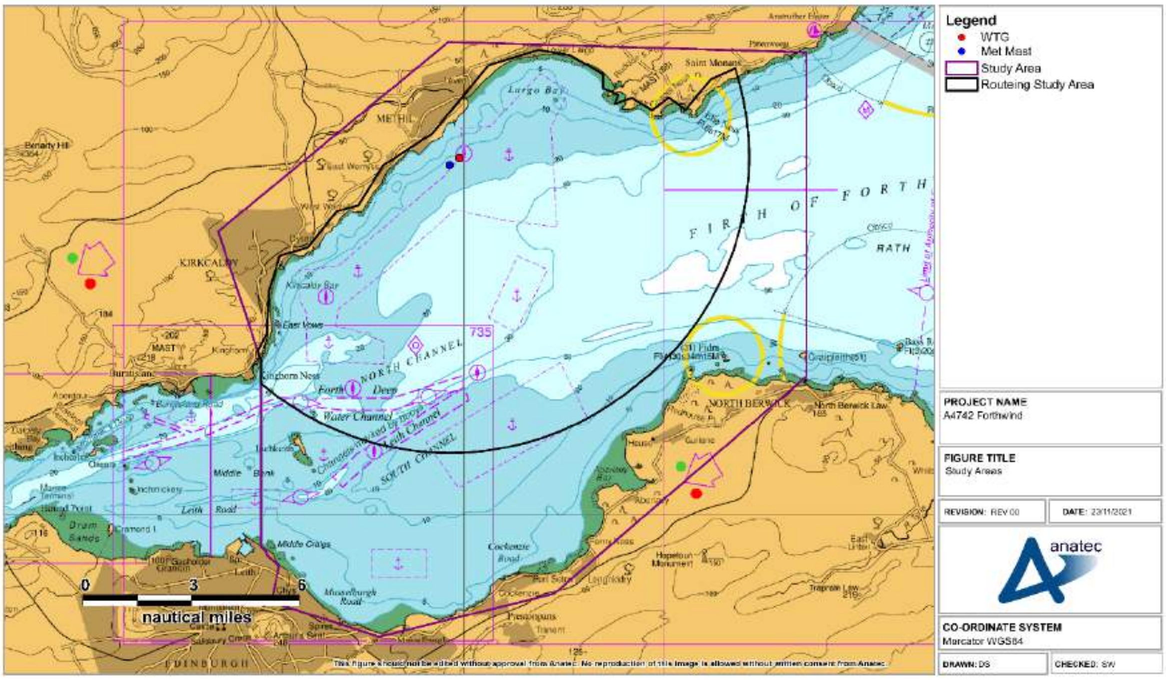

Figure 7.1 Study Areas

7.1.2 Routeing Study Area

51. For commercial vessel routeing, the traffic study area would incorporate significant volumes of vessels entering and exiting the Firth of Forth to the east and compressing for the Queensferry Bridge to the west. Such vessel traffic is not considered directly relevant to the assessment of shipping and navigation given the distance from the Proposed Development and therefore an 8 nm buffer of the two structures has been used for the purposes of identifying the main commercial routes and the collision and allision risk modelling.

7.2 Vessel Traffic Data

52. The primary vessel traffic dataset used to characterise vessel movements consists of 56 days of AIS data recorded during 2021. To account for seasonal variation, this is split into two 28-day datasets representing typical summer and winter activity:

- 24th January to 20th February 2021 (winter); and
- 3rd to 30th June 2021 (summer).

7.3 Summary of Data Sources

53. The main data sources used to characterise the shipping and navigation baseline relative to the Proposed Development are outlined in Table 7.1.

Table 7.1 Data Sources

Data	Source	Purpose
Vessel traffic	AIS data (56 days, January/February and June 2021)	Characterising vessel traffic movements in proximity to the Proposed Development.
	Anatec's ShipRoutes database (2021)	Validation of AIS data.
Maritime incidents	Royal National Lifeboat Institution (RNLI) incident data (2010 to 2019)	Characterising incident rates in proximity to the Proposed Development.
	MAIB marine accidents database (2010 to 2019)	
	Department for Transport (DfT) UK civilian SAR helicopter taskings (April 2015 to March 2021)	
Other navigational features	Admiralty Charts 734-0, 741-4 and 1407-0 (UKHO, 2021)	Characterising other navigational features in proximity to the Proposed Development.
	Admiralty Sailing Directions North Sea (West) Pilot NP54 (UKHO, 2021)	
Meteorological oceanography	*Methil Offshore Wind Farm Metocean Study* (ABPmer, 2015)	Characterising weather conditions in proximity to the Proposed Development for use as input to the collision and allision risk modelling.
	Admiralty Sailing Directions North Sea (West) Pilot NP54 (UKHO, 2021)	

7.4 Data Limitations

7.4.1 AIS Data

54. The carriage of AIS is required onboard all vessels of greater than 300 Gross Tonnage (GT) engaged on international voyages, cargo vessels of more than 500 GT not engaged on international voyages, passenger vessels irrespective of size built on or after 1st July 2002, and fishing vessels over 15 m Length Overall (LOA). Therefore, certain fishing vessels under 15 m and certain recreational craft may be underrepresented in the data. This was confirmed during consultation with RYA Scotland, although no additional data collection was deemed necessary.

7.4.2 Historical Incident Data

55. The RNLI incident data cannot be considered comprehensive of all incidents in the study area. Although hoaxes and false alarms are excluded, any incident to which an RNLI resource was not mobilised has not been accounted for in this dataset.

56. Although all UK commercial vessels are required to report accidents to the Marine Accident Investigation Branch (MAIB), non-UK vessels do not have to report unless they are in a UK port or within 12 nm territorial waters or carrying passengers to a UK port. There are also no requirements for non-commercial recreational craft to report accidents to the MAIB.

7.4.3 United Kingdom Hydrographic Office (UKHO) Charts

57. The UKHO Admiralty Charts are updated periodically and therefore the information shown may not reflect the real time features within the region with total accuracy. However, during consultation input has been sought from relevant stakeholders regarding the navigational features baseline.

8 Navigational Features

58. A plot of navigational features in proximity to the Proposed Development is presented in Figure 8.1. Each of the features shown is discussed in the following subsections and has been identified using the most detailed UKHO Admiralty Charts available.

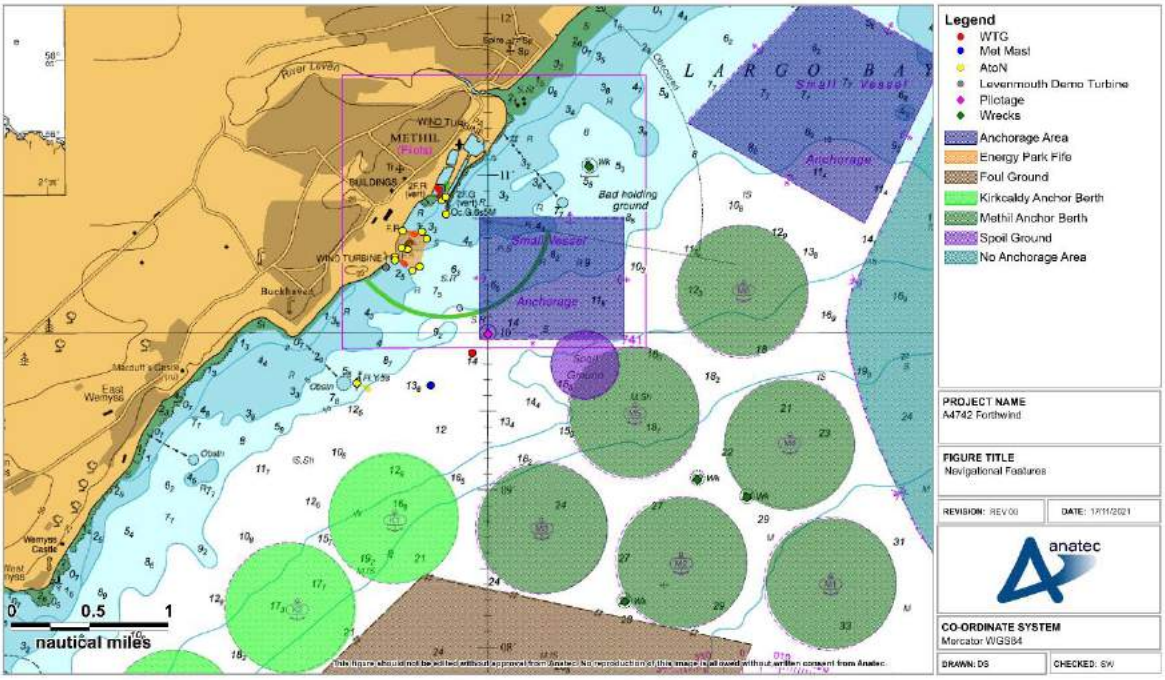

Figure 8.1 Navigational Features

8.1 Ports and Related Services

8.1.1 Ports and Harbours

59. Since the Proposed Development is situated within the Firth of Forth, there are numerous ports and harbours located in the area, as illustrated in Figure 8.2.

60. The closest port is the Port of Methil, located approximately 0.9 nm north of the Proposed Development. The Admiralty Sailing Directions describe Methil as *“a small commercial port handling timber, aggregate and general bulk cargoes”* (UKHO, 2021).

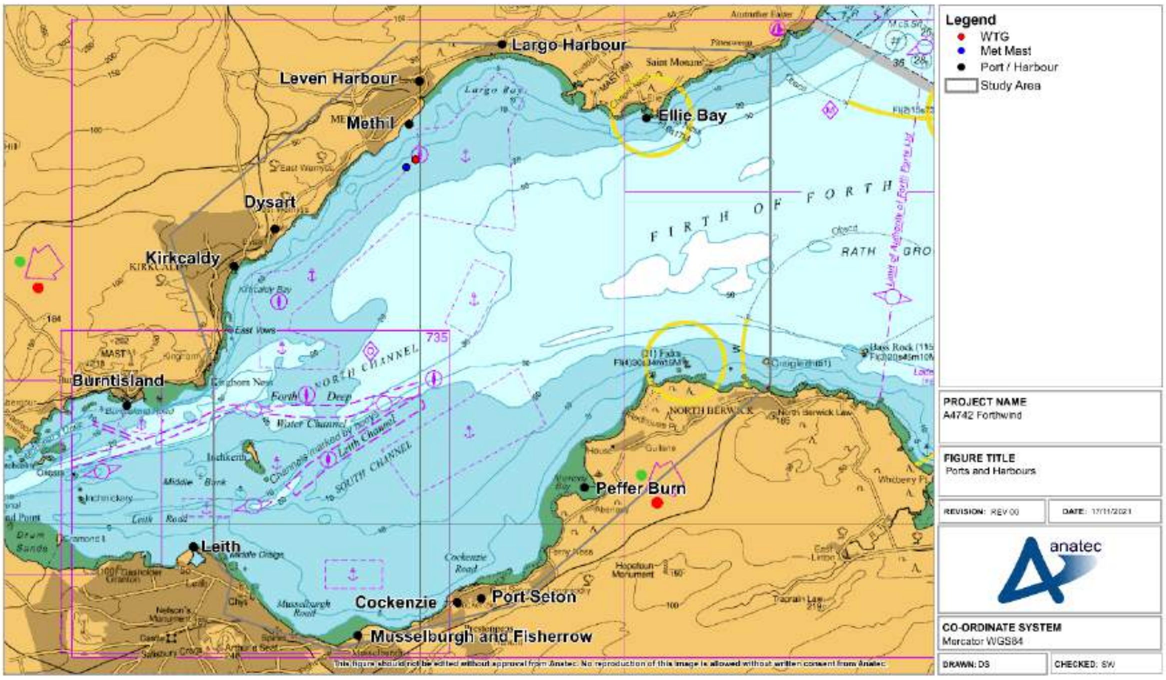

Figure 8.2 Ports and Harbours

8.1.2 Forth Ports and Vessel Traffic Service

61. The Firth of Forth lies within the area of jurisdiction of Forth Ports, the statutory harbour authority for ports within the area. A Vessel Traffic Service (VTS) – the Forth and Tay Navigation Service – is operated from Grangemouth and provides VHF and Radio Detection and Ranging (Radar) coverage of the Firth of Forth 24 hours a day.

8.1.3 Pilot Boarding Station

62. A pilot boarding station for the Port of Methil is located approximately 290 m north east of the WTG, as shown in Figure 8.1. Compulsory pilotage applies to vessels of length 45 m or more carrying dangerous cargoes, and all vessels of length 60 m or more, bound for Methil.

8.2 Anchorage Areas

63. There are numerous designated anchorage areas located in the area, as shown in Figure 8.1, with the closest being the small vessel anchorage associated with the Port of Methil, located approximately 170 m north east of the WTG. There are also deep water anchor berths associated with Methil and Kirkcaldy located south and east of the Proposed Development.

64. A no anchorage area is located approximately 2.4 nm east of the WTG and runs across the Forth to protect a gas pipeline.

8.3 Aids to Navigation

65. There are several aids to navigation situated in proximity to the Proposed Development, as shown in Figure 8.1, including:

- A special mark located approximately 0.5 nm west of the Met Mast designating a charted obstruction;
- Multiple spherical buoys located approximately 0.6 nm north west of the WTG designating the perimeter of Energy Park Fife; and
- Leading lights for the Port of Methil with a nominal range of 5 nm located approximately 0.9 nm north of the WTG.

66. The Levenmouth Demonstration Turbine is situated on the coast, approximately 0.8 nm north west of the WTG. The Craigkelly transmitter, which has three noticeable lights at night and is also situated on the coast, and was noted during consultation with RYA Scotland.

8.4 Other Charted Features

8.4.1 Spoil and Foul Grounds

67. An area of spoil ground is located approximately 940 m east of the WTG and a large area of foul ground is located approximately 1.2 nm south of the Met Mast, with the latter noted by Forth Ports during consultation as mine practice area that is no longer active.

8.4.2 Wrecks and Obstructions

68. There are no charted wrecks located in close proximity to the Proposed Development. However, there is an obstruction at a charted water depth of between 5 and 7 m below CD located approximately 0.6 nm west of the Met Mast (and marked by the special mark noted in Section 8.3).

9 Emergency Response and Historical Incidents

9.1 SAR Helicopters

9.1.1 SAR Facilities

69. Since April 2015, the Bristow Group have provided the helicopter SAR operation service in the UK with the next contract to be awarded sometime in 2022.

70. The SAR helicopter service is operated out of 10 base locations around the UK, with the closest to the Proposed Development being located at Prestwick, approximately 66 nm south west of the Proposed Development as shown in Figure 9.1. This base is the most likely to respond to any incident requiring SAR helicopter services, based upon the SAR helicopter data for the region (see Section 9.1.2)

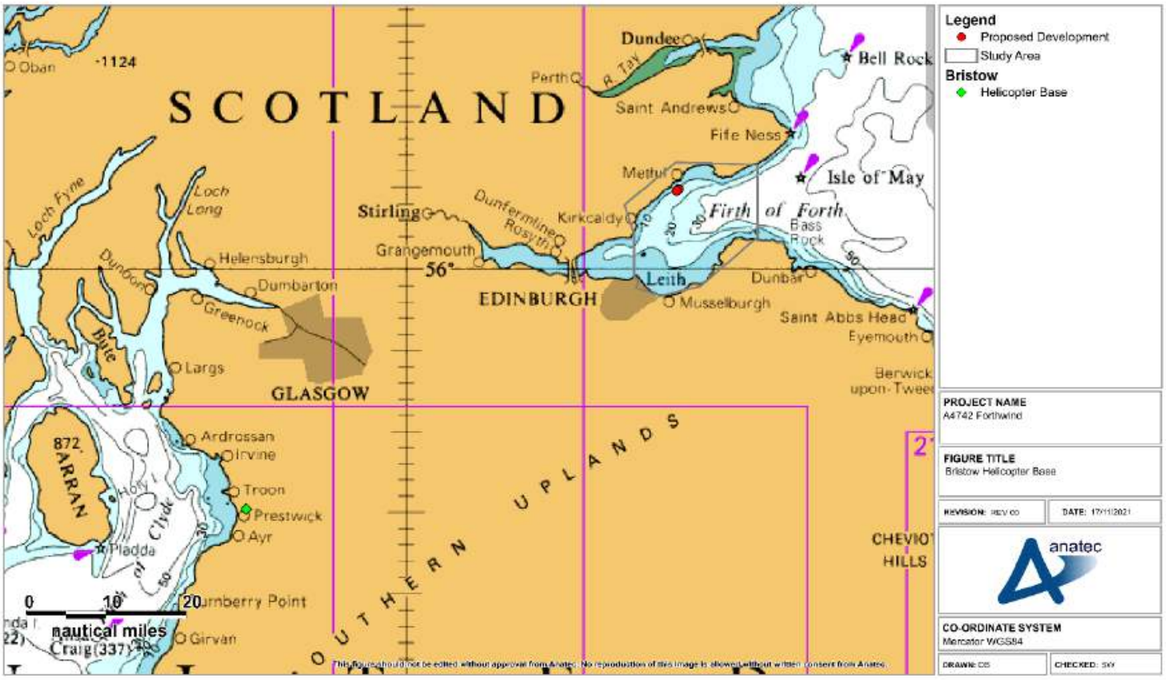

Figure 9.1 Bristow Helicopter Bases

9.1.2 DfT SAR Helicopter Taskings Data

71. The DfT has produced data on civilian SAR helicopter activity in the UK by the Bristow Group on behalf of the MCA since April 2015.

72. A total of 60 SAR helicopter taskings were undertaken for incidents within the traffic study area between April 2015 and March 2021, corresponding to an average of eight to nine taskings per year.

73. Figure 9.2 presents the SAR helicopter taskings undertaken within the traffic study area, colour coded by tasking type.

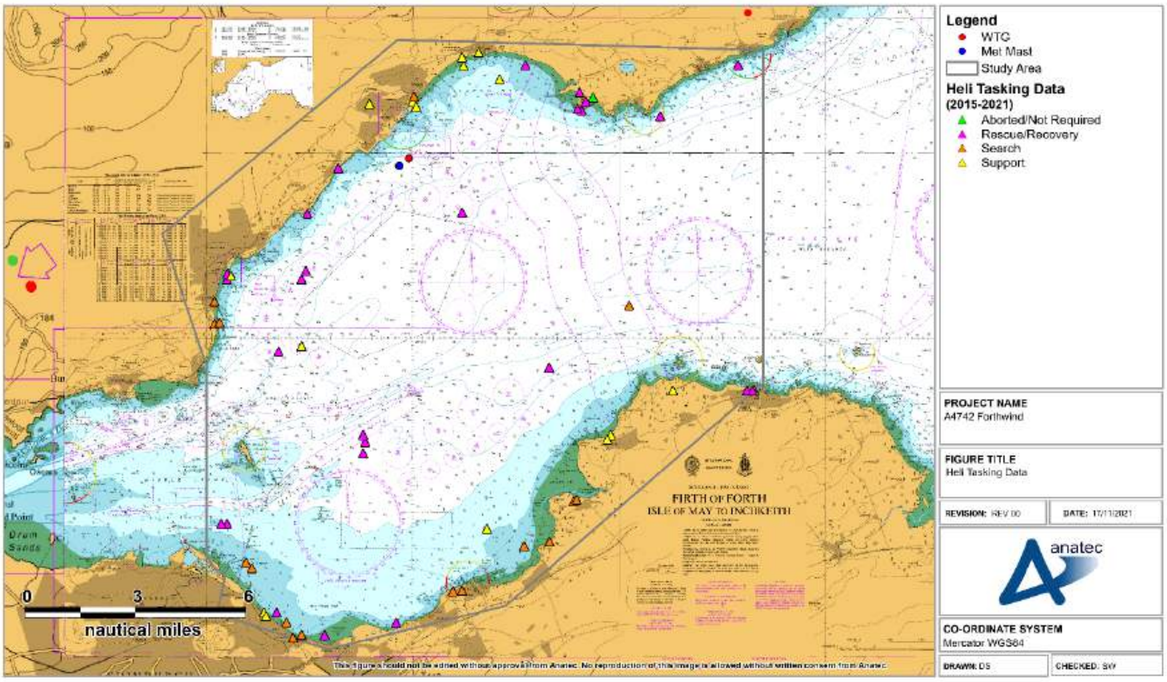

Figure 9.2 **Heli Tasking Data**

74. A total of 60 helicopter taskings were undertaken for incidents within the traffic study area, corresponding to an average of eight to nine taskings per year. The type of tasking involved was mainly distributed between “Rescue/Recovery” (43%), “Search” (28%) and “Support” (27%). Prestwick was the predominant base used for these taskings (82%).

9.2 Royal National Lifeboat Institution

9.2.1 RNLI Facilities

75. The RNLI is organised into divisions, with the relevant region for the Proposed Development being ‘Scotland’. Based out of more than 230 stations around the UK, there are over 400 active lifeboats across the RNLI fleet, including both All-Weather Lifeboats (ALB) and Inshore Lifeboats (ILB). Figure 9.3 presents the locations of RNLI stations in proximity to the Proposed Development and Table 9.1 summarises the types of lifeboat operated by the RNLI out of the five nearby stations.

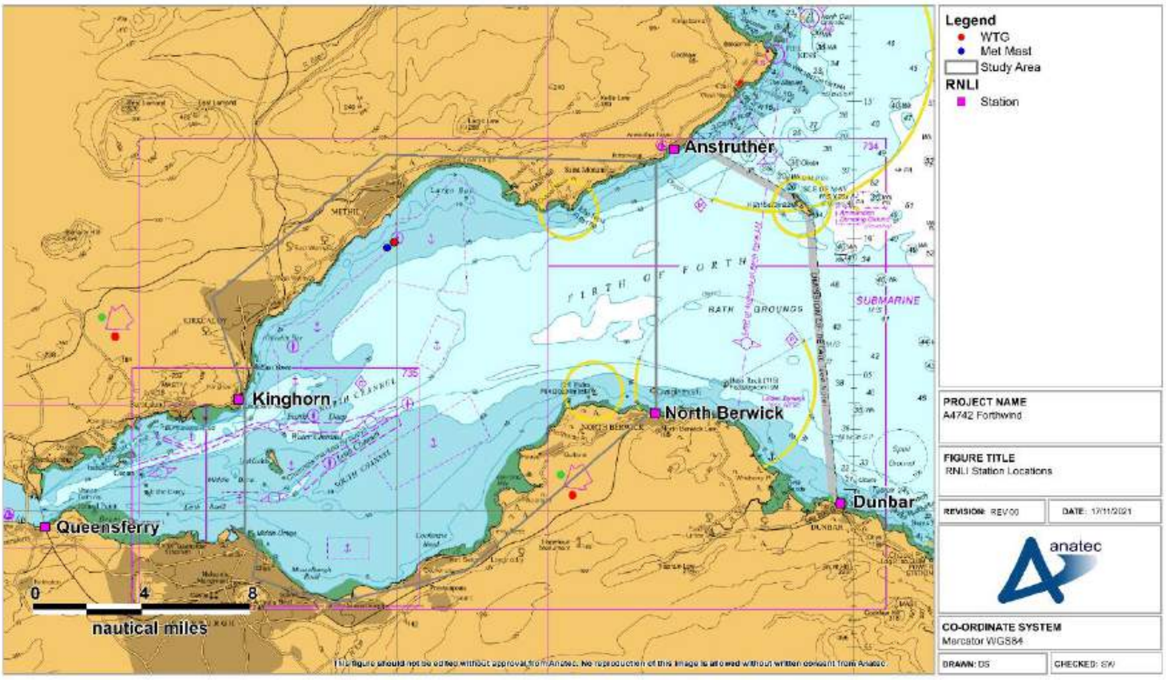

Figure 9.3 RNLI Station Locations

Table 9.1 RNLI Station Details

Station	Lifeboat(s)	ALB Class	ILB Class	Minimum Distance to Proposed Development (nm)
Kinghorn	ILB	–	B Class	7.8
Anstruther	ALB and ILB	Mersey	D Class	10.8
North Berwick	ILB	–	D Class	11.4
Queensferry	ILB	–	B Class	16.2
Dunbar	ALB and ILB	Trent	D Class	19.0

76. RNLI lifeboats are available on a 24-hour basis throughout the year. Given the proximity of the nearest stations to the Proposed Development, it is likely that an RNLI lifeboat would be launched to an incident which occurred in proximity to the Proposed Development.

9.2.2 RNLI Incident Data

77. The incidents responded to by the RNLI within the traffic study area between 2010 and 2019 are presented in Figure 9.4, colour-coded by incident type.

78. A total of 358 incidents were recorded by the RNLI within the study area between 2010 and 2019, which corresponds to an average of 36 incidents per year, noting that eight of these incidents occurred within 1 nm of the Proposed Development and details of these are presented in Table 9.2.

Table 9.2 RNLI Incidents with 1 nm of the Proposed Development

Year of Incident	Incident Type	Distance from Proposed Development (nm)
2018	Unspecified	0.5
2010	Person in Danger	0.8
2013	Machinery Failure	0.8
2015	Person in Danger	0.8
2011	Person in Danger	0.9
2017	Machinery Failure	0.9
2010	Person in Danger	1.0
2011	Person in Danger	1.0

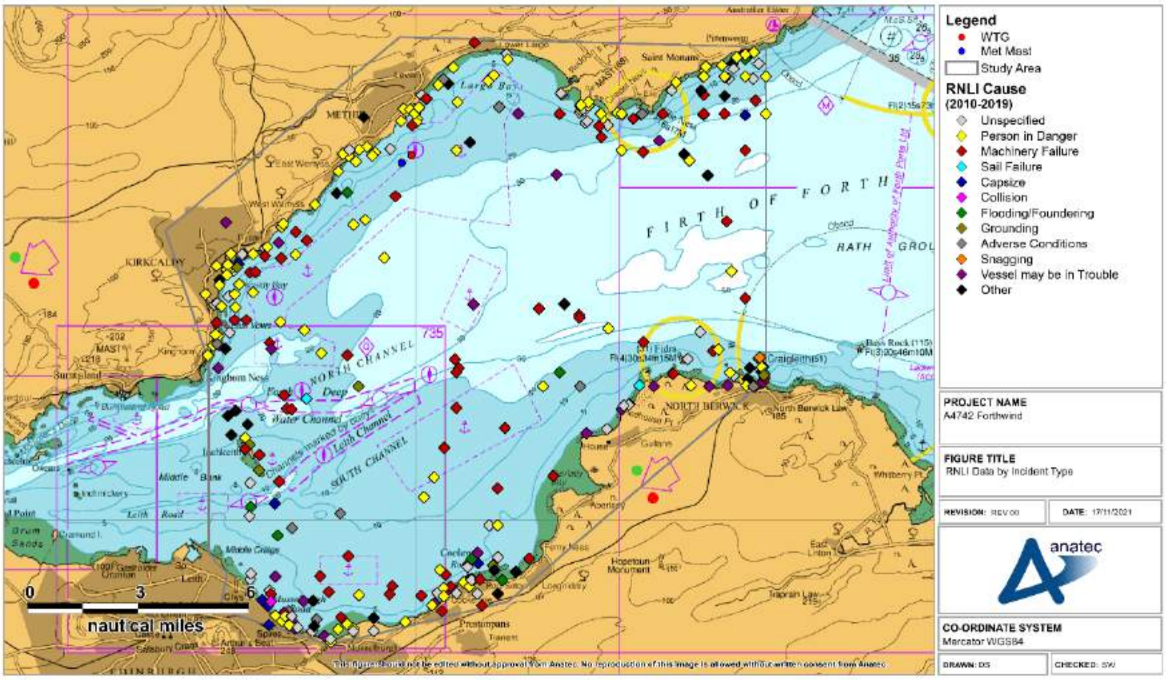

Figure 9.4 RNLI Data by Incident Type

79. There were 358 RNLI incidents recorded within the traffic study area between 2010 and 2019. The most common incident types were “Person in Danger” (35%) and “Machinery Failure” (19%). In terms of casualty type, “Person in Danger” (35%) was again the most common, followed by “Recreational” (25%). Kinghorn (58%) was the

station most commonly responding to incidents within the traffic study area, followed by Anstruther (24%) and North Berwick (13%)

9.3 Marine Accident Investigation Branch

9.3.1 Data Between 2010 and 2019

80. The incidents recorded by the MAIB within the traffic study area between 2010 and 2019 are presented in Figure 9.5, colour-coded by incident type.

81. A total of 32 incidents were reported to the MAIB within the traffic study area between 2010 and 2019, which corresponds to an average of four incidents per year. None of these incidents were within 1 nm of the Proposed Development, with the closest being a hazardous incident located approximately 3.3 nm south of the Proposed Development.

82. The most common incident types were "Machinery Failure", which accounted for 38% of the total, followed by "Accident to Person" (16%) and "Hazardous Incident" (13%). The vessel types involved in incidents were predominantly fishing vessels (63%).

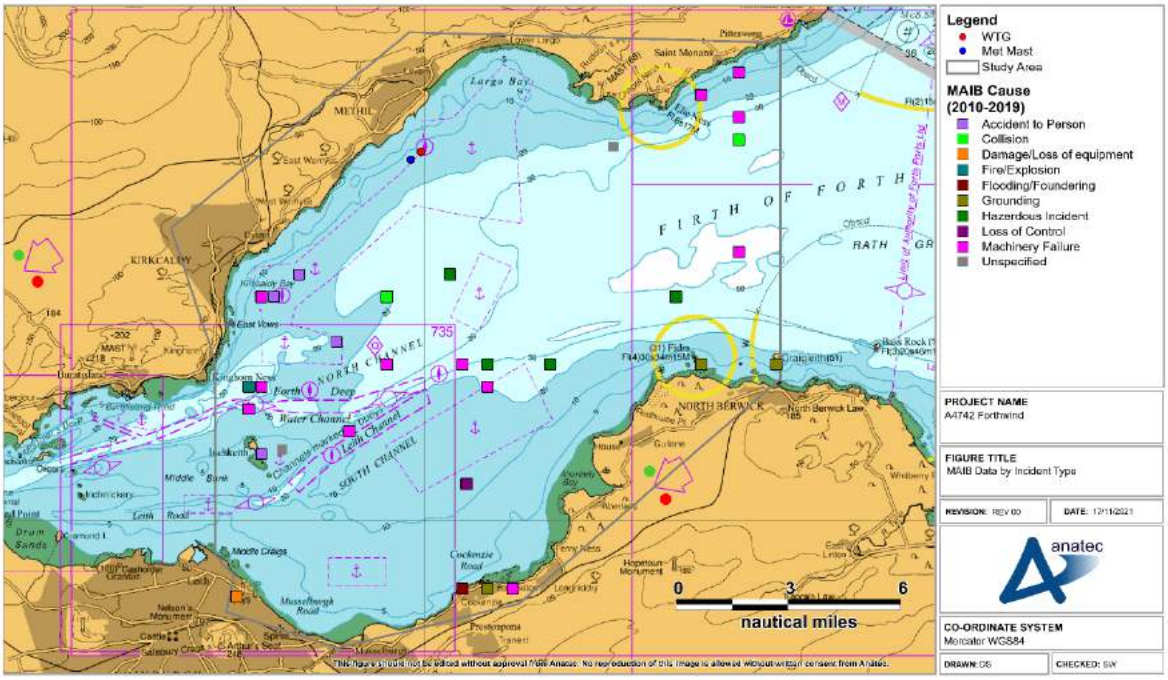

Figure 9.5 MAIB Data by Incident Type

9.3.2 Data Between 2000 and 2009

83. A high level review of an additional 10 years of MAIB incident data covering between 2000 and 2009 has also been undertaken although the most recent ten years available (Section 9.3.1) has remained the focus of the analysis.

84. A total of 74 incidents were reported to the MAIB within the traffic study area during the 10-year period between 2000 and 2009, which corresponds to an average of seven incidents per year. One incident occurred within 1 nm of the Proposed Development, this was a "Hazardous Incident" involving a fishing vessel recorded in 2007.

9.4 Her Majesty's Coastguard (HMCG)

85. HMCG, a division of the MCA, is responsible for requesting and tasking SAR resources made available to other authorities and for coordinating the subsequent SAR operations (unless the fall within military jurisdiction).

86. The HMCG coordinates SAR operations through a network of nine Maritime Rescue Coordination Centres (MRCC), a Maritime Rescue Sub Centre (MRSC) in London and the Joint Rescue Coordination Centre (JRCC) based in Hampshire. A corps of up to 3,500 volunteer Coastguard Rescue Officers (CRO) around the UK from around 350 Coastguard Rescue Teams (CRT) are involved in coastal rescue, searches, and surveillance.

87. All of the MCA's operations, including SAR, are divided into three geographical regions. The 'Scotland' region covers the area encompassing the Proposed Development. Each region is itself divided in six districts with its own MRCC, which coordinates the SAR response for maritime and coastal emergencies within its district boundaries. The closest MRCC to the Proposed Development is located in Anstruther, approximately 10.8 nm east of the proposed development.

9.5 Historical Wind Farm Incidents

88. As of November 2021, there are 39 fully commissioned and operational offshore wind farms in the UK, ranging from the North Hoyle Offshore Wind Farm (fully commissioned in 2003) to Kincardine Offshore Wind Farm (fully commissioned in 2021). To date, these developments consist of approximately 17,000 fully operational wind turbine years.

9.5.1 Incidents Involving UK Offshore Wind Farm Developments

89. MAIB incident data has been used to collate a list of historical collision and allision incidents involving UK offshore wind farm developments. Other sources have also been used to produce this list include the UK Confidential Human Factors Incident Reporting Programme (CHIRP) for Aviation and Maritime, International Marine Contractors Association (IMCA) and basic web searches. It is noted that this list is limited to collision and allision incidents given their specific relevance to shipping and navigation. It should also be considered that only incidents which have been formally reported are captured.

90. A total of 13 incidents are noted involving 15 vessels. Ten of the incidents were allisions, with eight of these involving a WTG (the others involved a disused pile and

buoy). Nine of the allisions involved a project vessel with the other involving a third-party fishing vessel.

91. Two of the incidents were collisions, one of which featured a project vessel colliding with a service vessel and other a project vessel colliding with a third-party vessel (within a harbour).

92. The worst consequences reported for vessels involved in a collision or allision incident involving a UK offshore wind farm development has been minor flooding, with no life-threatening injuries to persons reported.

93. As of November 2021, there have been no collisions involving third-party vessels as a result of the presence of an offshore wind farm in the UK, noting that the only collision incident involving a third-party vessel occurred within a harbour rather than at the location of the associated offshore wind farm development.

94. As of November 2021, there have been ten reported[2] cases of an allision between a vessel and a WTG (under construction, operational or disused) in the UK, with all but one involving a support vessel for the development and the errant vessel in each case under power rather than drifting. Therefore, there has been an average of approximately 1,700 years per WTG allision incident in the UK, noting that this is a conservative calculation given that only operational WTG hours have been included (whereas allision incidents counted include non-operational WTG).

9.5.2 Incidents Responded to by Vessels Associated with UK Offshore Wind Farm Developments

95. From news reports, basic web searches and experience at working with existing offshore wind farm developments, a list has been collated of historical incidents responded to by vessels associated with UK offshore wind farm developments. The list is comprised of only known incidents that were responded to by a wind farm vessel. Additional incidents associated with offshore wind farms themselves (typically involving an accident to person which requires medical attention, including emergency response, but does not affect the operation of the vessel involved) are also known to have occurred.

96. A total of 12 incidents are noted, involving a variety of incident types including (but not limited to) capsize, drifting, machinery failure and fire/explosion. None of these incidents were caused by or related directly to the offshore wind farm from which the responding vessel was associated.

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[2] Reported to an accident investigation branch or an anonymous reporting service. Unconfirmed incidents have not been considered noting that to date one further alleged incident has been rumoured but there is no evidence to confirm.

10 Vessel Traffic Movements

97. This section presents the results of analysis of 56 days of vessel traffic data. This dataset consists of two 28-day datasets to account for seasonal variation, as described in Section 7.2.

98. A number of vessel tracks recorded were classified as temporary (non-routine), such as tracks associated with survey operations. These have therefore been excluded from the analysis. Oil and gas platforms/drilling rigs moored within the traffic study area have been retained for analysis.

99. Figure 10.1 presents the vessels recorded (excluding temporary vessels) throughout the survey period within the traffic study area, colour-coded by vessel type. Following this, Figure 10.2 presents the corresponding vessel density.

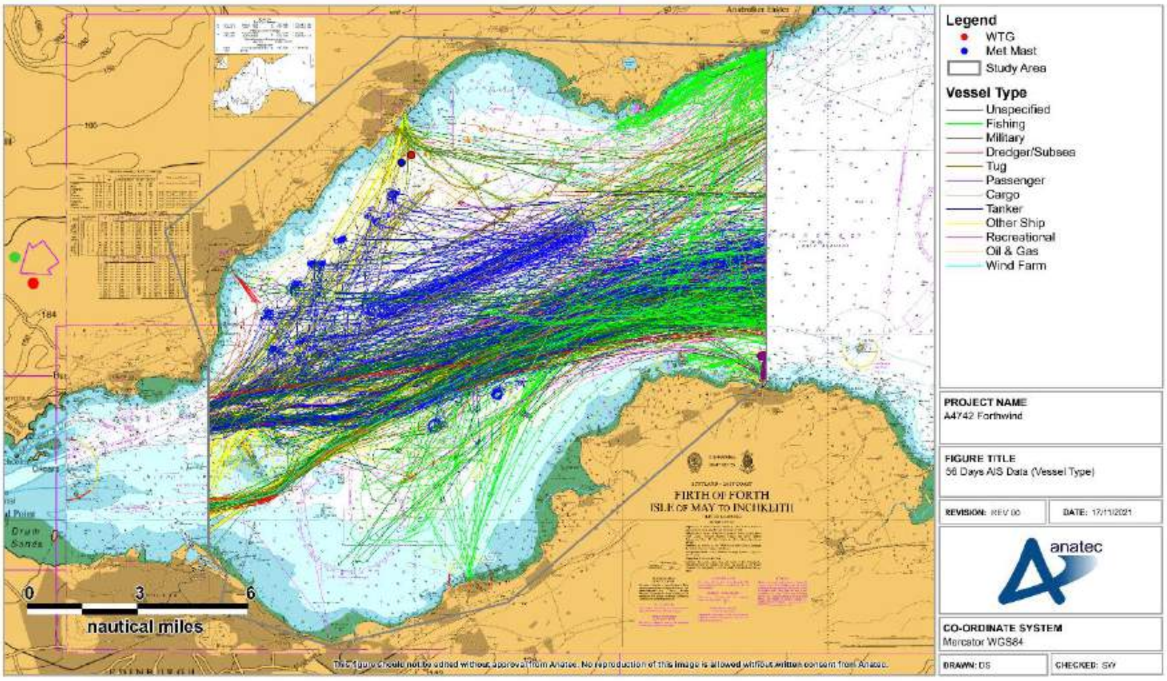

Figure 10.1 56 Days AIS Data (Vessel Type)

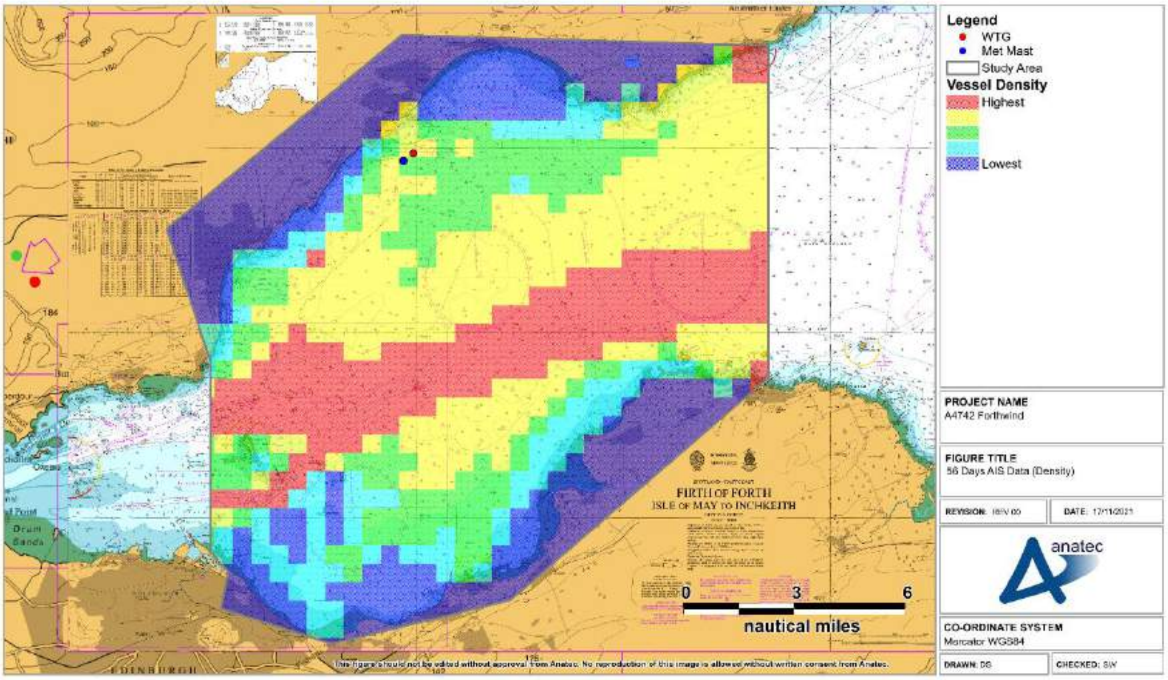

Figure 10.2 56 Days AIS Data (Density)

10.1 Vessel Counts

100. The number of unique vessels recorded per day within the study area is presented in Figure 10.3. Following this, Table 10.1 presents the unique number of vessels recorded during the busiest day, quietest day and average during the survey period within the study area.

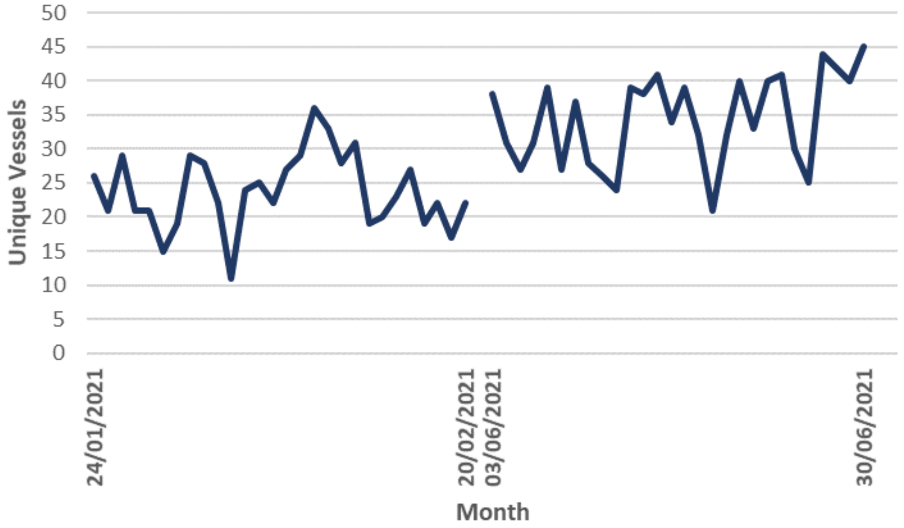

Figure 10.3 Unique Vessels Per Day

Table 10.1 Summary of Unique Vessels Recorded within Traffic Study Area

	Busiest Day	Quietest Day	Average
Summer	45	21	34
Winter	36	11	24
Combined	45	11	29
Date	30th June 2021	3rd February 2021	N/A

10.2 Vessel Types

101. The relative proportions of vessel types recorded within the study area during the survey period are presented in Figure 10.4.

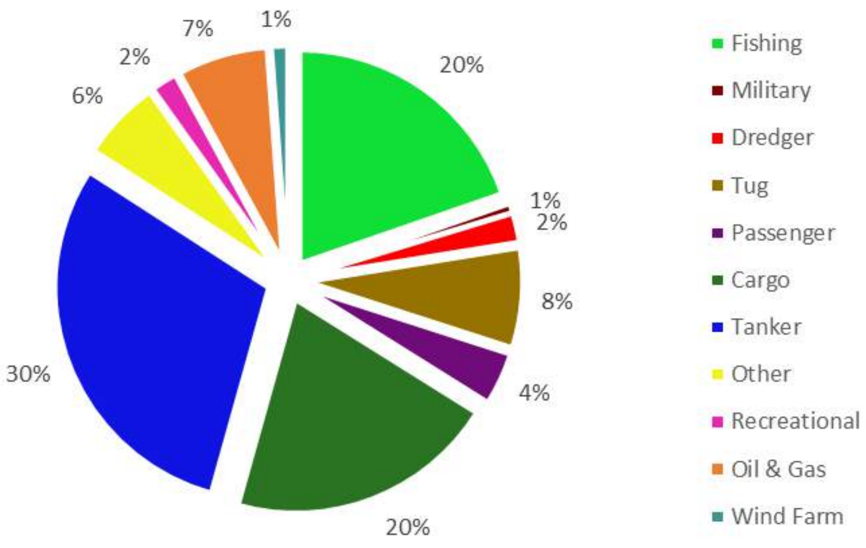

Figure 10.4 Vessel Type Distribution

102. The main vessel types recorded throughout the survey period within the study area were tankers (30%), cargo vessels (20%) and commercial fishing vessels (20%). This excludes traffic that was unspecified (less than 1%).

10.2.1 Tankers

103. Figure 10.5 presents a plot of tankers recorded throughout the survey period within the traffic study area.

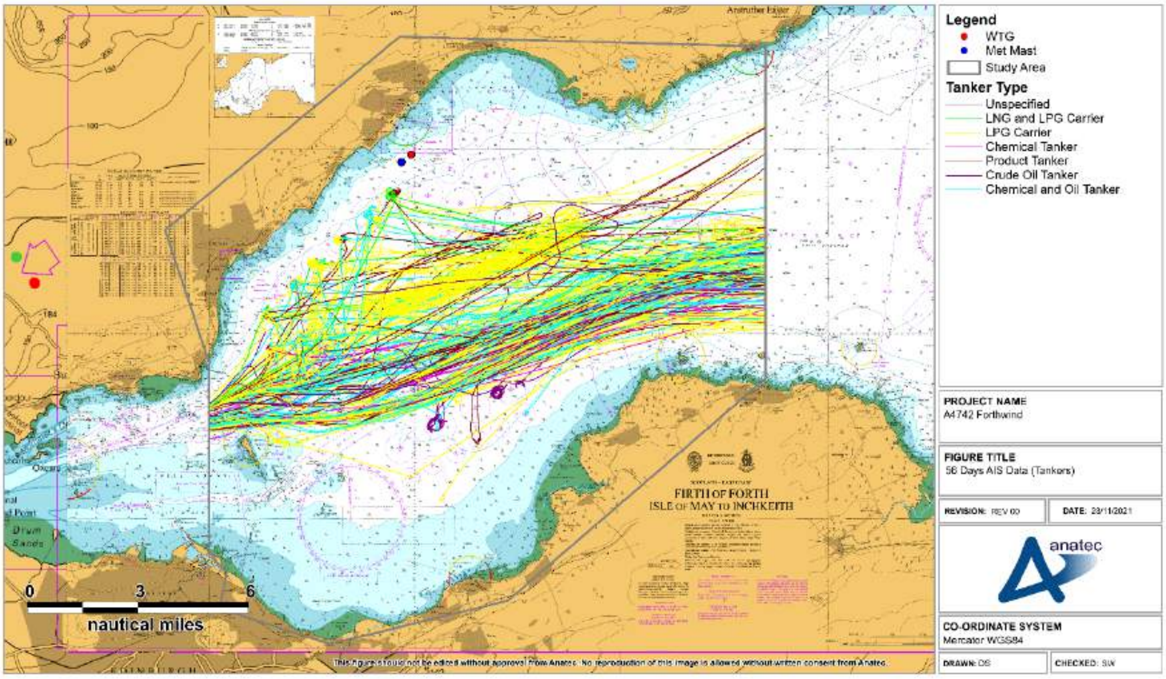

Figure 10.5 56 Days AIS (Tankers)

104. An average of eight to nine unique tankers per day were recorded within the traffic study area during the survey period, with the most common type being Liquid Petroleum Gas (LPG) carriers (48%).

105. Tankers were noted making use of the Kirkcaldy anchorage berths, the closest of which is located approximately 0.5 nm south of the Proposed Development. Further details on anchored vessels are provided in Section 10.2.6.

10.2.2 Cargo Vessels

106. Figure 10.6 presents a plot of cargo vessels recorded throughout the survey period within the traffic study area.

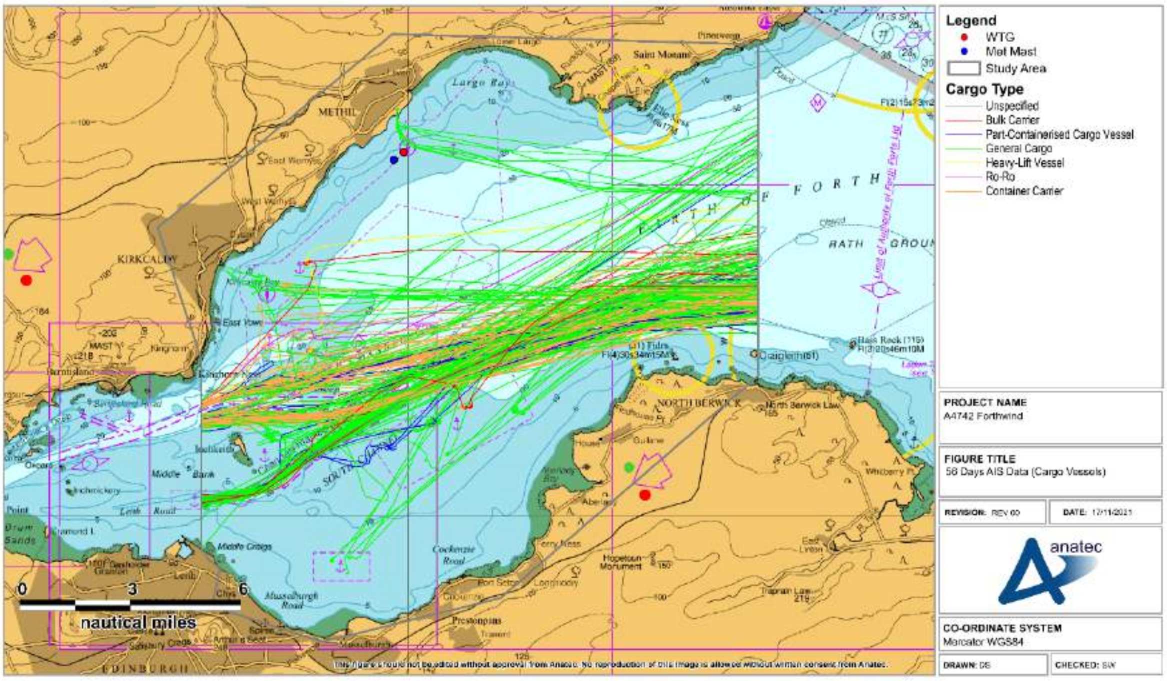

Figure 10.6 56 Days AIS (Cargo Vessels)

107. An average of six unique cargo vessels per day were recorded during the survey period within the traffic study area. The most common cargo type was general cargo (57%), followed by container carriers (30%).

108. Cargo vessels were typically recorded on transit through the Firth of Forth heading for major ports such as Grangemouth. A proportion of cargo vessels were noted utilising the Kirkcaldy anchorage berths. Further details on anchored vessels are provided in Section 10.2.6.

10.2.3 Commercial Fishing Vessels

109. Figure 10.7 presents a plot of commercial fishing vessels recorded throughout the survey period within the traffic study area.

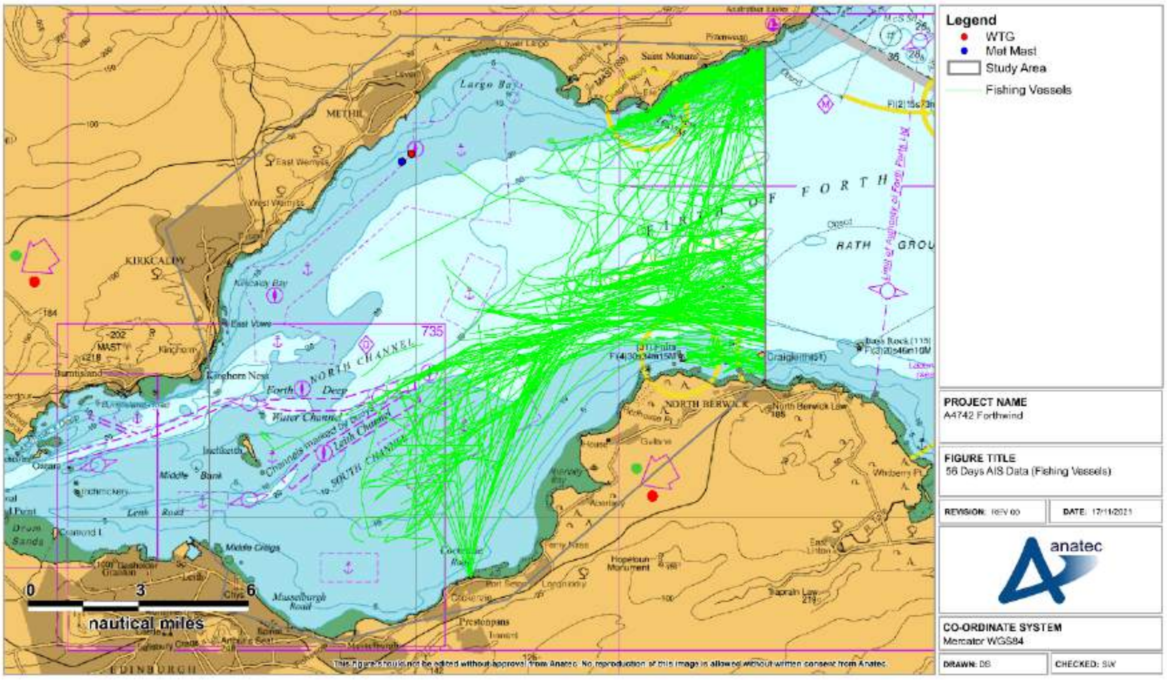

Figure 10.7 56 Days AIS (Commercial Fishing Vessels)

110. An average of six unique commercial fishing vessels were recorded during the survey period within the traffic study area. This included vessels in transit and those engaged in fishing (i.e., gear deployed).

111. Commercial fishing vessel traffic in general was recorded at the south and east of the traffic study area, typically operating out of Pittenweem, Cockenzie and Port Seton. Commercial fishing vessels were typically recorded on transit within the traffic study area, with active fishing undertaken further east on both the north and south coasts of the Forth.

112. Commercial fishing vessel activity in close proximity to the Proposed Development was very low. It is noted that as per consultation feedback, there are smaller commercial fishing vessels operate in the area which do not broadcast on AIS or which turn their AIS off whilst engaged in fishing activities.

10.2.4 Tugs

113. Figure 10.8 presents a plot of tugs recorded throughout the survey period within the traffic study area.

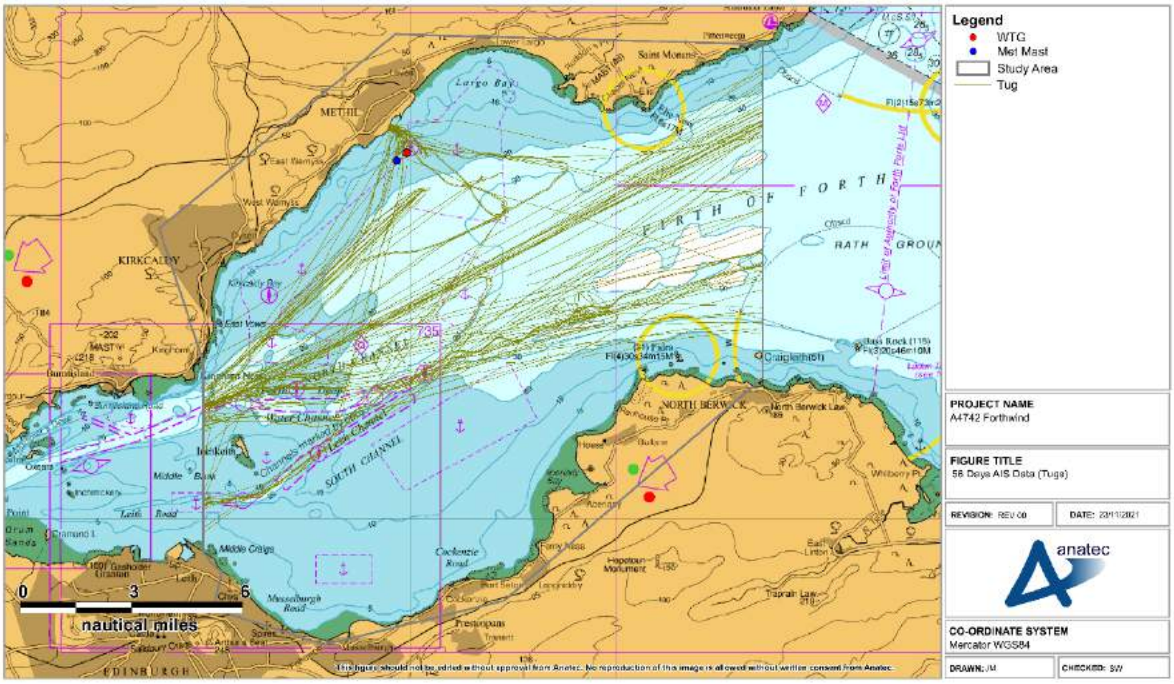

Figure 10.8 56 Days AIS (Tugs)

114. An average of two unique tugs per day were recorded during the survey period within the traffic study area.

115. Tugs were typically recorded on transit either through the Firth of Forth or in and out of the Port of Methil in proximity to the Proposed Development.

10.2.5 Recreational Vessels

116. Figure 10.10 presents a plot of recreational vessels recorded throughout the survey period within the traffic study area.

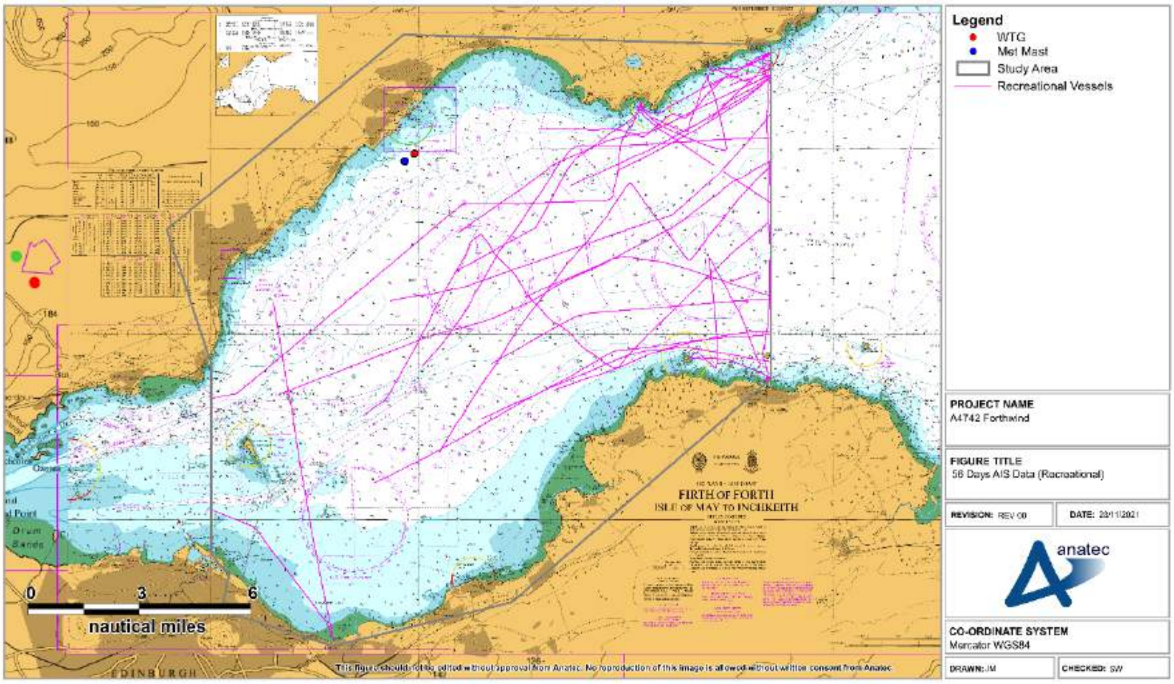

Figure 10.9 56 Days AIS (Recreational Vessels)

117. An average of one unique recreational vessel every two days was recorded during the survey period within the traffic study area.

118. Recreational vessel traffic in general was recorded at the east of the traffic study area, with activity noted out of Elie Bay and North Berwick. There are coverage limitations at the west of the traffic study area, and it is noted that non-AIS traffic is not included.

119. However, consultation feedback including the Hazard Workshop indicates that the majority of recreational vessel traffic (inclusive of non-AIS traffic) passes though the Firth of Forth or is headed to Port Edgar and Granton. Cruising routes are generally located in inshore areas and there a significant number of beach landings at Largo Bay and Elie where angling boats are launched from.

10.2.6 Anchored Vessels

120. Anchored vessels can be identified based upon the AIS navigational status which is programmed on the AIS transmitter on board a vessel. However, information is manually entered into the AIS, and therefore it is common for vessels not to update their navigational status if only at anchor for a short period of time.

121. For this reason, those vessels which travelled at a speed of less than 1 kt for more than 30 minutes had their corresponding vessel tracks individually checked for patterns characteristic of anchoring activity.

122. Figure 10.10 presents a plot of anchored vessels, recorded throughout the survey period within the traffic study area. A detailed view of the anchoring activity, including the designated anchorages in the area, is shown in Figure 10.11.

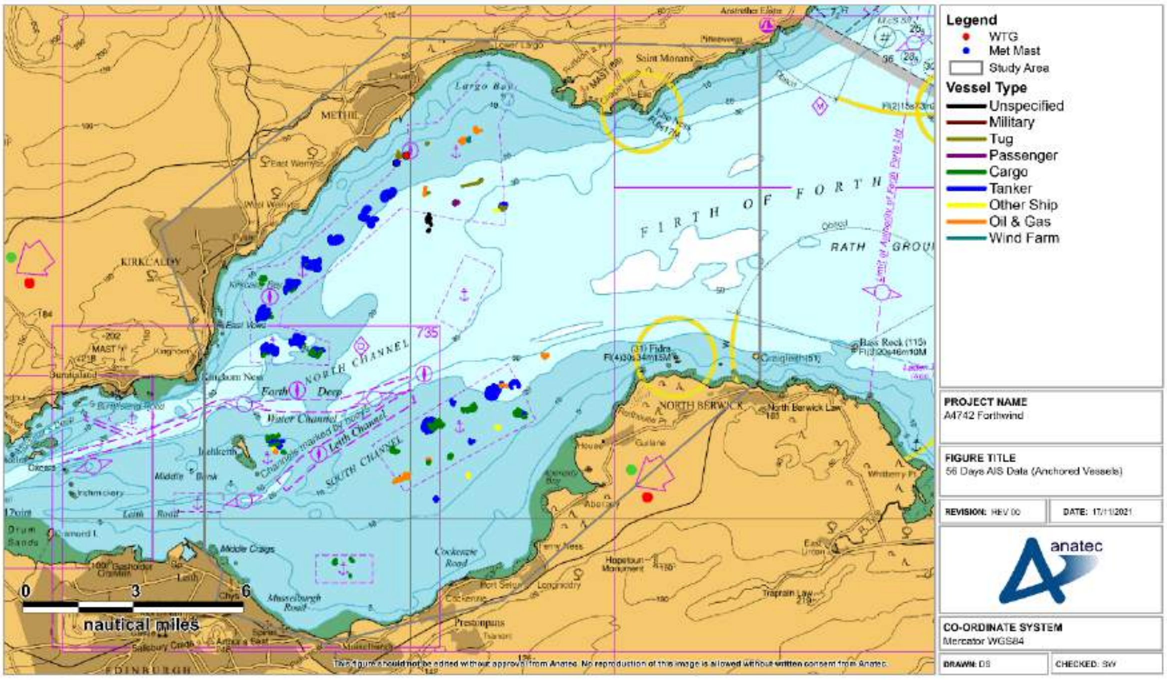

Figure 10.10 56 Days AIS (Anchored Vessels)

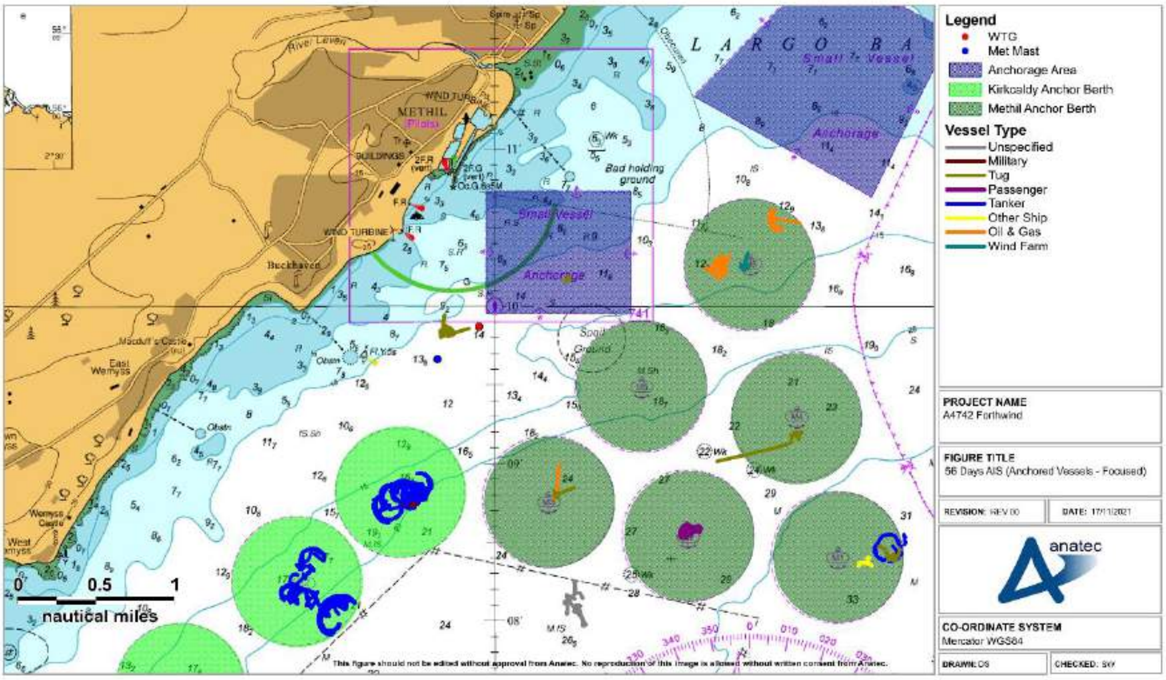

Figure 10.11 56 Days AIS (Anchored Vessels - Focused)

123. An average of ten unique vessels per day were recorded at anchor within the traffic study area during the survey period, the majority of which were tankers (57%). It is noted that consultation feedback indicated that when present semi-submersibles generally anchor within the designated anchorages for the Port of Methil.

124. Vessels typically anchored within the various charted anchorage areas. One tug was noted anchoring between the WTG and Met Mast locations on 14 unique days – this occurred during the summer period and was associated with operations at Energy Park Fife.

10.3 Vessel Size

125. Vessel length was available for approximately 87% of vessels recorded during the survey period.

126. Figure 10.12 presents the vessels recorded throughout the survey period within the traffic study area, colour-coded by vessel length. Following this, Figure 10.13 presents the distribution of vessel length.

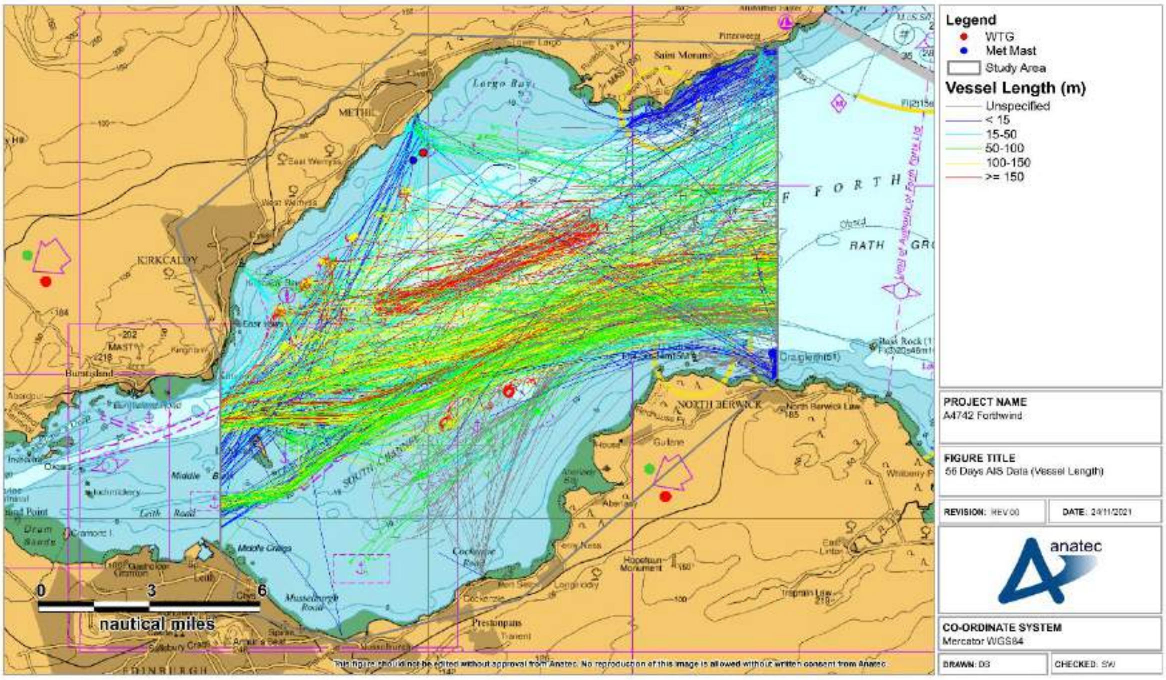

Figure 10.12 56 Days AIS (Vessel Length)

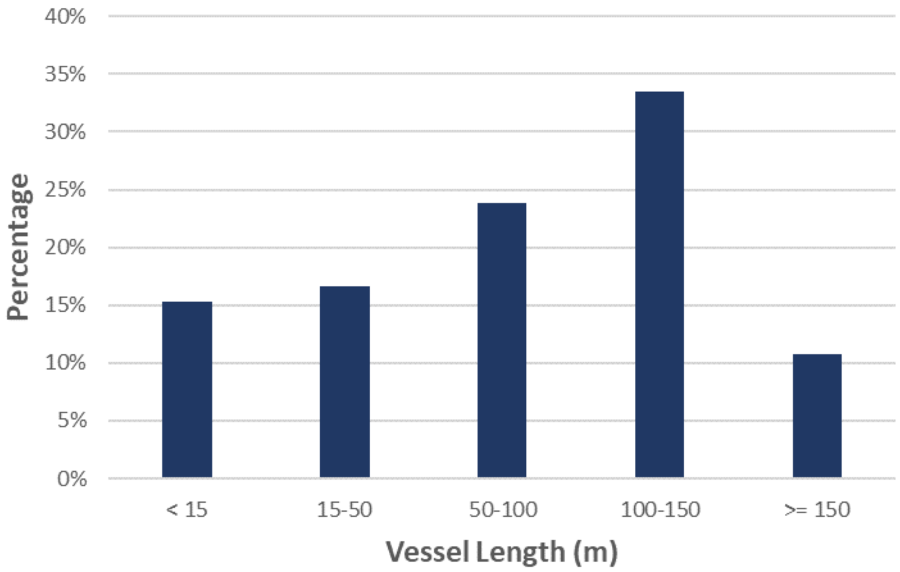

Figure 10.13 Vessel Length Distribution

127. The average length of all vessels (excluding unspecified) was 87 m. The largest vessel recorded was a crane vessel, with a length of 382 m. This vessel was recorded at anchor approximately 2.9 nm south east of the Proposed Development. The smallest vessels recorded were both Class D Lifeboats for the RNLI with a length of 5 m.

128. The smaller vessels (<50 m) in the traffic study area were typically inshore and accessing smaller ports while the larger vessels were seen at anchor or transiting through the traffic study area to the larger ports in the Firth of Forth.

10.4 Vessel Draught

129. The vessel draught information was available for 67% of vessels recorded during the survey period. Figure 10.14 presents the vessels recorded throughout the survey period within the traffic study area, colour-coded by vessel draught. Following this, Figure 10.15 presents the distribution of vessel draught.

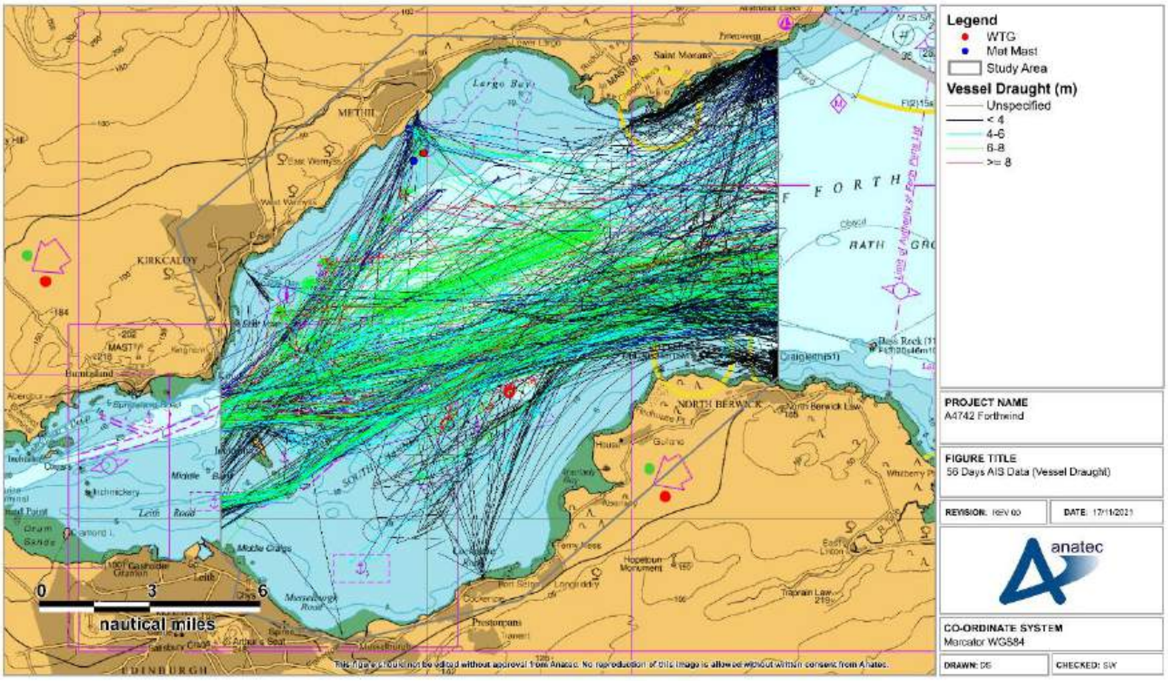

Figure 10.14 56 Days AIS (Vessel Draught)

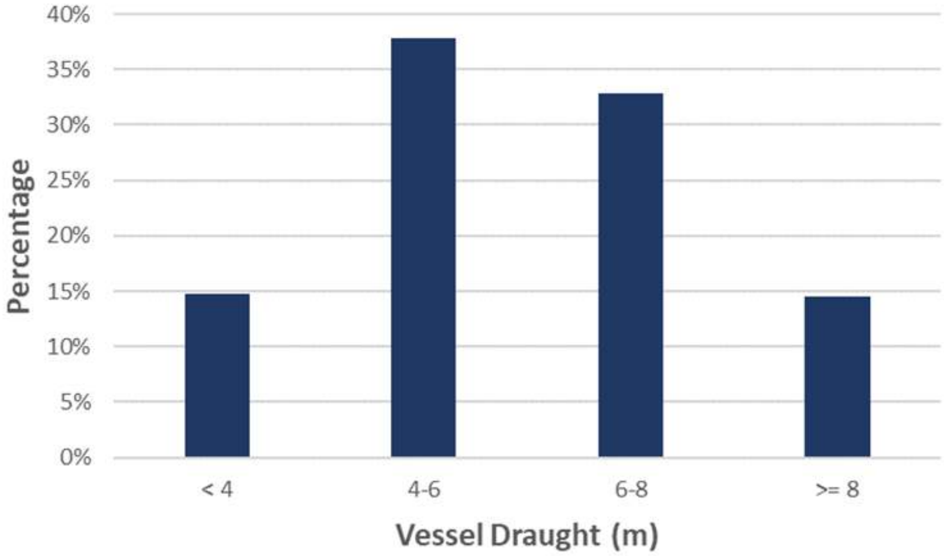

Figure 10.15 Vessel Draught Distribution

130. The average draught recorded (excluding vessels with an unspecified draught) was 6.0 m, however it should be considered that cases where draught information was unavailable tended to be associated with small craft. On this basis, it is likely that the true average draught less than 6.0 m.

131. The vessel with the largest draught was a crane vessel, with a draught of 21.8 m. It is noted that this was also the vessel with the largest length recorded (see Section 10.3).

132. Vessels with larger draughts were typically on transit through the traffic study area to/from the major ports within the Firth of Forth.

10.5 Vessel Routeing

10.5.1 Definition of a Main Commercial Route

133. Main commercial routes have been identified using the principles set out in MGN 654 (MCA, 2021). Vessel traffic data are assessed and vessels transiting at similar headings and locations are identified as a main commercial route. To help identify main commercial routes, vessel traffic data can also be analysed to show vessels (by name and/or operator) that frequently transit those routes identifying 'regular runner/operator routes'. The route width is then calculated using 90th percentile rule from the median line of the potential shipping route as shown in Figure 10.16.

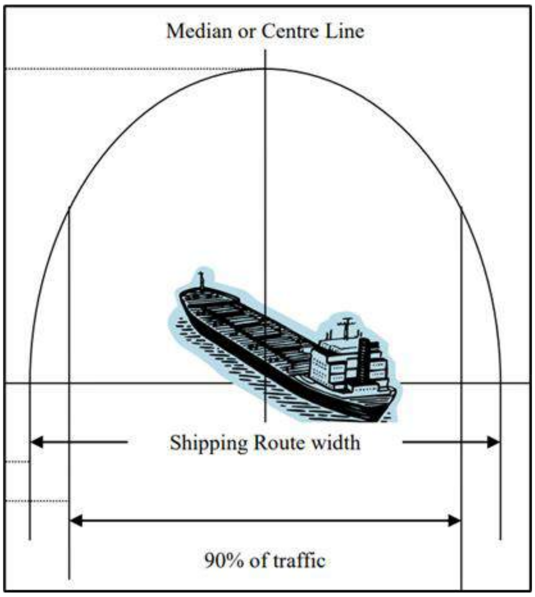

Figure 10.16 Illustration of Main Route Calculation (MCA, 2021)

10.5.2 Pre Wind Farm Main Commercial Routes

134. A total of nine main commercial routes were identified from the AIS data studied within the routeing study area. These routes and corresponding 90th percentiles are shown relative to the Proposed Development in Figure 10.17.

135. Following this, relevant details of each route are given in Table 10.2. This includes key destinations; however it should be considered that these are based on the most common destinations transmitted via AIS by vessels on those routes and therefore it should not be assumed that a transit on a given route will to be one of the destinations listed.

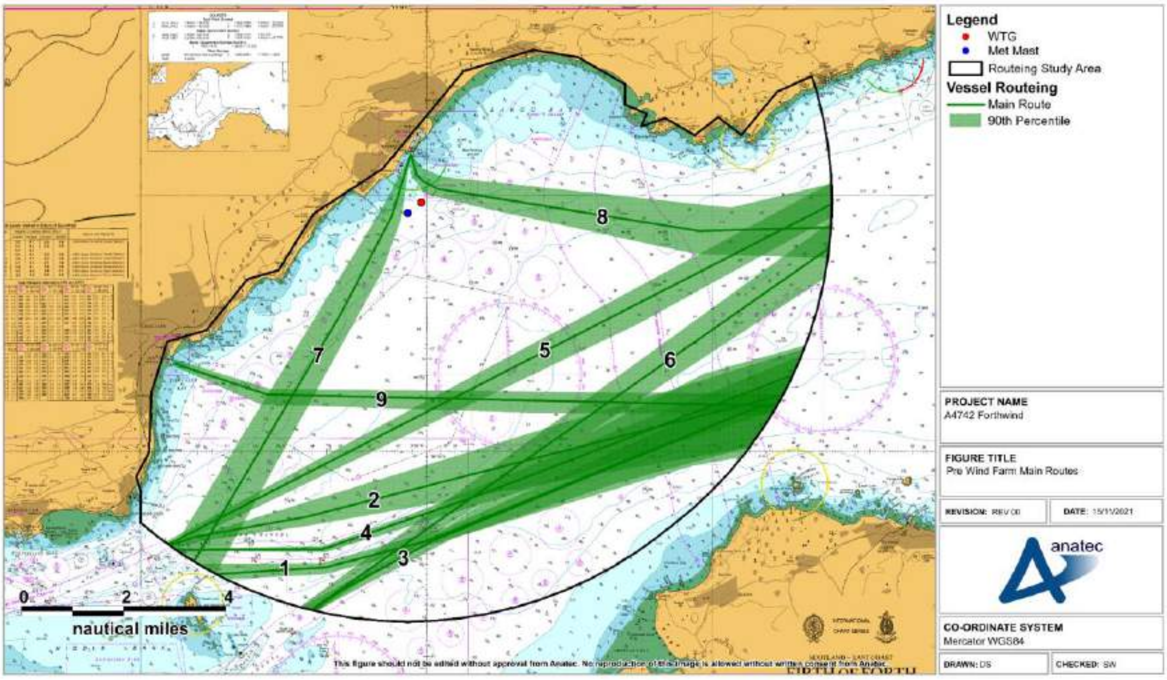

Figure 10.17 Pre Wind Farm Main Commercial Routes

Table 10.2 Main Commercial Route Details

Route	Key Destinations	Vessels per Day	Vessel Type Breakdown
1	Grangemouth (UK) to Rotterdam (Netherlands)	2 to 3	Tankers (54%) and cargo vessels (46%).
2	Rotterdam to Grangemouth	1 to 2	Cargo vessels (62%) and tankers (38%).
3	Leith (UK) / Mukran (Germany)	0 to 1	Cargo vessels (100%).
4	Rotterdam / Grangemouth	0 to 1	Tankers (48%), cargo vessels (33%) and oil and gas vessels (19%).
5	Scapa Flow (UK) / Grangemouth	0 to 1	Oil and gas vessels (59%), cargo vessels (24%) and tankers (17%).
6	Leith / Tay (UK)	0 to 1	Oil and gas vessels (62%), cargo vessels (38%).
7	Leith / Methil (UK)	0 to 1	Pilot vessels (60%) and tugs (40%).
8	Methil / Montrose (UK)	0 to 1	Tugs (51%) and cargo vessels (49%).
9	Antwerp (Belgium) / Kirkcaldy (UK)	0 to 1	Cargo vessels (100%).

10.5.3 Adverse Weather Routeing

136. Adverse weather includes wind, wave, and tidal conditions as well as reduced visibility due to fog that can hinder a vessel's standard route and/or speed of navigation. Adverse weather routes are assessed to be significant course adjustments to mitigate vessel motion in adverse weather conditions. When transiting in adverse weather conditions, a vessel is likely to encounter various types of weather and tidal phenomena, which may lead to severe roll motions, potentially causing damage to cargo, equipment, and/or discomfort and danger to persons on board. The sensitivity of a vessel to these phenomena will depend upon various factors, including stability parameters, hull geometry, vessel type, vessel size and speed.

137. From the vessel traffic data (noting that the data accounts for seasonality), no alternative routeing was observed in adverse weather in proximity to the Proposed Development. Therefore, also noting the scale of the Proposed Development, it is not anticipated that the presence of the Proposed Development will have any effect on adverse weather routeing.

10.6 Small Craft Use of Safe Havens

138. Potential small craft use of safe havens in proximity to the Proposed Development was monitored in the vessel traffic data (noting that the data accounts for seasonality). No sheltering using safe havens was observed from the vessel traffic data considered, although it is noted that some small craft may not be broadcasting on AIS, as per consultation feedback.

139. From the Admiralty Sailing Directions (UKHO, 2021), Elie Bay "*provides shelter for small vessels clear of outlying dangers*" and the small vessel anchorage in Largo Bay "*provides some shelter in gales from the east*". However, both of these locations are well clear of the Proposed Development and therefore, also noting the scale of the Proposed Development, it is not anticipated that the presence of the Proposed Development will have any effect on the ability of small craft to access these safe havens.

11 Navigation, Communication and Position Fixing Equipment

140. Given that the Proposed Development will be located approximately 0.8 nm off Methil and consist of two structures, it is not likely that there will be any impact on the operation of any navigation, communication or positioning fixing equipment.

141. As per the requirements of MGN 654 (MCA, 2021) historical research, lessons learnt from existing offshore wind farms and expert opinion have been considered in the review of risks to navigation, communication or position fixing equipment due to the presence of the Proposed Development. This includes the following sources:

- *Results of the Electromagnetic Investigations* (MCA and QinetiQ, 2004);
- *Interference to Radar Imagery from Offshore Wind Farms* (PLA, 2005);
- *Measurement of Underwater Noise Emitted by an Offshore Wind Turbine at Horns Rev* (ITAP, 2006);
- *Investigation of Technical and Operational Effects on Marine Radar Close to Kentish Flats Offshore Wind Farm* (BWEA, 2007);
- *Atlantic Array Offshore Wind Farm Draft Environmental Statement Annex 18.3: Noise and Vibration (Anthropogenic Receptors): Predictions of Operational Wind Turbine Noise Affecting Fishing Vessel Crews* (Atlantic Array, 2012); and
- *Horns Rev 3 Offshore Wind Farm – Technical Report No. 12: Radio Communication and Radars* (Energinet, 2014).

142. Following consideration of the sources available, Table 11.1 confirms the sensitivity of each type of navigation, communication or position fixing equipment and whether it is screened in or out of the FSA.

Table 11.1 Communication and Position Fixing Equipment Sensitivity and FSA Screening

Topic		Sensitivity	FSA Screening
Type	**Specific**		
Communication	Very High Frequency (VHF)	Following consideration of the research reports (noting that since the trials detailed above there have been no significant issues with regards to VHF observed or reported) and the scale of the Proposed Development there are not anticipated to be any risks to VHF.	Screened out
	VHF Direction Finding (DF)	As per VHF, there are not anticipated to be any risks to VHF DF.	Screened out
	AIS	No significant issues with interference to AIS transmission from operational offshore wind farms has been observed or reported to date and given the scale of the Proposed Development there are not anticipated to be any risks to AIS.	Screened out

Topic		**Sensitivity**	**FSA Screening**
Type	**Specific**		
	Navigation Telex (NAVTEX)	Although no specific trials have been undertaken, no significant risk to NAVTEX has been reported to date at operational developments and given the scale of the Proposed Development there are not anticipated to be any risks to NAVTEX.	Screened out
	Global Position System (GPS)	No significant issues with interference to GPS from operational offshore wind farms has been observed or reported to date and given the scale of the Proposed Development there are not anticipated to be any risks to GPS.	Screened out
Electromagnetic interference	Subsea cables	Current does not emit an EMF significant enough to impact marine magnetic compasses.	Screened out
	WTG	No problems with respect to magnetic compasses have been reported to date in any of the trials carried out (inclusive of SAR helicopters) nor at any operational offshore wind farms.	Screened out
Marine Radar	Marine Radar	Given the scale of the Proposed Development and the proximity to the shore where marine Radar operation already requires sensitive adjustment there are not anticipated to be any further risks upon its use.	Screened out
Sound Navigation Ranging Systems (Sonar)	Sonar	No evidence has been found to date with regard to existing offshore wind farms to suggest that SONAR systems produce any kind of SONAR interference which is detrimental to the fishing industry, or to military systems. No risk is therefore anticipated in relation to the Proposed Development.	Screened out
Noise	Underwater	There are no indications that the sound level of the Proposed Development below the sea surface will have a significant influence on marine safety.	Screened out
	Surface	There are no indications that the sound level of the Proposed Development above the sea surface will have a significant influence on marine safety.	Screened out

143. Since all elements of navigation, communication and position fixing equipment are screened out of the FSA, the hazard as a whole is screened out of the FSA.

12 Future Case Vessel Traffic Movements

144. This section presents the predicted future case levels of activity in proximity to the Proposed Development, and the anticipated shift in the mean positions of the main commercial routes post wind farm.

145. The future case scenario has been fed into the collision and allision risk modelling (see Section 13) and is considered throughout the FSA (see Section 15).

12.1 Increases in Commercial Traffic Activity

146. Future commercial traffic trends are dependent on various factors, and are hence difficult to predict. Such an example is the tug activity in the area which is greatly influenced by the needs of Energy Park Fife. Therefore, the NRA has assumed a conservative potential increase of 10% in commercial traffic volumes throughout the design life of the Proposed Development.

147. In terms of port activity, there are no known terminal or berth changes that would materially affect future traffic levels in the short or medium term. Longer term, wind farm related traffic associated with the ScotWind developments around Scottish waters may affect traffic levels, but at this stage there is insufficient information available to make any quantitative assumptions.

12.2 Increases in Commercial Fishing Vessel Activity

148. There is limited reliable information on future commercial fishing vessel activity levels within the Firth of Forth upon which any firm assumption can be made. Therefore, a conservate potential increase of 10% in commercial fishing vessel traffic volumes throughout the design life of the Proposed Development is assumed.

12.3 Increases in Recreational Activity

149. There are no known developments for which an increase in the activity of recreational vessels within the Firth of Forth is anticipated. As with commercial fishing vessel activity, given the lack of reliable information relating to future trends, a conservative 10% increase in recreational vessel traffic volumes throughout the design life of the Proposed Development is assumed.

12.4 Commercial Traffic Routeing

12.4.1 Methodology

150. MGN 654 provides guidance to offshore renewable energy developers on both the NRA process and design elements associated with the development of an offshore wind farm. Annex 3 of MGN 654 defines a methodology for assessing passing distances between offshore wind farm boundaries but states that it "*not a prescriptive tool but needs intelligent application*".

151. In the case of the Proposed Development, there is no offshore wind farm boundary as such given that there are only two structures proposed. To date, internal and external studies undertaken by Anatec on behalf of the UK Government and individual clients show that vessels do pass consistently and safely in proximity to established offshore installations and these distances vary depending upon the sea room available as well as the prevailing conditions. This evidence also demonstrates that the mariner defines their own safe passing distance based upon the conditions and nature of the traffic at the time, as well as any safety zones that may be in place.

152. Therefore, a minimum 500 m passing distance from the proposed structures has been considered, noting that a vessel passing any closer than 500 m may infringe upon a safety zone if theoretically in place.

12.4.2 Main Commercial Route Deviations

153. Of the nine main commercial routes identified in Section 10.5, seven are east-west routes through the Firth of Forth that do not pass in proximity to the Proposed Development. The other two main routes (Routes 7 and 8 in Section 10.5) do pass in proximity but the mean position is greater than 500 m from the structures. Although these routes do not therefore require a deviation, the standard deviation from the mean position when passing the structures has been reduced as standard to simulate the anticipated decrease in routeing variation when passing (i.e. a squeezing of vessel traffic given the reduction in available sea room). This results in vessels on these routes being more closely packed, and thus represents a worst-case scenario for collision risk.

13 Collision and Allision Risk Modelling

154. To inform the NRA, a quantitative assessment of the major hazards associated with collision and allision that may arise as a result of the Proposed Development has been undertaken. The following subsections outline the inputs and methodology used for the collision and allision risk modelling, followed by the results themselves.

13.1 Inputs and Methodology

13.1.1 Scenarios Assessed

155. For each element of the quantitative assessment, both a pre and post wind farm scenario with base and future case vessel traffic levels have been considered. This means the following four distinct scenarios have been modelled:

- Pre wind farm with base case vessel traffic levels;
- Pre wind farm with future case vessel traffic levels;
- Post wind farm with base case vessel traffic levels; and
- Post wind farm with future case vessel traffic levels.

13.1.2 Hazards Assessed

156. Hazards considered in the quantitative collision and allision risk modelling assessment are as follows:

- Increased vessel to vessel collision risk;
- Creation of powered vessel to structure allision risk; and
- Creation of drifting vessel to structure allision risk.

157. The pre wind farm collision risk assessment has used the vessel traffic data in combination with the outputs of consultation and other baseline data sources. Conservative assumptions have then been made with regards to route deviations and future shipping growth as discussed in Section 12.

13.1.3 Meteorological Ocean Data

158. This subsection presents meteorological and oceanographic statistics local to the Proposed Development. The data presented in this section has been used as input to the collision and allision risk modelling.

13.1.3.1 Wind Direction

159. Based on wind direction data reported in the *Methil Offshore Windfarm Metocean Study* (ABPmer, 2015), the proportion of wind direction within each 30-degree interval for this data source is presented in Figure 13.1 in the form of a wind rose. It can be seen that winds are predominantly from the southwest.

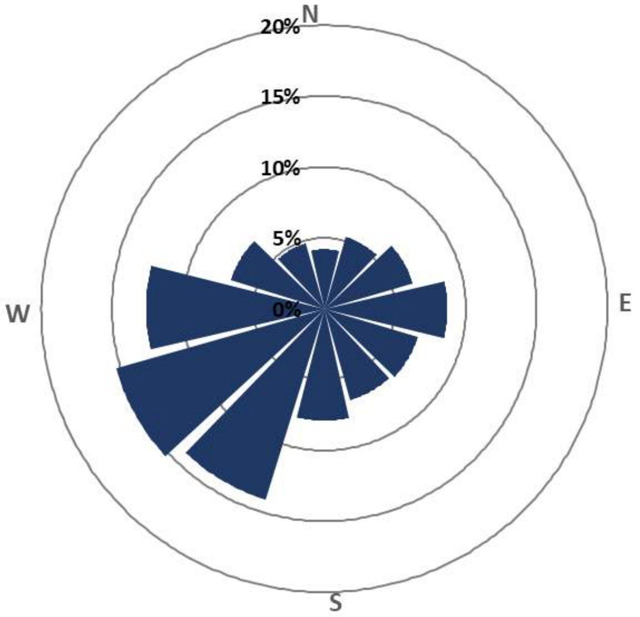

Figure 13.1 Wind Direction Distribution

13.1.3.2 Sea State

160. Based on significant wave height data reported in the *Methil Offshore Windfarm Metocean Study* (ABPmer, 2015) at a location nearby the Proposed Development, the proportion of the sea state within each of the three defined ranges for this data source, where the sea state is based upon significant wave height is presented in Table 13.1.

Table 13.1 Sea State Data

Sea State	Proportion (%)
Calm (<1 m)	93.1
Moderate (1 to 5 m)	6.9
Severe (≥5 m)	0.0

13.1.3.3 Visibility

161. It is assumed that the proportion of poor visibility (defined as the proportion of a year where the visibility can be expected to be less than 1 kilometre (km)) is 3%. This is based upon the *Admiralty Sailing Directions* (UKHO, 2021).

13.1.3.4 Flood and Ebb Tidal Speed and Direction

162. Tidal data to be used as input to the collision and allision modelling is based upon the information reported in the *Methil Offshore Windfarm Metocean Study* (ABPmer, 2015), and is provided in Table 13.2.

Table 13.2 Tidal Data

Tide	Current Speed (m/s)	Current Speed (knots)	Direction (°)
Flood	0.24	0.47	247
Ebb	0.20	0.39	067

163. Based upon the available data and the scale of the Proposed Development, no hazards are expected at high water that would not also be expected at low water, and vice versa. The wind farm structures are not expected to result in any additional risk on the existing tidal streams in relation to their effect on existing shipping and navigation users.

13.2 Pre Wind Farm Modelling

13.2.1 Encounters

164. An assessment of current vessel to vessel encounters in proximity to the Proposed Development has been undertaken by replaying the vessel traffic data at high speed. The model defines an encounter as two vessels passing within 1 nm of each another within the same minute. This helps to identify areas where existing shipping congestion is highest, and therefore where offshore developments could potentially increase this congestion and therefore also potentially increase the risk of encounters and collisions. It is noted that no account has been given as to whether the encounters are head on or stern to head; just whether the vessels involved were in close proximity.

165. On this basis a total of 1,208 encounters were identified within the 56 days of data. A density heat map for the encounters is presented in Figure 13.2.

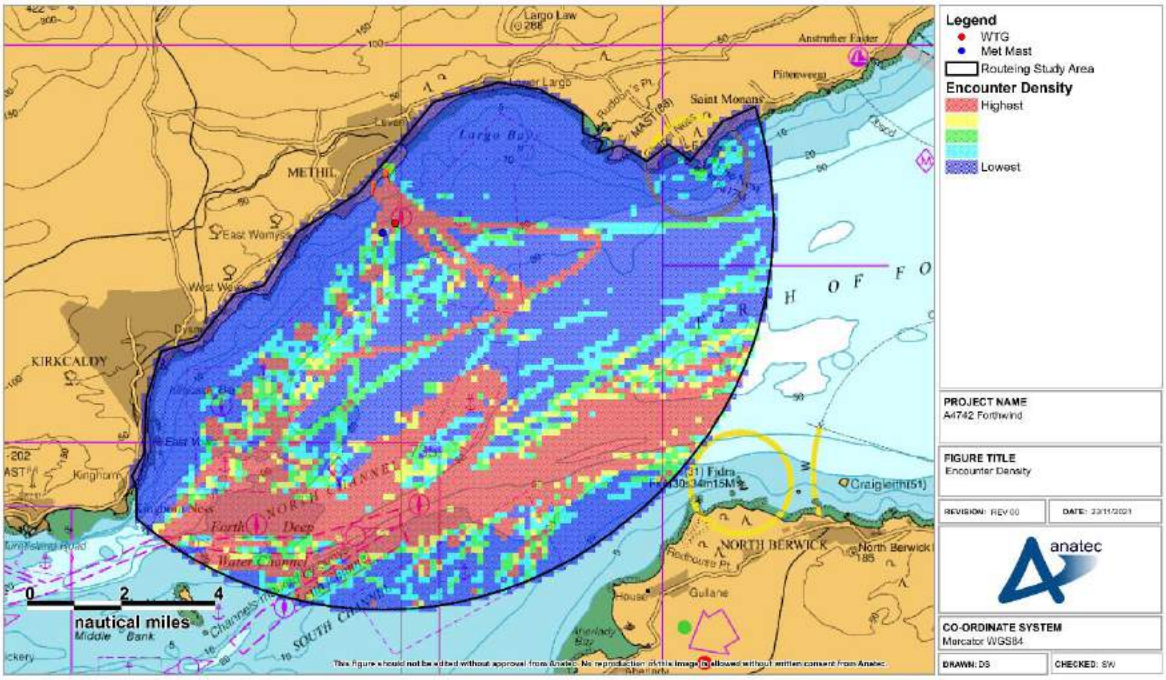

Figure 13.2 Encounter Density

166. The majority of encounters were observed to be associated with vessels utilising the main navigational channel through the Firth of Forth. Encounters involving anchored vessels were also noted at the charted anchorage berths for Methil and Kirkcaldy.

167. A high level of encounters were noted on the approach to the Fife Energy Park and the Port of Methil, with encounters in nearshore areas limited.

168. The number of encounters recorded per day is presented in Figure 13.3.

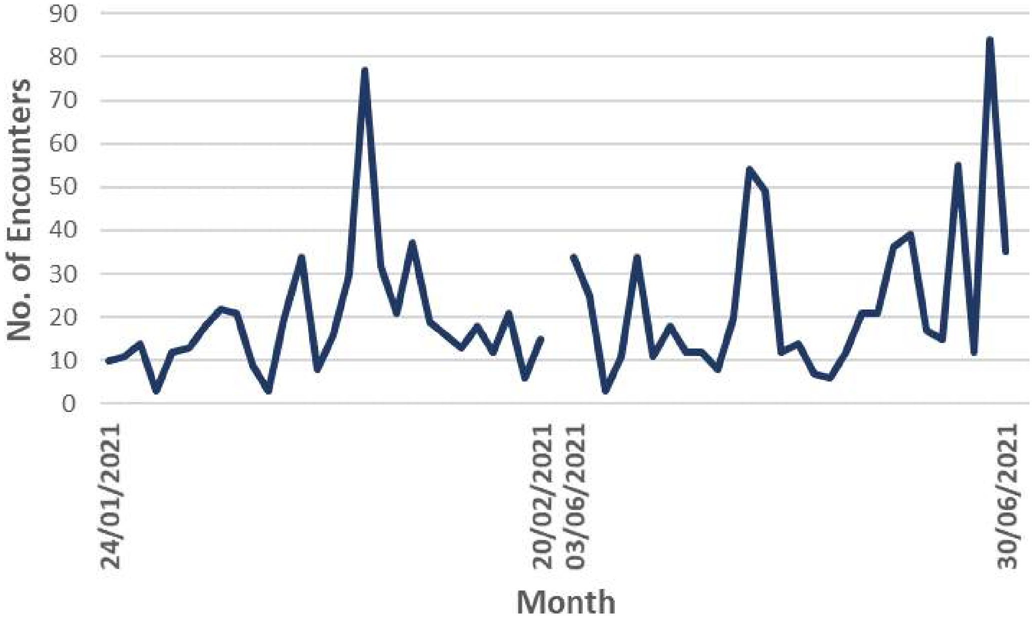

Figure 13.3 Encounters per Day

169. An average of 22 encounters per day were identified throughout the survey period. The busiest day in terms of encounters was 29th June 2021 when 84 encounters were recorded, while the quietest days were 27th January, 3rd February and 5th June 2021 when just three encounters were recorded.

13.2.1.1 Encounters by Vessel Type

170. The distribution of vessel types involved in the identified encounters is shown in Figure 13.4.

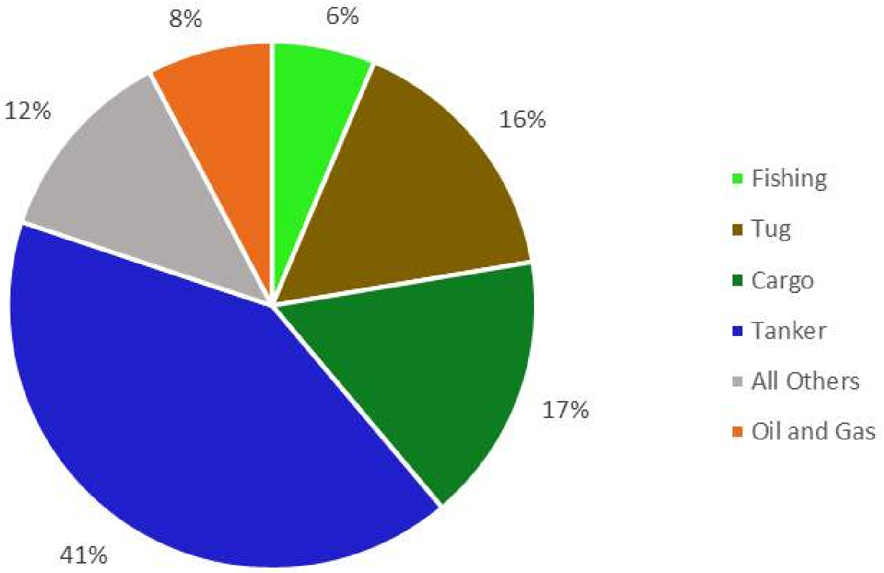

Figure 13.4 Encounters – Vessel Type Distribution

171. The majority of vessels involved in encounter were commercial, with tankers accounting for 41% and cargo vessels accounting for 17%. Encounters involving smaller vessel types were limited, noting that the dataset is limited to those vessels broadcasting on AIS.

13.2.2 Vessel to Vessel Collision Risk

172. Using the pre wind farm vessel routeing as input, Anatec's COLLRISK model has been run to estimate the vessel to vessel collision risk within the routeing study area.

173. The results of the pre wind farm collision assessment are presented graphically in Figure 13.5 which shows a collision risk heat map. A detailed view featuring the Proposed Development is presented in Figure 13.6 and future case results are included in Section 13.4.

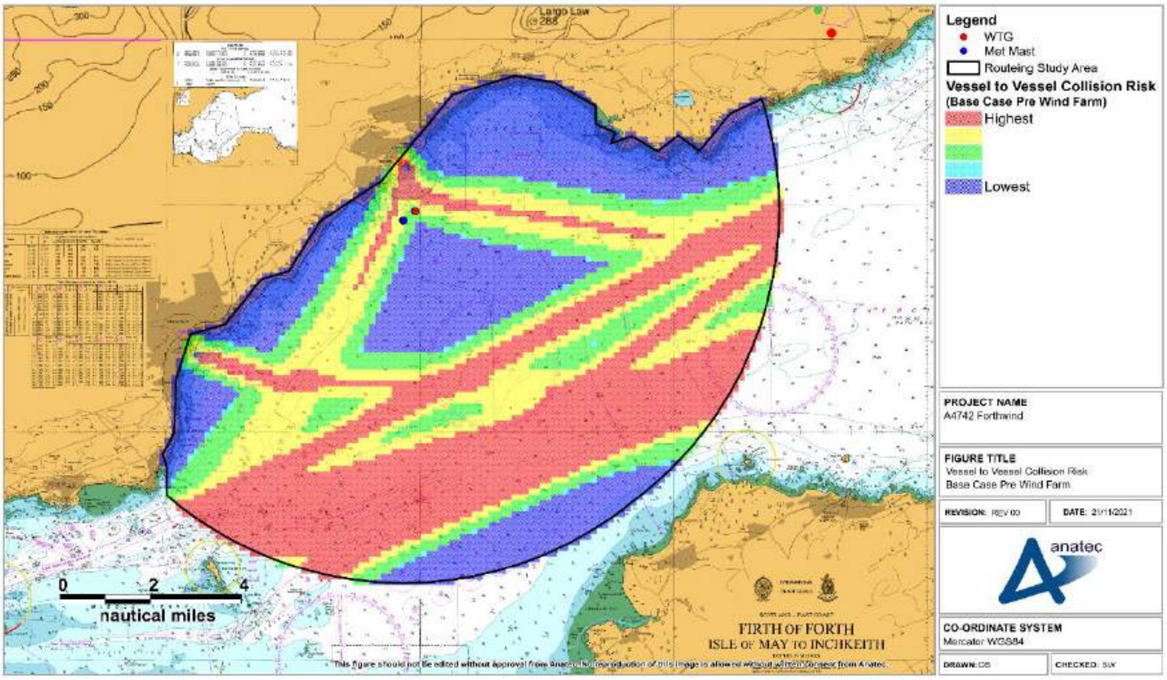

Figure 13.5 Vessel to Vessel Collision Risk – Base Case Pre Wind Farm

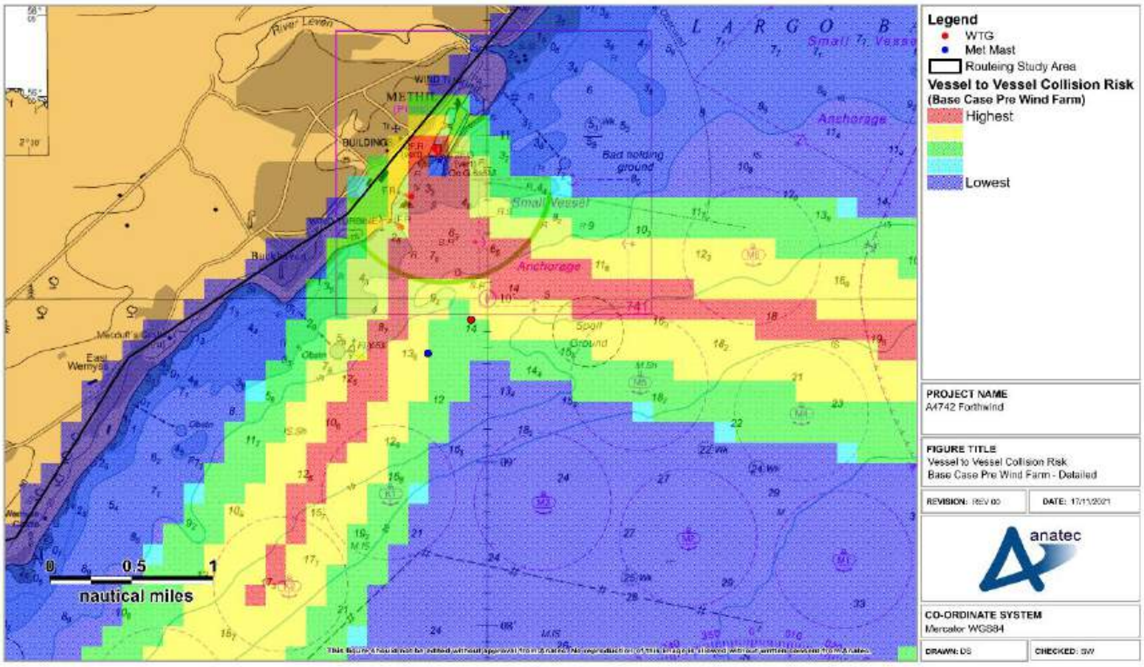

Figure 13.6 Vessel to Vessel Collision Risk – Base Case Pre Wind Farm – Detailed

174. Assuming base case traffic levels, it was estimated that a vessel would be involved in a collision once every 1,060 years pre wind farm. The most significant area of risk was the main navigational channel within the Firth of Forth, and its associated approaches and exits. Additionally, sections of routeing towards Methil and Kirkcaldy were noted as high risk.

13.3 Post Wind Farm Modelling

13.3.1 Vessel to Vessel Collision Risk

175. Using the predicted post wind farm routeing as input, Anatec’s COLLRISK model was run to estimate the vessel to vessel collision risk post wind farm within the routeing study area.

176. The results of the post wind farm collision assessment are presented graphically in Figure 13.7, which shows a collision risk heat map. A detailed view featuring the Proposed Development is presented in Figure 13.8 and future case results are included in Section 13.4.

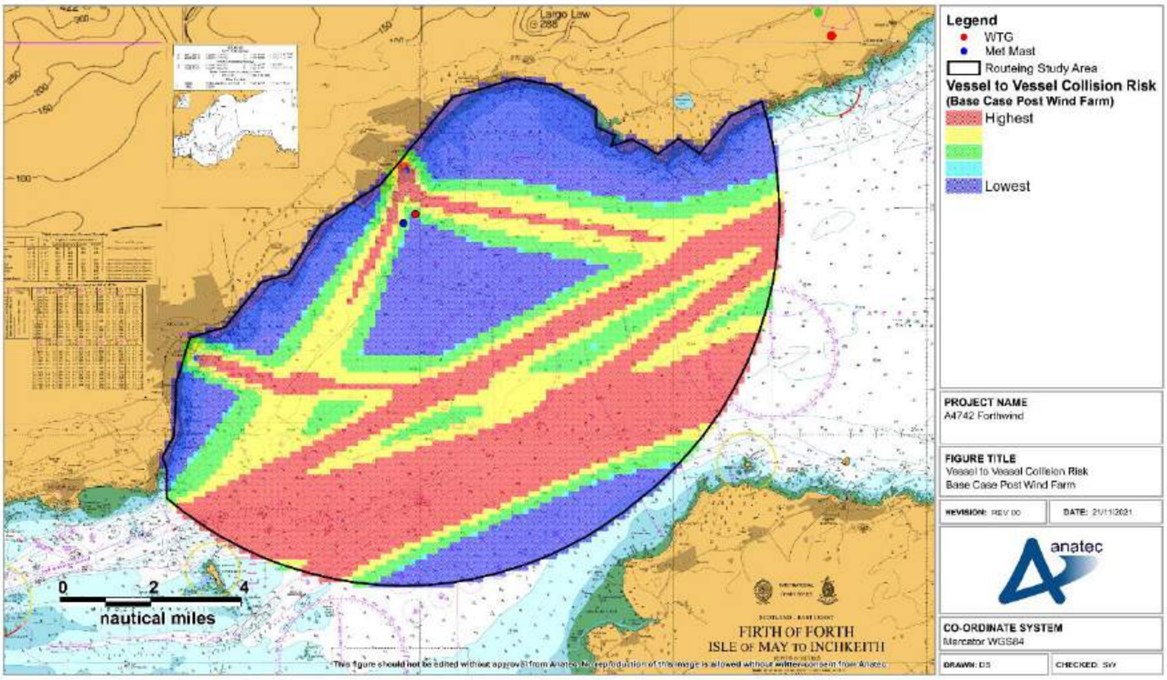

Figure 13.7 Vessel to Vessel Collision Risk – Base Case Post Wind Farm

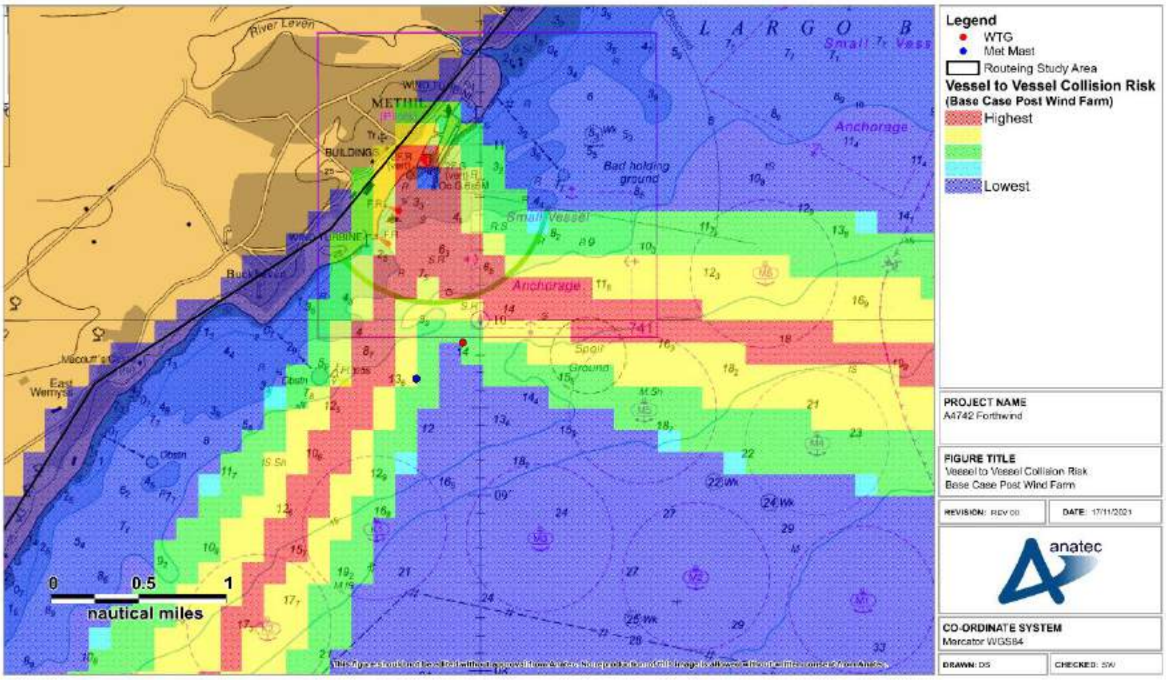

Figure 13.8 Vessel to Vessel Collision Risk – Base Case Post Wind Farm – Detailed

177. Assuming base case traffic levels, it was estimated that a vessel would be involved in a collision once every 1,060 years[3] post wind farm. This represents a negligible change in collision risk compared to the pre wind farm case and is indicative of the

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[3] One in 1,057.84 years post wind farm compared with 1,057.96 years pre wind farm.

minor deviations changes to routeing required which are wholly related to width rather than position. This is reflected in Figure 13.8 which indicates only very small changes to the distribution of collision risk in proximity to the structures compared to that illustrated in Figure 13.6.

13.3.2 Powered Vessel to Structure Allision Risk

178. Based upon the vessel routeing identified in the region, the anticipated change in routeing due to the Proposed Development, the mitigations in place, and levels of allision incidents to date associated with UK offshore wind farms, the frequency of an errant vessel under power deviating from its route to the extent that it comes into proximity with a structure is considered low.

179. From consultation with the shipping industry and observations at other constructing or operational UK developments, it is also assumed that commercial vessels would be highly unlikely to navigate between wind farm structures due to the restricted sea room and will instead be directed by the aids to navigation located in the region. In terms of the Proposed Development, this assumption applies to navigation between the WTG and Met Mast, noting that given the nature of routeing in the area such navigation is not anticipated (vessels approaching the Port of Methil typically do so west or north east of the Proposed Development). Local aids to navigation will primarily consist of lighting and marking of the structures (noting that this will be directed by and agreed with NLB).

180. Using the predicted post wind farm routeing as the primary input, Anatec's COLLRISK model was run to estimate the likelihood of a commercial vessel alliding with one of structures whilst under power. Full results are provided in Section 13.4.

181. Assuming base case traffic levels, it was estimated that a vessel would allide with a structure whilst under power once every 28,750 years. The structure with the greater allision risk was observed to be the Met Mast due to its slightly closer proximity to a main commercial route.

13.3.3 Drifting Vessel to Structure Allision Risk

182. Using the post wind farm routeing as the primary input, Anatec's COLLRISK model was run the estimate the likelihood of a drifting commercial vessel alliding with one of the structures. The model is based on the premise that propulsion on a vessel must fail before drifting will occur. The model takes account of the type and size of the vessel, the number of engines and the average time required to repair but does not consider navigational error cause by human actions.

183. The exposure times for a drifting scenario are based upon the vessel hours spent in proximity to the array. These have been estimated based upon the post wind farm routeing. The exposure is divided by vessel type and size to ensure these factors, which based upon analysis of historical incident data have been shown to influence incident rates, are taken into account within the modelling.

184. Using this information, the overall rate of mechanical failure within proximity to the array was estimated. The probability of a vessel drifting towards a structure and the drift speed are dependent upon the prevailing wind, wave, and tidal conditions at the time of the accident. Therefore, three drift scenarios were modelled, each using the meteorological ocean data outlined in Section 13.1.3:

- Wind;
- Peak spring flood tide; and
- Peak spring ebb tide.

185. The probability of vessel recovery from drift is estimated based upon the speed of drift and hence the time available before reaching the structure. Vessels which do not recover within this time are assumed to allide.

186. After modelling the drift scenarios, it was established that the flood tide dominated scenario produced the worst-case results.

187. Assuming base-case traffic levels, it was estimated that a drifting vessel would allide with a structure once every 760,000 years, which is considered a negligible value.

13.4 Results Summary

188. As per Section 13.1.1, both pre and post wind farm scenarios with base case and future case traffic levels have been run. Table 13.3 summarises the results of these four scenarios, noting that collision and allision frequencies are rounded to two decimal places.

Table 13.3 Risk Results Summary

Collision/ allision scenario	Base case			Future case		
	Pre wind farm	Post wind farm	Change	Pre wind farm	Post wind farm	Change
Vessel to vessel collision	9.45×10^{-4} (1 in 1,060 years)	9.45×10^{-4} (1 in 1,060 years)	1.04×10^{-7}	1.14×10^{-3} (1 in 870 years)	1.14×10^{-3} (1 in 870 years)	1.26×10^{-7}
Powered vessel to structure allision	N/A	3.48×10^{-5} (1 in 28,750 years)	3.48×10^{-5}	N/A	3.83×10^{-5} (1 in 26,100 years)	3.83×10^{-5}
Drifting vessel to structure allision	N/A	1.31×10^{-6} (1 in 760,000 years)	1.31×10^{-6}	N/A	1.45×10^{-6} (1 in 692,000 years)	1.45×10^{-6}
Total	**9.45×10^{-4} (1 in 1,060 years)**	**1.02×10^{3} (1 in 1,019 years)**	**3.61×10^{-5}**	**1.14×10^{-3} (1 in 870 years)**	**1.18×10^{-3} (1 in 850 years)**	**3.98×10^{-5}**

13.5 Consequences Assessment

189. A quantitative assessment of the potential consequences of a collision or allision incident has been undertaken based on the collision and allision risk results presented in the previous subsections and historical data regarding collision and allision incidents and oil pollution.

13.5.1 Fatality Risk

190. The details of over 12,000 accidents, injuries and hazardous incidents reported to the MAIB between 2000 and 2019 involving nearly 14,000 vessels have been analysed to identify collision and allision incidents and associated fatality cases. For collision incidents (vessel to vessel), a total of 481 incidents featuring six fatalities were reported to the MAIB between 2000 and 2019. For contact incidents (vessel to non-vessel structure), a total of 235 incidents featuring one fatality was reported to the MAIB between 2000 and 2019.

191. This data has been interrogated further to obtain a fatality probability for each main vessel category (commercial, fishing and recreational) based upon vessel type and People on Board (POB) information provided in the MAIB incident data. The findings are summarised in Table 13.4.

Table 13.4 Collision Incident Fatality Probability by Vessel Category (2000 to 2019)

Vessel Category	Sub Categories	Fatalities	People Involved	Fatality Probability
Commercial	Dry cargo, passenger, tanker, tug, etc.	1	9,847	1.0×10^{-4}
Fishing	Trawler, potter, dredger, etc.	2	115	1.7×10^{-2}
Pleasure craft	Yacht, small commercial motor yacht, etc.	3	571	5.3×10^{-3}

192. It can be seen that the fatality risk is higher by up to two orders of magnitude for POB small craft compared to larger commercial vessels.

193. Using an estimated average number of POB for the local vessels operating in proximity to the Proposed Development, the collision and allision risk modelling results and the estimated fatality probability for each vessel category, the annual increase in Potential Loss of Life (PLL) due to the Proposed Development for the base case is estimated to be 5.59×10^{-8} and for the future case is estimated to be 5.63×10^{-8}. The change is dominated by the commercial vessel category, which reflects the high presence of commercial traffic (tugs) which pass in close proximity to the wind farm structures.

194. Converting the PLL to individual risk based upon the average number of people exposed by vessel type, the annual change for commercial vessels for the base case is estimated to be 3.69×10^{-10} and for the future case is estimated to be 3.70×10^{-10}. These are negligible values compared to the background risk level for the UK sea transport industry of 1.02×10^{-4} per year.

195. The annual change for commercial fishing vessels for the base case is estimated to be 2.12×10^{-11} and for the future case is estimated to be 2.57×10^{-11}. These are negligible values compared to the background risk level for the UK sea fishing industry of 1.74×10^{-2}.

13.5.2 Pollution Risk

196. From research undertaken as part of the UK's DfT Marine Environment High Risk Areas (MEHRAs) project (DfT, 2001), it was estimated that 13% of vessel collisions result in a fuel oil spill and 39% of collisions involving a laden tanker result in a cargo oil spill (i.e. tankers).

197. For fuel oil spills, and considering the types and sizes of vessels exposed to the Proposed Development, an average spill size of 100 tonnes of fuel oil is considered a conservative assumption. For cargo oil spills, International Tanker Owners Pollution Federation (ITOPF) data suggests that 52% of spill are between seven and 700 tonnes with 31% less than seven tonnes and 17% greater than 700 tonnes. Therefore, an average spill size of 400 tonnes is considered a conservative assumption.

198. Such data on oil spill probability and size is not comprehensively available for commercial fishing vessels or recreational vessels and so it is conservatively assumed that 50% of all collisions involving these vessel types will lead to an oil spill with an average spill size of five tonnes for commercial fishing vessels and one tonne for recreational vessels.

199. Using these probabilities and the collision and allision risk modelling results, the annual increase in oil spilled due to the Proposed Development for the base case is estimated to be 4.71×10^{-4} tonnes and for the future case is estimated to be 4.73×10^{-4} tonnes. In both scenarios this value is in the majority produced by cargo vessels with negligible construction from the other vessel types. Overall, these are negligible values compared to the annual average of 16,111 tonnes of oil spilled in UK waters due to maritime incidents reported by the MEHRAs research between 1989 and 1998.

14 Risks Scoped into the Formal Safety Assessment

200. This section outlines the shipping and navigation risks which have been identified as requiring consideration in the FSA (see Section 15). Other risks scoped out of the FSA are outlined in the hazard list (see Appendix B) along with the justification for being scoped out.

14.1 Construction Phase

201. *Displacement of vessels due to the presence of construction activities associated with the Proposed Development and subsequent increased vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

202. *Disruption to pilot boarding activities due to the presence of construction activities associated with the Proposed Development.*

14.2 Operational Phase

203. *Displacement of vessels due to the presence of the Proposed Development and subsequent increased vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

204. *Creation of a vessel to structure allision risk for third-party vessels, including a vessel dragging anchor, due to the presence of surface infrastructure associated with the Proposed Development.*

205. *Increased grounding risk for third-party vessels due to the presence of subsea cable protection associated with the Proposed Development.*

206. *Disruption to emergency response and SAR operations due to the presence of the Proposed Development.*

207. *Disruption to pilot boarding activities due to the presence of surface infrastructure associated with the Proposed Development.*

208. *The presence of surface infrastructure associated with the Proposed Development may prevent the use of existing aids to navigation.*

14.3 Decommissioning Phase

209. *Displacement of vessels due to the presence of decommissioning activities associated with the Proposed Development and subsequent increased vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

210. *Disruption to pilot boarding activities due to the presence of decommissioning activities associated with the Proposed Development.*

15 Formal Safety Assessment

211. An FSA has been undertaken for the risks outlined in Section 14. The methodology outlined in Section 3.1 has been applied, including the assessment criteria, application of the IMO FSA process (IMO, 2018) and the risk ranking approach for significance of risk based upon frequency of occurrence and severity of consequence.

15.1 Worst Case Scenario for Shipping and Navigation Risks

212. The worst case scenario for each shipping and navigation risk is detailed in Table 15.1, based upon the project design information outlined in Section 6.

Table 15.1 Worst Case Scenario for Shipping and Navigation per Risk

Risk	Phase	Worst Case Scenario for Shipping and Navigation	Justification
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Construction	▪ Two phases of construction consisting of foundation and main structure installation taking place over a two to three month period. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3 ▪ Interconnector cable with length 625 m. ▪ Export cable with length 0.82 nm. ▪ One jack-up vessel for each phase of construction making minimal movements once on-site and a lifting vessel. ▪ One cable lay vessel and a possible secondary support vessel for cable installation. ▪ Use of an ROV for post cable installation inspection and burial.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.
Disruption to pilotage services	Construction	▪ Two phases of construction consisting of foundation and main structure installation taking place over a two to three month period. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ Interconnector cable with length 625 m. ▪ Export cable with length 0.82 nm. ▪ One jack-up vessel for each phase of construction making minimal movements once on-site and a lifting vessel. ▪ One cable lay vessel and a possible secondary support vessel for cable installation. ▪ Use of an ROV for post cable installation inspection and burial.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned). ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.

Risk	Phase	Worst Case Scenario for Shipping and Navigation	Justification
Allision risk for third-party vessels	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ WTG and Met Mast on monopile foundations.	Maximum extent, maximum number and size of surface infrastructure and maximum duration resulting in maximisation of vessel to structure allision risk.
Increased grounding risk for third-party vessels	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned. ▪ Interconnector cable with length 625 m. ▪ Export cable with length 0.82 nm. ▪ Target burial depth for subsea cables of 1 to 1.5 m. ▪ Use of cable protection where cable burial is not possible/effective.	Maximum extent of seabed infrastructure and maximum duration resulting in maximisation of grounding risk.
Disruption to emergency response and SAR operations	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ Use of a CTV to enable maintenance activities. ▪ Use of an ROV to undertake cable inspections with an appropriate frequency.	Maximum extent, maximum number of vessel activities, maximum number of surface infrastructure and maximum duration resulting in maximisation of disruption to emergency response and SAR operations.
Disruption to pilotage services	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ Use of a CTV to enable maintenance activities. ▪ Use of an ROV to undertake cable inspections with an appropriate frequency.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.
Prevention of use of aids to navigation	Operational	▪ Operational phase of 25 years for the WTG and five years for the Met Mast (remaining in situ until the WTG is decommissioned. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3.	Maximum extent and maximum duration resulting in maximisation of prevention of use of aids to navigation.

Risk	Phase	Worst Case Scenario for Shipping and Navigation	Justification
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Decommissioning	▪ Two phases of decommissioning consisting of foundation and main structure decommissioning taking place over a two to three month period. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ One jack-up vessel for each phase of decommissioning making minimal movements once on-site and a lifting vessel. ▪ Cables left in situ.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.
Disruption to pilotage services	Decommissioning	▪ Two phases of decommissioning consisting of foundation and main structure decommissioning taking place over a two to three month period. ▪ Locations of the WTG and Met Mast as per Table 6.1 and Table 6.3. ▪ One jack-up vessel for each phase of decommissioning making minimal movements once on-site and a lifting vessel. ▪ Cables left in situ.	Maximum extent, maximum number of vessel activities and maximum duration resulting in maximisation of vessel displacement.

15.2 Construction Phase

15.2.1 Vessel Displacement, Collision Risk and Restrictions on Port Access for Third-Party Vessels

213. *Displacement of vessels due to the presence of construction activities associated with the Proposed Development and subsequent increased vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

214. Offshore construction will be undertaken over a two to three month period in two phases (foundation installation and main structure installation). Across the two phases there will be a jack up vessel making minimal movements once on-site other than transiting between the WTG and Met Mast over a 0.5 day period and a lifting vessel. For the subsea cables, a cable lay vessel, a possible secondary support vessel and an ROV for post cable installation inspection and burial will be present.

215. These activities and the presence of the structure foundations once installed may result in the displacement of vessels. Given that only two structures will be installed and associated vessel activities will be local to the locations of the structures it follows that any vessel displacement will be limited to the proximity of the Proposed Development. From the vessel traffic data, there are two main commercial routes pass in proximity to the Proposed Development, headed in and out of the Port of Methil (Routes 7 and 8). Both of these routes are low use (each less than one vessel per day) and are typically operated by tugs, small cargo vessels and pilot vessels. However, as part of the pre wind farm modelling, it was identified that there are a high level of encounters occur on the approach to the Port of Methil.

216. No restrictions on navigation will be implemented in proximity to the Proposed Development by the Applicant, noting that since the Proposed Development is located within the jurisdiction of Forth Ports, it is possible that Forth Ports may implement safety zones, exclusion zones or speed restrictions. Based on experience at other under construction offshore installations, it is anticipated that commercial vessels will choose not to navigate in close proximity to the structures and will instead maintain a safe passing distance, including avoiding passing between the WTG and Met Mast locations. However, taking this and the existing mean positions of the main commercial routes in and out of Methil into account, no deviations from the mean positions of the routes are anticipated. Some squeezing of vessel traffic on the routes may occur to maintain safe distances from the structures and construction activities but will be limited. Subsequently the level of vessel to vessel collision risk for commercial vessels is not expected to increase substantially. This is reflected in the collision risk modelling undertaken which indicated a return period of one in 1,060 years for the base case post wind farm scenario, equating to an increase of 0.01% from the pre wind farm scenario, which is considered a negligible change.

217. Should vessels on the passing routes take a highly conservative approach, then there is sufficient sea room to allow some deviation, noting the need to account for the pilot boarding station for Methil, various designated anchorages and the nearshore

area. Any such deviations are not expected to affect a vessel's ability to access the Port of Methil.

218. For smaller craft (fishing vessels and recreational vessels), the vessel traffic data indicates very low volumes in the area. However, it is noted that there may be non-AIS vessel presence in the area, as indicated by the SFF and Forth Yacht Clubs Association during consultation. Small craft may be displaced by the presence of the construction activities but the level of displacement will be low, and there is sufficient sea room to allow such deviations. There may be a risk of displaced small craft interacting with the pilot boarding station for Methil and various designated anchorages but given the frequency of use of these navigational features, the risk is likely to be minimal. Subsequently the level of vessel to vessel collision risk for small craft is not expected to increase substantially.

219. In the event that an encounter between third-party vessels occurs, collision avoidance action will be implemented by the vessels in line with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) (IMO, 1972/77). Should the encounter develop into a collision incident then any contact would likely occur at low speeds given the proximity to the coast and the Port of Methil, resulting in minor damage to the vessels. The casualty vessels could then head for a local port and undertake a full inspection. Additionally, emergency response facilities are located locally in the area to provide swift assistance as required.

220. The following embedded mitigation measures will reduce the significance of risk:

- Charting of infrastructure – will assist in raising awareness of the Proposed Development and allow mariners to passage plan in advance, reducing the likelihood of a need for late course changes which would increase collision risk.
- Guard vessel – when on-site will assist in raising awareness of the Proposed Development and alerting a vessel on a closing point of approach to a project vessel.
- Lighting and marking – will assist in raising awareness of the Proposed Development, reducing the likelihood of a need for late course changes which would increase collision risk.
- Promulgation of information – will assist in raising awareness of the Proposed Development, reducing the likelihood of a need for late course changes which would increase collision risk.

221. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

15.2.2 Disruption to Pilotage Services

222. *Disruption to pilot boarding activities due to the presence of construction activities associated with the Proposed Development.*

223. Offshore construction will be undertaken over a two to three month period in two phases (foundation installation and main structure installation). Across the two phases there will be a jack up vessel making minimal movements once on-site other than transiting between the WTG and Met Mast over a 0.5 day period and a lifting vessel. For the subsea cables, a cable lay vessel, a possible secondary support vessel and an ROV for post cable installation inspection and burial will be present.

224. The pilot boarding station for the Port of Methil is located approximately 290 m north east of the WTG location. Its use is compulsory for vessels inbound to Methil over 60 m length or carrying dangerous cargoes and over 45 m length.

225. No use of pilot boarding services was observed in the vessel traffic data. Although the vessel traffic data includes AIS only, given the requirements for pilotage at the Port of Methil it is not anticipated that any non-AIS vessels would utilise the pilotage services. Furthermore, during consultation Forth Ports indicated that pilot boarding for the Port of Methil is not typically undertaken in proximity to the charted pilot boarding station and is typically done where the vessel has anchored within the anchorage area. RYA Scotland added that recreational vessels are unlikely to utilise the pilotage services.

226. Since the displacement of existing vessel traffic is expected to be limited, there is not anticipated to any additional interaction with the pilotage activities compared to the pre wind farm scenario, and thus minimal disruption. This was reflected by Forth Ports during consultation, with an indication that the pilot boarding station could be shifted further away from the Proposed Development, noting that the Proposed Development lies within a VTS area and therefore Forth Ports have jurisdiction over traffic movements.

227. In the unlikely event that there was disruption to pilotage activities, vessels requiring pilotage services may not be able to access the Port of Methil, with commercial implications. There would also be a vessel to vessel collision risk associated with vessels requiring pilotage but any contact would likely occur at low speeds given the proximity to the coast and the Port of Methil.

228. The following embedded mitigation measures will reduce the significance of risk:

- Charting of infrastructure – will assist with awareness of the Proposed Development and allow mariners to passage plan in advance, reducing the risk of an unsafe approach to or use of the pilot boarding station at the Port of Methil.
- Guard vessel – when on-site will assist in raising awareness of the Proposed Development and alerting a vessel on a closing point of approach to a project vessel.
- Lighting and marking – will assist in raising awareness of the Proposed Development, reducing the risk of an unsafe approach to or use of the pilot boarding station at the Port of Methil.

- Promulgation of information – will assist in raising awareness of the Proposed Development, reducing the risk of an unsafe approach to or use of the pilot boarding station at the Port of Methil.

229. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

15.3 Operational Phase

15.3.1 Vessel Displacement, Collision Risk and Restrictions on Port Access for Third-Party Vessels

230. *Displacement of vessels due to the presence of the Proposed Development and subsequent increased vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

231. The design life of the WTG and Met Mast is 25 years. Both the Met Mast and WTG will be decommissioned as a whole after 25 years operation. A CTV will be used to enable maintenance activities to be undertaken on-site and an ROV will be used to undertake cable inspections with an appropriate frequency.

232. The presence of the structures and maintenance activities may result in the displacement of vessels. As with the equivalent construction phase hazard, given that only two structures will be installed and associated vessel activities will be local to the locations of the structures it follows that any vessel displacement will be limited to the proximity of the Proposed Development.

233. The affected users and extent of the deviations is anticipated to be similar to the construction phase. Therefore, no deviations from the mean positions of the routes are anticipated. Some squeezing of vessel traffic on the routes may occur to maintain safe distances from the structures and construction activities but will be limited. Subsequently the level of vessel to vessel collision risk for commercial vessels is not expected to increase substantially and a vessel's ability to access the Port of Methil is not expected to be affected. It is also noted that, given the duration of the operational phase, mariners navigating in the area will develop a high level of familiarity and awareness with the Proposed Development.

234. The consequences in the event of an encounter or collision incident occurring are analogous to those described for the equivalent construction phase hazard. The same embedded mitigation measures are proposed as for the equivalent construction phase hazard.

235. Overall, the frequency of the hazard is considered **Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Tolerable with Monitoring**.

15.3.2 Allision Risk for Third-Party Vessels

236. *Creation of a vessel to structure allision risk for third-party vessels, including a vessel dragging anchor, due to the presence of surface infrastructure associated with the Proposed Development.*

237. The design life of the WTG and Met Mast is 25 years. Both the Met Mast and WTG will be decommissioned as a whole after 25 years operation.

238. Allision risk is considered in three distinct parts:

- Powered allision risk;
- Drifting allision risk; and
- Anchor dragging risk.

239. In all three cases any risk is limited to within proximity of the Proposed Development.

240. For powered allision risk, vessels navigating in and out of the Forth will have good awareness of navigating in proximity to offshore installations given the presence of the Outer Firth of Forth offshore wind farms (with the first to start construction, NnG, expected to be fully commissioned in November 2022 (EDF Renewables, 2020)). Those vessels which navigate exclusively within the Forth (typically smaller craft) may have less awareness.

241. Noting that since the Proposed Development is located within the jurisdiction of Forth Ports, it is possible that Forth Ports may implement safety zones, exclusion zones or speed restrictions thus enforcing a greater passing distance for vessels.

242. With the main commercial route deviations associated with the post wind farm scenario in place, the powered allision return period is estimated to be one in 28,800 years for the base case scenario. This is very low compared to the return period estimated for other UK offshore wind farm developments and is reflective of the low number of structures and relatively low volume of vessel traffic in the area.

243. Based on historical incident data, there has been one reported instance of a third-party vessel alliding with an operational wind farm structure in the UK. Given that the Proposed Development is located in proximity to the Port of Methil and several navigational features (such as a pilot boarding station and designated anchorages) it is anticipated that the masters of third-party vessels will have a heightened level of alertness. It is also noted that, given the duration of the operational phase, mariners navigating in the area will develop a high level of familiarity and awareness with the Proposed Development.

244. In the event that an allision incident occurs, the consequences will depend on multiple factors including the energy of the impact, structural integrity of the vessel and sea state at the time of impact. Small craft (commercial fishing vessels and recreational vessels) are most susceptible given the potential for non-steel construction, although any allision would likely occur at low speeds given the

proximity to the coast and the Port of Methil, resulting in minor damage to the vessel. The casualty vessel could then head for a local port and undertake a full inspection. Additionally, emergency response facilities are located locally in the area to provide swift assistance as required.

245. For recreational vessels under sail there are additional risks to consider such as wind shear, masking and turbulence. From previous studies of offshore wind farm developments it has been concluded that WTGs do reduce wind velocity downwind of a WTG (MCA, 2008) but no negative effects on recreational craft have been reported, noting that such an instance would be short-term (especially given that there are only two structures) and similar to that experienced when passing a large vessel or close to other large structures (such as bridges) or the coastline.

246. For recreational vessels with a mast there is an additional risk of blade allision if navigating in proximity to the WTG. The RYA recommend a minimum blade tip clearance of 22 m above HAT to minimise this allision risk.

247. For drifting allision risk, and with the main commercial route deviations associated with the post wind farm scenario in place, the drifting allision return period is estimated to be one in 760,000 years for the base case scenario, which is considered a negligible value. This is very low compared to the return period estimated for other UK offshore wind farm developments and is reflective of the low number of structures and relatively low volume of vessel traffic in the area.

248. It is also noted that a vessel adrift may only develop into an allision situation if in proximity to the Proposed Development. This is only the case where the adrift vessel is located in close proximity to the structures and the direction of the wind and/or tide directs the vessel towards one of the structures. From meteorological data the predominant wind direction is from the south west and therefore a vessel would be more likely to drift towards a structure on the north-south approach to and from the Port of Methil.

249. Based on historical incident data, there have been no reported instances of a drifting third-party vessel alliding with an operational wind farm structure in the UK. Moreover, in the local area the majority of incidents responded to by the RNLI have involved a person in danger with no potential for a drifting vessel.

250. In the unlikely event that a drifting allision incident develops, the adrift vessel would initiate emergency response procedures to avoid an allision occurring. This may include emergency anchoring following a check of relevant nautical charts, noting that the only subsea features in proximity which may influence a decision to emergency anchor would be an obstruction approximately 0.6 nm west of the Met Mast and the subsea cables for the Proposed Development itself. Additionally, other vessels including project vessels if on-site may be able to render assistance including under International Convention for the Safety of Life at Sea (SOLAS) obligations (IMO, 1974) and there is a possibility the adrift vessel could regain power prior to an allision

occurring, albeit the likelihood of this is low given the likely short distance that would be covered between the vessel becoming adrift and the contact occurring.

251. The consequences of a drifting allision occurring would be similar to those noted for a powered allision, with the addition that the adrift vessel would be even more likely to make contact at low speed given that propulsion would be dictated primarily by the wind and/or tide. Again, emergency response facilities are located locally in the area and would be able to provide swift assistance as required.

252. Anchor snagging is considered a special case of drifting, and refers to an instance where, despite having the anchor deployed, a vessel drifts without holding power. In the case of the Proposed Development, anchor snagging would likely occur from one of the designated anchorages, including the small vessel anchorage for the Port of Methil located approximately 170 m north east of the WTG.

253. An average of 10 unique vessels per day were recorded at anchor within the traffic study area throughout the survey period, with the majority tankers in the anchor berths south of the Proposed Development. There was infrequent use of the small vessel anchorage and also a case of a tug anchoring between the proposed structures. During consultation, RYA Scotland confirmed that recreational vessels would not be expected to anchor in the area given water depths.

254. The likelihood of an anchor failing to hold and a vessel drifting is very low, and in any case Forth Ports have acknowledged during consultation that this is not a significant issue since sensitive anchor berths may be moved or removed, noting that there are numerous designated anchorage locations in the area and the Proposed Development lies within a VTS area (therefore Forth Ports have jurisdiction over traffic movements). As with a standard drifting incident, a vessel dragging anchor may only develop into an allision situation if in proximity to the Proposed Development and with the direction of the wind and/or tide directing the vessel towards one of the structures.

255. The consequences of a drifting allision arising from anchor snagging would be similar to those noted for a powered and drifting allision, with the addition that the anchor could be damaged or snagged on subsea infrastructure such as the subsea cables associated with the Project. However, the latter option would likely prevent an allision from occurring. Again, emergency response facilities are located locally in the area and would be able to provide swift assistance as required.

256. The following embedded mitigation measures will reduce the significance of risk:

- Charting of infrastructure – will assist in raising awareness of the Proposed Development and allow mariners to passage plan in advance, reducing the likelihood of a need for late course changes which would increase powered allision risk.

- Development within a VTS area – will assist in ensuring clear coordination and communication for all vessels including project vessels in relation to providing assistance under SOLAS obligations should a drifting allision incident develop.
- Guard vessel – when on-site will assist in raising awareness of the Proposed Development, alerting a vessel on a closing point of approach to a wind farm structure or in the event of a lighting and marking failure.
- Lighting and marking – will assist in raising awareness of the Proposed Development, reducing the likelihood of a need for late course changes which would increase powered allision risk.
- Minimum blade tip clearance – ensures compliance with RYA recommendations for minimum blade tip clearance for minimising blade allision risk.
- Promulgation of information – will assist in raising awareness of the Proposed Development, reducing the likelihood of a need for late course changes which would increase powered allision risk.

257. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

15.3.3 Increased Grounding Risk for Third-Party Vessels

258. *Increased grounding risk for third-party vessels due to the presence of subsea cable protection associated with the Proposed Development.*

259. The design life of the WTG and Met Mast is 25 years. Both the Met Mast and WTG will be decommissioned as a whole after 25 years operation. An ROV will be used to undertake cable inspections with an appropriate frequency.

260. MGN 654 (MCA, 2021) states that any cable protection should not reduce the under keel clearance by more than 5%, with any changes greater than 5% to be discussed in consultation with the MCA and NLB. This stance is supported by the RYA which recommend that "*minimum safe under keel clearance over submerged structures and associated infrastructure should be determined in accordance with the methodology set out in MGN 543 [now superseded by MGN 654]*" (RYA, 2019).

261. From the vessel traffic data, there is one main commercial route passes in proximity to the Proposed Development including crossing the subsea cables, headed in and out of the Port of Methil (Route 7). This route is low use (less than one vessel per day) and is typically operated by tugs and pilot vessels with draughts up to 3 m. The draught of vessels on this route (where available) are under 2.5 m against charted water depths of between 7 and 10 m where the route crosses the export cable.

262. Given the length of the subsea cables and that cable protection will only be implemented where cable burial is not possible/effective, it is not anticipated that there will be a large presence of cable protection. Taking into account the requirements of MGN 654, maintaining a 5% change in water depth may be challenging given the shallow waters where vessel traffic crosses the export cable.

However, this is offset by the relatively low draughts of vessels navigating in the area, resulting in a very low likelihood of a an underwater allision occurring.

263. In the unlikely event of an underwater allision incident occurring, the vessel in question would likely suffer minor damage and be able to make port noting the proximity of the Port of Methil. As a worst case, the vessel could be grounded and require assistance to be released. Emergency response facilities are located locally in the area and would be able to provide swift assistance as required. A grounding could result in pollution but this is considered highly unlikely.

264. The following embedded mitigation measure will reduce the significance of risk:

- Cable burial risk assessment – will help ensure the under keel clearance is sufficient for safe navigation (either by cable burial or protection), reducing the likelihood of an underwater allision incident.
- Compliance with MGN 654 – will help ensure the under keel clearance in relation to cable protection is reduced by no more than 5%.

265. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

15.3.4 Disruption to Emergency Response and Search and Rescue Operations

266. *Disruption to emergency response and SAR operations due to the presence of the Proposed Development.*

267. The presence of the Proposed Development may increase the number of incidents in the area and reduce access for emergency responders, hindering the ability to respond to an incident including SAR operations.

268. The design life of the WTG and Met Mast is 25 years. Both the Met Mast and WTG will be decommissioned as a whole after 25 years operation. A CTV will be used to enable maintenance activities to be undertaken on-site and an ROV will be used to undertake cable inspections with an appropriate frequency.

269. The most likely immediate responder to an incident in the area is the RNLI given that there are multiple RNLI lifeboat stations located within the Forth, with the closest at Kinghorn approximately 8.1 nm to the south west. From historical incident data, there are a relatively high number of incidents in the area responded to by the RNLI (an average of 43 incidents per year within the traffic study area over the 10-year period between 2010 and 2019) including eight incidents within 1 nm of the Proposed Development.

270. On this basis, the likelihood of an incident requiring an emergency response in proximity to the Proposed Development is high. However, since there will be only two structures, it is not anticipated that their presence will materially affect the likelihood of an incident, noting that only 10 collision or allision incidents associated

with UK offshore wind farms have been reported to date, corresponding to an average of one incident per 1,700 operational WTG years (as of November 2021).

271. Additionally, it is not anticipated that the Proposed Development will impede upon the capability of emergency responders including SAR assets. The lack of the internal array characteristic of large-scale offshore wind farm developments will allow SAR assets greater freedom in the approach to undertaking a search in proximity and the 625 m spacing between the two structures is sufficient to allow both marine and air based searches to navigate between the structures.

272. In the event of an incident occurring in proximity that requires emergency response, other vessels including project vessels if on-site may be able to render assistance including under SOLAS obligations (IMO, 1974). This is reflected in past experience, with nine known instances of a vessel (or persons on a vessel) being assisted by an industry vessel for a nearby UK offshore wind farm.

273. It is also noted that Forth Ports, as the competent harbour authority in the area, have a suite of emergency plans in place for responding to an incident within their jurisdiction, including a contingency plan.

274. In the unlikely event of an incident occurring where the presence of the Proposed Development hinders emergency responders, the consequences could be significant, including PLL and pollution.

275. The following embedded mitigation measures will reduce the significance of risk:

- Compliance with MGN 654 – will ensure the Proposed Development is designed and operated in line with the requirements of SAR Annex 5, including the implementation of an ERCoP and completion of a SAR checklist.
- Development within a VTS area – will assist in ensuring clear coordination and communication for all vessels including project vessels in relation to providing assistance under SOLAS obligations as support for emergency responders.

276. Overall, the frequency of the hazard is considered **Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Tolerable with Monitoring**.

15.3.5 Disruption to Pilotage Services

277. *Disruption to pilot boarding activities due to the presence of surface infrastructure associated with the Proposed Development.*

278. As noted for the equivalent construction phase hazard, the pilot boarding station for the Port of Methil is located approximately 290 m north east of the WTG location. Its use is compulsory for vessels inbound to Methil over 60m length or carrying dangerous cargoes and over 45 m length.

279. No use of pilot boarding services was observed in the vessel traffic data. Although the vessel traffic data includes AIS only, given the requirements for pilotage at the Port of Methil it is not anticipated that any non-AIS vessels would utilise the pilotage services. Furthermore, during consultation Forth Ports indicated that pilot boarding for the Port of Methil is not typically undertaken in proximity to the charted pilot boarding station and is typically done where the vessel has anchored within the anchorage area. RYA Scotland added that recreational vessels are unlikely to utilise the pilotage services.

280. This hazard is considered to be broadly similar in nature to that assessed for the equivalent construction phase hazard. Additionally, given the duration of the operational phase, mariners navigating in the area will develop a high level of familiarity and awareness with the Proposed Development, including when approaching the pilot boarding station for the Port of Methil. The same embedded mitigation measures are proposed as for the equivalent construction phase hazard.

281. Overall, the frequency of the hazard is considered **Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Tolerable with Monitoring**.

15.3.6 Prevention of Use of Existing Aids to Navigation

282. *The presence of surface infrastructure associated with the Proposed Development may prevent the use of existing aids to navigation.*

283. The design life of the WTG and Met Mast is 25 years. Both the Met Mast and WTG will be decommissioned as a whole after 25 years operation. Aids to navigation local to the Proposed Development include:

- Special mark located approximately 0.5 nm west of the Met Mast designating a charted obstruction;
- Multiple spherical buoys located approximately 0.6 nm north west of the WTG designating the perimeter of Energy Park Fife; and
- Leading lights for the Port of Methil with a nominal range of 5 nm located approximately 0.9 nm north of the WTG.

284. The special mark and spherical buoys are designed for navigational use when in close proximity and so the presence of the Proposed Development is anticipated to have a negligible effect on their use, noting that during consultation Forth Ports indicated that the Proposed Development is located far enough away from navigational features in the area, including Energy Park Fife.

285. For the leading lights at the Port of Methil, the nominal range of 5 nm will result in interaction with the Proposed Development. From the vessel traffic data, there are two main commercial routes in and out of the Port of Methil (Routes 7 and 8), with both low use (less than one vessel per day).

286. For Route 8, there is not expected to be a negligible effect given that vessels on this route will not have the Proposed Development directly between them and the port at any time. For Route 7, there may be some blocking of the leading lights for vessels on approach to the Port of Methil, although this will be limited up until 1 nm from the port at which point vessels will be passing the Met Mast.

287. During consultation RYA Scotland noted that the Craigkelly transmitter has three noticeable lights at night and in suitable conditions the Inch Cape Met Mast can be seen from a far distance.

288. However, with only two structures present, the risk will be minor and short-term in nature, with the mostly likely consequence temporary visual confusion. As a worst-case a mariner may lose track of their vessel’s position and allide with one of the structures or run aground in the nearshore area. However, such a scenario is considered highly unlikely, particularly given that mariners navigating in the area will develop a high level of familiarity and awareness with the Proposed Development.

289. The following embedded mitigation measures will reduce the significance of risk:

- Lighting and marking – will assist in providing alternative means of navigation for vessels approaching the Port of Methil to navigate if use of the leading lights is compromised.
- Promulgation of information – will assist in raising awareness of possible short-term periods where the leading lights for the Port of Methil are compromised, reducing the risk of temporary visual confusion.

290. Overall, the frequency of the hazard is considered **Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Tolerable with Monitoring.**

15.4 Decommissioning Phase

15.4.1 Vessel Displacement, Collision Risk and Restrictions on Port Access for Third-Party Vessels

291. *Displacement of vessels due to the presence of decommissioning activities associated with the Proposed Development and subsequent vessel to vessel collision risk and/or restrictions on port access for third-party vessels.*

292. Offshore decommissioning is expected to follow a similar process, method and timescale to offshore construction, as detailed in Section 6.4, although the subsea cables are assumed to be left in situ. Therefore, the hazard is expected to be similar in nature to the equivalent construction phase hazard including no deviations from the mean positions of the routes and limited squeezing of vessels. The same embedded mitigation measures are proposed as for the equivalent construction phase hazard.

293. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

15.4.2 Disruption to Pilotage Services

294. *Disruption to pilot boarding activities due to the presence of decommissioning activities associated with the Proposed Development.*

295. Offshore decommissioning is expected to follow a similar process, method and timescale to offshore construction, as detailed in Section 6.4, although the subsea cables are assumed to be left in situ. Therefore, the hazard is expected to be similar in nature to the equivalent construction phase hazard including minimal disruption to pilotage activities. The same embedded mitigation measures are proposed as for the equivalent construction phase hazard.

296. Overall, the frequency of the hazard is considered **Extremely Remote** and the consequences are considered **Minor**. Therefore, the significance of the risk is considered **Broadly Acceptable**.

16 Mitigation Measures

16.1 Embedded Mitigation Measures

297. The risk assessment undertaken in Section 15 introduces a number of mitigation measures which are embedded into the Proposed Development and included to reduce the significance of risk of those hazards assessed in the FSA. Details of these embedded mitigation measures are provided in Table 16.1.

298. It is noted that an application for statutory safety zones has not been included on the basis that Forth Ports – as the competent harbour authority in the area – will implement safety zones, exclusion zones or speed restrictions as deemed necessary at each phase of the Proposed Development. This is reflected in the inclusion of an additional mitigation measure relating to ongoing consultation with Forth Ports (see Section 16.2).

Table 16.1 Summary of Embedded Mitigation Measures

Embedded Mitigation Measure	Details
Cable burial risk assessment	Cable protection will be suitably implemented and monitored where adequate burial depth as identified via risk assessment is not feasible, with any damage, destruction or decay of cables notified to MCA, NLB, Kingfisher and UKHO no later than 24 hours after discovered.
Charting of infrastructure	Infrastructure associated with the Proposed Development (both surface and subsea) will be appropriately marked on UKHO Admiralty Charts.
Compliance with MGN 654	Compliance with the requirements of MGN 654 and its annexes, including SAR Annex 5 (MCA, 2021), will ensured, where applicable.
Development within VTS area	Will allow Forth Ports as the competent harbour authority to control the movement of vessels including project vessels.
Guard vessel	Use of a guard vessel as required by risk assessment.
Lighting and marking	Lighting and marking of the Proposed Development will be in agreement with NLB and in accordance with IALA Recommendation O-139 (IALA, 2013).
Marine licence conditions	The marine licence may specify additional documentation post consent to further manage vessel traffic.
Minimum blade tip clearance	The minimum blade tip clearance of the WTG will be at least 25 m above HAT.

Embedded Mitigation Measure	Details
Promulgation of information	Information relating to the Proposed Development including project vessel routes, timings and locations will be promulgated via Kingfisher Bulletins.

16.2 Additional Mitigation Measures

299. An additional mitigation measure has been identified for reducing risk to As Low as Reasonably Practicable (ALARP) (i.e. the residual risk). Details of this additional mitigation measure are provided in Table 16.2.

Table 16.2 Summary of Additional Mitigation Measures

Additional Mitigation Measures	Details
Ongoing consultation with Forth Ports	Since Forth Ports is the competent harbour authority and operator of the VTS area within which the Proposed Development is located, consultation will be ongoing throughout all phases of the Proposed Development.

300. This additional mitigation measure is considered vital throughout all phases of the Proposed Development and is relevant for all of the hazards which have been assessed in the FSA. The residual risk with this additional mitigation measure considered is provided in Section 18.5.

17 Through Life Safety Management

Quality, Health, Safety and Environment (QHSE) documentation including a Safety Management System will be in place and continually updated throughout the development process. Table 17.1 provides an overview of various documentation and how it will be maintained and reviewed with reference, where required, to specific marine documentation.

Monitoring, reviewing and auditing will be carried out on all procedures and activities and feedback actively sought. The designated person (identified in QHSE documentation), managers and supervisors are to maintain continuous monitoring of all marine operations and determine if all required procedures and processes are being correctly implemented.

Table 17.1 Summary of QHSE Documentation

Documentation	Details
Incident reporting	An incident report will be completed following any incidents, including near misses. A review will then be undertaken to determine any possible need for operational changes, be it corrective or preventive action. Where appropriate, the designed person (noted within the ERCoP) should inform the MCA and Forth Ports of any exercise or incidents including any implications on emergency response, with the MCA and Forth Ports invited to participate in debriefs.
Review of documentation	The Proposed Development will be responsible for reviewing and updating all documentation including the risk assessments, ERCoP, safety management system and, if required, will convene a review panel of stakeholders to quantify risk. A review of potential risks and response procedures will be undertaken annually.
Inspection of resources	All vessels, facilities, and equipment necessary for marine operations are to be subject to appropriate inspection and testing to determine fitness for purpose and availability in relation to their performance standards, including aids to navigation relative to the performance standards specified by NLB.
Audit of performance	Audits will be undertaken periodically to evaluate the efficiency of the marine safety documentation and possible corrective actions should be undertaken in accordance with standard procedures with audit results and reviews brought to the attention of responsible personnel.
Safety management system	An integrated safety management system will be established to ensure the safety and environmental impact of activities undertaken are ALARP. This includes the use of remote monitoring and switching for aids to navigation to ensure that a quick fix for a faulty light can be instigated, thus ensuring IALA availability requirements are satisfied.
Cable monitoring	The subsea cables will be subject to periodic inspection post construction to monitor cable burial depths and protection. If exposed cables or ineffective cable protection measures are identified, these would be promulgated to relevant sea users including via Notifications to Mariners and Kingfisher Bulletins and if there was deemed to be an immediate risk additional temporary measures may be deployed until such time as the risk is permanently mitigated.
Hydrographic surveys	As required by MGN 654, detailed and accurate hydrographic surveys will be undertaken periodically at intervals agreed with the MCA.

Documentation	Details
Decommissioning Plan	A decommissioning plan will be developed. For shipping and navigation, this will include consideration of the scenario where upon decommissioning and completion of removal operations, an obstruction is left on-site which is considered a danger to safe navigation and has not been possible to remove.

18 Summary

18.1 Consultation

301. Dedicated meetings with the MCA, Forth Ports and RYA Scotland have been undertaken. Additionally, a Hazard Workshop was undertaken with the following organisations:

- MCA;
- NLB;
- RYA Scotland;
- Forth Ports;
- Forth Yacht Clubs Association;
- Fife Fishermen's Association; and
- SFF.

18.2 Baseline Characterisation

18.2.1 Navigational Features

302. There are numerous ports and harbours located in the area, with the closest being the Port of Methil, located approximately 0.9 nm north of the Proposed Development. The Proposed Development lies within the area of jurisdiction of Forth Ports and a VTS is operated out of Grangemouth.

303. A pilot boarding station for the Port of Methil is located approximately 290 m north east of the WTG.

304. There are numerous designated anchorage areas located in the area, with the closest being the small vessel anchorage associated with the Port of Methil, located approximately 170 m north east of the WTG. There are also deep water anchor berths associated with Methil and Kirkcaldy located south and east of the Proposed Development.

305. There are several aids to navigation located in the area, including a special mark located approximately 0.5 nm west of the Met Mast, multiple spherical buoys associated with the Energy Fife Park and the leading lights for the Port of Methil.

18.2.2 Emergency Response and Incidents

306. The closest SAR helicopter base location to the Proposed Development is Prestwick, located approximately 66 nm to the south west. DfT SAR helicopter taskings data for the period between April 2015 and March 2021 indicates an average of eight to nine taskings per year in the area, with none within 1 nm of the Proposed Development.

307. There are a number of RNLI stations located within the Firth of Forth, with the closest being at Kinghorn, located approximately 7.8 nm to the south west. RNLI incident

data for the period between 2010 and 2019 indicates an average of 43 incidents per year in the area, including eight incidents within 1 nm of the Proposed Development.

308. MAIB incident data for the period between 2010 and 2019 indicates an average of four incidents per year in the area, with none within 1 nm of the Proposed Development.

18.2.3 Vessel Traffic Movements

309. There was an average of 29 unique vessels recorded per day within the traffic study area during the survey period. The most common vessel types were tankers (30%), cargo vessels (20%) and commercial fishing vessels (20%).

310. Commercial vessels (cargo vessels and tankers) were generally recorded transiting east-west through the Firth of Forth to and from major ports such as Grangemouth. A proportion of tankers were noted utilising the Kirkcaldy anchorage berths. Commercial traffic is considered a suitable distance from the Proposed Development that it would not require deviation.

311. Commercial fishing vessels were recorded both in transit and actively fishing, with these vessels generally recorded at the south and east of the traffic study area. Limited recreational activity was recorded within the traffic study area during the survey period.

312. A total of nine main commercial routes were identified from the AIS data studied. Of these, two are anticipated to require a change in the standard deviation from the mean position as a result of the Proposed Development, noting that a deviation is not required for the mean position itself.

18.3 Collision and Allision Risk Modelling

313. Assuming base case traffic levels, the annual vessel to vessel collision risk was estimated as one in 1,060 years post wind farm, representing a negligible increase compared to the pre wind farm scenario.

314. Assuming base case traffic levels, the annual powered vessel tor structure allision risk was estimated as one in 28,750 years post wind farm.

315. After modelling three drift scenarios it was established that the flood tide dominated scenario produced the worst-case results. Assuming base case traffic levels, the annual drifting vessel to structure allision risk was estimated as one in 760,000 years post wind farm, which is considered a negligible value.

18.4 Cumulative Effect Assessment

316. The only offshore development (operational or planned) within the Firth of Forth relevant to shipping and navigation is Energy Park Fife, located approximately 400 m south west of the Port of Methil. Since this development is operational and included

in the characterisation of the baseline environment, it is considered a baseline development rather than a cumulative development.

317. Therefore, with no cumulative developments screened in to the CEA, no assessment of cumulative risk has been undertaken in this NRA.

18.5 Risk Identification and Formal Safety Assessment

318. Using the baseline characterisation, the outputs of consultation and the outputs of collision and allision risk modelling, hazards relating to shipping and navigation that may arise as a result of the presence of the Proposed Development and associated activities have been identified and assessed based upon a worst case scenario for shipping and navigation. Table 18.1 summarises the outcomes of the FSA undertaken, including the:

- Hazards scoped into the FSA;
- Embedded mitigation measures applied to each hazard assessed to reduce the significance of risk;
- Frequency of occurrence and severity of consequence rankings for each hazard and subsequent significance of risk;
- Additional mitigation measures applied to each hazard assessed to further reduce the significance of risk; and
- Residual risk with the additional mitigation measures applied.

Table 18.1 Outcomes of FSA Including Residual Risk

Hazard	Phase	Embedded Mitigation Measures	Frequency of Occurrence	Severity of Consequence	Significance of Risk	Additional Mitigation Measures	Residual Risk
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Construction	▪ Charting of infrastructure; ▪ Guard vessel; ▪ Lighting and marking; and ▪ Promulgation of information.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Disruption to pilotage services	Construction	▪ Charting of infrastructure; ▪ Guard vessel; ▪ Lighting and marking; and ▪ Promulgation of information.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Operational	▪ Charting of infrastructure; ▪ Guard vessel; ▪ Lighting and marking; and ▪ Promulgation of information.	Remote	Minor	Tolerable with Monitoring	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable

Hazard	Phase	Embedded Mitigation Measures	Frequency of Occurrence	Severity of Consequence	Significance of Risk	Additional Mitigation Measures	Residual Risk
Allision risk for third-party vessels	Operational	▪ Charting of infrastructure; ▪ Development within a VTS area; ▪ Guard vessel; ▪ Lighting and marking; ▪ Minimum blade tip clearance; and ▪ Promulgation of information.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Increased grounding risk for third-party vessels	Operational	▪ Cable burial risk assessment; and ▪ Compliance with MGN 654.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Disruption to emergency response and SAR operations	Operational	▪ Compliance with MGN 654; and ▪ Development within a VTS area.	Remote	Minor	Tolerable with Monitoring	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Disruption to pilotage services	Operational	▪ Charting of infrastructure; ▪ Lighting and marking; and ▪ Promulgation of information.	Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable

Hazard	Phase	Embedded Mitigation Measures	Frequency of Occurrence	Severity of Consequence	Significance of Risk	Additional Mitigation Measures	Residual Risk
Prevention of use of aids to navigation	Operational	▪ Lighting and marking; and ▪ Promulgation of information.	Remote	Minor	Tolerable with Monitoring	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Vessel displacement, collision risk and restrictions on port access for third-party vessels	Decommissioning	▪ Charting of infrastructure; ▪ Guard vessel; ▪ Lighting and marking; and ▪ Promulgation of information.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable
Disruption to pilotage services	Decommissioning	▪ Charting of infrastructure; ▪ Guard vessel; ▪ Lighting and marking; and ▪ Promulgation of information.	Extremely Remote	Minor	Broadly Acceptable	▪ Ongoing consultation with Forth Ports.	Broadly Acceptable

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Appendix A Marine Guidance Note 654 Checklist

319. The MGN 654 checklist can be divided into two distinct checklists, one considering the main MGN 654 guidance document and one considering the *Methodology for Assessing Marine Navigational Safety and Emergency Response Risks of OREIs* (MCA, 2021) which serves as Annex 1 to MGN 654.

320. The checklist for the main MGN 654 guidance document is presented in Table A.1. Following this, the checklist for the MCA's methodology annex is presented in Table A.2. For both checklists, references to where the relevant information and/or assessment is provided in the NRA is given.

Table A.1 MGN 654 Checklist for Main Document

Issue	Compliance	Reference and Notes
Site and Installation Co-ordinates. Developers are responsible for ensuring that formally agreed coordinates and subsequent variations of site perimeters and individual OREI structures are made available, on request, to interested parties at relevant project stages, including application for consent, development, array variation, operation and decommissioning. This should be supplied as authoritative GIS data, preferably in Environmental Systems Research Institute (ESRI) format. Metadata should facilitate the identification of the data creator, its date and purpose, and the geodetic datum used. For mariners' use, appropriate data should also be provided with latitude and longitude coordinates in WGS84 (European Terrestrial Reference System 1989 (ETRS89)) datum.		
Traffic Survey. Includes:		
All vessel types	✓	**Section 10: Vessel Traffic Movements** All vessel types are considered with specific breakdowns by vessel type given for the Proposed Development (see Section 10) shipping and navigation study area.
At least 28 days duration, within either 12 or 24 months prior to submission of the ES.	✓	**Section 7: Data Sources** A total of 56 full days of AIS data from January/February 2021 and June 2021 has been assessed within the Proposed Development shipping and navigation study area.
Multiple data sources	✓	**Section 7: Data Sources** In addition to the AIS data, Anatec's ShipRoutes database and consultation feedback (including with Forth Ports as the operator of the VTS in the area) has been used to characterise vessel traffic movements.
Seasonal variations	✓	**Section 7: Data Sources** The AIS data covers two separate 28-day periods in January/ February 2021 (winter) and June 2021 (summer) to account for seasonal variation.
MCA consultation	✓	**Section 4: Consultation** The MCA were consulted via a stakeholder meeting.
General Lighthouse Authority (GLA) consultation	✓	**Section 4: Consultation** NLB attended the Hazard Workshop.

Issue	Compliance	Reference and Notes
UK Chamber of Shipping consultation	✓	**Section 4: Consultation** UK Chamber of Shipping were invited to the Hazard Workshop but were unable to attend.
Recreational and fishing vessel consultation	✓	**Section 4: Consultation** The Forth Yacht Clubs Association, Fife Fishermen's Association and SFF attended the Hazard Workshop.
Port and navigation authorities consultation, as appropriate	✓	**Section 4: Consultation** A meeting with Forth Ports is planned and Forth Ports attended the Hazard Workshop.
Assessment of the cumulative and individual effects of (as appropriate):		
i. Proposed OREI site relative to areas used by any type of marine craft.	✓	**Section 10: Vessel Traffic Movements** Vessel traffic data in proximity to the Proposed Development has been analysed. **Section 14: Hazards Scoped into the Formal Safety Assessment** The hazards due to the Proposed Development which require consideration in the FSA have been identified for each phase. **Section 15: Formal Safety Assessment** The hazards due to the Proposed Development have been assessed for each phase.
ii. Numbers, types and sizes of vessels presently using such areas.	✓	**Section 10: Vessel Traffic Movements** Vessel traffic data in proximity to the Proposed Development has been analysed and includes breakdowns of daily count, vessel type and vessel size.
iii. Non-transit uses of the area, e.g. fishing, day cruising of leisure craft, racing, aggregate dredging, personal watercraft etc.	✓	**Section 10: Vessel Traffic Movements** Non-transit activity in proximity to the Proposed Development has been analysed and includes fishing and anchoring activity.
iv. Whether these areas contain transit routes used by coastal or deep-draught or international scheduled vessels on passage.	✓	**Section 10: Vessel Traffic Movements** Main commercial routes have been identified using the principles set out in MGN 654 in proximity to the Proposed Development with these routes taking into account coastal, deep-draught and internationally scheduled vessels.
v. Alignment and proximity of the site relative to adjacent shipping routes.	✓	**Section 10: Vessel Traffic Movements** Main commercial routes have been identified using the principles set out in MGN 654 in proximity to the Proposed Development.
vi. Whether the nearby area contains prescribed routeing schemes or precautionary areas.	✓	**Section 8: Navigational Features** There are no IMO routeing measures or precautionary areas in proximity to the Proposed Development.

Issue	Compliance	Reference and Notes
vii. Proximity of the site to areas used for anchorage (charted or uncharted), safe haven, port approaches and pilot boarding or landing areas.	✓	**Section 8: Navigational Features** Designated anchorage areas and pilot boarding stations in proximity to the Proposed Development have been identified. **Section 10: Vessel Traffic Movements** Safe havens in proximity to the Proposed Development have been identified.
viii. Whether the site lies within the jurisdiction of a port and/or navigation authority.	✓	**Section 8: Navigational Features** The Proposed Development lies within the jurisdiction of Forth Ports.
ix. Proximity of the site to existing fishing grounds, or to routes used by fishing vessels to such grounds.	✓	**Section 10: Vessel Traffic Movements** Vessel traffic data in proximity to the Proposed Development has been analysed and includes consideration of commercial fishing vessels.
x. Proximity of the site to offshore firing/bombing ranges and areas used for any marine military purposes.	✓	**Section 8: Navigational Features** There are no military practice and exercise areas charted in proximity to the Proposed Development or referenced in the Admiralty Sailing Directions.
xi. Proximity of the site to existing or proposed submarine cables or pipelines, offshore oil/gas platform, marine aggregate dredging, marine archaeological sites or wrecks, Marine Protected Area or other exploration/ exploitation sites.	✓	**Section 8: Navigational Features** Charted wrecks in proximity to the Proposed Development have been identified. There are no submarine cables or pipelines, oil/gas platforms, marine aggregate dredging areas or other sites in proximity to the Proposed Development.
xii. Proximity of the site to existing or proposed OREI developments, in cooperation with other relevant developers, within each round of lease awards.	✓	**Section 8: Navigational Features** The Levenmouth Demonstration Turbine has been noted but there are no other offshore wind farm developments in proximity to the Proposed Development.
xiii. Proximity of the site relative to any designated areas for the disposal of dredging spoil or other dumping grounds.	✓	**Section 8: Navigational Features** Spoil and foul grounds in proximity to the Proposed Development have been identified.
xiv. Proximity of the site to aids to navigation and/or VTS in or adjacent to the area and any impact thereon.	✓	**Section 8: Navigational Features** Aids to navigation in proximity to the Proposed Development have been identified. The Proposed Development is located in a VTS area (the Forth and Tay Navigation Service).

Issue	Compliance	Reference and Notes
xv. Researched opinion using computer simulation techniques with respect to the displacement of traffic and, in particular, the creation of "choke points" in areas of high traffic density and nearby or consented OREI sites not yet constructed.	✓	**Section 13: Collision and Allision Risk Modelling** Collision and allision risk modelling has been undertaken in proximity to the Proposed Development.
xvi. With reference to xv. above, the number and type of incidents to vessels which have taken place in or near to the proposed site of the OREI to assess the likelihood of such events in the future and the potential impact of such a situation.	✓	**Section 9: Emergency Response and Historical Incidents** Historical vessel incident data published by DfT, RNLI and MAIB in proximity to the Proposed Development have been considered alongside historical offshore wind farm incident data throughout the UK.
xvii. Proximity of the site to areas used for recreation which depend on specific features of the area.	✓	**Section 10: Vessel Traffic Movements** Non-transit activity in proximity to the Proposed Development has been analysed and includes (limited) recreational activity.
Predicted effect of OREI on traffic and interactive boundaries. Where appropriate, the following should be determined:		
a. The safe distance between a shipping route and OREI boundaries.	✓	**Section 12: Future Case Vessel Traffic Movements** A methodology for post wind farm routeing is outlined and includes consideration of the minimum passing distance for main commercial routes.
b. The width of a corridor between sites or OREIs to allow safe passage of shipping.	✓	There are no corridors in the layout of the Proposed Development.
OREI structures. The following should be determined:		
a. Whether any feature of the OREI, including auxiliary platforms outside the main generator site, mooring and anchoring systems, inter-device and export cabling could pose any type of difficulty or danger to vessels underway, performing normal operations, including fishing anchoring and emergency response.	✓	**Section 14: Hazards Scoped into the Formal Safety Assessment** Allision risk, grounding risk and emergency response are identified as hazards scoped into the FSA. **Section 15: Formal Safety Assessment** The risk due to the Proposed Development on allision, grounding and disruption to emergency response has been assessed.

Issue	Compliance	Reference and Notes
b. Clearances of fixed or floating wind turbine blades above the sea surface are not less than 22 m (above Mean High Water Springs (MHWS) for fixed). Floating turbines allow for degrees of motion.	✓	**Section 16: Embedded Mitigation Measures** The minimum blade tip clearance of the WTG will be at least 25 m above HAT.
c. Underwater devices: i. Changes to charted depth; ii. Maximum height above seabed; and iii. Under keel clearance.	✓	**Section 6: Project Description** The specifications for the subsea cables are provided. **Section 14: Hazards Scoped into the Formal Safety Assessment** Grounding risk is identified as a hazard scoped into the FSA. **Section 15: Formal Safety Assessment** The risk due to the Proposed Development of grounding has been assessed.
d. Whether structure block or hinder the view of other vessels or other navigational features.	✓	**Section 14: Hazards Scoped into the Formal Safety Assessment** The prevention of use of existing aids to navigation is identified as a hazard scoped into the FSA. **Section 15: Formal Safety Assessment** The risk due to the Proposed Development of the prevention of use of existing aids to navigation has been assessed.
The effects of tides, tidal streams and weather. It should be determined whether:		
a. Current maritime traffic flows and operations in the general area are affected by the depth of water in which the proposed installation is situated at various states of the tide, i.e. whether the installation could pose problems at high water which do not exist at low water conditions, and vice versa.	✓	**Section 6: Project Description** The range of water depths in proximity to the Proposed Development is provided. **Section 13: Collision and Allision Risk Modelling** Peak flood and ebb tidal data local to the Proposed Development is provided and used as input to the collision and allision risk modelling. **Section 14: Hazards Scoped into the Formal Safety Assessment** Grounding risk is identified as a hazard scoped into the FSA. **Section 15: Formal Safety Assessment** The risk due to the Proposed Development of grounding has been assessed.
b. The set and rate of the tidal stream, at any state of the tide, has a significant effect on vessels in the area of the OREI site.	✓	**Section 13: Collision and Allision Risk Modelling** Peak flood and ebb tidal data local to the Proposed Development is provided and used as input to the collision and allision risk modelling.

Issue	Compliance	Reference and Notes
c. The maximum rate tidal stream runs parallel to the major axis of the proposed site layout, and, if so, its effect.	✓	
d. The set is across the major axis of the layout at any time, and, if so, at what rate.	✓	
e. In general, whether engine failure or other circumstance could cause vessels to be set into danger by the tidal stream, including unpowered vessels and small, low speed craft.	✓	**Section 13: Collision and Allision Risk Modelling** Peak flood and ebb tidal data local to the Proposed Development is provided and used as input to the collision and allision risk modelling. The drifting allision model also considers whether machinery failure could cause vessels to be set into danger.
f. The structures themselves could cause changes in the set and rate of the tidal stream.	✓	**Section 13: Collision and Allision Risk Modelling** No risks are anticipated.
g. The structures in the tidal stream could be such as to produce siltation, deposition of sediment or scouring, affecting navigable water depths in the wind farm area or adjacent to the area.	✓	**Section 16: Embedded Mitigation Measures** The minimum blade tip clearance of the WTG will be at least 25 m above HAT.
h. The site, in normal, bad weather, or restricted visibility conditions, could present difficulties or dangers to craft, including sailing vessels, which might pass in close proximity to it.	✓	**Section 13: Collision and Allision Risk Modelling** Weather and visibility data local to the Proposed Development is provided and used as input to the collision and allision risk modelling. **Section 10: Vessel Traffic Movements** Recreational activity in proximity to the Proposed Development has been analysed.
i. The structures could create problems in the area for vessels under sail, such as wind masking, turbulence or sheer.	✓	**Section 15: Formal Safety Assessment** The risks due to the Proposed Development on allision have been assessed and include consideration of wind masking, turbulence or sheer for vessels under sail.
j. In general, taking into account the prevailing winds for the area, whether engine failure or other circumstances could cause vessels to drift into danger, particularly if in conjunction with a tidal set such as referred to above.	✓	**Section 13: Collision and Allision Risk Modelling** The drifting allision model takes into account weather and tidal conditions and considers whether machinery failure could cause vessels to be set into danger.

Issue	Compliance	Reference and Notes
Assessment of access to and navigation within, or close to, an OREI. To determine the extent to which navigation would be feasible within the OREI site itself by assessing whether:		
a. Navigation within or close to the site would be safe:		
i. For all vessels.	✓	**Section 10: Vessel Traffic Movements** Adverse weather routeing has been considered. **Section 13: Collision and Allision Risk Modelling** Weather and visibility data local to the Proposed Development is provided and used as input to the collision and allision risk modelling. **Section 14: Hazards Scoped into the Formal Safety Assessment** Vessel displacement and allision risk are identified as hazards scoped into the FSA. **Section 15: Formal Safety Assessment** The risks due to the Proposed Development of vessel displacement and allision have been assessed.
ii. For specified vessel types, operations and/or sizes.	✓	
iii. In all directions or areas.	✓	
iv. In specified directions or areas.	✓	
v. In specified tidal, weather or other conditions.	✓	
b. Navigation in and/or near the site should be prohibited or restricted:		
i. For specified vessel types, operations and/or sizes.	✓	**Section 16: Embedded Mitigation Measures** Forth Ports – as the competent harbour authority in the area – will implement safety zones, exclusion zones or speed restrictions as deemed necessary for each phase of the Proposed Development.
ii. In respect of specific activities.	✓	
iii. In all areas or directions.	✓	
iv. Prohibited in specified areas or directions.	✓	
v. In specified tidal or whether conditions.	✓	
c. Where it is not feasible for vessels to access or navigate through the site it could cause navigational, safety or routeing problems for vessels operating in the area e.g. by preventing vessels from responding to calls for assistance from persons in distress.	✓	**Section 14: Hazards Scoped into the Formal Safety Assessment** Vessel displacement and emergency response are identified as hazards scoped into the FSA. **Section 15: Formal Safety Assessment** The risks due to the Proposed Development of vessel displacement and disruption to emergency response have been assessed.
d. Guidance on the calculation of safe distance of OREI boundaries from shipping routes has been considered.	✓	**Section 12: Future Case Vessel Traffic Movements** A methodology for post wind farm routeing is outlined and includes consideration of the minimum passing distance for main commercial routes.

Issue	Compliance	Reference and Notes
SAR, maritime assistance service, counter pollution and salvage incident response.		
The MCA, through HM Coastguard, is required to provide SAR and emergency response within the sea area occupied by all OREIs in UK waters. To ensure that such operations can be safely and effectively conducted, certain requirements must be met by developers and operators.		
a. An ERCoP will be developed for the construction, operation and decommissioning phases of the OREI.	✓	**Section 16: Embedded Mitigation Measures** Compliance with the requirements of MGN 654, which includes the provision of an ERCoP, need to fulfil the requirements of the stated MCA guidance document and completion of the SAR checklist, will be ensured.
b. The MCA's guidance document *Offshore Renewable Energy Installations: Requirements, Guidance and Operational Considerations for Search and Rescue and Emergency Response* (MCA, 2018) for the design, equipment and operation requirements will be followed.	✓	
c. A SAR checklist will be completed to record discussions regarding the requirements, recommendations and considerations outlined in Annex 5 (to be agreed with MCA).	✓	
Hydrography. In order to establish a baseline, confirm the safe navigable depth, monitor seabed mobility and to identify underwater hazards, detailed and accurate hydrographic surveys are included or acknowledged for the following stages and to MCA specifications:		
Pre construction: The proposed generating assets area and proposed cable route.	✓	**Section 16: Embedded Mitigation Measures** Compliance with the requirements of MGN 654, which includes the stated hydrographic surveys, will be ensured.
ii. On a pre-established periodicity during the life of the development.	✓	
ii. Post construction: Cable route(s).	✓	
iii. Post decommissioning of all or part of the development: the installed generating assets area and cable route.	✓	

Issue	Compliance	Reference and Notes
Communications, Radar and positioning systems. To provide researched opinion of a generic and, where appropriate, site specific nature concerning whether:		
a. The structures could produce radio interference such as shadowing, reflections or phase changes, and emissions with respect to any frequencies used for marine positioning, navigation and timing (PNT) or communications, including Global Maritime Distress and Safety System (GMDSS) and AIS, whether ship borne ashore or fitted to any of the proposed structures, to:		
i. Vessels operating at a safe navigational distance.	✓	**Section 11: Navigation, Communication and Position Fixing Equipment** Potential hazards relating to the different communication and position fixing equipment used in and around offshore wind farms are assessed.
ii. Vessels by the nature of their work necessarily operating at less than the safe navigational distance to the OREI, e.g. support vessels, survey vessels, SAR assets.	✓	
iii. Vessels by the nature of their work necessarily operating within the OREI.	✓	
b. The structures could produce Radar reflections, blind spots, shadow areas or other adverse effects:		
i. Vessel to vessel	✓	**Section 11: Navigation, Communication and Position Fixing Equipment** Potential hazards relating to the different communication and position fixing equipment used in and around offshore wind farms are assessed including Radar interference, SONAR interference, noise and electromagnetic interference.
ii. Vessel to shore	✓	
iii. VTS Radar to vessel	✓	
iv. Racon to/from vessel	✓	
c. The structures and generators might produce SONAR interference affecting fishing, industrial or military systems used in the area.	✓	
d. The site might produce acoustic noise which could mask prescribed sound signals.	✓	
e. Generators and the seabed cabling within the site onshore might produce Electromagnetic Fields (EMF) affecting compasses and other navigation systems.	✓	

Issue	Compliance	Reference and Notes
Risk mitigation measures recommended for OREI during construction, operation and decommissioning.		
Mitigation and safety measures will be applied to the OREI development appropriate to the level and type of risk determined during the EIA. The specific measures to be employed will be selected in consultation with the MCA and will be listed in the developer's ES. These will be consistent with international standards contained in, for example, Chapter V of SOLAS (IMO, 1974), and could include any or all of the following:		
i. Promulgation of information and warnings through notices to mariners and other appropriate MSI dissemination methods.	✓	**Section 16: Embedded Mitigation Measures** information relating to the Proposed Development including project vessel routes, timings and locations will be promulgated via Kingfisher Bulletins.
ii. Continuous watch by multi-channel VHF, including DSC.	✓	**Section 16: Embedded Mitigation Measures** The Proposed Development is located within a VTS area and therefore the competent harbour authority will monitor the movement of vessels.
iii. Safety Zones of appropriate configuration, extent and application to specified vessels[4].	✓	**Section 16: Embedded Mitigation Measures** Forth Ports – as the competent harbour authority in the area – will implement safety zones, exclusion zones or speed restrictions as deemed necessary for each phase of the Proposed Development.
iv. Designation of the site as an area to be avoided (ATBA)	✓	
v. Provision of aids to navigation as determined by the GLA.	✓	**Section 16: Embedded Mitigation Measures** Lighting and marking of the Proposed Development will be in agreement with NLB and in accordance with IALA Recommendation O-139 (IALA, 2013).
vi. Implementation of routeing measures within or near to the development.	✓	It is not planned to implement any new routeing measures within or near to the Proposed Development.
vii. Monitoring by Radar, AIS, Closed Circuit Television (CCTV) or other agreed means.	✓	**Section 16: Embedded Mitigation Measures** The Proposed Development is located within a VTS area and therefore the competent harbour authority will monitor the movement of vessels.
viii. Appropriate means for OREI operators to notify, and provide evidence of, the infringement of Safety Zones.	✓	**Section 16: Embedded Mitigation Measures** Forth Ports – as the competent harbour authority in the area – will implement safety zones, exclusion zones or speed restrictions as deemed necessary for each phase of the Proposed Development.
ix. Creation of an ERCoP with the MCA's SAR branch for the construction phase onwards.	✓	**Section 16: Embedded Mitigation Measures** Compliance with the requirements of MGN 654, which includes the provision of an ERCoP, will be ensured.
x. Use of guard vessels, where appropriate.	✓	**Section 16: Embedded Mitigation Measures** A guard vessel will be used as required by risk assessment.

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[4] As per SI 2007 No 1948 "The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007.

Issue	Compliance	Reference and Notes
xi. Update NRAs every two years, e.g. at testing sites.	✓	It is assumed that this is not required for the Proposed Development.
xii. Device-specific or array-specific NRAs.	✓	**Section 6: Project Description** All offshore elements of the Proposed Development have been considered in this NRA including the WTG, Met Mast and subsea cables.
xiii. Design of OREI structures to minimise risk to contacting vessels or craft.	✓	**Section 16: Embedded Mitigation Measures** The minimum blade tip clearance of the WTG will be at least 25 m above HAT.
xiv. Any other measures and procedures considered appropriate in consultation with other stakeholders.	✓	**Section 16: Embedded Mitigation Measures** Mitigation measures embedded into the Proposed Development to reduce the significance of risk of hazards are detailed.

Table A.2 MGN 654 Annex 1 Checklist

Item	Compliance	Comments
A risk claim is included that is supported by a reasoned argument and evidence.	✓	The FSA undertaken in Section 15 provides a risk claim for a range of hazards identified in Section 14 which is based on a number of inputs including baseline data, expert opinion, outputs of the Hazard Workshop, level of stakeholder concern and lessons learnt from existing offshore developments.
Description of the marine environment.	✓	Relevant navigational features in proximity to the Proposed Development have been described in Section 8 including ports and related services, anchorage areas and aids to navigation. A screening of cumulative developments has been undertaken in Section 3 based on various criteria.
SAR overview and assessment.	✓	Existing SAR resources in the Firth of Forth are summarised in Section 9 including the UK SAR operations contract, RNLI stations and assets and HMCG stations. The risks due to the Proposed Development of disruption to emergency response have then been assessed in Section 15.
Description of the OREI development and how it changes the marine environment.	✓	The maximum extent of the Proposed Development for which any shipping and navigation hazards are assessed is provided in Section 15 based on the project description in Section 6. Future case vessel traffic movements are considered in Section 12.
Analysis of the marine traffic, including base case and future traffic densities and types.	✓	Vessel traffic data in proximity to the Proposed Development has been analysed in Section 10.

Item	Compliance	Comments
Status of the hazard log: ▪ Hazard identification; ▪ Risk assessment; ▪ Influences on level of risk; ▪ Tolerability of risk; and ▪ Risk matrix.	✓	The hazard list is provided in full in Appendix B with the tolerability matrix used to determine the tolerability of hazards provided in Section 3.
NRA: ▪ Appropriate risk assessment; ▪ MCA acceptance for assessment techniques and tools; ▪ Demonstration of results; and ▪ Limitations.	✓	MGN 654 and the IMO's FSA guidelines are the primary guidance documents used for the assessment alongside MGN 372, as described in Section 2. Collision and allision risk modelling has been undertaken in Section 13 with the results outlined numerically and graphically (where appropriate).
Risk control log	✓	Mitigation measures embedded into the Proposed Development to reduce the significance of risk of hazards are detailed in Section 16.

Appendix B Hazard List

321. The complete hazard list, compiled following the Hazard Workshop, is presented in Table B.1. The preliminary risk represents the result of the high-level review of each risk prior to the FSA being undertaken with those risks scoped out of the FSA indicated alongside the rationale for their scoping out.

Table B.1 Hazard List

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of construction/ decommissioning activities associated with the Proposed Development	Vessel displacement	Construction/ decommissioning	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of construction/ decommissioning activities associated with the Proposed Development	Vessel displacement from adverse weather routes	Construction/ decommissioning	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	Scoped out	No alternative routeing was observed in adverse weather in proximity to the Proposed Development as part of the NRA (see Section 10.5.3).

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of construction/ decommissioning activities associated with the Proposed Development	Collision risk	Construction/ decommissioning	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of construction/ decommissioning activities associated with the Proposed Development	Collision risk	Construction/ decommissioning	▪ Project vessels	Broadly Acceptable	Scoped out	Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS (see Section 6.4).
Presence of construction/ decommissioning activities associated with the Proposed Development	Restrictions on port access	Construction/ decommissioning	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of construction/ decommissioning activities associated with the Proposed Development	Restrictions on safe haven access	Construction/ decommissioning	▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	Scoped out	No sheltering using safe havens was observed in proximity to the Proposed Development with known safe havens located well clear, as noted in the NRA (see Section 10.6).

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of construction/ decommissioning activities associated with the Proposed Development	Disruption to pilotage services	Construction/ decommissioning	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Vessel displacement	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Vessel displacement from adverse weather routes	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	Scoped out	No alternative routeing was observed in adverse weather in proximity to the Proposed Development as part of the NRA (see Section 10.5.3).

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Collision risk	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Tolerable with Monitoring	**Scoped in**	N/A
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Collision risk	Construction/ decommissioning	▪ Project vessels	Broadly Acceptable	Scoped out	Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS (see Section 6.4).
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Restrictions on port access	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Restrictions on safe haven access	Operational	▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	Scoped out	No sheltering using safe havens was observed in proximity to the Proposed Development with known safe havens located well clear, as noted in the NRA (see Section 10.6).

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of surface infrastructure associated with the Proposed Development	Powered allision risk	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure associated with the Proposed Development	Powered allision risk	Operational	▪ Project vessels	Broadly Acceptable	Scoped out	Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS (see Section 6.4).
Presence of surface infrastructure associated with the Proposed Development	Drifting allision risk	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure associated with the Proposed Development	Drifting allision risk	Operational	▪ Project vessels	Broadly Acceptable	Scoped out	Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS (see Section 6.4).

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of surface infrastructure associated with the Proposed Development	Drifting allision risk arising from anchor snagging risk for third-party vessels	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure associated with the Proposed Development	Drifting allision risk arising from anchor snagging risk for project vessels	Operational	▪ Project vessels	Broadly Acceptable	Scoped out	Since the Proposed Development lies within the jurisdiction of Forth Ports as the competent harbour authority which operates a VTS, project vessel movements will be managed by the VTS (see Section 6.4).
Presence of subsea cable protection associated with the Proposed Development	Grounding risk for third-party vessels	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of the Proposed Development and associated maintenance activities	Disruption to emergency response and SAR operations	Operational	▪ Emergency responders	Tolerable with Monitoring	**Scoped in**	N/A

Cause	Hazard	Phase	User(s)	Preliminary Risk	Scoped In/Out of FSA	Rationale for Scoping Out of FSA (Where Applicable)
Presence of surface infrastructure and maintenance activities associated with the Proposed Development	Disruption to pilotage services	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	**Scoped in**	N/A
Presence of surface infrastructure associated with the Proposed Development	Prevention of use of existing aids to navigation	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Tolerable with Monitoring	**Scoped in**	N/A
Presence of the Proposed Development	Effects on communication, Radar and position fixing equipment	Operational	▪ Commercial vessels; ▪ Commercial fishing vessels; and ▪ Recreational vessels.	Broadly Acceptable	Scoped out	An assessment of sensitivity for navigation, communication and position fixing equipment based on historical research, lessons learnt and expert opinion indicates low sensitivity for all aspects of the hazard as outlined in the NRA (see Section 11).

FORTHWIND

FORTHWIND OFFSHORE WIND DEMONSTRATION PROJECT

PRE-APPLICATION CONSULTATION REPORT

FW-REP-0002

REV	**DATE**	**PURPOSE OF ISSUE**	**PREPARED**	**CHECKED**	**APPROVED**
A1	31/03/2021	Draft for information	G Lee	M Murray	M Murray

Contents

1. INTRODUCTION

This pre-application consultation (PAC) report has been prepared by Forthwind Ltd to explain the consultation process that has been undertaken to inform the proposals for the Proposed Development of a 20 Megawatt (MW) offshore Wind Demonstration project off the coast of Methil, Fife, Scotland.

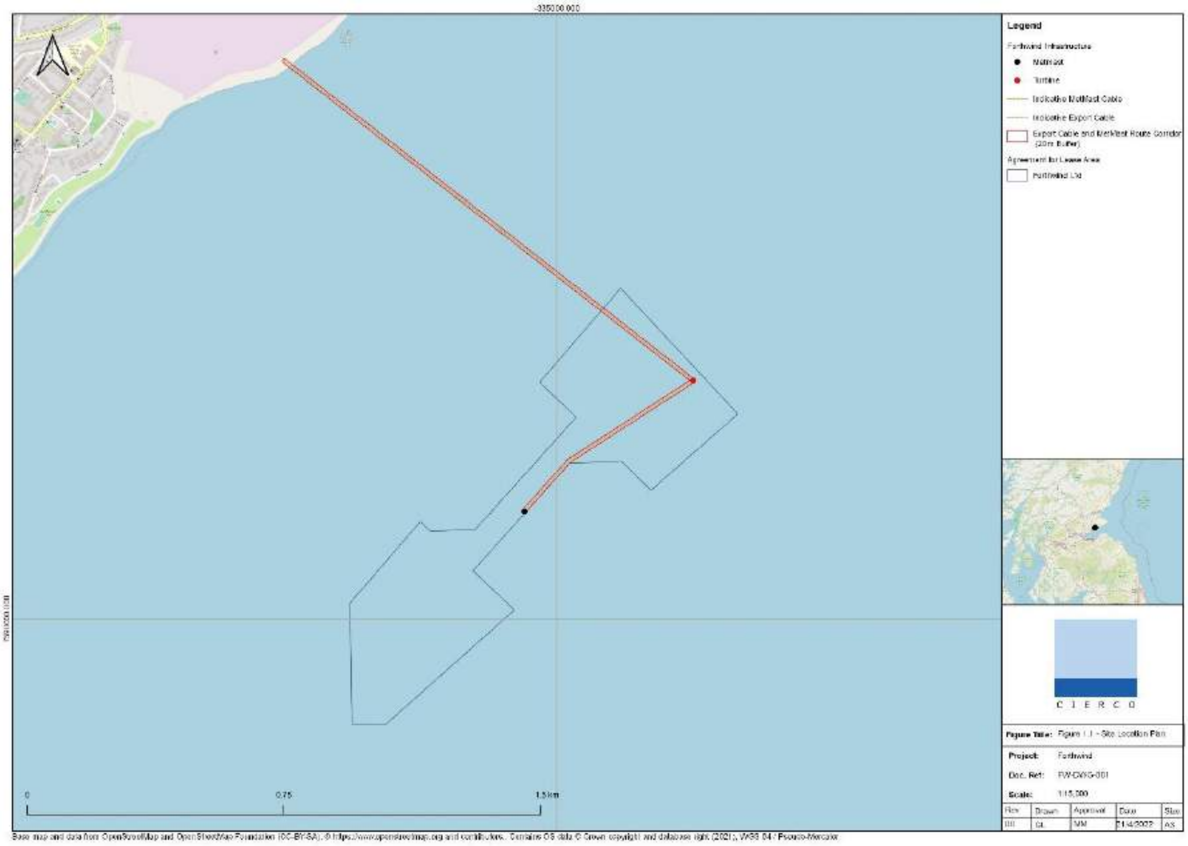
It is anticipated that total area of seabed disturbed as a result of the Forthwind renewable energy structure (turbine, metmast and cable corridors) will not exceed 9,500m2 (under the 10,000m2 threshold stated within the Marine Licensing (Pre-application Consultation) (Scotland) Regulations 2013) and as such does not fall under PAC requirements. The Forthwind project has committed to the spirit of the Pre-Application Consultation and therefore have completed this PAC report. This PAC report will be submitted to Marine Scotland at the same time as the Marine Licence and Section 36 consent application for the Proposed Development.

2. Pre-Application Consultation Activities

2.1. Description of the Proposed Development

Forthwind Ltd is proposing to develop an offshore wind technology demonstration site in the Firth of Forth, just offshore Methil in Fife. The Proposed Development, consisting of an offshore wind turbine with a rated capacity of up to 20 MW available to export to the national grid. The project will use new offshore wind technology currently being developed.

Figure 2.1 - Site Location Plan



The key components of the proposals are:

- Installation of wind turbine and associated sub-structure (pin pile foundations);
- Installation of a meteorological mast (metmast) and associated sub-structure (monopile foundation);
- Installation of export cable from wind turbine to landing point; and
- Installation of communications cable between wind turbine and metmast.

More information on the project proposal can be accessed from the Project Description section of the Forthwind Offshore Wind Demonstration Project Environmental Impact Assessment Report, Chapter 3.

2.2. Applicant Details

Address: Forthwind Ltd,
The Boathouse,
Silversands, Hawkcraig Road
Aberdour
KY3 0TZ

Telephone: 07510 075141

Email: gemma.lee@ciercoenergy.com

2.3. Notification of the Pre-Application Consultation Event

The following stakeholder organisations were notified by email on 2/11/2021 that Forthwind were to hold a public event:

- The commissioners of Northern Lighthouses
- The Maritime and Coastguard Agency
- The Scottish Environment Protection Agency
- NatureScot
- Fife Council

The notification provided basic information about the application, the time and location of the consultation events and a website address on the Forthwind web pages that provided further information about the project and application. The project website can be accessed at:

https://forthwind.co.uk

2.4. The Public Event

The pre-application public consultation event was held on Monday 13th December, between 11:00 and 19:00 at Fife Renewables Innovation Centre, Ajax Way, Methil Docks, Business Park, Methil, KY8 3RS. The event was held as a "drop-in" style event, allowing the public to attend, view the presentation material and ask questions to one of the Forthwind Project team who attended at all times. Public Notices advertising the event were placed in:

- The East Fife Mail on 27th October 2021
- Fife Free Press on 28th October 20210
- Glenrothes Gazette on 3rd November 2021
- Herald & Citizen on 29th October 2021
- FifeToday.co.uk on 27th October 2021

Copies of these notices are included in Appendix A of this report.

The event presented details of the Proposed Development through a series of display boards throughout the exhibition space; including projections of the visual aspects of the offshore infrastructure from the following key locations:

- Shore Street, Buckhaven;
- Fife Coastal Path, West Wemyss;
- Fife Coastal Path, Leven; and
- Gullane Bach, East Lothian.

Copies of the exhibition panels used for the public exhibition can be found in Appendix B of this report.

Figure 2.2 Entrance to the Forthwind Public Exhibition at Fife Renewables Energy Centre

There were around five attendees at the exhibition including councilman David Graham, and a few individuals who either work, or just happened to be, in the Fife Renewables Energy Centre that day.

Those whom attended the event noted the following aspects:

- Current Scottish and UK Renewable Energy incentives and renewable energy policy;
- Socio-economic impact of the Proposed Development at a local level (including the potential of utilising the Harland and Wolff yard in Methil as a manufacturing, deployment and/or project host site);
- Potential for alternative forms of energy (including hydrogen);
- Local visual impact; and
- Project timescales.

Opportunities to provide written feedback on the Proposed development was provided through the supply of a “have your say” feedback form. The form also provided contact details (both email and postal address) where comments on the Proposed Development could be sent.

A number of visitors took a copy of the “Have Your Say” forms with them, however none were filled in during the event. An email from one visitor was received on 15th December. This response included two comments with regards to the inclusion of a Community Benefit payment being made, as well as including training and employment opportunities for the local population. A copy of this response is included within Appendix C.

No other comments from stakeholders in response to the public exhibition have been sent to Forthwind following the event.

2.5. Conclusion

No specific comments on the project design or layout have been received from the public during the pre-application consultation process. The feedback provided focussed mainly on the local economic impacts the Proposed Development could have on the local and Scottish supply chain.

APPENDIX A - PUBLIC NOTICES

EAST FIFE MAIL PUBLIC NOTICE

Wednesday, October 27, 2021

Classified

PERSONAL

PERSONAL FINANCE

PUBLIC NOTICES

PLANNING NOTICES

PUBLIC EXHIBITION FOR A PROPOSED OFFSHORE WIND DEMONSTRATION TURBINE AT METHIL, FIFE

Forthwind Ltd, a subsidiary company of Cierco Energy Ltd, will hold a pre-application consultation event regarding a proposed development of an Offshore Wind Test and Demonstration site offshore Methil. The project team will be available to explain the proposal and answer your questions.

The proposed project consists of the installation of one offshore wind demonstration turbine and one temporary offshore meteorological mast, both approximately 1.5km offshore the Fife Energy Park.

The pre-application consultation event will be held between 11am and 7pm on **Monday 13th December 2021** at:

Fife Renewables Innovation Centre, Ajax Way, Methil Docks Business Park, Methil, KY8 3RS.

All are welcome to drop in, find out more about the proposed project and take the opportunity to provide us with you feedback. Further information on the Forthwind Project can also be found at www.forthwind.co.uk

If you wish to provide comments on the proposal, these should be made in writing, not later than 15th December 2021, by email to:
gemma.lee@ciercoenergy.com or by post to:
Forthwind Ltd. The Boathouse, Hawkcraig Road, Aberdour KY3 0TZ.

Comments made to Forthwind Ltd are not representations to the Scottish Ministers. When Forthwind Ltd submits an application for a marine licence, an opportunity will be given for representations to be made to the Scottish Ministers on the application.

PUBLIC NOTICES

GENERAL NOTICES

R R WOOD'S EDUCATIONAL BEQUEST TRUST
Student Application Form

The Trust has a limited amount of money to assist certain persons in undergoing full-time education.

Those eligible to apply:-

- Sole applicants must be over 16 years of age (applicants who are

Mrs Wei Dai trading as Wing Fung (Fife) Ltd of Unit 9 Hayfield Place, Hayfield Industrial Estate, Kirkcaldy, Fife, KY2 5DH is applying to change an existing Licence as follows: To keep an extra 2 goods vehicle and 0 trailers at the operating centre at Unit 9 Hayfield Place, Hayfield Industrial Estate, Kirkcaldy, Fife, KY2 5DH. Owners or occupiers of land (including buildings) near the operating centre(s) who believe that their use or enjoyment of that land would be affected, should make written representations to the Traffic Commissioner at Hillcrest House, 386 Harehills Lane, Leeds, LS9 6NF, stating their reasons, within 21 days of this notice. Representors must at the same time send a copy of their representations to the applicant at the address given at the top of this notice. A Guide to Making Representations is available from the Traffic Commissioner's office.

Goods Vehicle Operator's Licence

Sandy Allan (Blacksmiths) Ltd of 5 Small Holdings, Thornton Road, Kirkcaldy, KY1 3NN is applying to change an existing licence as follows: To keep an extra 3 goods vehicles and 1 trailers at the operating centre at 5 Small Holdings, Thornton Road, Kirkcaldy, KY1 3NN. Owners or occupiers of land (including buildings) near the operating centre(s) who believe that their use or enjoyment of that land would be affected, should make written representations to the Traffic Commissioner at Hillcrest House, 386 Harehills Lane, Leeds, LS9 6NF, stating their reasons, within 21 days of this notice. Representors must at the same time send a copy of their representations to the applicant at the address given at the top of this notice. A Guide to Making Representations is available from the Traffic Commissioner's office.

GLENROTHES GAZETTE PUBLIC NOTICE

Classified

PUBLIC NOTICES

GVOL

Goods Vehicle Operator's Licence

RON GREIG Trading as RG CONSTRUCTION AND CONSULTANTS, OF RAITH SQUARE, RAITH, KIRKCALDY, KY2 5YB is applying for a licence to use: UNIT 7, BLOCK 1, MUIRHEAD, MITCHELSTON INDUSTRIAL ESTATE, KIRKCALDY, KY1 3PB as an operating centre for 3 GOODS VEHICLES AND 1 TRAILER. Owners or occupiers of land (including buildings) near the operating centre who believe that their use or enjoyment of that land would be affected, should make written representations to the Traffic Commissioner at Hillcrest House, 386 Harehills Lane, Leeds, LS9 6NF stating their reasons within 21 days of this notice. Representors must at the same time send a copy of their representations to the applicant at the address given at the top of this notice. A Guide to Making Representations is available from the Traffic Commissioner's office.

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The Trust has a limited amount of money to assist certain persons in undergoing full-time education.

Those eligible to apply:-

- Sole applicants must be over 16 years of age (applicants who are under 16 should make sure their forms are counter-signed by their parent/guardian).
- Applicants should have been offered a place on, or be attending, a full-time educational course.
- Applicants should be resident in, or have been born in Thornton, Fife as that settlement is described as the Thornton Settlement Envelope, Mid Fife Local Plan 2012.

Criteria for Awards

The number and value of the awards made are entirely at the discretion of the Trustees subject to a maximum sum to one person in any one year of £2,000

Applicants should please note the following:-

- All awards made under this scheme are for full-time educational purposes only.
- The Trust reserves the right to obtain, from the educational establishment attended, proof of the applicant's satisfactory attendance and academic progress.

An application form may be requested in writing
(including e-mail) from:-
Messrs McKenzies Solicitors
26 East Fergus Place
Kirkcaldy Fife KY1 1XT
e-mail: enquiries@mckenzies.legal

PLANNING NOTICES

PUBLIC EXHIBITION FOR A PROPOSED OFFSHORE WIND DEMONSTRATION TURBINE AT METHIL, FIFE

Forthwind Ltd, a subsidiary company of Cierco Energy Ltd, will hold a pre-application consultation event regarding a proposed development of an Offshore Wind Test and Demonstration site offshore Methil. The project team will be available to explain the proposal and answer your questions.

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MOTORS

VEHICLES WANTED

APPENDIX B – PUBLIC EXHIBITION PANELS

Welcome to the Forthwind Offshore Wind public exhibition

Thank you for coming along today. We aim to introduce you to all aspects of the Forthwind Offshore Wind Demonstration Project proposal. We hope you take the opportunity to tell us your thoughts on what will be a pioneering step in offshore wind. Please don't hesitate to ask Gemma or Marc if you have any questions.

This project will unlock new capacities in offshore wind generation providing a significant contribution to a low carbon future worldwide and creating green energy jobs to deliver on essential climate change targets – and all pioneered on Fife's energy coast.

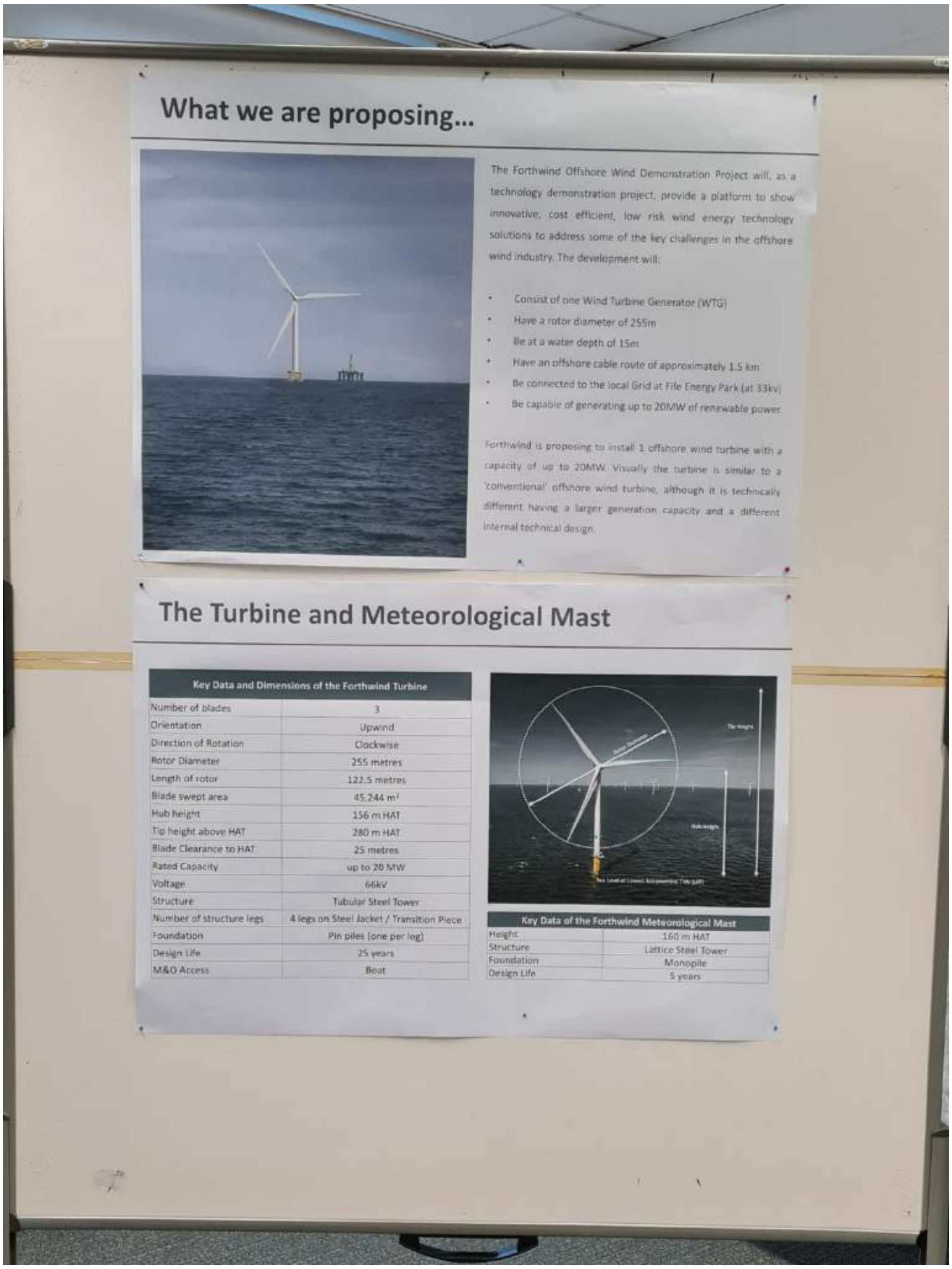
Please take your time in viewing the information provided - we intend to submit a Section 36 and Marine Licence application to Marine Scotland early in 2022 and there will be an opportunity to record. We are part of the Fife local community and we will maintain an open dialogue as we move forward. Please check out our website www.Forthwind.co.uk or contact us at info@ciercoenergy.com

Overview

Cierco Ltd is the developer of the Forthwind Offshore Wind Demonstration Project. Cierco is a Scottish renewable energy development company based in Aberdour, Fife that aims to facilitate the commercialisation of new marine renewable energy technologies.

A test and demonstration seabed lease agreement has been secured from the Crown Estate Scotland and the turbine will be located approximately 1.5 kilometres (km) from the Methil coastline.

The Methil site was chosen following detailed analysis of technical, economic and environmental factors. Criteria that informed the site selection process included: sensitive habitats and species, seabed conditions, port facilities, metocean conditions and proximity to a grid connection.



What we are proposing…

The Forthwind Offshore Wind Demonstration Project will, as a technology demonstration project, provide a platform to show innovative, cost efficient, low risk wind energy technology solutions to address some of the key challenges in the offshore wind industry. The development will:

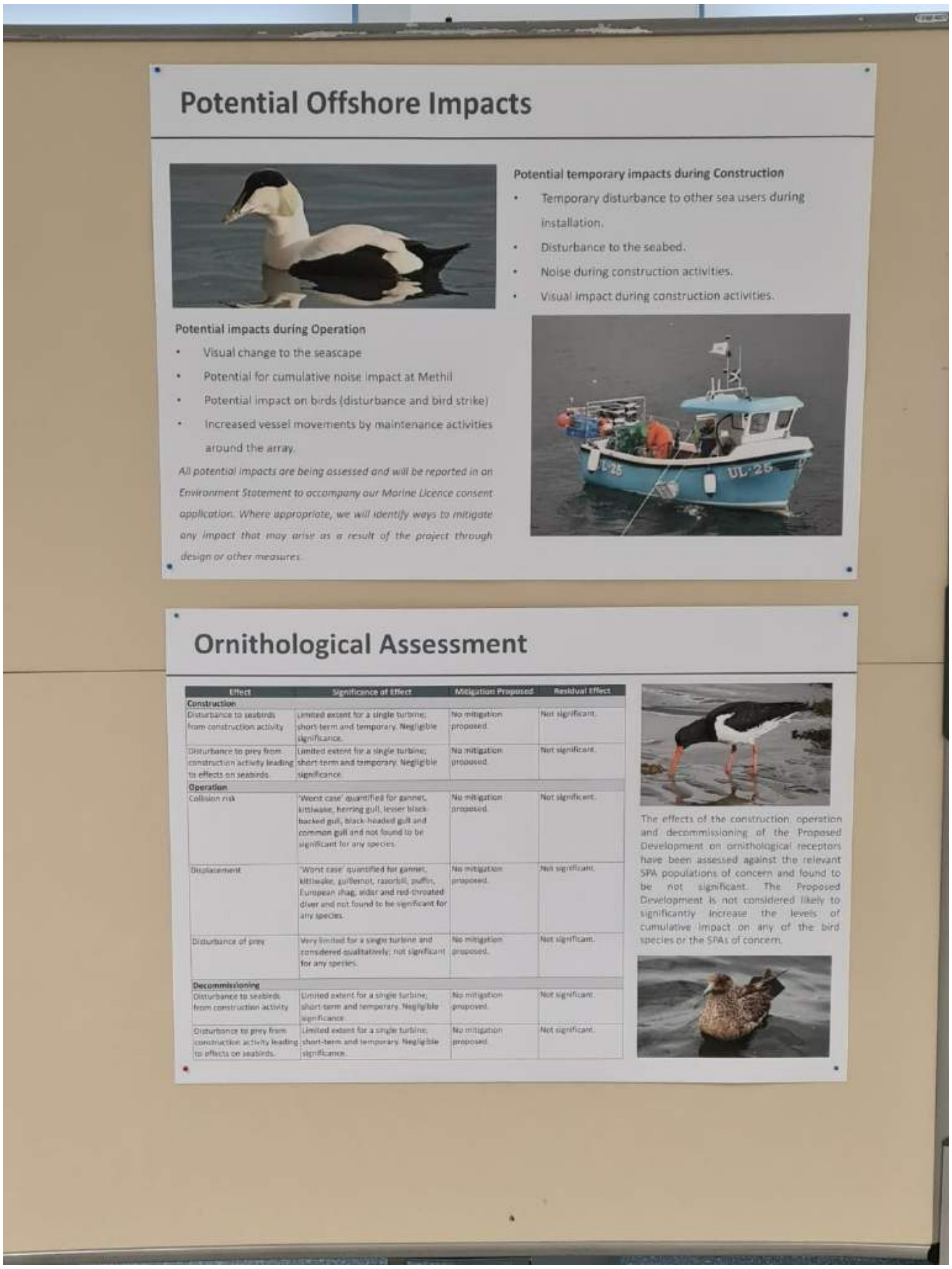
- Consist of one Wind Turbine Generator (WTG)
- Have a rotor diameter of 255m
- Be at a water depth of 15m
- Have an offshore cable route of approximately 1.5 km
- Be connected to the local Grid at Fife Energy Park (at 33kv)
- Be capable of generating up to 20MW of renewable power.

Forthwind is proposing to install 1 offshore wind turbine with a capacity of up to 20MW. Visually the turbine is similar to a 'conventional' offshore wind turbine, although it is technically different having a larger generation capacity and a different internal technical design.

The Turbine and Meteorological Mast

Key Data and Dimensions of the Forthwind Turbine	
Number of blades	3
Orientation	Upwind
Direction of Rotation	Clockwise
Rotor Diameter	255 metres
Length of rotor	122.5 metres
Blade swept area	45,244 m²
Hub height	156 m HAT
Tip height above HAT	280 m HAT
Blade Clearance to HAT	25 metres
Rated Capacity	up to 20 MW
Voltage	66kV
Structure	Tubular Steel Tower
Number of structure legs	4 legs on Steel Jacket / Transition Piece
Foundation	Pin piles (one per leg)
Design Life	25 years
M&O Access	Boat

Key Data of the Forthwind Meteorological Mast	
Height	160 m HAT
Structure	Lattice Steel Tower
Foundation	Monopile
Design Life	5 years



Potential Offshore Impacts

Potential temporary impacts during Construction

- Temporary disturbance to other sea users during installation.
- Disturbance to the seabed.
- Noise during construction activities.
- Visual impact during construction activities.

Potential impacts during Operation

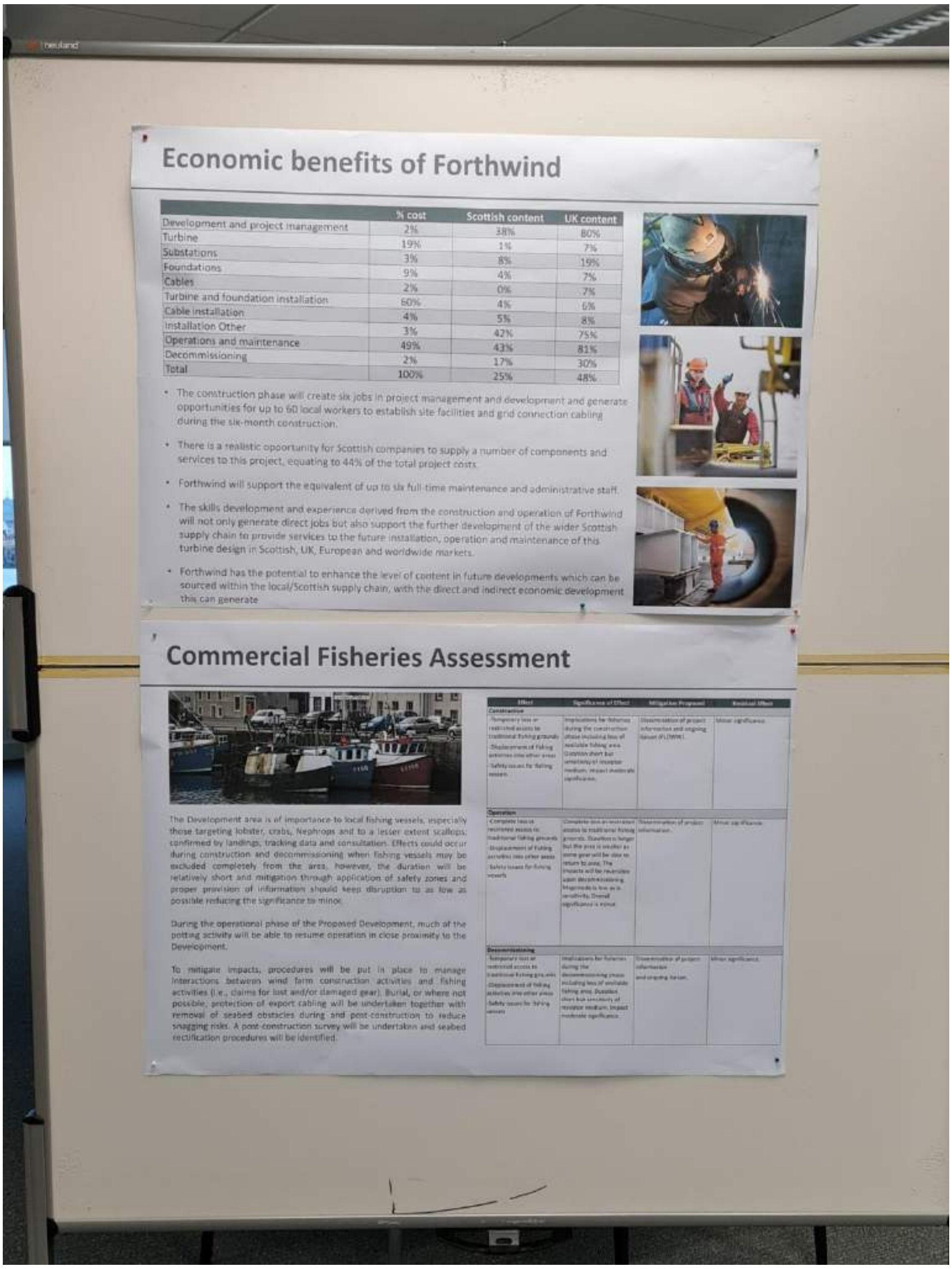
- Visual change to the seascape
- Potential for cumulative noise impact at Methil
- Potential impact on birds (disturbance and bird strike)
- Increased vessel movements by maintenance activities around the array.

All potential impacts are being assessed and will be reported in an Environment Statement to accompany our Marine Licence consent application. Where appropriate, we will identify ways to mitigate any impact that may arise as a result of the project through design or other measures.

Ornithological Assessment

Effect	Significance of Effect	Mitigation Proposed	Residual Effect
Construction			
Disturbance to seabirds from construction activity	Limited extent for a single turbine; short-term and temporary. Negligible significance.	No mitigation proposed.	Not significant.
Disturbance to prey from construction activity leading to effects on seabirds	Limited extent for a single turbine; short-term and temporary. Negligible significance.	No mitigation proposed.	Not significant.
Operation			
Collision risk	'Worst case' quantified for gannet, kittiwake, herring gull, lesser black-backed gull, black-headed gull and common gull and not found to be significant for any species.	No mitigation proposed.	Not significant.
Displacement	'Worst case' quantified for gannet, kittiwake, guillemot, razorbill, puffin, European shag, eider and red-throated diver and not found to be significant for any species.	No mitigation proposed.	Not significant.
Disturbance of prey	Very limited for a single turbine and considered qualitatively; not significant for any species.	No mitigation proposed.	Not significant.
Decommissioning			
Disturbance to seabirds from construction activity	Limited extent for a single turbine; short-term and temporary. Negligible significance.	No mitigation proposed.	Not significant.
Disturbance to prey from construction activity leading to effects on seabirds.	Limited extent for a single turbine; short-term and temporary. Negligible significance.	No mitigation proposed.	Not significant.

The effects of the construction, operation and decommissioning of the Proposed Development on ornithological receptors have been assessed against the relevant SPA populations of concern and found to be not significant. The Proposed Development is not considered likely to significantly increase the levels of cumulative impact on any of the bird species or the SPAs of concern.



Economic benefits of Forthwind

	% cost	Scottish content	UK content
Development and project management	2%	38%	80%
Turbine	19%	1%	7%
Substations	3%	8%	19%
Foundations	9%	4%	7%
Cables	2%	0%	7%
Turbine and foundation installation	60%	4%	6%
Cable installation	4%	5%	8%
Installation Other	3%	42%	75%
Operations and maintenance	49%	43%	81%
Decommissioning	2%	17%	30%
Total	100%	25%	48%

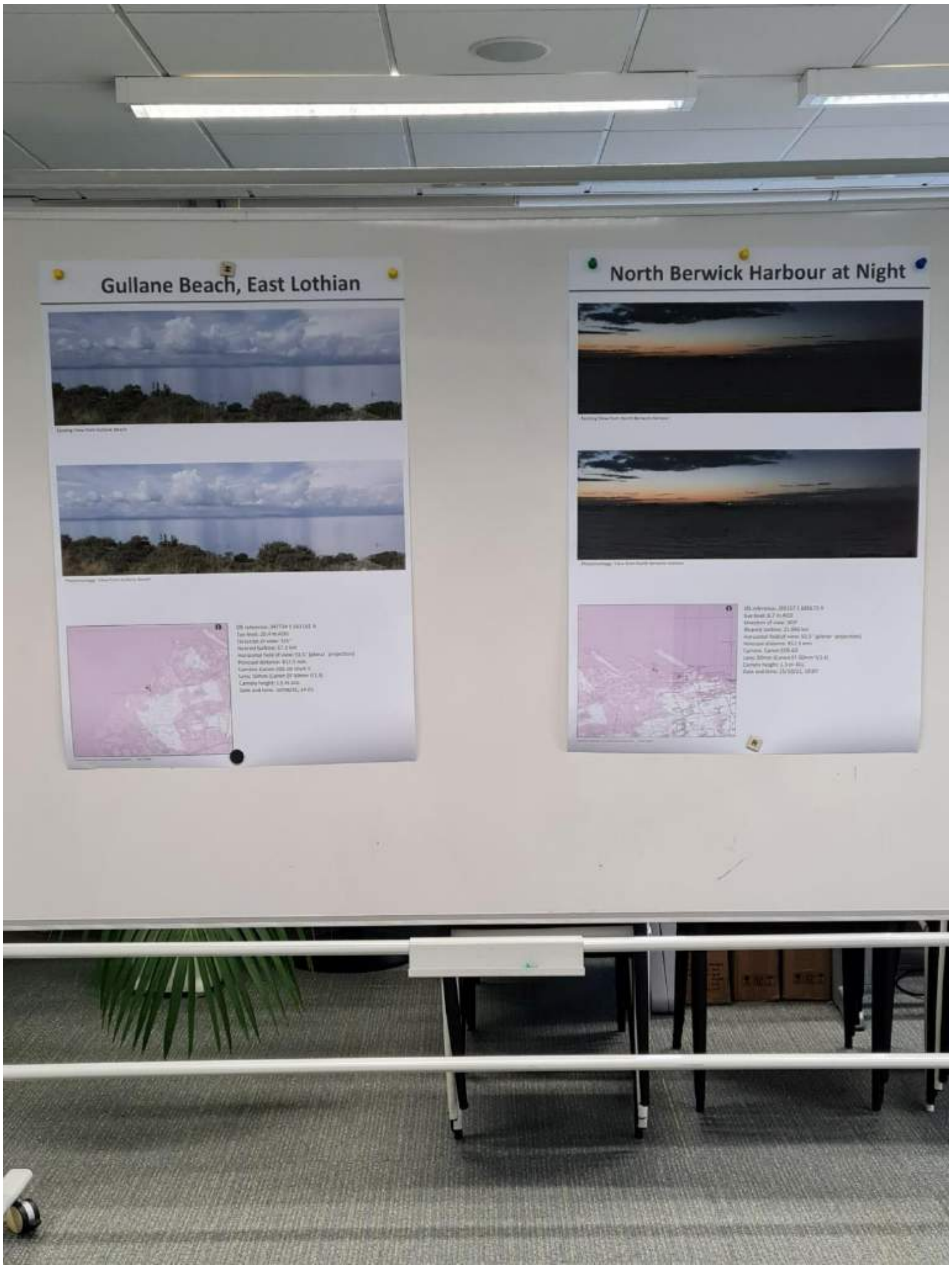
- The construction phase will create six jobs in project management and development and generate opportunities for up to 60 local workers to establish site facilities and grid connection cabling during the six-month construction.
- There is a realistic opportunity for Scottish companies to supply a number of components and services to this project, equating to 44% of the total project costs.
- Forthwind will support the equivalent of up to six full-time maintenance and administrative staff.
- The skills development and experience derived from the construction and operation of Forthwind will not only generate direct jobs but also support the further development of the wider Scottish supply chain to provide services to the future installation, operation and maintenance of this turbine design in Scottish, UK, European and worldwide markets.
- Forthwind has the potential to enhance the level of content in future developments which can be sourced within the local/Scottish supply chain, with the direct and indirect economic development this can generate

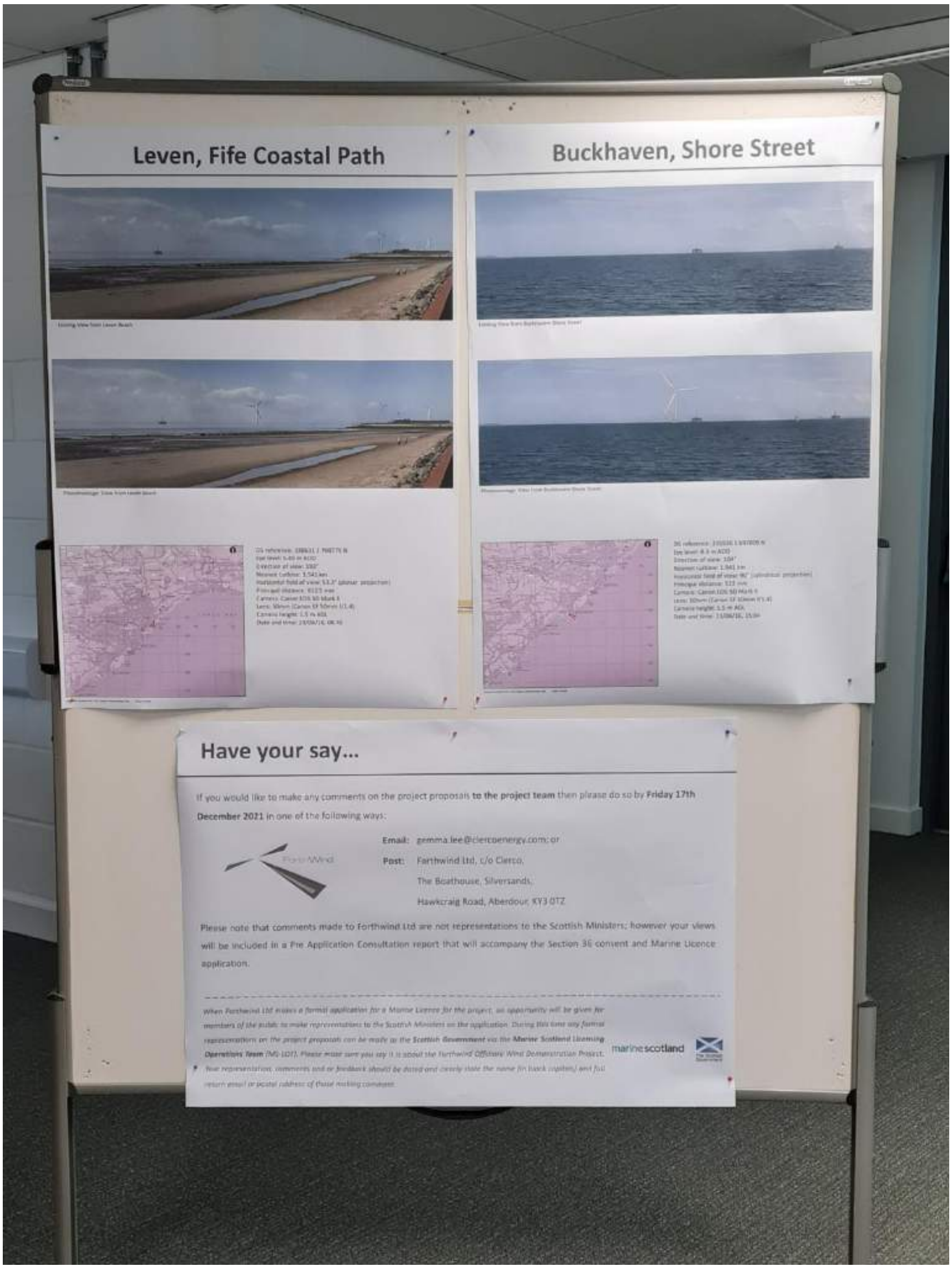
Commercial Fisheries Assessment

The Development area is of importance to local fishing vessels, especially those targeting lobster, crabs, Nephrops and to a lesser extent scallops; confirmed by landings, tracking data and consultation. Effects could occur during construction and decommissioning when fishing vessels may be excluded completely from the area, however, the duration will be relatively short and mitigation through application of safety zones and proper provision of information should keep disruption to as low as possible reducing the significance to minor.

During the operational phase of the Proposed Development, much of the potting activity will be able to resume operation in close proximity to the Development.

To mitigate impacts, procedures will be put in place to manage interactions between wind farm construction activities and fishing activities (i.e., claims for lost and/or damaged gear). Burial, or where not possible, protection of export cabling will be undertaken together with removal of seabed obstacles during and post-construction to reduce snagging risks. A post-construction survey will be undertaken and seabed rectification procedures will be identified.


Gullane Beach, East Lothian
North Berwick Harbour at Night



Leven, Fife Coastal Path

Buckhaven, Shore Street

Have your say…

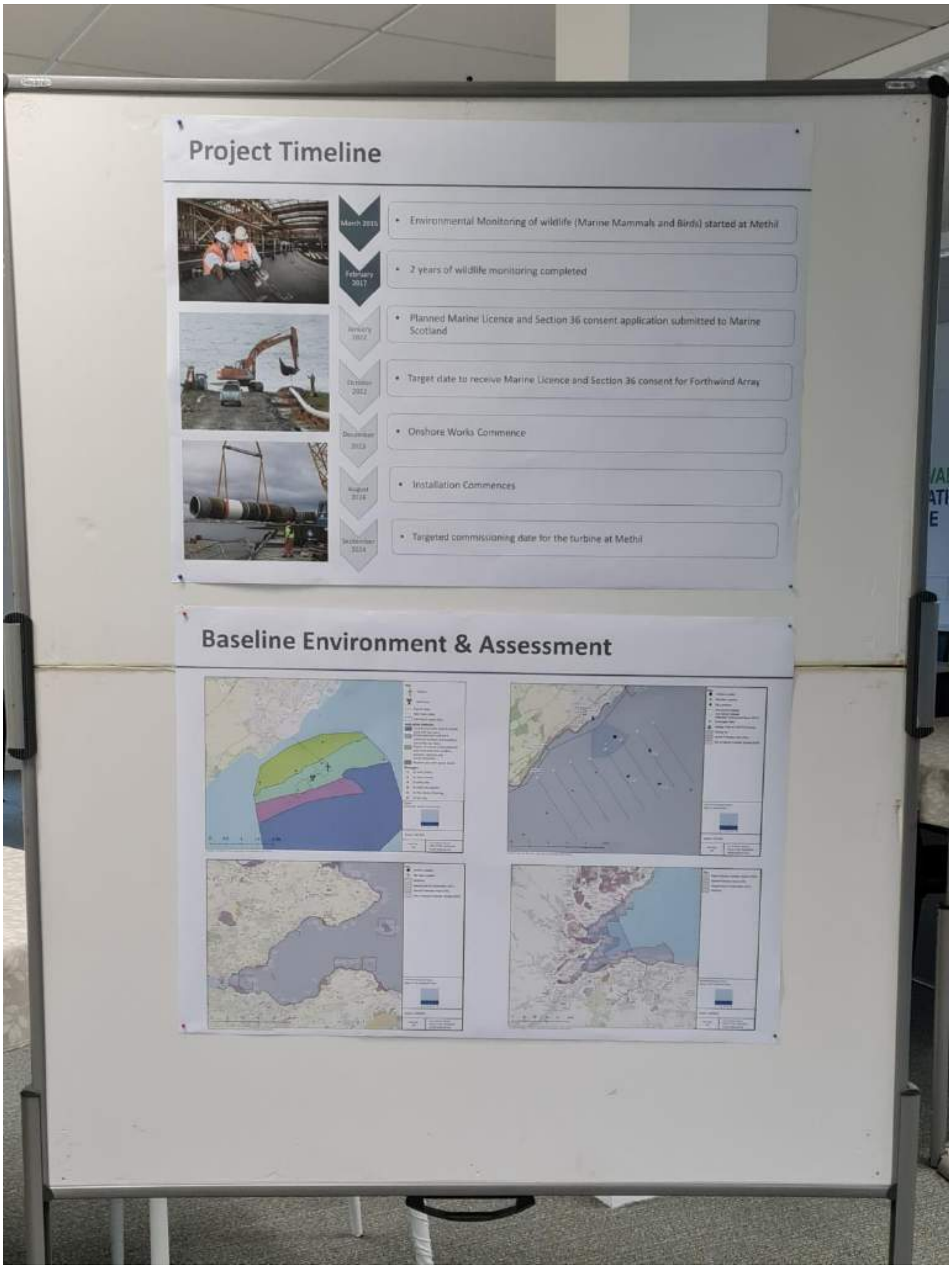
If you would like to make any comments on the project proposals **to the project team** then please do so by **Friday 17th December 2021** in one of the following ways:

Email: gemma.lee@ciercoenergy.com; or

Post: Forthwind Ltd, c/o Cierco,
The Boathouse, Silversands,
Hawkcraig Road, Aberdour, KY3 0TZ

Please note that comments made to Forthwind Ltd are not representations to the Scottish Ministers; however your views will be included in a Pre Application Consultation report that will accompany the Section 36 consent and Marine Licence application.

When Forthwind Ltd makes a formal application for a Marine Licence for the project, an opportunity will be given for members of the public to make representations to the Scottish Ministers on the application. During this time any formal representations on the project proposals can be made to the ***Scottish Government*** *via the* ***Marine Scotland Licensing Operations Team*** *(MS-LOT). Please make sure you say it is about the Forthwind Offshore Wind Demonstration Project. Your representation, comments and or feedback should be dated and clearly state the name (in block capitals) and full return email or postal address of those making comment.*



Project Timeline

- March 2015: Environmental Monitoring of wildlife (Marine Mammals and Birds) started at Methil
- February 2017: 2 years of wildlife monitoring completed
- January 2022: Planned Marine Licence and Section 36 consent application submitted to Marine Scotland
- October 2022: Target date to receive Marine Licence and Section 36 consent for Forthwind Array
- December 2023: Onshore Works Commence
- August 2024: Installation Commences
- September 2024: Targeted commissioning date for the turbine at Methil

Baseline Environment & Assessment

APPENDIX C – CONSULTATION RESPONSE

Gemma Lee

Subject: RE: Forthwind consultation comment

From: [REDACTED]
Sent: 15 December 2021 12:29
To: [REDACTED]
Subject: Forthwind consultation comment

Hi [REDACTED]

Nice to meet you on Monday at FRIC.

Here are my comments for the community consultation for the Forthwind Offshore Wind Demonstration project.

I speak as someone that has an office at Methil and looks over the proposed site, and also a Director of FCCAN.

1. Community benefit payments should be made. The fact that it is a demonstration project and community benefit payments are not mandatory, doesn't make any difference to the local community - they are still looking at the turbine. Its in their ascetic space.
Forthwind must be a socially responsible partner and make a contribution to the local community, for example to CLEAR Buckhaven, the local NGO that does work in Methil and Buckhaven.

2. Training and employment opportunities. Opportunities for local young people should be built into the project from the start. I suggest you contact at Fife College which has a Levenmouth campus to discuss this. Too much of the offshore wind spend is leaving Fife (and Scotland) entirely. There is currently comparatively little to show for it.

I'm content for these comments to be published anonymously.

Many thanks

[REDACTED]

[REDACTED]
[REDACTED]
[REDACTED]

FORTHWIND

FORTHWIND DEMONSTRATION PROJECT

WATER FRAMEWORK DIRECTIVE ASSESSMENT

Confidentiality Status: Draft for Consultation

SIGNATURES					
0		Final Issue	TJ	NM	MM
Rev	**Date**	**Purpose of Issue**	**Prepared by**	**Checked by**	**Approved by**

Contents

1. INTRODUCTION

1.1. Background

AECOM was commissioned by Forthwind Ltd ('The Applicant') to produce a Water Framework Directive (WFD) Assessment for the proposed Forthwind Demonstration Site (hereafter referred to as the 'Proposed Development'). The WFD Assessment Report has been provided as a supplement to the Environmental Impact Assessment Report (EIAR) for the Proposed Development.

The scope of this document pertains to the offshore elements of the Proposed Development only. No consideration is given herein to onshore elements of the Proposed Development.

New developments that have the potential to impact the current or targeted WFD status of a water body should determine their compliance against the WFD objectives of the potentially affected water bodies. WFD waterbodies include both surface water and groundwater catchments, and includes ecological, chemical and hydromorphological elements. Under the Water Environment and Water Services (Scotland) Act 2003, the Scottish Environment Protection Agency (SEPA) is the competent authority empowered with operational implementation of the Directive, whilst local authorities and other bodies share some duties and responsibilities.

This report assesses compliance with the WFD by determining whether the Proposed Development has the potential to:

- Cause a deterioration of a waterbody from its current status or potential; and / or
- Prevent future attainment of good status or potential where not already achieved.

A three-stage approach to the assessment has been adopted:

- Stage 1: WFD Screening;
- Stage 2: WFD Scoping; and
- Stage 3: WFD Impact Assessment.

This approach has been developed from the UK Government's Planning Inspectorate Advice Note Eighteen and the Environment Agency guidance for completing WFD assessments for coastal and transitional waters (Environment Agency, 2016). While not the competent authorities in Scotland, these documents are considered to provide a robust framework for the assessment.

This report presents the findings of Stages 1-2, which have been undertaken in relation to the Proposed Development. It has been deemed appropriate to scope out further detailed assessment, as outlined later in the report.

This Appendix should be read in conjunction with the following documents:

- EIAR Chapter 3: Project Description (Volume I of the EIAR);
- ES Chapter 6: Physical Processes and Water Quality (Volume I of the 2015 ES);
- EIAR Chapter 6: Ornithology (Volume I of the EIAR);
- EIAR Chapter 7: Marine Mammals (Volume I of the EIAR);
- EIAR Chapter 10: Fish and Shellfish Ecology (Volume I of the EIAR); and
- EIAR Chapter 15: Benthic Ecology (Volume I of the EIAR).

1.2. The Proposed Development

The Proposed Development is located on the northern shore of the Firth of Forth at Methil, Scotland, and is approximately 1.5 km from the mean high water springs (MHWS).

The Project Development Footprint Envelope consists principally of the following:

- A single turbine and sub-structure (foundation and tubular jacket if required) located at National Grid Reference (NGR) NT 37812 97333. A 100 m micrositing allowance from the centre point for the turbine and associated infrastructure is required for the final selection of turbine location.

- An electricity export cable corridor of up to 1.43 ha in area, within which cable will be laid in a trench measuring approximately 1500 m, and not more than 1800 m in length. This will contain the cable that transmits the electricity generated by the turbine to the onshore transformer.
- A metmast and sub-structure comprising a lattice steel tower located at NGR NT 37314 96959. The sub-structure includes foundations, a platform in the event of monopile foundation, and transition piece. A 100 m micrositing allowance from the centre point for the metmast and associated infrastructure is required for the final selection of metmast location.
- A communications cable approximately 625 m in length, comprising a 20 mm^2 fibre optic cable, running alongside a power cable will be located between the turbine and the metmast.

1.2.1. Offshore Site Characteristics

The Proposed Development is located on the northern shore of the Firth of Forth at Methil, Scotland. The Firth of Forth is formed by the estuary of the River Forth, extending approximately 96 km from the tidal water limit at Stirling to the Isle of May. The coastline in this section runs in a southwest to northeast direction and consists of a reclaimed area of land made of colliery waste. The residential areas of Methil and Buckhaven are located further inland. Much of the coastline in this section of the Forth is characterised by intertidal rock platforms, covered by thin veneers of sand.

The stretch of coastline extending from Buckhaven to Methil is defended by a rock armour revetment, except for a sheet pile quay at the shorefront of the Fife Energy Park. Further west, between East Wemyss and Buckhaven, the coastline is formed by a soil and vegetation embankment. To the northeast, there are the docks of Methil and a concrete seawall that extends up to Leven.

The mean tidal ranges in the Proposed Development area are 2.5 m for neap tides, and 5.0 m for spring tides. Wind wave characteristics (height and period) are mostly determined by the available fetch, or the distance over which the wave generating wind is blowing. The largest fetch in the Proposed Development area is to the southeast out of the Firth of Forth and across the North Sea to mainland Europe. Wind and waves in this area reach maximum heights of 1.2 m, although heights up to 0.5 m are more likely.

The prevailing wind at the Proposed Development site is from the southwest. Refer to 2015 ES (Volume I) Chapter 6: Physical Processes and Water Quality, for further details.

1.2.2. The Development

Forthwind Ltd is the developer of the Forthwind Offshore Wind Demonstration Project. Forthwind Ltd is a fully owned subsidiary of Cierco Ltd, specifically established to develop the Proposed Development. Cierco Ltd is a Scottish renewable energy development company based in Aberdour established with the aim to facilitate the commercialisation of new marine renewable energy technologies into the marketplace.

Forthwind Ltd currently holds a S36 consent and a Marine Licence at the same location, granted in December 2016, for the development of a two-turbine array with a total capacity of 30MW (updated in June 2019). Since the consent award, several factors have emerged to make Forthwind re-evaluate the consented project envelope and identify the need to submit a new application for a revised project.

This Proposed Development involves the construction and operation of and wind turbine and meteorological mast (metmast) with associated infrastructure including foundations, scour protection, transformers, an onshore transformer station and personnel facilities, and electricity export cables connecting the turbine to the onshore substation. The offshore demonstration unit will be deployed on a site 1.5 km offshore from the Fife Energy Park in Methil, Scotland.

Key data and dimensions for the Proposed Development are included within Chapter 3: Project Description (EIAR, Volume 1) in Tables 3.2 – 3.5.

There are two options for the turbine foundations: monopile and pin pile. The permanent footprint of the former would be 1,963.5m^2 (10 m diameter foundations plus scour protection). The permanent footprint of the pin pile base would be a maximum of 1,346.5 m^2 (including scour protection). The metmast permanent footprint would be 1256.6 m^2 (including scour protection).

The monopile foundation consists of a single steel tubular section made from several sections of rolled steel plate welded together. The size of the pile used will vary depending on a number of factors including ground conditions, structural loading and hydrological regime, although it is anticipated that the monopile will not exceed 10 m in diameter and inserted to a depth of up to 50 m.

The pin pile foundation alternative involves a steel peg ('the pin pile') that is inserted into the seabed to secure the turbine in place. Each leg in contact with the seabed will require one pin pile. The size of the piles used will vary depending on a number of factors including ground conditions, structural loading and hydrological regime.

The pin piles will be inserted to a depth of up to 50 m, and will have a diameter of up to 3.5 m. The piles will be installed using a drill pile technique, as the ground conditions are not suitable for hammer techniques (pile driving). Once installed, piles will be secured by grouting, which involves the injection of cement into the small space between the pile and the pile sleeve.

Electrical export cables are required for each turbine (132 kV cables). If cables are buried then installation methods will be either ploughing, jetting or trenching. Alternatively, if ground conditions don't allow for these methods, cables may be surface laid and protected. Maximum trench dimensions if buried would be 3 m x 1.5 m. Maximum dimensions if burial not possible would be 5 m x 1 m. There would be a maximum length of 1800 m offshore for each cable and a target depth of 1.5 m. There are some sections of the cable route (maximum 100 m) where the cables will be laid on the seabed and protected by a suitable method.

The maximum area of disturbance for the jack up barge / vessel footprint would be 1,200 m^2. This equates to a total maximum area of disturbance of 10,840.1 m^2.

Once the cable makes landfall at Fife Energy Park it will connect to a small onshore sub-station and the electricity exported to the grid. The connection from the sub-station to the grid will be subject to a separate consenting process and is not considered further within this WFD assessment.

Refer to Chapter 3: Project Description of the EIAR (Volume I) for further details of the Proposed Development.

1.3. Structure of the Report

The remainder of this report is set out as follows:

- Section 2 provides a summary of the WFD requirements and screening process.
- Section 3 describes the assessment methodology.
- Section 4 describes the screening assessment.
- Section 5 provides the scoping assessment, considering mitigation that has been built into the Proposed Development.
- Section 6 presents the conclusions.

2. OVERVIEW OF THE WATER FRAMEWORK DIRECTIVE

2.1. Legislative Context

The Water Framework Directive (WFD) (European Union, 2000) aims to protect and enhance the quality of the water environment across all European Union (EU) member states. It takes a holistic approach to the sustainable management of water by considering the interactions between surface water (including transitional and coastal waters, rivers, streams and lakes), groundwater and water-dependent ecosystems. The main aims of the directive are:

- To prevent further deterioration and protect and enhance the status of aquatic ecosystems;
- Promote sustainable water use based on a long-term protection of available water resources;
- Aims at enhanced protection and improvement of the aquatic environment, inter alia, through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;
- Ensures the progressive reduction of pollution of groundwater and prevents its further pollution, and
- Contribute to mitigating the effects of floods and droughts.

The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (SEPA, 2021) – more commonly known as the Controlled Activity Regulations (CAR) – and their further amendments of 2013 and 2017, apply regulatory controls over activities which may affect Scotland's water environment. This legislation arose from the WFD becoming law in Scotland as the Water Environment and Water Services Act (Scotland) Act 2003 (WEWS Act, 2003). The Controlled Activity Regulations take a risk-based regulatory approach whereby different levels of authorisation apply to the risk to the water environment presented by an activity. Therefore, SEPA concentrate regulatory efforts where the risk is greatest, without imposing heavy regulatory burdens on low-risk activities.

Under the WFD, 'water bodies' are the basic management units, defined as all or part of a river system or aquifer. Water bodies form part of a larger 'river basin district' (RBD), for which 'River Basin Management Plans' (RBMPs) are used to summarise baseline conditions and set broad improvement objectives.

In Scotland, SEPA is the competent authority for implementing the WFD, although many objectives will be delivered in partnership with other relevant public bodies and private organisations (for example, local planning authorities, water companies, Rivers Trusts, large private landowners and developers).

In determining whether a development is compliant or non-compliant with the WFD objectives for a water body, SEPA must also consider the conservation objectives of any Protected Areas (i.e., European sites or water dependent Sites of Special Scientific Interest (SSSI)) and adjacent WFD water bodies, where relevant.

2.2. Surface Water Body Status

Under the WFD, surface water body status is classified on the basis of chemical and ecological status or potential. Ecological status is assigned to surface water bodies that are natural and considered by SEPA not to be artificial or heavily modified. Ecological potential is assigned to surface water bodies that are considered by SEPA to be artificial or heavily modified. The overall objective for natural surface water bodies is to achieve Good Ecological Status and Good Chemical Status. Good Ecological Status represents only a small degree of departure from pristine conditions, which are otherwise known as High Ecological Status. SEPA classify the status of each quality element (i.e., a biological indicator, a chemical or physicochemical indicator or a hydromorphological indicator) by comparing the results of monitoring and/or modelling with the environmental standards and condition limits in The Scotland River Basin District (Standards) Directions (2014). There are five quality element categories; their status definitions are provided in Table 1.

Table 1 Definition of quality element status in the Water Framework Directive from The Scotland River Basin District (Status) Directions 2014 (The Scottish Government, 2014b)

Status	Definition
High	where its condition is equal to, or better than, all the highest standards and condition limits applicable to that quality element as specified in the Standards Directions
Good	where its condition is worse than one or more standards or condition limits for "high" applicable to that quality element as specified in the Standards Directions and of a condition equal to, or better than, any and all applicable standards and condition limits for "good";
Moderate	where its condition is worse than one or more standards or condition limits for "good" applicable to that quality element as specified in the Standards Directions and of a condition equal to or better than any and all applicable standards and condition limits for "moderate";
Poor	where its condition is worse than one or more standards or condition limits for "moderate" applicable to that quality element as specified in the Standards Directions, but equal to or better than any and all applicable standards or condition limits for "poor";
Bad	where its condition is worse than one or more standards or condition limits for "poor" applicable to that quality element as specified in the Standards Directions.

Ecological status or potential is defined by the overall health or condition of the watercourse. This is assigned on a scale of High, Good, Moderate, Poor or Bad as per Table 1 and on the basis of four quality elements (European Parliament, 2000), as follows:

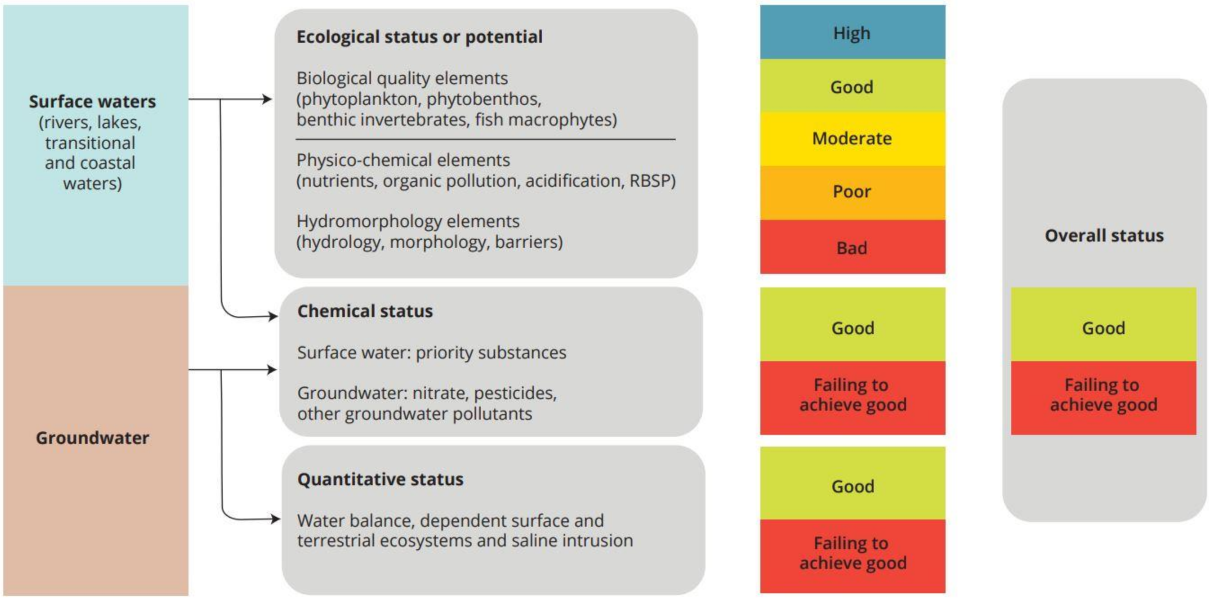
- **Biological**: This test is designed to assess the status indicated by a biological quality element such as the abundance of fish, invertebrates or algae and by the presence of invasive species. The biological quality elements can influence an overall water body status from Bad through to High.
- **Physico-chemical:** This test is designed to assess compliance with environmental standards for supporting physicochemical conditions, such as dissolved oxygen, phosphorus and ammonia. The physicochemical elements can only influence an overall water body status from Moderate through to High.
- **Specific pollutants:** This test is designed to assess compliance with environmental standards for concentrations of specific pollutants, such as zinc, cypermethrin or arsenic. As with the physico-chemical test, the specific pollutant assessment can only influence an overall water body status from Moderate through to High.
- **Hydromorphology:** For natural, considered by SEPA not to be artificial or HMWB's, this test is undertaken when the biological and physico-chemical tests indicate that a water body may be of High status. It specifically assesses elements such as water flow, sediment composition and movement, continuity, and structure of the habitat against reference or 'largely undisturbed' conditions. If the hydromorphological elements do not support High status, then the status of the water body is limited to Good overall status. For artificial or HMWBs, hydromorphological elements are assessed initially to determine which of the biological and physico-chemical elements should be used in the classification of ecological potential. In all cases, assessment of baseline hydromorphological conditions are an important factor in determining possible reasons for classifying biological and physico-chemical elements of a water body as less than Good, and hence in determining what mitigation measures may be required to address these failing water bodies.

SEPA implement the following classification system in exercise of the powers conferred by section 40(1) and (2) of the Environment Act 1995 and section 2(6) of the Water Environment and Water Services (Scotland) Act 2003.

The subsequent text summarises the general system and has been informed by The Scotland River Basin District (Standards) Directions (The Scottish Government, 2014a); This general system is summarised below in

Plate 1.

Plate 1 WFD classification elements for surface waterbody status (European Environment Agency, 2018)



2.2.1. *Status of bodies of surface water (not artificial or heavily modified)*

For each body of surface water (other than an artificial or heavily modified body of surface water – HMWB's) SEPA classify its ecological status, and its surface water chemical status. The Water Classification Hub (SEPA, 2022) is the tool which provides information on current status and future targets.

2.2.1.1. Ecological Status

Ecological status of surface water bodies (other than artificial or heavily modified body of surface water) are classified according to relevant biological, physico-chemical, and hydromorphological parameters on a five-point scale (See Table 1) as either High, Good, Moderate, Poor or Bad Ecological Status. The classification system is based on a worst-case 'one-out all-out' system, meaning that the overall ecological status is based on the lowest individual parameter score.

2.2.1.2. Chemical Status

Chemical status is defined by compliance with environmental standards for chemicals that are priority substances and/or priority hazardous substances, in accordance with the Environmental Quality Standards from the Directive 2008/105/EC of the European Parliament and of the Council (European Union, 2008). This is assigned on a scale of good or fail. Surface water bodies are only monitored for priority substances where there are known discharges of these pollutants; otherwise, surface water bodies are reported as being at good chemical status.

2.2.2. *Status of artificial or heavily modified bodies of surface water*

For each artificial or heavily modified body of surface water, SEPA classify its ecological potential, and its surface water chemical status.

2.2.2.1. Ecological Potential

Ecological potential is assigned on a scale by SEPA of maximum, good, moderate, poor and bad, and their definitions are as follows:

- **Maximum ecological potential**: all mitigation measures have been taken and all the applicable quality elements are classified as "high status";

- **Good ecological potential:** all mitigation measures have been taken and the lowest classified applicable quality element is classified as "good status", or all mitigation measures have been taken (other than those mitigation measures considered by SEPA to accumulatively achieve only a very minor improvement in the ecological quality of the body), and all applicable quality elements are classified as "high status" or "good status";
- **Moderate ecological potential:** the lowest classified applicable quality element has "moderate status", or the chemical and physicochemical condition of the body is lower than "moderate status", but no other applicable quality element is lower than "moderate status";
- **Poor ecological potential:** the lowest classified applicable quality element (aside from any chemical or physicochemical quality element) has "poor status"; and
- **Bad ecological potential**: the lowest classified applicable quality element (aside from any chemical or physicochemical quality element) has "bad status".

A summary of the surface water classifications for non-artificial and artificial water bodies are outlined in Table 2.

Table 2 Summary of Surface Water Classification for non-artificial (not heavily modified) and artificial (heavily modified) water bodies.

Status of bodies of surface water (not artificial or heavily modified)	How status is achieved	Status of artificial or heavily modified bodies of surface water	How status is achieved
High	High ecological status and good surface water chemical status	**Maximum**	Maximum ecological potential and good surface water chemical status
Good	Good ecological status and good surface water chemical status	**Good**	Good ecological potential and good surface water chemical status
Moderate	High or good ecological status and failing to achieve good surface water chemical status	**Moderate**	Maximum or good ecological potential and is failing to achieve good surface water chemical status.
If the body's ecological status is moderate, poor or bad, SEPA (irrespective of the body's chemical status) classify its surface water status as the same as its ecological status.		*If the body's ecological potential is moderate, poor or bad, SEPA (irrespective of the body's chemical status) classify its surface water status as the same as its ecological potential*	

2.3. Status of bodies of groundwater

Under the WFD, groundwater body status is classified on the basis of quantitative and chemical status. The worst-case classification is assigned as the overall groundwater body status, in a 'one-out all-out' system. SEPA determine if there is a risk of the groundwater quantitative and chemical status of the body being poor by identifying whether one or more of the indicators for poor groundwater quantitative status apply to the body, and where this is the case, further investigation is required to determine whether the criteria corresponding to each applicable indicator are satisfied.

Given that this WFD assessment focuses on the offshore aspects of the Proposed Development, where there are no groundwater bodies, status of groundwater bodies are not considered any further.

3. ASSESSMENT METHODOLOGY

3.1. Overview

New developments that therefore have the potential to impact the current or targeted WFD status of a water body are required to assess their compliance against the WFD objectives of the potentially affected water bodies.

A three-stage approach to assessment has been adopted, based on the UK Government's Planning Inspectorate Advice Note Eighteen (PINS, 2017) given that this provides a robust and relevant approach to the assessment:

- **Stage 1: WFD Screening** - Identification of the proposed work activities that are to be assessed and determination of which WFD water bodies could potentially be affected through identification of a zone of influence. This step also provides a rationale for any water bodies screened out of the assessment.
- **Stage 2: WFD Scoping** - For each water body identified in Stage 1, an assessment is carried out to identify the effects and potential risks to quality elements from all activities. The assessment is made taking into consideration embedded mitigation (measures that can reasonably be incorporated into the design of the proposed works) and good practice mitigation (measures that would occur with or without input from the WFD assessment process)
- **Stage 3: WFD Impact Assessment** – If necessary, depending on the outcomes of Stage 1 and Stage 3, a detailed assessment of the water bodies and activities carried forward from the WFD screening and scoping stages. This would involve:
  - The baseline conditions of the concerned water bodies;
  - An assessment of the risk of deterioration (either in isolation or cumulatively);
  - A description of any additional mitigation that is required (if applicable) and how it will be implemented; and,
  - An explanation of any positive contributions to the RBMP objectives proposed, and how they will be delivered.

3.2. Defining No Deterioration

Originally, deterioration in WFD terms was considered to mean deterioration from one status class to a lower one, however following a ruling by the Court of Justice of the European Union (CJEU) in July 2015 (Case C-461/13 on the 1st July 2016 (Bund für Umwelt und Naturschutz Deutschland eV v Bundesrepublik Deutschland) (Court of Justice of the European Union, 2015)), this has been redefined. The CJEU ruling clarified that:

- 'Deterioration of the status' of the relevant water body includes a fall by one class of any element of the 'quality elements' even if the fall does not result in a change in the classification of the water body as a whole;
- 'Any deterioration' in quality elements in the lowest class constitutes deterioration; and
- Certainty regarding a project's compliance with the Directive is required at the planning consent stage; hence, where deterioration 'may' be caused, derogations under Article 4.7 of the WFD are required at this stage.

Whilst deterioration within a status class does not contravene the requirements of the WFD, (except for Drinking Water Directive parameters in drinking water protected areas), the WFD requires that action should be taken to limit within-class deterioration as far as practicable. For groundwater quality, measures must also be taken to reverse any environmentally significant deteriorating trend, whether or not it affects status or potential.

The no deterioration requirements are applied independently to each of the elements coming together to form the water body classification as required by Appendix V of the Water Framework Directive (European Union, 2000) and Article 4 of the Groundwater Daughter Directive (European Union, 2006).

For surface waters, to manage the risk of deterioration of the biological elements of surface waters, the no deterioration requirements are applied to the environmental standards for the physico-chemical elements, including those for the Moderate/Poor and Poor/Bad boundaries.

For groundwater, the no deterioration requirements are applied to each of the four component tests for quantitative status and the five component tests for chemical status.

The no deterioration requirement may not apply to elements at High status and elements at High status may be permitted to deteriorate to "Good status", provided that:

- The water body's overall status is not High;
- The RBMP has not set an objective for the water body of High status;
- The objectives and requirements of other domestic or European Community legislation are complied with; and
- Action is taken to limit deterioration within High or Good status or potential classes as far as practicable.

3.3. Surface Water Assessment

Table 3 presents the matrix used to assess the effect of a project on surface water status or potential class. It ranges from a major beneficial effect, a positive change in overall WFD status, through no effect, and down to deterioration in overall status class.

The assessment considers all water bodies that may be directly or indirectly affected (adjacent water bodies). It has also considered any Protected Areas as defined by other European Directives such as Special Areas of Conservation (SAC) and Special Protection Areas (SPA), and water dependent SSSIs. Where more stringent (than WFD) standards apply (such as conservation objectives) these have also been considered.

Table 3 Surface water assessment Matrix

Effect	Description / Criteria	Outcome
Major beneficial	Impacts that taken on their own or in combination with others have the potential to lead to the improvement in the ecological status or potential of a WFD quality element for the entire waterbody	Increase in status of one or more WFD element giving rise to a predicted rise in status class for that waterbody.
Minor / localised beneficial	Impacts when taken on their own or in combination with others have the potential to lead to a minor localised or temporary improvement that does not affect the overall WFD status of the waterbody or any quality elements	Localised improvement, no change in status of WFD element
Green (no impact)	No measurable change to any quality elements.	No change
Yellow - Localised/ **temporary adverse effect**	Impacts when taken on their own or in combination with others have the potential to lead to a minor localised or temporary deterioration that does not affect the overall WFD status of the waterbody or any quality elements or prevent improvement. Consideration will be given to mitigation measures such as habitat creation or enhancement measures.	Localised deterioration, no change in status of WFD element when balanced against mitigation measures embedded in the scheme.
Orange - Adverse effect on class of WFD element	Impacts when taken on their own or in combination with others have the potential to lead to the deterioration in the WFD status class of one or more biological quality elements, but not in the overall status of the waterbody. Consideration will be given to mitigation measures such as habitat creation or enhancement measures.	Decrease in status of WFD element when balanced against positive measures embedded in the scheme.

Effect	Description / Criteria	Outcome
Red – Adverse effect on overall WFD class of waterbody	Impacts when taken on their own or in combination with others have the potential to lead to the deterioration in the ecological status or potential of a WFD quality element, which then lead to a deterioration of status/potential of waterbody.	Decrease in status of overall WFD waterbody status when balanced against positive measures embedded in the scheme.

3.4. Future Status Objectives

RBMPs are used to outline water body pressures and the actions that are required to address them. The future status objective assessment considers the ecological potential of a surface water body and the mitigation measures that defined the ecological potential. Assessments undertaken for the Proposed Development should consider the significant actions defined in the River Basin Management Plan for Scotland 2021-2027 (SEPA, 2021). The screening assessment should consider whether the project has the potential to prevent the implementation or impact the effectiveness of the defined measures.

3.5. Article 4.7 Derogations

Article 4.7 of the WFD allows derogation from the Directive but only where new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or for deterioration from high to good status have occurred, and when the following four stringent tests have been met:

- Test (a): All practicable steps are to be taken to mitigate the adverse impacts on the water body concerned;
- Test (b): the reasons for modifications or alterations are specifically set out and explained in the RBMP;
- Test (c)(1): There is an overriding public interest in the Proposed Development and/or Test (c)(2) whereby its benefits outweigh the benefits of the WFD objectives (i.e. that the benefits of the project to human health, human safety or sustainable development outweigh the benefits of achieving the WFD objectives); and
- Test (d): The benefits of the project cannot be achieved by a significantly better environmental option (that are technically feasible and do not lead to disproportionate cost).

In addition, the Proposed Development must not permanently exclude or compromise achievement of the WFD objectives in other bodies of water within the same RBD and must be consistent with the implementation of other EU environmental legislation (Article 4.8). In applying Article 4.7, steps must also be taken to make sure that the new provisions guarantee at least the same level of protection as the existing EU legislation (Article 4.9).

3.6. General Approach and Scheme Assumptions

The following provides a description of the scope of works. The assessment is mainly qualitative and based on readily available data and information, including ecological surveys. It appraises the potential for non-compliance with the core WFD objectives of no deterioration or failure to improve, taking into account Protected Areas and adjacent water bodies.

Data and information upon which this assessment is based is summarised below.

3.6.1. Desk study

The desk study has been used as the basis for a qualitative review of the Development and to identify components requiring assessment of WFD compliance, or where mitigation or further investigation and assessment will be required. Full details of the desk study are provided in the EIAR (Volume I). Of particular relevance to this chapter are Chapter 3: Project Description; Chapter 10 Fish and Shellfish; and Chapter 15 Benthic Ecology. Details from the earlier 2015 ES Chapter 6: Physical Processes and Water Quality are also used where appropriate.

3.6.2. Source-Pathway-Receptor Approach

The impact assessment is based on a source-pathway-receptor model. For an impact on the water environment to exist the following is required:

- An impact source (such as the release of polluting chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or the loss or damage to all or part of a water body);
- A receptor that is sensitive to that impact (i.e. waterbodies and the services they support); and
- A pathway by which the two are linked.

The first stage in applying the Source-Pathway-Receptor model is to identify the causes or 'sources' of potential impact from a development. The sources have been identified through a review of the details of the Proposed Development, including the size and nature of the development, potential construction methodologies and timescales. The next step in the model is to undertake a review of the potential receptors, that is, the water environment receptors themselves that have the potential to be affected. Water bodies including their attributes have been identified through desk study and site surveys. The last stage of the model is, therefore, to determine if there is a viable exposure pathway or a 'mechanism' linking the source to the receptor. This has been undertaken in the context of local conditions relative to water receptors within the study area, such as topography, geology, climatic conditions and the nature of the impact (e.g. the mobility of a liquid pollutant or the proximity to works that may physically impact a water body).

The assessment of the likely significant effects is qualitative, and considers both construction and operation phases, as well as cumulative effects with other developments. This assessment has considered the risk of pollution to surface water bodies directly and indirectly from construction activities.

3.6.3. Assumptions and Limitations

The assessment is undertaken on the basis of the maximum parameters for the Development, outlined in Chapter 3 of the EIAR (Volume I).

The assessment has been undertaken using available data and Development design details at the time of writing the EIAR.

4. SCREENING ASSESSMENT

4.1. Overview

The water bodies screened into the assessment have been selected based on the following criteria:

- All water bodies that may potentially be directly or indirectly impacted by the proposed works.
- The relevant water bodies have been determined using a Zone of Influence (ZoI) approach, which firstly requires the identification of all potential pathways to an effect on all quality elements, and secondly determination of the extent of the effect (i.e., the ZoI).

Section 1 above provides a brief description of the Proposed Development, with additional detail available in EIAR (Volume I) Chapter 3: Project Description. All potential pathways to an effect and ZoIs have been identified from this understanding of the Proposed Development. In accordance with Article 4.9 of the WFD, potential for effects on protected areas has also been considered with those WFD protected areas within 2 km of the proposed works screened in for further consideration.

The proposed works are located within the Scotland River Basin District. The River Basin Management Plan for Scotland 2021-2027 was published in December 2021 (SEPA, 2021).

4.2. Relevant WFD Water Bodies

Table 4 provides a summary of the baseline status/potential of WFD waterbodies that have been identified within 1 km of the scheme boundary. There is only one relevant waterbody, which is the Elie to Buckhaven WFD coastal waterbody (ID: 200050). The waterbody is shown in Figure 1.

The full water environment and ecology baseline for the Proposed Development is provided in Chapter 6: Physical Processes and Water Quality of the 2015 ES, Chapter 7: Marine Mammals, Chapter 10: Fish and Shellfish Ecology and Chapter 15: Benthic Ecology, of the EIAR (Volume I), and so is not repeated in full here. Refer to these chapters of the 2015 ES and 2022 EIAR, where relevant, for further details.

Table 4 WFD waterbodies in the study area

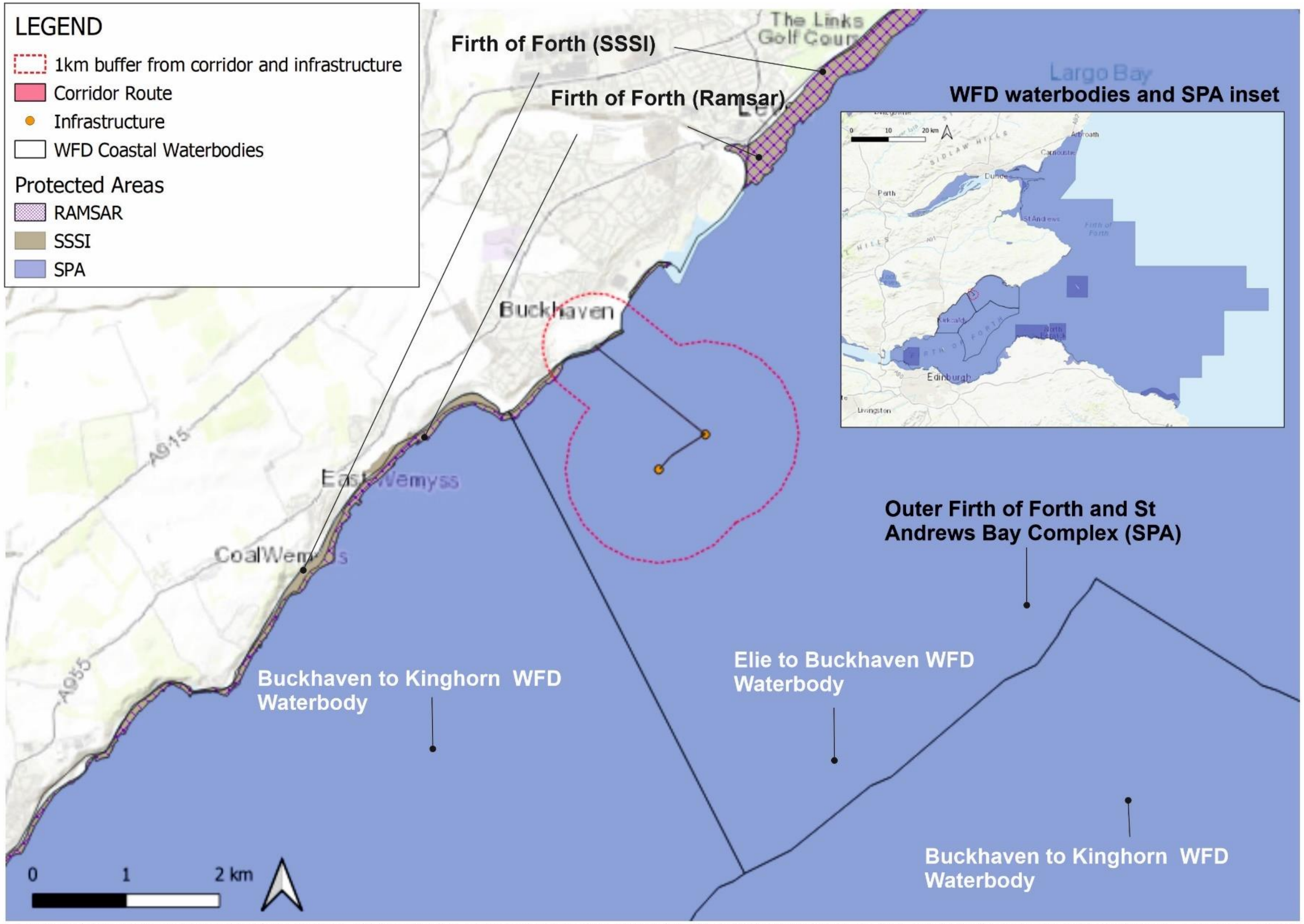
Waterbody	Ecological Status / Potential	Water Quality	Overall Target Objective	Designation
Elie to Buckhaven (ID: 200050)	Good	Good	Good (2027)	Elie to Buckhaven is a coastal waterbody where the development lies in the Western extent. It is 90.5 km^2 in area. It spans east from Buckhaven to Elie.
Further details: The coastline in the study area around Buckhaven for this waterbody is lined with coastal defence boulders. There are docks to the north east of these boulder defences, consisting of large concrete structures that divide the three docks that jut into the waterbody. However, the majority of the coastal margin is sandy beaches (forming part of Largo Bay) with several small residential areas spread along its length, such as Leven, Lower Largo, Earlsferry and Elie. There are two leisure caravan/holiday parks located along the coastline at Levern Beach and Shell Bay Beach. Between Lower Largo and Shell Bay lies Dumbarnie Links Nature Reserve which is characterised by lime-rich dune grasslands. **Protected Areas**: Outer Firth of Forth and St Andrews Bay Complex Special Protection Area (SPA), Firth of Forth SPA, Firth of Forth SSSI, Firth of Forth Ramsar.				

4.3. Zone of Influence

WFD water bodies have been screened into this assessment using a ZoI approach and on the basis of whether they are:

- A designated WFD water body within the ZoI; and
- A designated WFD water body indirectly affected by the ZoI.

Table 5 sets out the pathways to an effect, the extent of the ZoI and the water bodies that are directly within the ZoI.



Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 1 Development Locations and WFD Waterbodies

Table 5 ZOI's and relevant WFD waterbodies

Potential pathway	ZoI and basis for determination	Relevant water bodies	Adjacent / Other water bodies
Construction / Decommissioning			
Identified potential impacts to physical processes and water quality: • Increased suspended sediment levels from disturbance of seabed from trenching and installation of turbine foundations could impact water quality of waterbody; • Accidental leaks and spillages from plant and vessels could impact water quality of waterbody; • Deposition of sediment plumes from disturbed sediment could affect waterbody quality and morphology; • Release of sediment contaminants following disturbance could impact water quality of waterbody; **Identified potential impacts to ecology:** • Direct seabed and intertidal habitat loss beneath Development footprint; • Indirect habitat impacts related to deposition of sediment plumes; • Direct disturbance of marine mammals; • Indirect changes to prey availability; • Potential effect of underwater noise and vibration on fish and shellfish populations within the waterbody associated with the movement of construction vessels and the action of pin pile drilling, which have the potential to increase the noise level above natural background conditions.	All waterbodies within and immediately adjacent to the Development Site or boundary could be impacted. However, given the dynamic nature of coastal waterbodies with high dilution and dispersal, a zone of influence up to 1 km surrounding the Development is considered appropriate for the WFD assessment.	Elie to Buckhaven (ID: 200050)	The adjacent waterbodies are Buckhaven to Kinghorn WFD waterbody, Fife Ness to Elie WFD waterbody, Firth of Forth Inner – Offshore and Kinghorn to Leith Docks WFD waterbody. All are outside the ZoI and so are not considered further.
Operations			

Identified potential impacts to physical processes and water quality: - Turbine foundations causing changes to water levels, wave heights and currents; - Impacts on hydrodynamics could impact sediment transport and morphology of the waterbody; - Accidental spillage of chemicals during maintenance impacting water quality. **Identified potential impacts to ecology:** - Visual and underwater sound disturbance of marine mammals (and birds) from presence of vessels within the study area. - Net loss of original benthic habitat; - Introduction of new hard substrate which has potential to lead to colonisation including by non-native species; - Temporary habitat disturbance should jack-up vessels be required; - Electromagnetic field generation / head effects impacting benthic ecology and fish; - Potential effect of underwater noise and vibration on fish and shellfish populations within the waterbody associated with any required maintenance works	All waterbodies within and immediately adjacent to the Development Site or boundary could be impacted. However, given the dynamic nature of coastal waterbodies with high dilution and dispersal, a zone of influence up to 1 km surrounding the Development is considered appropriate for the WFD assessment.	Elie to Buckhaven (ID: 200050)	The adjacent waterbodies are Buckhaven to Kinghorn WFD waterbody, Fife Ness to Elie WFD waterbody, Firth of Forth Inner – Offshore and Kinghorn to Leith Docks WFD waterbody. All are outside the ZoI and so are not considered further.

4.4. Screening Outcome

The following water bodies have been identified within the study area and are screened in on the basis of Table 6 for further consideration under the Scoping Assessment (Section 5):

- Elie to Buckhaven (ID: 200050) – potential impacts identified for construction, operation and decommissioning phases if not appropriately mitigated.

5. SCOPING ASSESSMENT

5.1. Overview

For the Elie to Buckhaven waterbody identified in Section 4, a scoping assessment is carried out to identify the effects and potential risks to quality elements.

The assessment is made taking into consideration embedded mitigation as outlined in the EIAR (Volume I) (measures that can reasonably be incorporated into the design of the proposed works) and good practice mitigation (measures that would occur with or without input from the WFD assessment process).

A scoping assessment is required to determine whether any waterbody receptors may be impacted by the Proposed Development once the embedded mitigation has been considered, and therefore needs further detailed assessed at the WFD impact assessment. These receptors are defined on the basis of the Environment Agency Clearing the Waters Guidance (Environment Agency, 2016) which is considered best practice despite not being directly applicable to Scotland, combined with classification criteria on the SEPA Water Classification Hub (SEPA, 2020) and are based on the water body's quality elements. The receptors for surface water include:

- Hydromorphology;
- Water quality;
- Biology – fish and habitats;
- Protected areas; and
- The scoping assessment also considers Invasive Non-Native Species (INNS).

5.2. Elie to Buckhaven Coastal Waterbody

The footprint of the Proposed Development is within the western extent of the Elie to Buckhaven Coastal Water body. This water body stretches east from Buckhaven to Elie.

The Elie to Buckhaven Coastal WFD waterbody is currently at Good overall status, good overall ecological status and good water quality.

The waterbody has an objective of maintaining Good Status, meaning that there should be no deterioration from its current status.

5.2.1. Hydromorphology

The Proposed Development has the potential to affect hydromorphological quality elements in the Elie to Buckhaven Coastal WFD waterbody and surrounding area through the sediment removal activities during the seabed preparation works. This will include the construction of two monopile base foundations (as a worst case although pin pile foundations are still an available option) with a footprint up to 3,220.16 m^2, and burial of two export cables using jetting.

To construct the foundations, it is estimated that up to a total of 5,640 m^3 could be removed. In addition, due to their large dimension they can cause an effect on the hydrodynamics. The hydrodynamics variation can lead into alteration of sediment transport patterns which can affect the adjacent coastline. In addition, it is anticipated that decommissioning activities could also affect sediment pattern, although to a lesser degree than during construction.

Nonetheless, the suspension of the coarse sediments around the Proposed Development area would remain localised to the vicinity of the works, before settling back on the seabed. Therefore, changes to the sediment patterns would be a localised and temporary effect.

The scoping assessment of the potential effects to hydromorphology is provided in Table 6.

Table 6 Scoping assessment of risks to hydromorphology

Risk	Proposed Mitigation	Requires Detailed Impact Assessment	Detailed Impact Assessment Not Required	Hydromorphology Risk Issue(s)
Could significantly impact the hydromorphology (i.e., bed morphology and substrate) of any water body – *this risk is due to the works required to install the turbine foundations on the seabed including excavation of the bed and the electrical export cable in a trench and/or placed on the seabed. The turbines once installed could also alter hydrodynamics, induce scour and impact hydromorphology.*	Good practice will be followed in all aspects of construction, operation and decommissioning, specifically through a Construction and Environmental Management Plan (CEMP) and Pollution Prevention Plan (PPP). Turbine and metmast restricted to two structures and so any changes are anticipated to be restricted to the immediate vicinity of the Proposed Development and very small. Previous studies undertaken for the environmental assessment of the effects of monopile foundations (which are considered here as the worst-case option) have indicated that any effects of these foundations on hydrodynamics are likely to be minimal but could cause some increase in sedimentation in the lee of the foundations but would be restricted to the immediate vicinity of the structures (see ES Volume I Chapter 6). Scour of the seabed around each individual structure location occurs typically as a result of locally accelerated near bottom currents. To mitigate this effect, scour protection may be placed surrounding each foundation, reducing the degree of scour, which would be limited to the edges of scour protection material. This will alter the sediment type around the turbine and metmast. However, due to the very small area affected (as only two structures will be installed), this is not		✓	Any residual risk to hydromorphology following mitigation would be restricted to the immediate surroundings of the turbines and electrical export route. The total footprint of the Proposed Development including temporary jack-up-barge during construction is 10,840.1 m^2. In the context of the 90.5 km^2 waterbody this equates to 0.012% of the waterbody area. As such, any residual hydromorphological impact is not considered significant at the scale of the Elie to Buckhaven WFD waterbody and would not lead to deterioration or prevention of future improvement. On this basis it is considered that hydromorphology can be scoped out of additional detailed assessment.

	considered to have a significant effect on sediment dynamics in the wider area. The total area occupied by the foundations and scour protection is anticipated to be up to 3,220.16 m^2. The sediment removed by the seabed preparation works for the monopile foundations (if used) will be disposed of at an existing off-site disposal facility under a Marine Licence or re-used as ballast material within the foundations. This will reduce the amount of resuspended sediment as a result of seabed preparation works. Despite the mitigation it is possible that deposition of suspended sediment would occur over a small area, not expected to exceed 50m, on either side of the works (for spring tides). Smaller fines may travel further but there are few fines in the substrate in the working area based on baseline study (based on data presented in 2015 ES Volume I Chapter 6). Sediment deposition from any sediment plume associated with construction work is expected to be small in magnitude with only thin veneers of fine material over a wider area expected and well within natural variation (see 2022 EIAR Chapter 15).		
Could impact on the hydromorphology (e.g., morphology or tidal patterns) of a water body at high status	Na – waterbody not at high status	✓	Elie to Buckhaven Coastal WFD waterbody is at good status. This is therefore scoped out of further assessment.
Activity is in a water body that is heavily modified for the same use as your activity	Na – waterbody not designated heavily modified for the same use as the proposed activity	✓	Elie to Buckhaven Coastal WFD waterbody not designated heavily modified for turbines. This is therefore scoped out of further assessment.

5.2.2. Water Quality

Release of contaminants from sediments during construction and decommissioning works could temporarily affect the quality of the water within Elie to Buckhaven Coastal WFD waterbody.

2015 ES (Volume I) Chapter 6: Physical Processes and Water Quality indicates that sediments around the Firth of Forth are likely to contain concentrations of contaminants as a result of historic human activity such as waste inputs and industrial activity. Sediments in the Development area were analysed for contaminants as part of the intertidal ecology survey. Contaminants analysed included Polycyclic Aromatic Hydrocarbons (PAH), metals (aluminium, arsenic, cadmium, chromium, copper, iron, lithium, lead, mercury, nickel, zinc), polychlorinated biphenyls (PCB), tributyltin (TBT) and Total Petroleum Hydrocarbons (TPH). Concentrations of PAH, metals and TBT were below the revised Marine Scotland Action Levels (as described in the Marine Scotland pre-dredge guidelines) and PCB levels were below the OSPAR Environmental Assessment Criteria (EAC), below which contaminant levels are considered of no concern. TPH levels were above the revised Marine Scotland Action Levels. This is consistent with high concentrations of total hydrocarbons in the wider Firth of Forth that have been reported previously.

Accidental leaks and spillages of polluting substances during construction, operational maintenance activities and decommissioning (i.e., drilling chemicals, fuels, and/or oils) could potentially pollute nearby surface watercourses temporarily if their use or removal is not carefully controlled.

The scoping assessment of the potential effects to water quality is provided in Table 7.

Table 7 Scoping assessment of risks to water quality

Risk	Proposed Mitigation	Requires Impact Assessment	Detailed Impact Assessment Not Required	Water Quality risk issue(s)
Could affect water clarity, temperature, salinity, oxygen levels, nutrients or microbial patterns continuously for longer than a spring neap tidal cycle (about 14 days) during construction and decommissioning phase	Good practice will be followed in all aspects of construction and decommissioning, specifically through a Construction and Environmental Management Plan (CEMP) and Pollution Prevention Plan (PPP). The sediment removed by the seabed preparation works for the monopile foundations (if used) will be disposed of at an existing off-site disposal facility under a Marine Licence or re-used as ballast material within the foundations. This will significantly reduce the amount of resuspended sediment as a result of seabed preparation works. If required, drilling operations will use Water Base Mud (WBM) of low toxicity and water soluble, which will minimise potential effects on sediment and water quality.		✓	Increases in suspended sediment concentrations would be intermittent over a three month period, across a period of approximately six months. Given this, the proposed preparatory works and the implementation of best practice through the CEMP and PPP to control leaks and spillages, no impact on water quality would be expected at the scale of the WFD waterbody, and risks to water quality can be scoped out of further, more detailed assessment.
Is in a water body with a phytoplankton status of moderate, poor or bad	Na– phytoplankton status is high		✓	Na – phytoplankton status is high
Is in a water body with a history of harmful algae	Na - no known history of harmful algae		✓	Na - no known history of harmful algae
The chemicals are on the Environmental Quality Standards Directive (EQSD) list.	As outlined above mitigation has been incorporated into the Proposed Development to minimise sediment disturbance, and thus mobilisation of contaminants.		✓	Given the mitigation and requirements for a Marine License application, there are not anticipated to be any adverse impacts

It disturbs sediment with contaminants above Marine Scotland Action Levels	Nonetheless, there is potential for TPHs to be disturbed which are above Marine Scotland Action Levels. Although impacts would not be anticipated at the WFD watercourse scale, any additional mitigation requirements will be determined during the process of applying for a Marine License in line with the Marine (Scotland) Act 2010.		on the scale of the WFD waterbody, and further, more detailed assessment can be scoped out.

5.2.3. Biology

5.2.3.1. Marine habitat

Habitats should be included as part of the WFD impact assessment if the footprint of the activity is any of the following (Environment Agency, 2016), noting that this also includes the footprint of thermal or sediment plumes:

- 0.5 km^2 or larger in area within the estuarine or coastal water body;
- 1% or more of the water body's area; and
- Within 500 m of any higher sensitivity habitat or covering 1% or more of any lower sensitivity habitat area.

A maximum of four pin piles for the turbine foundation and one monopile for the meteorological mast foundation will be installed, totalling 0.000048 km^2 of seabed disturbance, plus associated scour protection. There will be a temporary loss of seabed habitat as the turbine and meteorological mast are installed by a single jack-up vessel with six feet, totalling 0.000072 km2 of seabed disturbance. Complete surface lay of export and inter array cables with associated protection materials will result in a maximum seabed loss of 0.01070825 km2 for both cables. In reality, this apparent maximum loss associated with cable installation will not be realised as the preferred option for all cabling is burial to a depth of 1.5 m, where seabed conditions allow, avoiding the necessity of applying protection and the consequent habitat alteration. There will also be a temporary loss of habitat of up to 0.001544 km2 associated with cable laying vessel anchors.

ES (Volume I) Chapter 15: Benthic Ecology indicates that none of the ecological biotopes within the footprint of the turbine foundations or cabling area is considered rare, geographically restricted or of specific conservation importance. Furthermore, they do not play any important role in supporting either the seabird or seaduck and diver interests of the SPA. Effects on biotope diversity or designated nature conservation features are not therefore forecast and any effect on a biodiversity or the functional role of the habitats in question is considered highly unlikely.

Biotopes CR.MCR.EcCr and CR.HCR.XFa can found in the Habitats Directive Annex I as Reef habitats. The area of the Development is not within or near to an SAC. The nearest SAC with Reef identified as a qualifying feature is the Isle of May, some 28 km to the east. The JNCC has noted that potential Annex I reef may be present in many locations in the surrounding region including immediately northeast of the turbines and in the nearshore area likely to be crossed by the proposed export cable route corridor. The site-specific survey (Technical Appendix 10A of the 2022 EIAR) identified CR.MCR.EcCr and CR.HCR.XFa as present. The assessment of 'reefiness' indicated four nearshore sites with a resemblance to Reef. Two of these sites (3 and 6) where on the proposed export cable route and had medium resemblance to Annex I Reef and the other two sites (15 and 17) were just over 1 km southwest and northeast of this, respectively, and had low resemblance. These rocky nearshore areas may be unsuitable for cable burial and consequently the cable would be laid on the surface of the seabed and protected by either concrete mattressing or rock placement. The mattressing / rock placement would cover any potential Annex I Reef which may be present but is highly likely to be quickly colonised by fauna and flora that are representative of local populations. However, given that it will be made from a different material (artificial or non-local rock), possibly with reduced / different habitat complexity, relative to the ambient rocky habitat, the colonising community may not exactly match that of the surrounding communities. This would constitute a negative effect, although its spatial extent would be localised around the area of the mattressing / rock placement. Consequently, effect magnitude would be small and receptor sensitivity is considered low.

More broadly, any loss that may occur is considered of small magnitude within the wider geographical context. However, long term habitat loss will occur locally with all biotopes and associated fauna and flora having a low tolerance to removal or burial of the natural environment, where directly affected. Effects associated with the meteorological masts will be short term, lasting the duration of its operational phase of the Proposed Development (5 years), but will be reversible upon decommissioning with removal of the mast and scour protection material. Effects associated with the turbine will last for the duration of its operational phase (25 years) but will be reversed upon decommissioning with removal of the turbine and scour protection material. Following decommissioning the subsequent recoverability of affected areas will be high. Receptor sensitivity is therefore considered to be low. The scoping assessment of the potential effects to biological habitat is provided in Table 8.

Table 8: Scoping assessment of risks to biological marine habitats

Footprint is:	Proposed Mitigation	Requires Impact Assessment	Detailed Impact Assessment Not Required	Biological Marine Habitat Risk Issue(s)
0.5 km^2 or larger (including any sediment plume)	Should monopile foundations be selected, spoil from the ground preparation works will either be re-used as ballast or removed and disposed off-site. This will reduce the amount of sediment available to cause effects relating to increased suspended sediment concentrations and smothering from sediment deposition.		✓	Footprint of the Development not larger than 0.5 km^2. Temporary sediment plume may be formed but is not considered likely to exceed 0.5 km^2
1% or more of the water body's area	The Proposed Development will operate a pollution / spill prevention plan. This will limit the risk of accidental spillages or releases occurring and ensure that adequate contingency is in place (i.e., through a Marine Pollution Contingency Plan (MPCP)) to resolve any incidents quickly.		✓	Footprint of the Proposed Development not larger than 1% of waterbody area. Temporary sediment plume may be formed but is not considered likely to exceed 1% of waterbody area.
Within 500 m of any higher sensitivity habitat	All subsea electricity cables will be buried, subject to ground conditions, or covered with cable protection material. As such any heating or EMF effects which might have directly influenced sensitive habitats or species will be limited.		✓	n/a - No higher sensitivity habitat identified in Chapter 15 of the EIAR (Volume I)
1% or more of any lower sensitivity habitat	Space frame foundation piles will be drilled into the seabed and not pile driven using a pneumatic hammer. This will significantly reduce the level of underwater noise and vibration generated during the construction phase.		✓	While the footprint including sediment plume may be over 1% of lower sensitivity habitat, the assessment in Chapter 15 of the EIAR (Volume I) indicates that benthic receptors largely have a low intolerance and high recoverability. Given the mitigation built into the Development, no adverse impacts to marine habitats would be anticipated at a scale which might impact ecological WFD classifications for the waterbody.

5.2.3.2. Fish

The study area is known to support several nationally and internationally protected migratory fish species, such as salmon *Salmo salar*, European eel *Anguilla Anguilla* and sea *trout Salmo trutta*, see ES (Volume I) Chapter: 10 Fish and Shellfish Ecology.

The potential physical disturbance of the bed associated with construction and decommissioning, plus maintenance activities during operation, could affect fish within the water body with potential impacts including habitat loss, water quality deterioration, underwater sound and visual stimuli.

Table 9 provides a scoping assessment for fish.

Table 9 Scoping assessment of risks to fish

Risk	Proposed Mitigation	Requires Impact Assessment	Impact Assessment Not Required	Biological Marine Habitat or Fish Risk Issue(s)
Is in an estuary and could affect fish in the estuary, or could affect fish migrating through the estuary	Space frame foundation piles will be drilled into the seabed and not pile driven using a pneumatic hammer. This will significantly reduce the level of underwater noise and vibration generated during the construction phase;All subsea electricity cables will be buried, subject to ground conditions, or covered with cable protection material to ensure a distance separation between the cables and fish and shellfish receptors. This will reduce the electromagnetic fields; and thus, potential effects on sensitive species, particularly elasmobranchs; In the event that monopile base foundations are used, spoil from the ground preparation works for the monopile foundations will either be re-used as ballast or removed and disposed off-site. This will reduce the amount of sediment available to cause effects relating to increased suspended sediment concentrations that might affect fish or shellfish; and The Proposed Development will operate a pollution / spill prevention plan. This will limit the risk of accidental spillages or releases occurring and ensure that adequate contingency is in place (i.e., through a Marine Pollution Contingency Plan (MPCP)) to resolve any incidents quickly.		✓	Considering the proposed mitigation, no significant effects to fish have been identified in EIAR (Volume I) Chapter 10: Fish and Shellfish Ecology (or within the 2015 ES) relating to construction, operational or decommissioning activities (including relating to noise, vibration, seabed disturbance, sediment plumes, chemical spillages or leaks, electromagnetic field or heat emissions or changes in hydrodynamic regimes. Given the mitigation that is embedded in the Proposed Development, no impacts that would affect fish at the WFD waterbody scale are anticipated, and so no further assessment is proposed.
Could impact on normal fish behaviour like movement, migration, or spawning (e.g., creating a physical barrier, noise, chemical change or change in depth or flow			✓	

5.2.4. WFD protected areas

The location of the Proposed Development in relation to the following WFD Protected Areas has been considered:

- Special areas of conservation (SAC);
- Special protection areas (SPA);
- Shellfish waters;
- Bathing waters; and
- Nutrient sensitive areas.

The following sites have been identified:

- *The Firth of Forth SSSI* comprises an extensive mosaic of intertidal and coastal habitats including saltmarsh, sand dune, fen, coastal sluiced saline lagoons, calcareous grassland, neutral grassland, dune grassland and maritime grassland. Extensive mudflats make up much of the intertidal area with areas of sand, shingle, rock and boulders as well as numerous valuable geological features. The mudflats are invertebrate rich and form important feeding grounds for the abundant waders and wildfowl in the Forth.
- *The Firth of Forth SPA* comprises an area in excess of 6,000 ha. It qualifies as an SPA by regularly supporting wintering populations and post-breeding populations of European importance of numerous Annex 1 bird species. It further qualifies by supporting wintering populations of both European and international importance of five migratory bird species. In addition to this the Firth of Forth also qualifies by supporting wintering wildfowl assemblages of European importance.
- *The Outer Frith of Forth and St Andrews Bay Complex SPA* is a large estuarine/marine site on south-east coast of Scotland consisting of the two closely adjacent Firths of Forth and Tay. In the mid Firth of Forth a belt of mud-rich sediments lies between areas of sandy gravels and shell material on either side along the shore. As the estuary widens towards the outer firth, there are extensive areas of sandy and gravelly muds and fine sediments. In contrast St Andrews Bay contains clean sands and gravel with only small areas of muddy sediments. Water depth is variable but large areas, in both the Firth of Forth and St Andrews Bay, are shallow and less than 10 m deep. The site qualifies by regularly supporting a non-breeding population of birds of European importance.
- *The Firth of Forth Ramsar* qualifies as a site under Criterion 3a by regularly supporting over 20,000 waterfowl in winter. The site supported a 1993/94–97/98 winter peak mean of 95,000 waterfowl, comprising 45,000 wildfowl and 50,000 waders.

There are no other statutory designated sites within 2 km of the Proposed Development.

The outcome of the scoping assessment for WFD protected areas is shown in Table 10.

Table 10 Scoping assessment of risks to WFD protected areas

Risk	Proposed Mitigation	Requires Impact Assessment	Impact Assessment Not Required	Protected Site issue(s)
Activity is within 2 km of any WFD protected area - *the intertidal area at the proposed cable landfall location is part of the Firth of Forth SSSI, SPA and Ramsar sites.*	Refer to mitigation outlined in Tables 6-9 of this WFD assessment. In addition, trenching is possible options for crossing the intertidal area with only the latter resulting in localised potential effects on the benthic ecology. A Pollution Prevention Plan will be in place to protect birds from pollution during construction, operation and decommissioning. The estimated collision risk to each bird species using the SPA is considered to be negligible or low. Modelling in Technical Appendix 6C of the EIAR indicates that for all species, except gannet, the seasonal collision risk mortalities are zero. This is not surprising given that the Proposed Development is a single turbine located relatively close to the shore. Any monitoring effort required to detect collisions would not be commensurate with the scale of the predicted effect		✓	Activity is within 2 km of WFD protected areas - the Firth of Forth SSSI, the Firth of Forth SPA, the Firth of Forth Ramsar, and the Outer Frith of Forth and St Andrews Bay Complex SPA. Given the mitigation, no significant effects have been identified to protected sites with the EIAR (Volume I) and there is therefore expected to be no non-compliance with the objectives of the WFD, and further assessment is scoped out.

5.2.5. Invasive Non-Native Species (INNS)

INNS harm the environment. They can be small and hard to spot so are easily spread on damp equipment and clothing. If the Proposed Development risks introducing or spreading INNS this should be included in the WFD impact assessment. The risks of introducing or spreading INNS includes marine vessels, marine plant, construction materials or equipment being used that have come from, have been used in or have travelled through other water bodies and activities that help spread existing INNS either within the immediate water body or to other waterbodies.

The INNS scoping assessment is presented in Table 11.

Table 11 Scoping assessment of risks from INNS

Risk	Proposed Mitigation	Requires Impact Assessment	Impact Assessment Not Required	INNS issue(s)
Activity may introduce or spread INNS to a water body – there is potential for INNS growth on new substrate related to the turbine foundations and cable route, which may be transported to site on maintenance vessels.	The site-specific survey (Technical Appendix 10A of the 2022 EIAR) did not identify the presence of any invasive non-native species in the core study area. The Proposed Development and implementation of a Biosecurity Plan which includes ballast water and anti-fouling management plans for construction and maintenance vessels will reduce the risk of introducing marine non-native species during the life of the Proposed Development. A draft Biosecurity Plan is contained in Volume 4: Compliance Plans of the EIAR (2022).		✓	No specific information is available to suggest that reefs associated with offshore wind farms will provide uniquely beneficial opportunities not currently available to alien species to assist their invasion in UK waters. The Proposed Development will only represent a very small contribution to any increased risk of spreading non-native species, as there are already other artificial hard structures present in the area and which may be equally suitable for colonisation. Given the mitigation, there is not considered a likelihood of adverse impact at the WFD waterbody scale, and INNS assessment is therefore scoped out of additional assessment.

5.2.6. Summary

Overall, it is considered that given the mitigation provided, that impacts to Elie to Buckhaven Coastal WFD waterbody can be scoped out of detailed assessment for the Development. Mitigation should be agreed with SEPA and Marine Science Scotland, and it is considered that further assurance of environmental good practice will be obtained through the Marine Licensing and consents process. No deterioration or prevention of future improvement in the Elie to Buckhaven Coastal WFD waterbody is anticipated. Furthermore, no impact is predicted on adjacent WFD waterbodies or protected site designations.

6. CONCLUSIONS

The WFD assessment indicates that, based on the current understanding of the Proposed Development, no significant adverse impacts to WFD relevant water bodies will occur. Therefore, the Proposed Development is considered compliant with the WFD objectives for the Elie to Buckhaven Coastal Waterbody, provided that the outlined mitigation measures are implemented.

It has been possible to scope out detailed assessment based on the robust mitigation measures included in the Proposed Development design.

Several permissions will be required to permit the Proposed Development, principally the Marine License from Marine Scotland where works are seaward of the MHWS, and preparation of the seabed for these works, as required under the Marine (Scotland) Act 2010.

7. REFERENCES

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