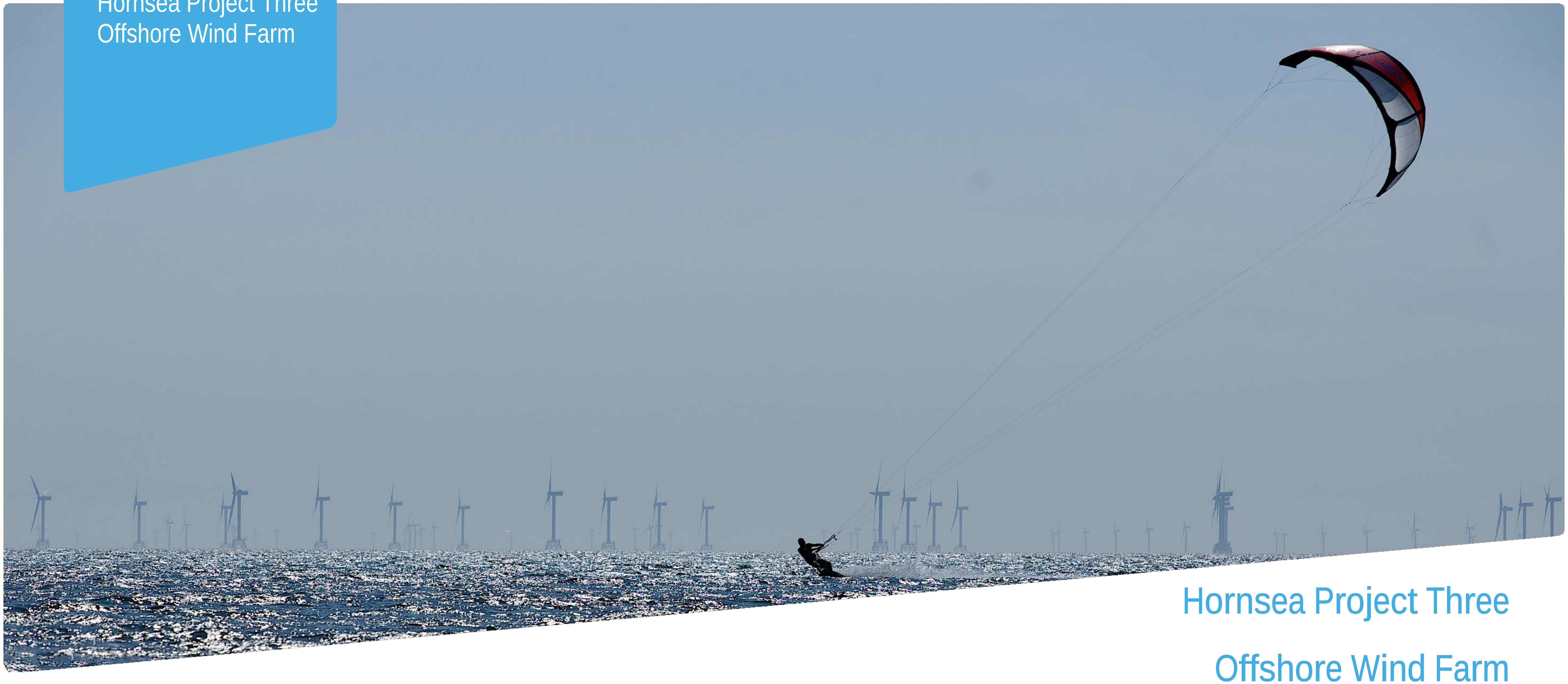
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Preliminary Environmental Information Report: Annex 7.1 – Navigational Risk Assessment (Part 2)

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 5 – Offshore

Annex 7.1 – Navigational Risk Assessment

Report Number: P6.5.7.1

Version: Final

Date: July 2017

This report is also downloadable from the Hornsea Project Three offshore wind farm website at:
www.dongenergy.co.uk/hornseaproject3

DONG Energy Power (UK) Ltd.

5 Howick Place,

London, SW1P 1WG

Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

Liability

This report has been prepared by Anatec, with all reasonable skill, care and diligence within the terms of their contract with DONG Energy Power (UK) Ltd

Prepared by Anatec

Contributors: ASC Ltd.

Checked by: Hywel Roberts and Kieran Bell.

Accepted by: Sophie Banham

Approved by: Stuart Livesey

17. Future Case Marine Traffic

17.1 Introduction

17.1.1.1 This section presents the future case level of activity in the Hornsea Three array area shipping and navigation study area and the Hornsea Three offshore HVAC booster stations shipping and navigation study area, which has been input into the collision and allision risk modelling. Future case is 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. This is considered both with and without the wind farm and Hornsea Three offshore HVAC booster stations being present.

17.2 Increases in traffic associated with ports

17.2.1.1 Due to the distance offshore of the Hornsea Three array area, it is not considered likely that any increase in port traffic would impact on the general traffic levels around the Hornsea Three array area; therefore within the collision and allision modelling scenarios an indicative increase of 10% was used to show an example future case scenario in traffic.

17.3 Increases in fishing vessel activity

17.3.1.1 For commercial fishing vessel transits a 10% increase was used to demonstrate potential impacts; this value is used as a standard value throughout future case modelling to demonstrate what changes would occur to the area if vessel activity increased. This value is used due to there being limited reliable information on future activity levels on which any firm assumption could be made. Increases in fishing activities have been covered in a separate study of commercial fishing (volume 2, chapter 6: Commercial Fisheries).

17.4 Increases in recreational vessel activity

17.4.1.1 In terms of recreational vessel activity, there are no known major developments that will increase the activity of these vessels within the southern North Sea.

17.4.1.2 As with fishing activity, given the lack of reliable information into future trends a set 10% is considered as a conservative increase.

17.5 Increases in traffic associated with Hornsea Three operations

17.5.1.1 During the construction period there may be as many as 11,776 return trips made by vessels involved in the installation of Hornsea Three. During the operation and maintenance period there may be up to 2,433 CTV visits per year scheduled, along with many visits from supply vessels and other support vessels.

17.5.1.2 Although not considered in the collision and allision risk modelling since routes will not be defined, this traffic has been considered within the hazard log (see Appendix B).

17.6 Collision and allision probabilities

17.6.1.1 The increased activity would also increase the probability of vessel to vessel encounters and hence collisions. Whilst this is not a direct result of Hornsea Three, the increased congestion caused by the potential displacement of traffic due to the Hornsea Three array area and Hornsea Three offshore HVAC booster stations may have an influence. Again, a 10% overall increase was assumed on base case with wind farm collision risk given the lack of reliable information of likely shipping trends, especially given the distance from a port, of the Hornsea Three array area. Developments in ports and subsequent changes to vessel sizes are the most likely factors to influence traffic levels, and these are most notable and quantifiable near ports and harbours.

17.6.1.2 The potential increase in vessel activity levels would increase the probability of vessel to structure allisions (both powered and drifting). Whilst in reality the risk would vary by vessel type, size and route, it is estimated that this would lead to a linear 10% increase on the base case with wind farm allision risk. This is used in order to demonstrate how allision risk may change if the number of vessels increase within the area.

17.7 Commercial traffic routeing

17.7.1.1 The following section analyses the potential alternative routeing options for routes where displacement may occur. It is not possible to consider all options and so the shortest and therefore mostly likely alternatives have been considered. Assumptions for re-routes include:

- All alternative routes maintain a minimum distance of 1 nm from offshore installations and potential turbine boundaries in line with the MGN 543 shipping template (MCA, 2016). This distance is considered for shipping and navigation from a safety perspective as explained below; and
- All mean routes take into account sandbanks and known routeing preferences.

17.7.1.2 MGN 543 (MCA, 2016) provides guidance to offshore renewable energy developers on both the assessment process and design elements associated with the development of an offshore wind farm. Annex 3 of MGN 543 defines a methodology for assessing passing distances between wind farm boundaries but states that it is “not a prescriptive tool but needs intelligent application”.

17.7.1.3 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 within 1 nm of established offshore wind farms (including between different wind farms) and these distances vary depending on the sea room available as well as the prevailing conditions. This evidence also demonstrates that the Mariner defines their own safe passing distance based on the conditions and nature of the traffic at the time, but they are shown to frequently pass 1 nm off established developments. The NRA also aims to establish the maximum design scenario case based on navigational safety parameters, and when considering this the conservative (realistic) for vessel routeing is considered to be when main routes pass 1 nm off developments. Evidence collected at an industry level confirms that it is a safe and reasonable distance for vessels to pass however it is likely that a large number of vessels would instead choose to pass at a greater distance depending on their own passage plan and the current conditions.

17.7.1.4 It should be noted that alternatives do not consider adverse weather routeing; however due to the open sea room and navigable water depths in the vicinity of the Hornsea Three array area the ability for vessels to alter their headings to reduce the impacts of adverse weather is not considered to be reduced (see section 16).

18. Collision and Allision Risk Modelling and Assessment

18.1 Introduction

18.1.1.1 This section assesses the major hazards associated with the development of the Hornsea Three offshore wind farm. This consists of a base case and future case assessment for the Hornsea Three array area, both in isolation and cumulatively, as well as a base case and future case assessment for the Hornsea Three offshore HVAC booster stations. These assessments include major hazards associated with:

- Increased vessel to vessel collision risk;
- Additional vessel to structure allision risk;
- Additional fishing vessel to structure allision risk;
- Additional recreational craft (sailing/cruisers) allision risk;
- Additional risk associated with vessels Not Under Command (NUC); and
- Anchor/cable interaction.

18.1.1.2 The base case assessment used the present day vessel activity level identified from the marine traffic surveys, consultation and other data sources. The future case assessment made assumptions on shipping traffic growth over the life of Hornsea Three.

18.1.1.3 The modelling for the Hornsea Three array area for the in isolation assessments was undertaken using Layout A (see section 9) as this layout presents the maximum design scenario for collision and allision due to the maximum number of turbines. Further detail on the models and results can also be found in Appendix A.

18.1.1.4 The modelling for the Hornsea Three array area cumulative assessment did not consider any layouts, only the Area for Lease (AfL) boundaries which are considered the maximum design scenario for route deviations, encounters and collision risk.

18.1.1.5 The modelling for the Hornsea Three offshore HVAC booster stations was undertaken using the maximum design scenario dimensions appearing in the Design Envelope equivalent to four Hornsea Three offshore HVAC booster stations positioned in a square and connected by bridge links. Further detail on design parameters is contained within section 9.5.

18.2 Hornsea Three array area in isolation assessment

18.2.1 Base case without Hornsea Three

Vessel to vessel encounters

18.2.1.1 An assessment of current vessel to vessel encounters was carried out by replaying at high speed 40 days of AIS, visual and Radar data from the *Neptune* and *RV Aora* (June/July 2016 and November/December 2016). It is noted that encounters involving two recreational craft participating in the *500 Mile North Sea Race* on 28 June 2016 have been excluded from this assessment since these vessels were transiting in a race pattern in the same direction (and are likely to get in close proximity to each other) and are therefore not representative of the vessel traffic within the region.

18.2.1.2 Within the model, an encounter is defined as two vessels passing within 1 nm of one another within one minute. This helps to illustrate where existing vessel congestion is highest and therefore where offshore developments, such as a wind farm, could potentially increase congestion and therefore also increase the risk of encounters and collisions. No account has been given to whether the encounters are head on or stern to head; just close proximity.

18.2.1.3 A heat map based on the geographical distribution of vessel encounter tracks within a 0.5×0.5 nm grid of cells is presented in Figure 18.1.

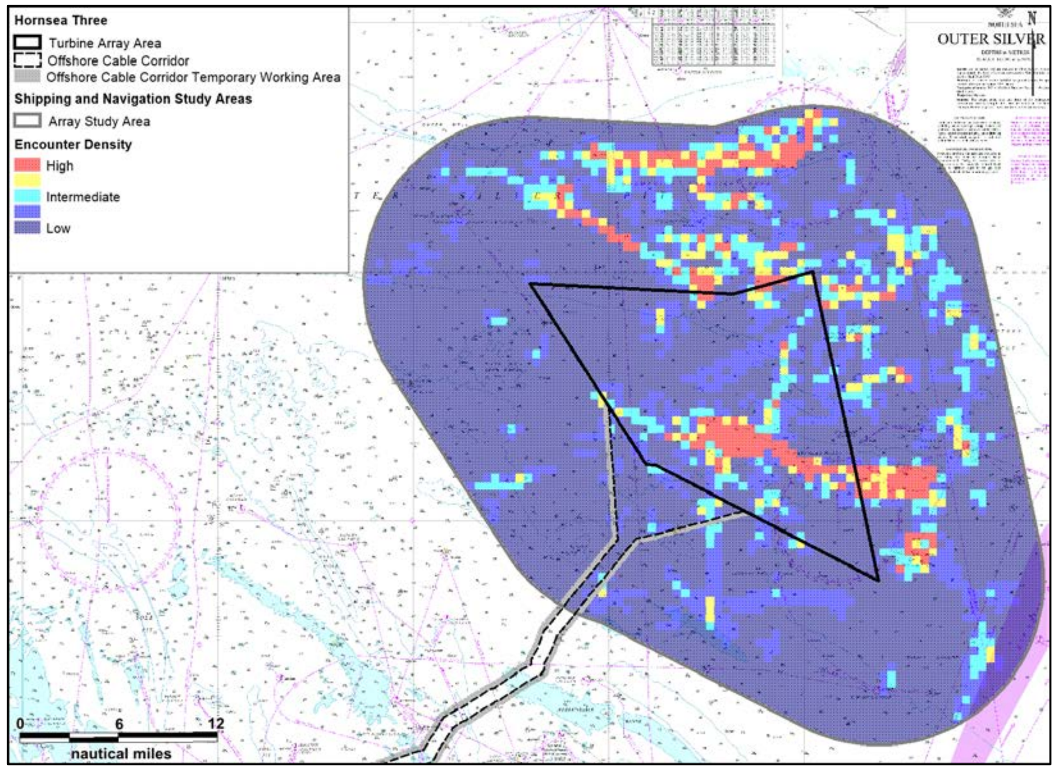


Figure 18.1: Vessel encounters density from AIS, visual and Radar within the Hornsea Three array area shipping and navigation study area (40 days summer and winter 2016).

18.2.1.4 It can be seen that the density of vessel encounters in the vicinity of the Hornsea Three array area is variable, with higher vessel encounter density occurring across the centre of the Hornsea Three array area as well as to the north and east. This is due to the moderate level of fishing activity in the region, with the longer duration fishing vessels present within the Hornsea Three array area shipping and navigation study area resulting in an increased number of vessel encounters. There are also high density spots at the locations of the Markham and Grove gas platforms. Again given the slow speed that fishing vessels operate it is likely that they will encounter each other but not be at risk of collision.

18.2.1.5 Figure 18.32 and Figure 18.3 present the number of vessel encounters per day throughout the summer and winter survey period respectively.

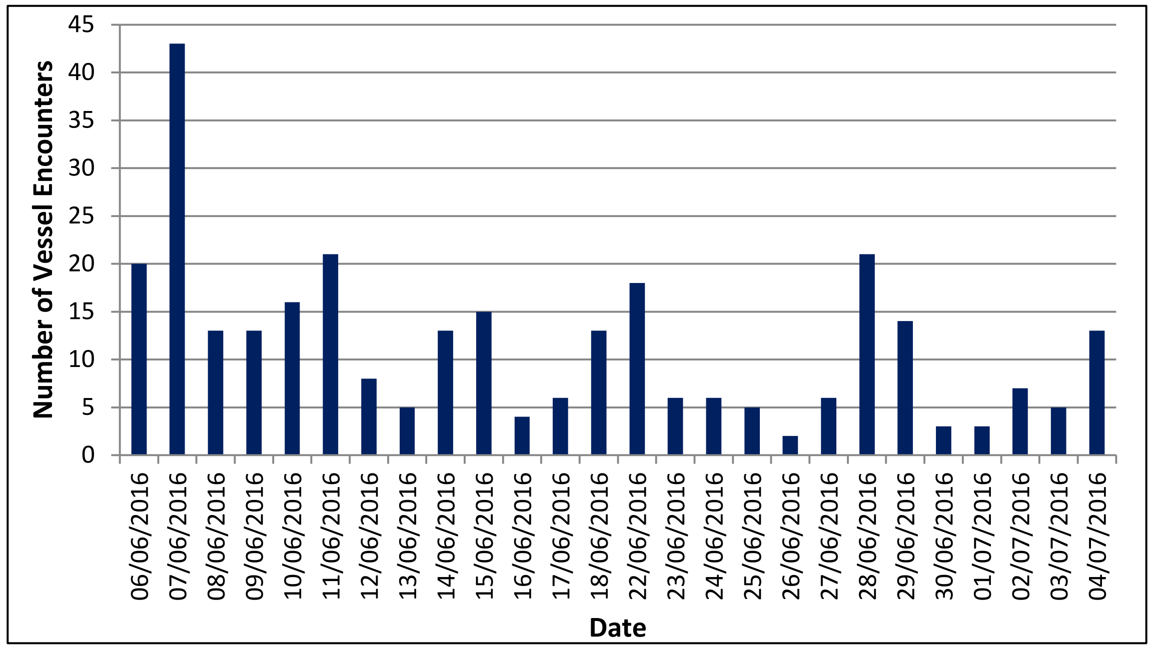


Figure 18.2: Vessel encounters per day within the Hornsea Three array area shipping and navigation study area during 26 days summer 2016 (AIS, visual and Radar).

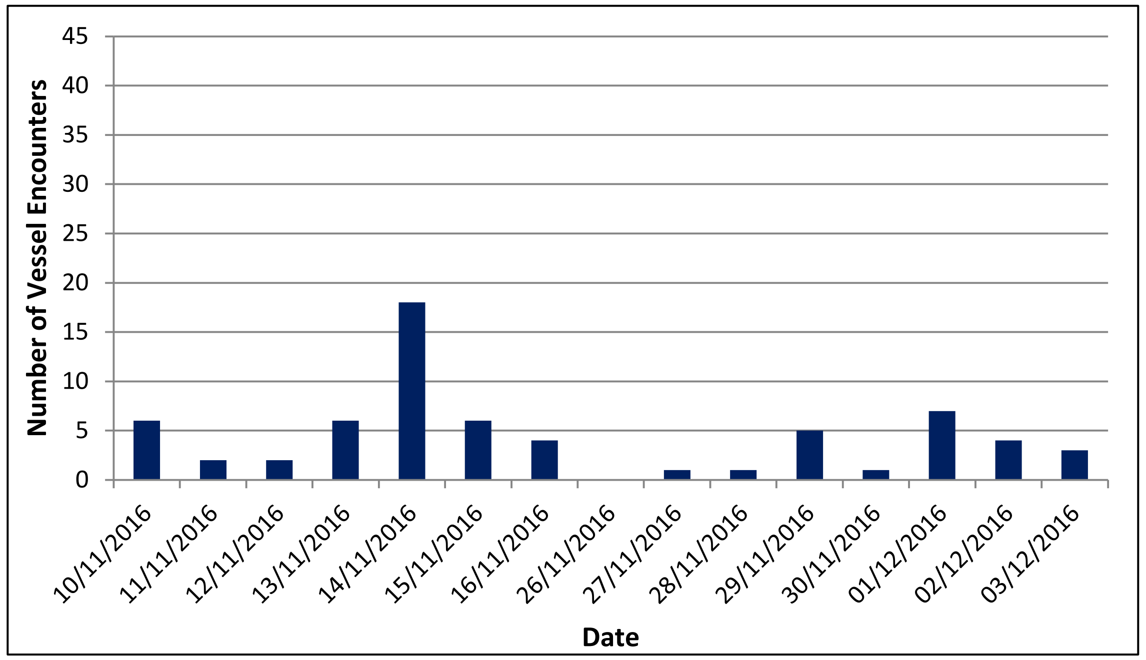


Figure 18.3: Vessel encounters per day within the Hornsea Three array area shipping and navigation study area during 14 days winter 2016 (AIS, visual and Radar).

18.2.1.6 There were 365 encounters observed throughout the 40 day period, corresponding to an average of nine encounters per day. The day with the most vessel encounters was 7 June with 43 unique encounters observed. In contrast there were three days during the winter period with just one vessel encounter.

18.2.1.7 Figure 18.4 presents the distribution of vessel types involved in encounters within the Hornsea Three array area shipping and navigation study area.

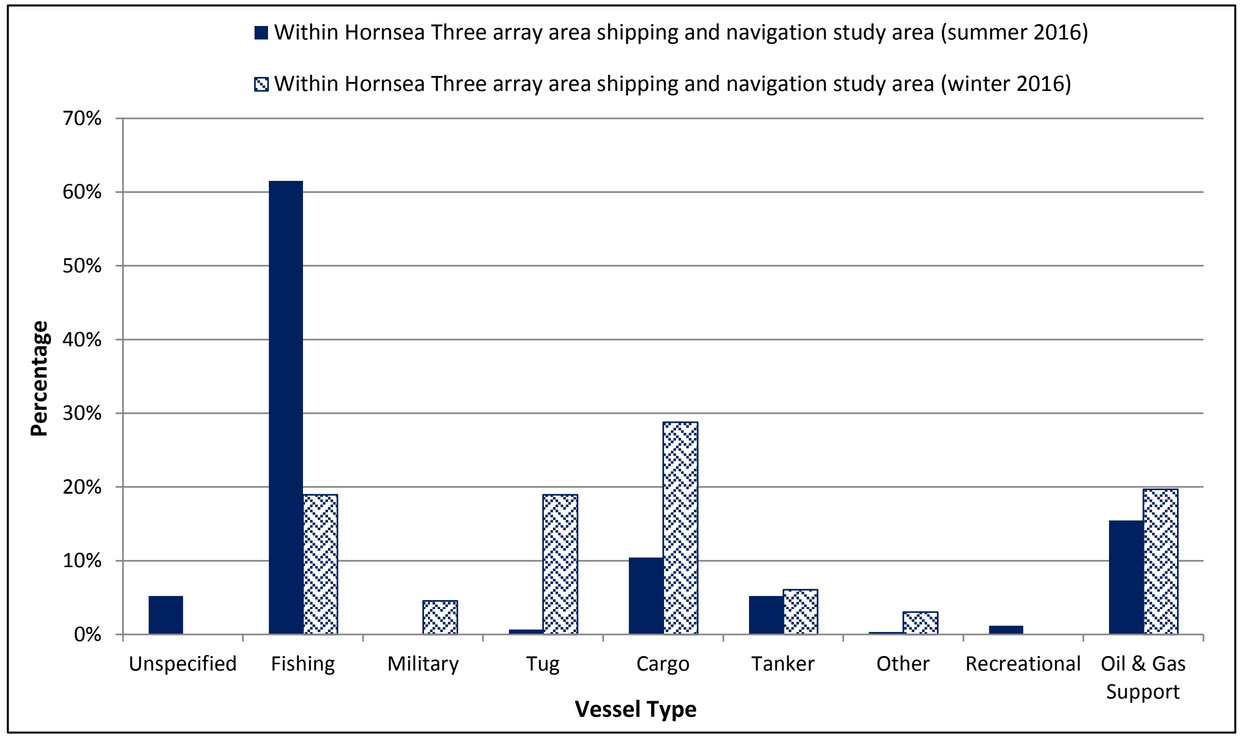


Figure 18.4: Distribution of encounter vessel types within the Hornsea Three array area shipping and navigation study area during 40 days summer and winter 2016 (AIS, visual and Radar).

18.2.1.8 The majority of encounters involved fishing vessels (61% during summer and 19% during winter), oil and gas affiliated vessels (15% during summer and 20% during winter) and cargo vessels (10% during summer and 14% during winter).

18.2.1.9 The sections of vessel tracks associated with encounters, colour-coded by vessel type, observed throughout the 40 day period are presented in Figure 18.5.

18.2.1.10 Military vessel encounters were also noted within the Hornsea Three array area, it is likely that these vessels were undertaking operations where they were required to transit in parallel and were not at risk of collision.

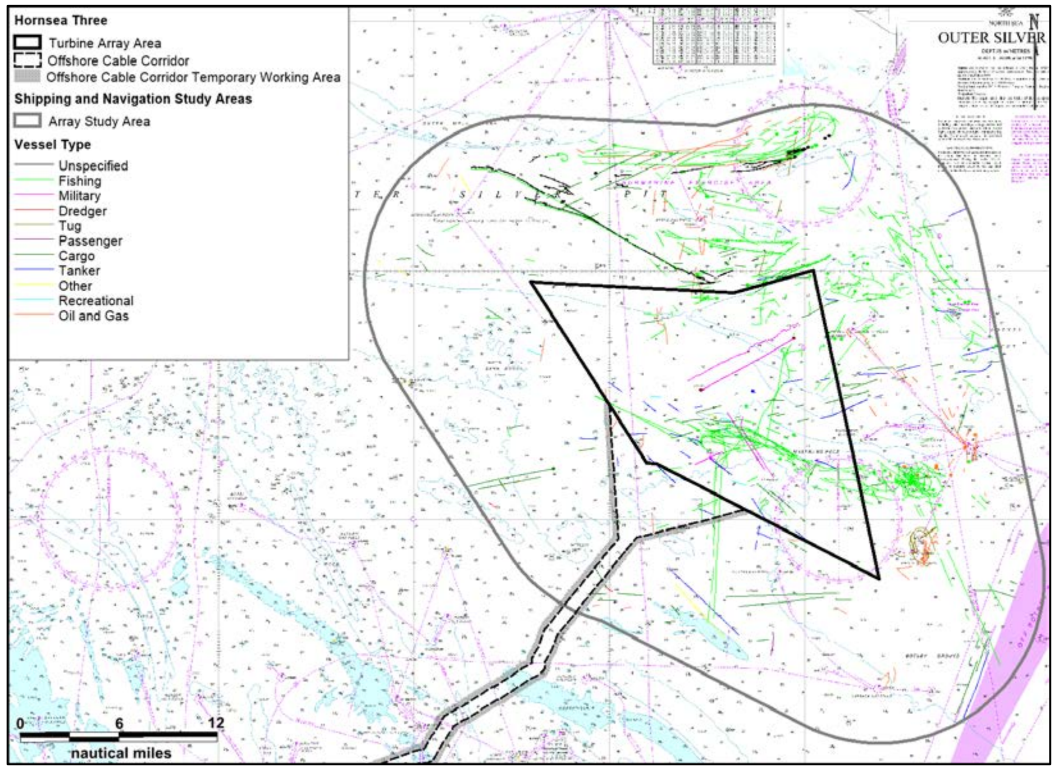


Figure 18.5: Overview of AIS, visual and Radar vessel encounters within the Hornsea Three array area shipping and navigation study area (40 days summer and winter 2016).

Vessel to vessel collisions

18.2.1.11 Based on the existing routeing and encounter levels in the area, Anatec's COLLRISK model has been run to estimate the existing vessel to vessel collision risks within the vicinity of the Hornsea Three array area. The route positions and widths are based on the marine traffic survey dataset, with the annual densities based on port logs and Anatec's ShipRoutes database, which take seasonal variations into consideration.

18.2.1.12 The annual vessel to vessel collision frequency prior to the installation of Hornsea Three was 5.18×10^{-3}, corresponding to a major collision return period of one in 193 years. It is emphasised that the model is calibrated based on major incident data at sea which allows for benchmarking but does not cover all incidents, such as minor impacts. Other incident data from the MAIB and RNLI is presented in section 13, which includes other minor incidents.

18.2.2 Base case with Hornsea Three

Post-Hornsea Three main route deviations

18.2.2.1 An illustration of the anticipated shift in main route positions following the development of Hornsea Three is presented in Figure 18.6.

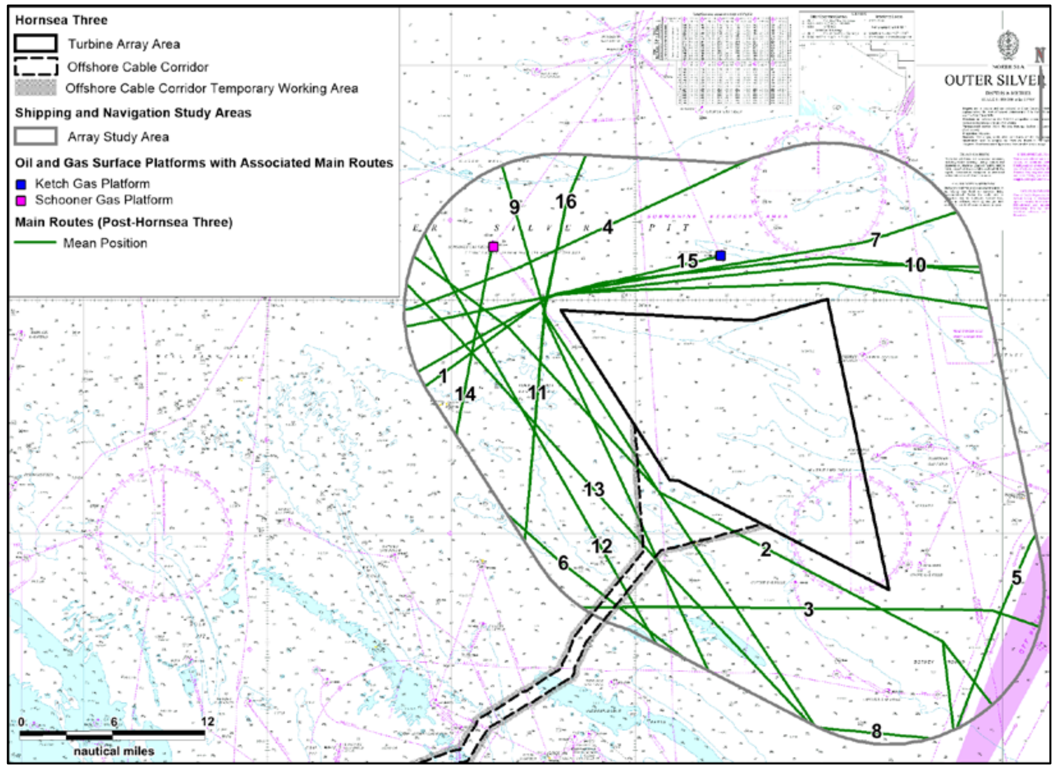


Figure 18.6: Post-Hornsea Three main routes within the Hornsea Three array area shipping and navigation study area.

18.2.2.2 Deviations would be required for eight of the 16 main routes identified, with the level of deviation required varying between 5.59 nm for route 1 (eastbound) and 0.21 nm for route 2 (eastbound). For the displaced routes, the increase in distance, both in terms of distance and percentage change, are presented in Table 18.1. It is noted that increases in route length are based on indicative final destinations, and those routes for which a differing deviation is reported in each direction of transit followed a different passage in each direction of transit in the base case scenario.

Table 18.1: Summary of future case main route deviations within the Hornsea Three array area shipping and navigation study area.

Route number	Increase in distance (nm)	Increase in total route length
Route 1 (eastbound)	4.62	1.59%
Route 1 (westbound)	4.21	1.44%
Route 2 (eastbound)	0.21	0.05%
Route 2 (westbound)	0.51	0.13%
Route 7	0.51	0.16%
Route 9 (eastbound)	0.56	0.05%
Route 9 (westbound)	0.55	0.05%
Route 10 (eastbound)	0.38	0.13%
Route 10 (westbound)	0.51	0.17%
Route 11	0.29	0.27%
Route 15	5.59	5.48%
Route 16	3.17	2.69%

Simulated Automatic Identification System (AIS)

18.2.2.3 Anatec's AIS Track Simulation program was used to gain an insight into the potential re-routed traffic following the installation of the Hornsea Three array area. The AIS Simulator uses identified routes within the Hornsea Three array area shipping and navigation study area, standard deviations and the average number of vessels on each route to simulate the tracks. It is noted that fishing vessels and recreational vessels are not included in the identified main routes given the AIS carriage requirements but also due to the lack of trend within routeing. They have therefore been excluded from the simulation. Figure 18.7 presents the simulated AIS.

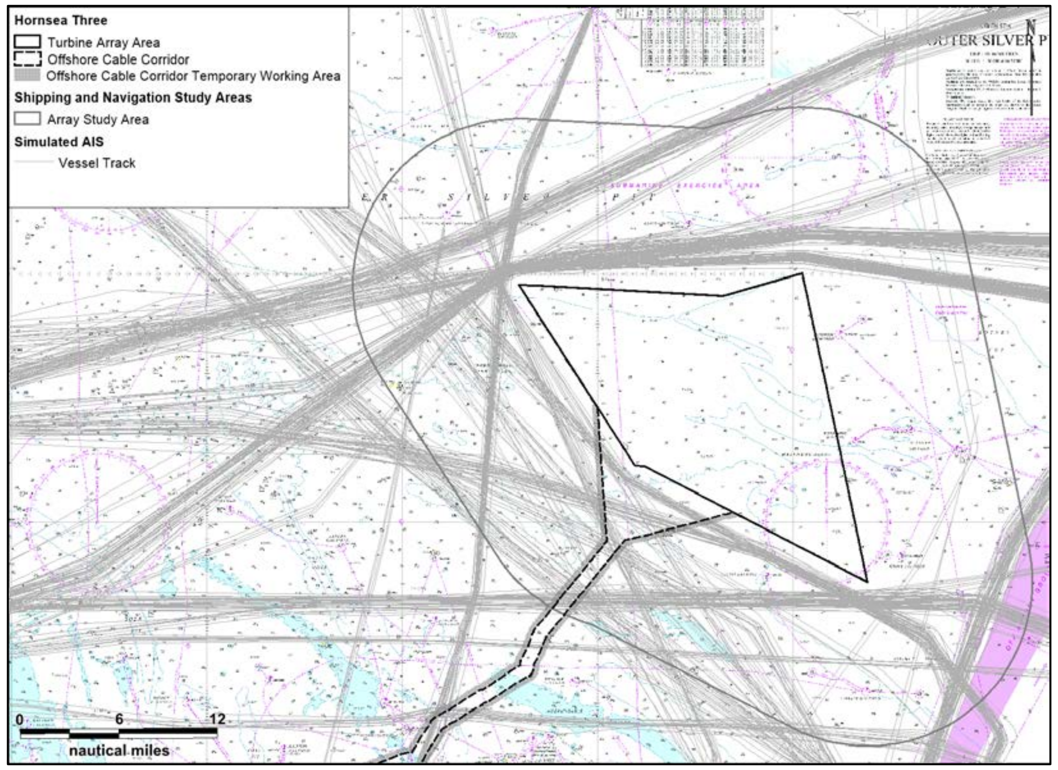


Figure 18.7: Simulated AIS following installation of Hornsea Three array area (40 days).

18.2.2.4 It can be seen that the areas of highest density produced are the three Hornsea Three array area corners along the southern and western boundaries. There is a relatively small number of routeing vessels to the east of the Hornsea Three array area, with no routes required to deviate along the eastern boundary of the Hornsea Three array area. It is noted that this simulated AIS is a maximum design scenario based on 1 nm passing distance for the Hornsea Three array area for deviated routes.

Potential for increased vessel to vessel collisions

18.2.2.5 The revised routeing pattern following construction of the Hornsea Three array area has been estimated for Layout A based on the review of impact on navigation (see section 17).

18.2.2.6 The annual vessel to vessel collision frequency following the installation of Hornsea Three was 6.59×10^{-3}, corresponding to a major collision return period of one in 152 years. This represents a 21.4% increase in collision frequency compared to the pre-wind farm result.

18.2.2.7 The following potential effects have not been quantified but may indirectly influence the vessel to vessel collision risk and have been discussed in section 18 and section 22:

- Interference with communication equipment; and
- Collisions associated with the structures obstructing the visibility of vessels to other vessels.

Potential for additional vessel to structure allision risk

18.2.2.8 The two main scenarios for passing vessels colliding with structures such as turbines are:

- Powered allision where the vessel is under power but errant; and
- NUC (drifting) allision where a vessel on a passing route experiences propulsion failure and drifts under the influence of the prevailing conditions.

<u>Powered vessel to structure allision</u>

18.2.2.9 Based on the vessel routeing identified for the region, the anticipated change in routeing due to the Hornsea Three array area, and assumptions that mitigation measure adopted as part of Hornsea Three are in place (section 23), the frequency of an errant vessel under power deviating from its route to the extent that it comes into proximity with the Hornsea Three array area is not considered to be a probable occurrence.

18.2.2.10 From consultation with the shipping industry it is also assumed that commercial vessels would be highly unlikely to navigate between structures due to the restricted sea room and will be directed by the navigational aids located in the region.

18.2.2.11 Based on modelling of the revised routeing (see Figure 18.6 and Table 18.1), proposed layouts and local metocean data, the annual powered vessel to structure allision frequency was 9.22×10^{-4}, corresponding to an allision return period of one in 1,084 years.

18.2.2.12 This is a higher allision frequency than the historical average of 5.3×10^{-4} per operational year for offshore installations (i.e. oil and gas infrastructure) on the UKCS (one in 1,900 years). The risk to Hornsea Three is estimated to be approximately 1.75 times higher. This reflects the high number of structures included in Layout A and the moderate level of traffic passing nearby.

18.2.2.13 The individual wind farm structure allision frequencies ranged from 5.39×10^{-4} for the structures located on the southeastern corner of the Hornsea Three array area to negligible for a number of structures located within the centre and to the east of the Hornsea Three array area. Figure 18.8 presents the annual powered allision frequency for each structure, including turbines, offshore HVAC collector substations, offshore HVDC substations and accommodation platforms.

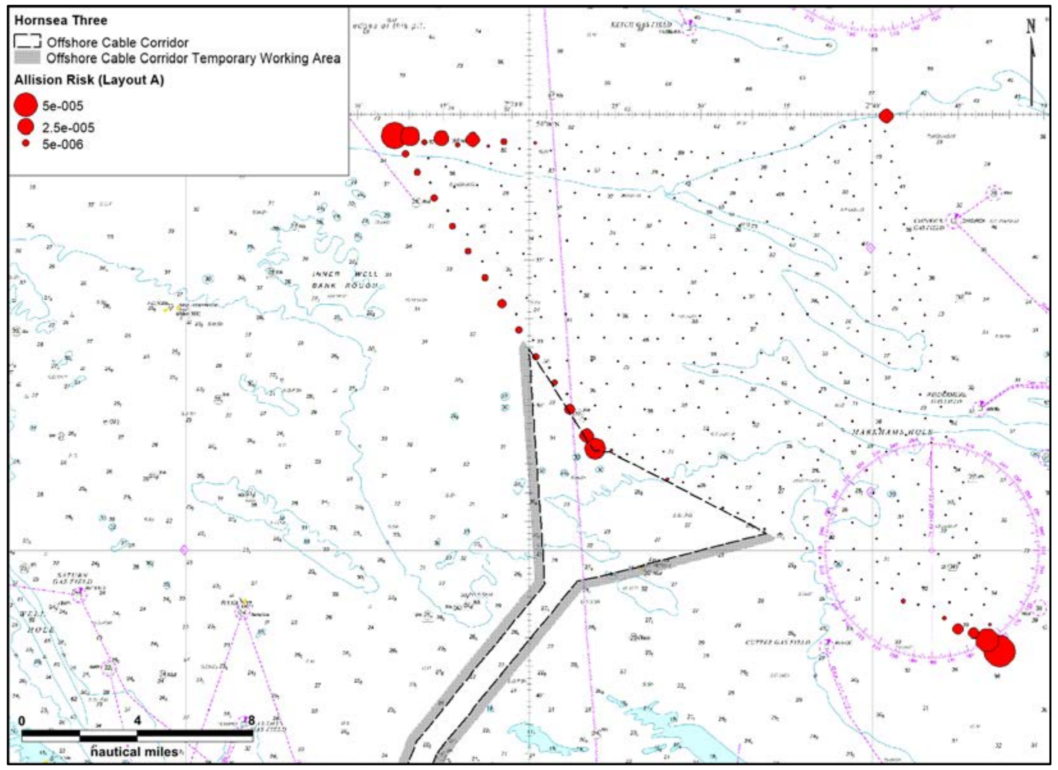


Figure 18.8: Annual powered vessel to structure allision frequency by structure.

Not Under Command (NUC) vessel to structure allision

18.2.2.14 The risk of a vessel losing power and drifting into a wind farm structure was assessed using Anatec's COLLRISK model. This model is based on the premise that propulsion on a vessel must fail before a vessel will drift. The model takes into account the type and size of the vessel, number of engines and average time to repair in different conditions but it does not consider navigational error caused by human actions.

18.2.2.15 The exposure times for a NUC scenario are based on the vessel-hours spent in proximity to the Hornsea Three array area (up to 10 nm from the perimeter). These have been estimated based on the traffic levels, speeds and revised routeing pattern. The exposure is divided by vessel type and size to ensure these factors, which based on analysis of historical accident data have been shown to influence accident rates, are taken into account within the modelling.

18.2.2.16 Using this information the overall rate of mechanical failure within the area surrounding the Hornsea Three array area was estimated. The probability of a vessel drifting towards a wind farm structure and the drift speed are dependent on the prevailing wind, wave and tidal conditions at the time of the accident.

18.2.2.17 The following drift scenarios were modelled, using the Metocean data detailed in section 11:

- Wind;
- Peak spring flood tide; and
- Peak spring ebb tide.

18.2.2.18 The probability of vessel recovery from drift is estimated based on the speed of drift and hence the time available before reaching the wind farm structure. Vessels that do not recover within this time are assumed to collide.

18.2.2.19 After modelling each of the drift scenarios it was established that wind-dominated drift produced the worst case results. The annual NUC vessel to structure allision frequency for the wind-dominated drift was 7.31×10^{-4}, corresponding to an allision return period of one in 1,369 years.

18.2.2.20 NUC allisions are assessed to be less frequent than powered allisions which reflect historical data. There have been no reported "passing" NUC vessel allisions with offshore installations on the UKCS in over 6,000 operational years. Whilst a large number of NUC vessels have occurred each year in UK waters, most vessels have been recovered in time, (such as by anchoring, restarting engines or being taken in tow). There have also been a small number of "near-misses".

18.2.2.21 The majority of the annual NUC vessel allision frequency is associated with those structures located on the western and southern boundary of the Hornsea Three array area since the prevalent wind direction in the region is from the southwest; noting that future case traffic routes are also denser to the southwest of the proposed Hornsea Three array area. Figure 18.9 presents the annual NUC allision frequency for each structure, including turbines, offshore HVAC collector substations, offshore HVDC substations and accommodation platforms.

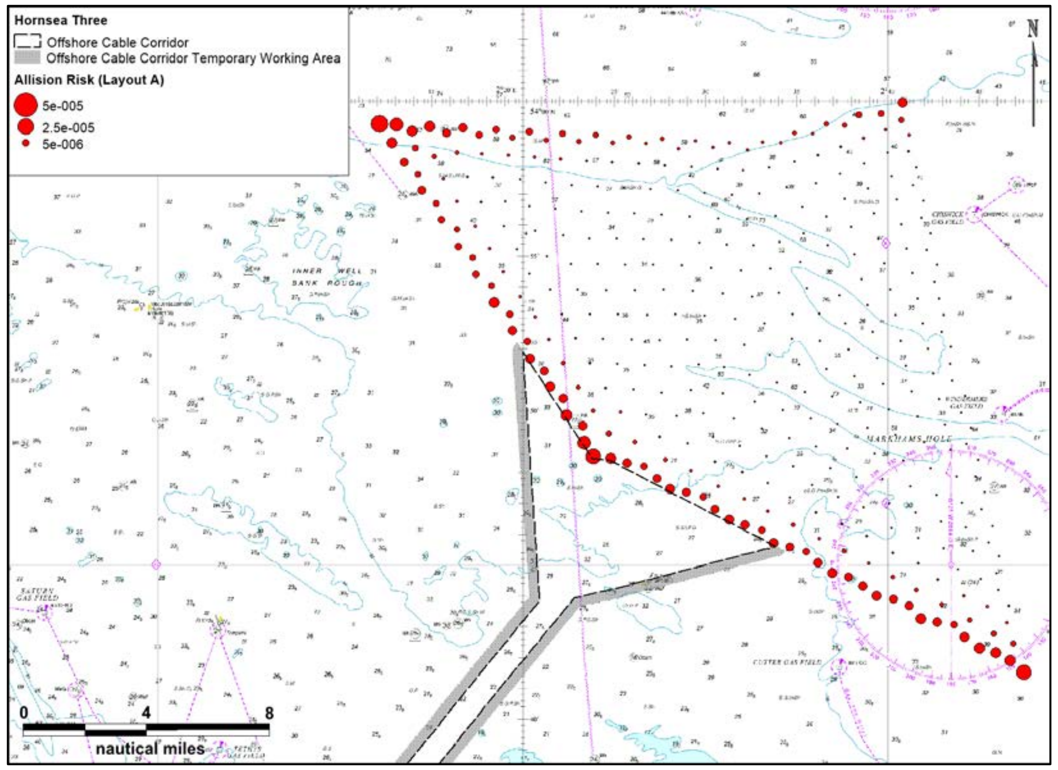


Figure 18.9: Annual NUC vessel to structure allision frequency.

Potential for fishing vessel to structure allision

18.2.2.22 Anatec's COLLRISK fishing vessel risk model has been calibrated using fishing vessel activity data along with offshore installation operating experience in the UK (oil and gas) and the experience of collisions between fishing vessels and UKCS offshore installations gathered from HSE statistics noted within appendix A.

18.2.2.23 The two main inputs to the model are the fishing vessel density for the area and the wind farm structure details. The fishing vessel density in the Hornsea Three array area was based on the AIS, visual and Radar dataset from the marine traffic survey. The wind farm structures used were for jackets rather than floating foundations since for fishing vessels internal navigation is considered unlikely in comparison to jackets.

18.2.2.24 Using the site-specific data as an input to the model, the annual fishing vessel to structure allision frequency was estimated for Layout A. The annual fishing vessel to structure allision frequency was 1.88×10^{-1}, corresponding to an estimated allision return period of one in 5.33 years for an allision at surface level.

18.2.2.25 This is a moderate level of allision frequency when compared to other areas of the UK and reflects the relatively medium level of fishing vessel activity within the region. It is noted that the model assumes that the fishing vessel density remains the same as current levels following the installation of Hornsea Three, and is therefore a conservative estimate, whereas in reality vessel activity would decrease as well as be affected by seasonal and annual fluctuations. The model does not assume the severity of the allision and could account for a low energy and low impact allision.

Potential for recreational vessel to structure allision

18.2.2.26 The RYA considers that the largest risk to recreational craft from offshore wind developments is the risk of rotor blade allision and under keel allision. An allision between a turbine blade and the mast of a yacht or damage to the keel could result in the structural failure of a yacht.

18.2.2.27 To determine the extent to which yacht masts could interact with the rotor blades, details on the air draughts of the International Rating Certificate (IRC) fleet are presented in Figure 18.10 based on a fleet size of over 2,500 vessels. IRC is a rating (or "handicapping" system) used worldwide which allows vessels of different sizes and designs to race on equal terms. The UK IRC fleet, although numerically only a small proportion of the total number of sailing yachts in the UK, is considered representative of the range of modern sailing boats in general use in UK waters.

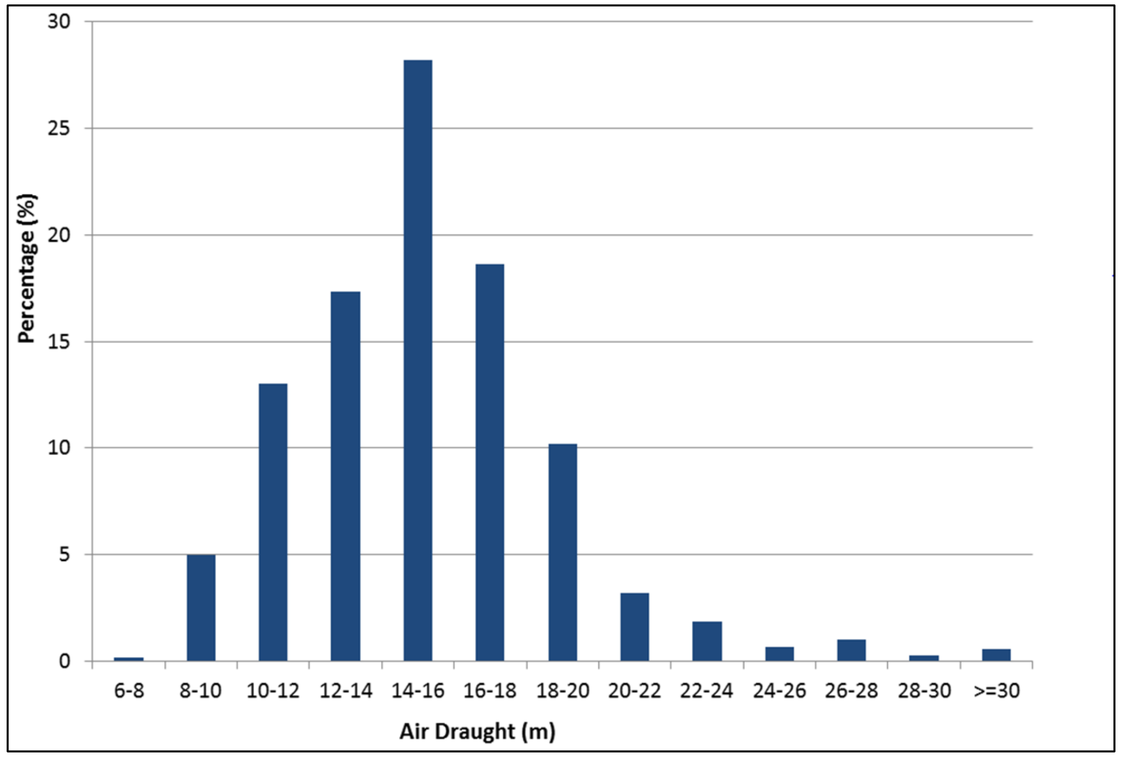


Figure 18.10: Air draught data for IRC fleet (collected 2009 to 2011) (RYA, 2015).

18.2.2.28 From these data, approximately 1% of boats have air draughts exceeding 30 m and noting that the minimum blade clearance is 34.97 m Lowest Astronomical Tide (LAT) a negligible amount of vessels would be at risk of dismasting if they were directly under a rotating blade in the worst-case conditions.

18.2.2.29 The turbines will be equipped with access ladders. MGN 543 states that these "could conceivably be used, in an emergency situation, to provide refuge on the turbine structure for distressed mariners". MGN 543 (annex 5) (MCA, 2016) states that this scenario should be considered when identifying the optimum position of such ladders and take into account the prevailing wind, wave and tidal conditions. This should provide a place of refuge until such time as rescue services arrive.

18.2.2.30 It should be noted that following the approach outlined in MGN 543 may not be appropriate for all recreational vessels or foundation types based on, for example, the potential for insufficient underwater clearance in the immediate vicinity of the structures. The marine traffic survey recorded a low level of recreational vessel activity in the Hornsea Three array area shipping and navigation study area, and suitable promulgation of information will be defined to alert recreational vessels of any underwater clearance issues – notably associated with the maximum design scenario floating foundations (dependant on touchdown of mooring lines and type of floating foundation used).

18.2.3 Risk results summary

18.2.3.1 The base case with Hornsea Three and future case with Hornsea Three (based on the assumptions detailed in section 17) is summarised in Table 18.2. The change in risk is also shown, (namely the estimated collision risk with the Hornsea Three array area minus the baseline collision risk without the Hornsea Three array area (which are zero except for vessel to vessel collisions)). Following this Figure 18.11 presents a graphical summary of the collision risk results.

Table 18.2: Summary of annual collision and allision frequency levels for the Hornsea Three array area.

Allision and collision scenario	Base case			Future case		
	Without Hornsea Three array area	With Hornsea Three array area	Change	Without Hornsea Three array area	With Hornsea Three array area	Change
Vessel to vessel collision	5.18×10^{-3}	6.59×10^{-3}	1.41×10^{-3}	5.70×10^{-3}	7.25×10^{-3}	1.55×10^{-3}
Powered vessel to structure allision	0.00×10^{0}	9.22×10^{-4}	9.22×10^{-4}	0.00×10^{0}	1.01×10^{-3}	1.01×10^{-3}
NUC vessel to structure allision	0.00×10^{0}	7.31×10^{-4}	7.31×10^{-4}	0.00×10^{0}	8.04×10^{-4}	8.04×10^{-4}
Fishing vessel to structure allision	0.00×10^{0}	1.88×10^{-1}	1.88×10^{-1}	0.00×10^{0}	2.06×10^{-1}	2.06×10^{-1}
Total	5.18×10^{-3}	1.96×10^{-1}	1.91×10^{-1}	5.70×10^{-3}	2.15×10^{-1}	2.10×10^{-1}

18.3 Hornsea Three array area cumulative effect assessment

18.3.1 Base case without Hornsea Three, Hornsea Project One and Hornsea Project Two

Pre-Hornsea Three, Hornsea Project One and Hornsea Project Two route deviations

18.3.1.1 Twenty five main routes have been identified as transiting through or in close proximity to Hornsea Three, Hornsea Project One or Hornsea Project Two. A plot of the main routes is presented in Figure 18.11. It is noted that only the array areas have been considered given that neither the offshore cable corridors nor the offshore HVAC booster station will contribute to a cumulative routeing effect.

18.3.1.2 It is noted that this section considers the main routes within a larger study area encompassing Hornsea Three, Hornsea Project One and Hornsea Project Two. Further details regarding the Hornsea Three cumulative shipping and navigation study area can be found in section 5.2.4.

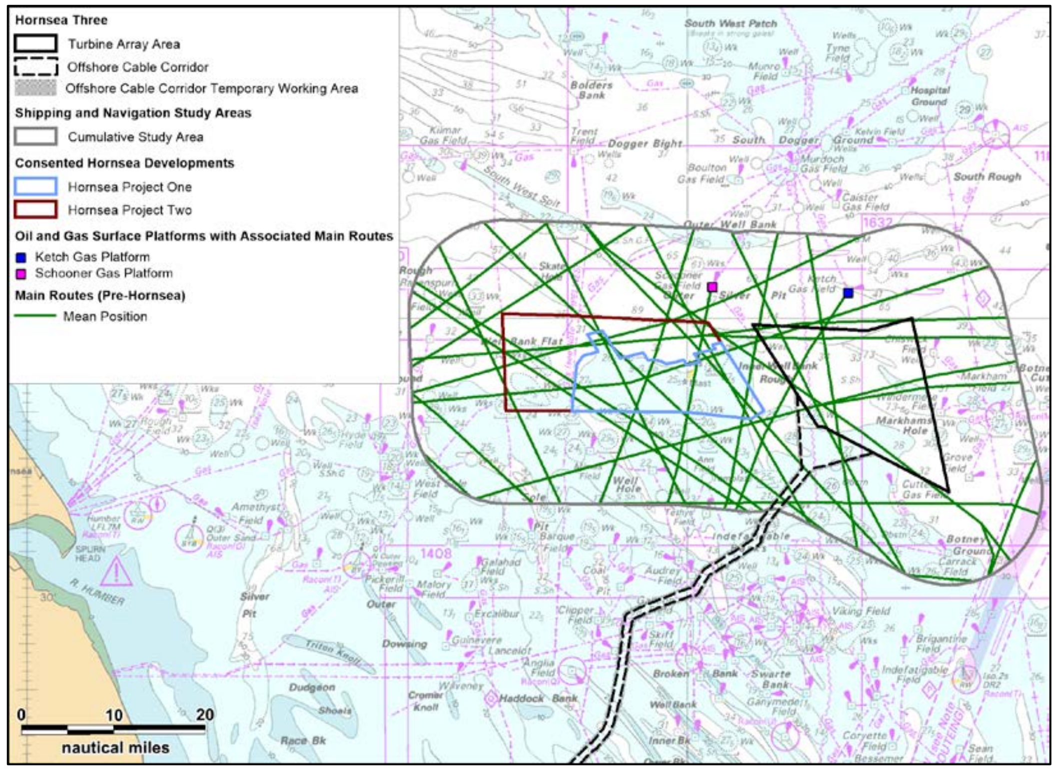


Figure 18.11: Pre-Hornsea Three, Hornsea Project One and Hornsea Project Two main routes within the Hornsea Three cumulative shipping and navigation study area.

Vessel to vessel collisions

18.3.1.3 Based on the existing routeing in the area, Anatec's COLLRISK model has been run to estimate the existing vessel to vessel collision risks within the vicinity of the array areas for Hornsea Project One, Hornsea Project Two and Hornsea Three. The route positions and widths are based on the marine traffic survey dataset and Anatec's ShipRoutes, with the annual densities based on port logs and Anatec's ShipRoutes database, which take seasonal variations into consideration.

18.3.1.4 The annual vessel to vessel collision frequency prior to the installation of Hornsea Three, Hornsea Project One and Hornsea Project Two was 8.62×10^{-3}, corresponding to a major collision return period of one in 116 years. As stated in section 18.2, it is emphasised that the model is calibrated based on major incident data at sea which allows for benchmarking but does not cover all incidents, such as minor impacts.

18.3.1.5 Other cumulative routeing impacts are considered in section 22.

18.3.2 Base case with Hornsea Three, Hornsea Project One and Hornsea Project Two

18.3.2.1 An illustration of the anticipated shift in main route positions following the development of Hornsea Three, Hornsea Project One and Hornsea Project Two is presented in Figure 18.12.

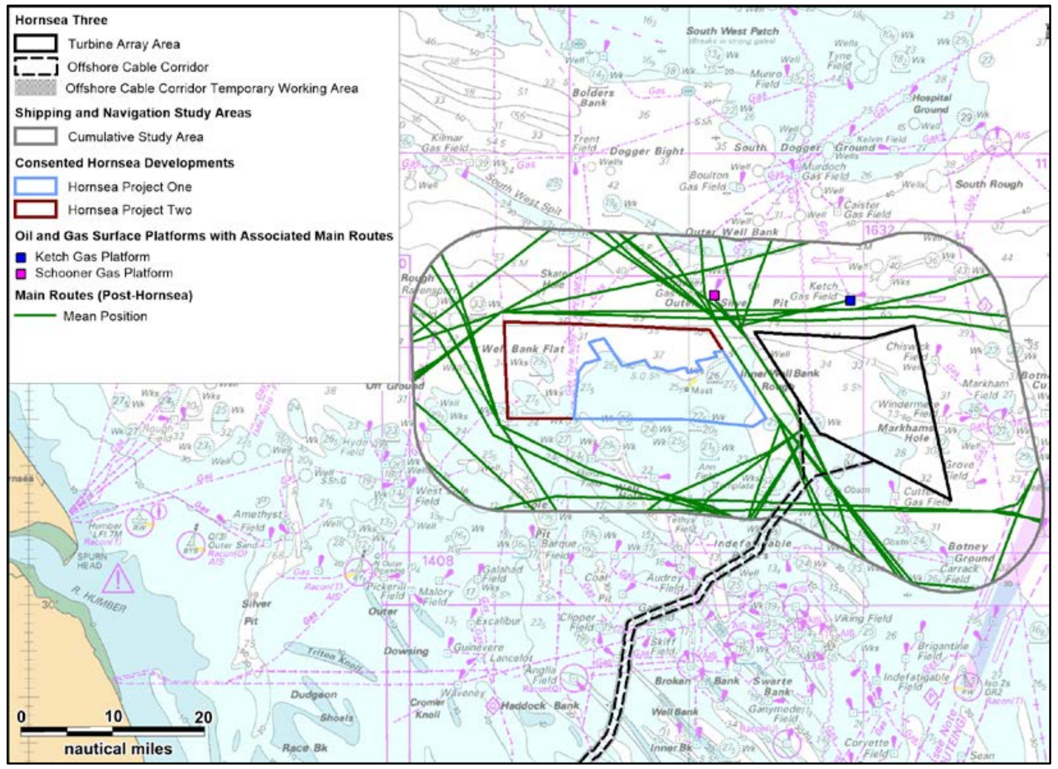


Figure 18.12: Post-Hornsea Three, Hornsea Project One and Hornsea Project Two main routes within the Hornsea Three cumulative shipping and navigation study area.

Potential for increased vessel to vessel collisions

18.3.2.2 The revised routeing pattern following construction of Hornsea Three, Hornsea Project One and Hornsea Project Two has been estimated based on the review of impact on navigation carried out as part of the SNSOWF assessment in 2013 (which considered project development within the former Hornsea Zone including Hornsea Three), but validated against the results of the marine traffic surveys.

18.3.2.3 The annual vessel to vessel collision frequency following the installation of Hornsea Three, Hornsea Project One and Hornsea Project Two was 9.55×10^{-3}, corresponding to a major collision return period of one in 105 years. This represents a 9.72% increase in collision frequency compared to the pre-wind farm result.

18.4 Hornsea Three offshore HVAC booster stations assessment

18.4.1 Base case without Hornsea Three offshore HVAC booster stations

18.4.1.1 Nine main routes have been identified as transiting through or in close proximity to the Hornsea Three offshore HVAC booster station search area. The plots of the main routes are presented in Figure 18.13.

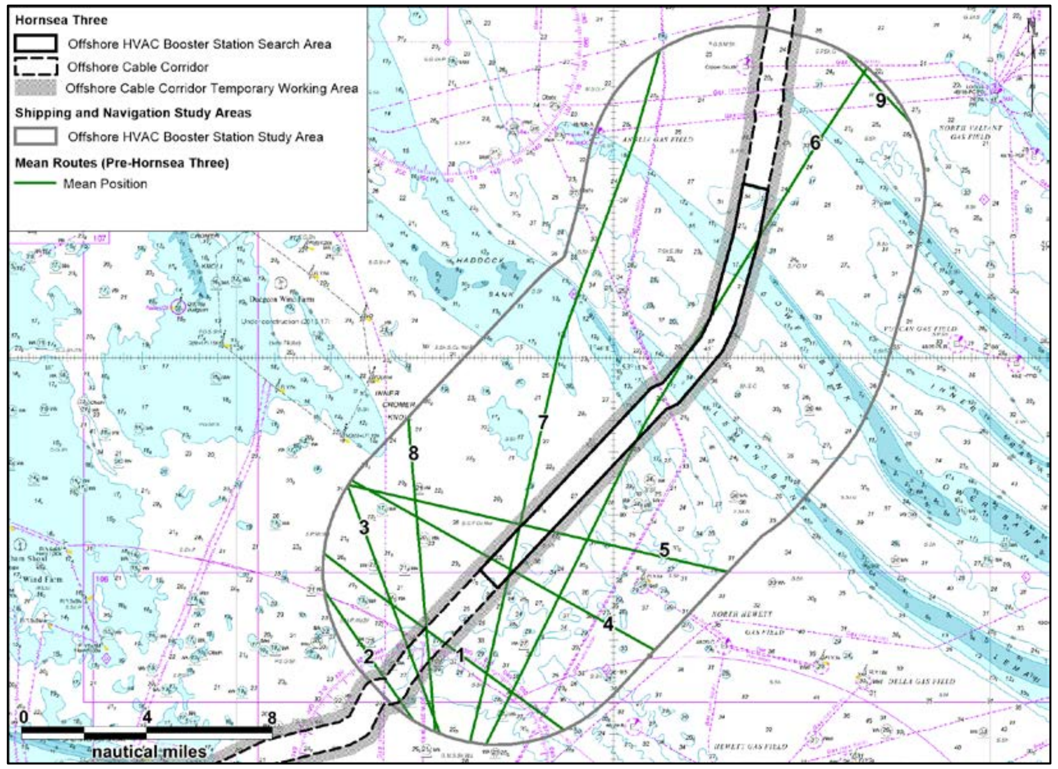


Figure 18.13: Pre-Hornsea Three, main routes within the Hornsea Three offshore HVAC booster station shipping and navigation study area.

18.4.2 Base case with Hornsea Three offshore HVAC booster stations

Overview

18.4.2.1 Three separate locations within the Hornsea Three offshore HVAC booster station search area were modelled, as shown in Figure 18.14. These maximum design scenario locations were selected based upon the relatively high density of vessel traffic within the vicinity, including a number of main routes identified.

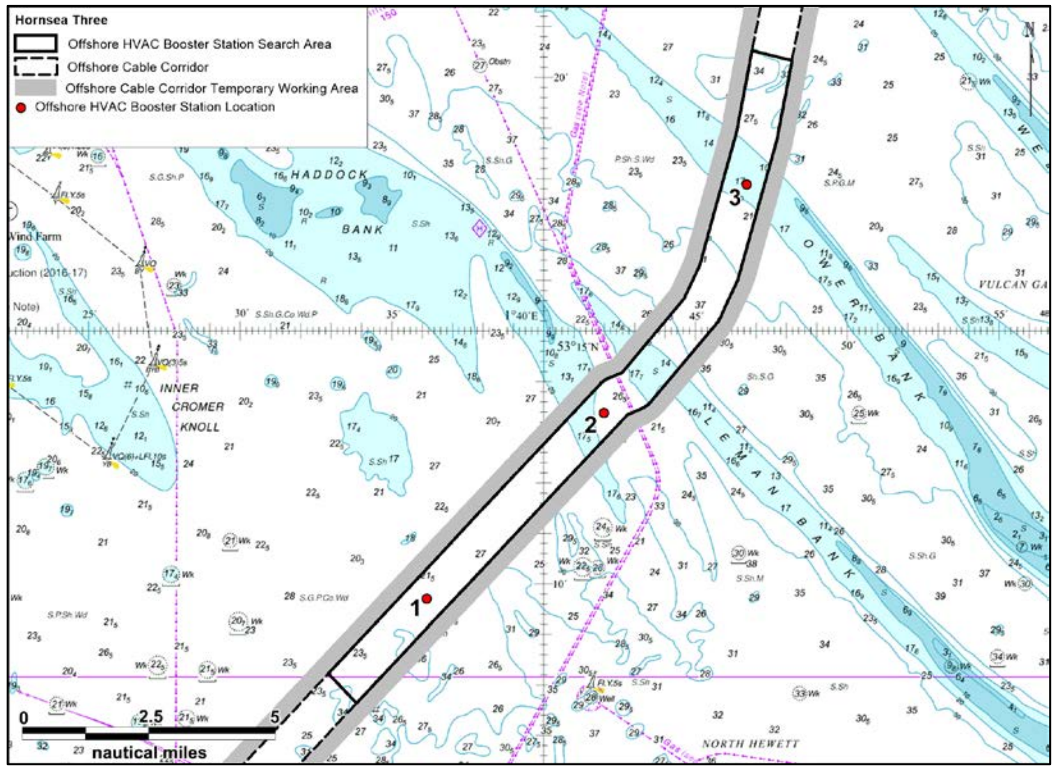


Figure 18.14: Hornsea Three offshore HVAC booster station locations used for modelling.

Post-Hornsea Three main route deviations

18.4.2.2 An illustration of the anticipated shift in main route positions following the installation of the Hornsea Three offshore HVAC booster stations at each modelled location are presented in Figure 18.15 to Figure 18.17.

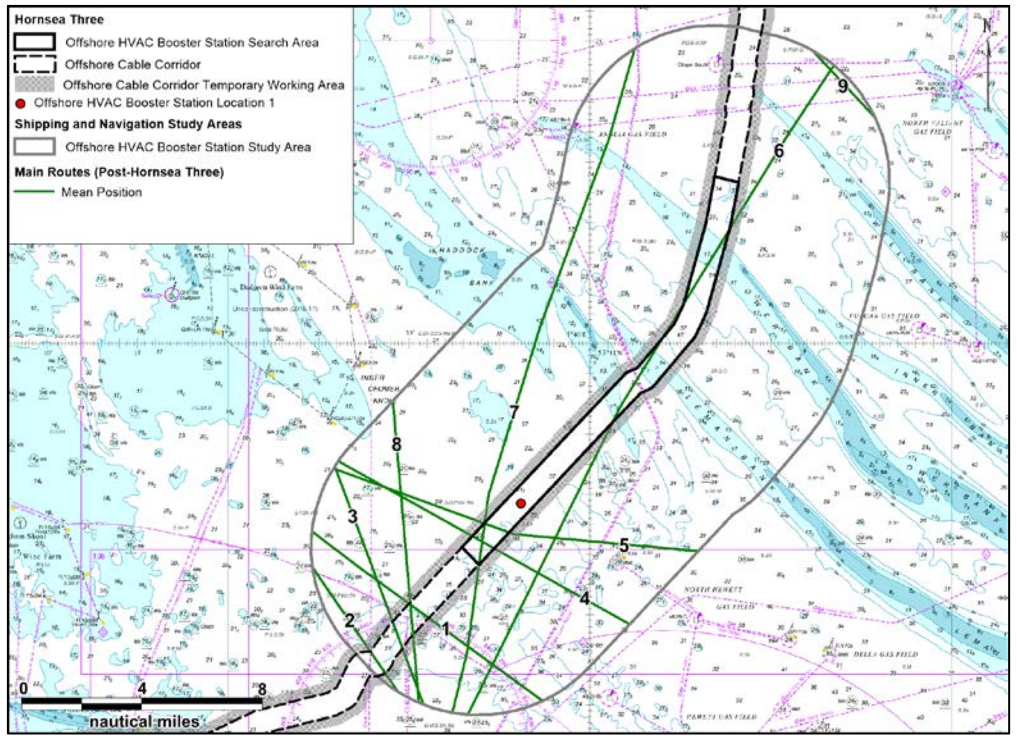


Figure 18.15: Post-Hornsea Three main routes within offshore HVAC booster station shipping and navigation study area for Location 1.

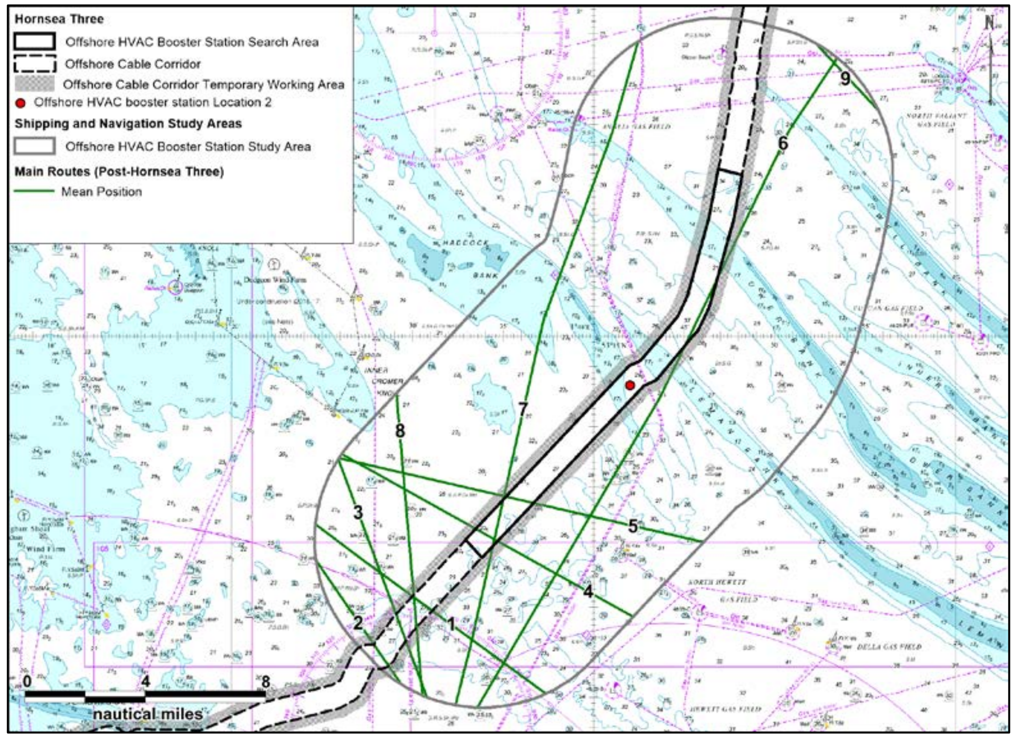


Figure 18.16: Post-Hornsea Three main routes within offshore HVAC booster station shipping and navigation study area for Location 2.

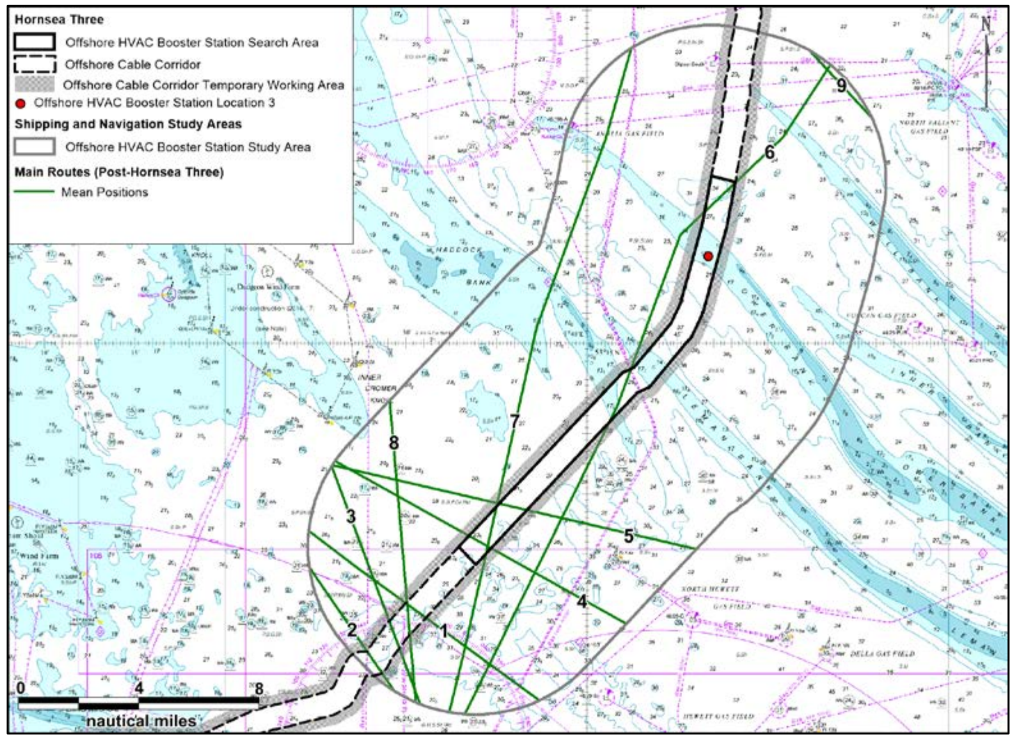


Figure 18.17: Post-Hornsea Three main routes within offshore HVAC booster station shipping and navigation study area for Location 3.

18.4.2.3 Location 1 would require deviations for two of the nine main routes identified, whilst Location 2 and Location 3 would each require deviations for one of the nine main routes identified. The level of deviation required was generally small, with the highest deviation 0.55 nm for route 5 with location 1. For each of the Hornsea Three offshore HVAC booster station locations, the increase in distance for the displaced routes, both in terms of distance and percentage change, are presented in Table 18.3 to Table 18.5. It is noted that increases in route length are based on indicative final destinations.

Table 18.3: Summary of future case main route deviations within offshore HVAC booster station shipping and navigation study area for Location 1.

Route number	Increase in distance (nm)	Increase in total route length
Route 5	0.55	0.32%
Route 7	0.04	0.07%

Table 18.4: Summary of future case main route deviations within offshore HVAC booster station shipping and navigation study area for Location 2.

Route number	Increase in distance (nm)	Increase in total route length
Route 6	-0.00[a]	-0.01%

[a] This deviation results in the total route length decreasing by a small quantity.

Table 18.5: Summary of future case main route deviations within offshore HVAC booster station shipping and navigation study area for Location 3.

Route number	Increase in distance (nm)	Increase in total route length
Route 6	0.27	0.42%

Potential for additional vessel to structure allision risk

18.4.2.4 As previously mentioned (paragraph 18.2.2.8) the two main scenarios for passing vessels alliding with OREIs such as turbines and other wind farm structures are powered allision and NUC (drifting) allision.

Powered vessel to structure allision

18.4.2.5 Based on the vessel routeing identified for the region, the anticipated change in routeing due to the Hornsea Three offshore HVAC booster stations, and assumptions that the mitigation measures adopted as part of Hornsea Three (section 23) are in place, the frequency of an errant vessel under power deviating from its route to the extent that it comes into proximity with a Hornsea Three offshore HVAC booster station is not considered to be a probable occurrence.

18.4.2.6 Based on modelling of the revised routeing (see Figure 18.15 to Figure 18.17), proposed layouts and local metocean data, the annual powered vessel to structure allision frequency for each of the three Hornsea Three offshore HVAC booster station locations is presented in Table 18.6.

Table 18.6: Powered vessel to structure allision probabilities for Hornsea Three offshore HVAC booster station locations.

Hornsea Three offshore HVAC booster station location	Annual powered vessel to structure allision frequency	Allision return period
Location 1	2.15×10^{-4}	One in 4,653 years
Location 2	5.96×10^{-5}	One in 16,779 years
Location 3	3.23×10^{-5}	One in 30,950 years

18.4.2.7 These are lower allision frequencies than the historical average of 5.3×10^{-4} per operational year for offshore installations on the UKCS (one in 1,900 years). The risk to the Hornsea Three offshore HVAC booster stations is estimated to be approximately 0.4 times lower, depending on the location of the Hornsea Three offshore HVAC booster stations. This reflects the relatively low level of traffic passing nearby.

Not Under Command (NUC) vessel to structure allision

18.4.2.8 The risk of a vessel losing power and drifting into a wind farm structure was assessed using Anatec's COLLRISK model. As outlined previously this model is based on the premise that propulsion on a vessel must fail before a vessel will drift, and takes into account the type and size of the vessel, number of engines and average time to repair in different conditions. However human error is not considered by the model.

18.4.2.9 Again, the following drift scenarios were modelled:

- Wind;
- Peak spring flood tide; and
- Peak spring ebb tide.

18.4.2.10 The probability of vessel recovery from drift is estimated based on the speed of drift and hence the time available before reaching the wind farm structure. Vessels that do not recover within this time are assumed to collide.

18.4.2.11 After modelling each of the drift scenarios it was established that weather-dominated drift generally produced the worst case results across the three Hornsea Three offshore HVAC booster station locations. The annual NUC vessel to structure allision frequency for each of the three Hornsea Three offshore HVAC booster station locations is presented in Table 18.7.

Table 18.7: NUC vessel to structure allision probabilities for Hornsea Three offshore HVAC booster station locations.

Hornsea Three offshore HVAC booster station location	Annual NUC vessel to structure allision frequency	Allision return period
Location 1	2.38×10^{-5}	One in 42,058 years
Location 2	3.91×10^{-6}	One in 255,997 years
Location 3	8.19×10^{-8}	One in 12,211,034 years

18.4.2.12 NUC allisions are assessed to be less frequent than powered allisions which reflect historical data. As stated previously, there have been no reported "passing" NUC Vessel allisions with offshore installations on the UKCS in over 6,000 operational years.

Potential for fishing and recreational vessel to structure allision

18.4.2.13 As shown in section 15.4.7, the level of fishing and recreational vessel activity within the offshore HVAC booster station shipping and navigation study area was very low throughout the marine traffic survey. Only five unique fishing vessel tracks and four unique recreational vessel tracks were recorded throughout the 28 day survey period. The fishing vessels recorded were all in transit rather than actively engaged in fishing activities, and none intersected the Hornsea Three offshore HVAC booster station search area.

18.4.2.14 Given that the fishing vessel and recreational densities for the area are one of the main inputs to Anatec's COLLRISK fishing vessel risk model (which may also be applied to recreational data), it was not considered reasonable to analyse the fishing or recreational vessel to structure allision risk.

18.4.3 Risk results summary

18.4.3.1 The base case with the Hornsea Three offshore HVAC booster stations and future case with the Hornsea Three offshore HVAC booster stations (based on the assumptions detailed in section 17) annual levels of risk at each location are summarised in Table 18.8 to Table 18.10. Following this Figure 18.18 presents a graphical summary of the allision risk results across all three locations.

Table 18.8: Summary of risk results for Hornsea Three offshore HVAC booster stations at Location 1.

Allision scenario	Base case	Future case
Powered vessel to structure allision	2.39×10^{-4}	2.36×10^{-4}
NUC vessel to structure allision	2.38×10^{-5}	2.62×10^{-5}
Total	2.39×10^{-4}	2.63×10^{-4}

Table 18.9: Summary of risk results for Hornsea Three offshore HVAC booster stations at Location 2.

Allision scenario	Base case	Future case
Powered vessel to structure allision	5.96×10^{-5}	6.56×10^{-5}
NUC vessel to structure allision	3.91×10^{-6}	4.30×10^{-6}
Total	6.35×10^{-5}	6.99×10^{-5}

Table 18.10: Summary of risk results for Hornsea Three offshore HVAC booster stations at Location 3.

Allision scenario	Base case	Future case
Powered vessel to structure allision	3.25×10^{-5}	3.55×10^{-5}
NUC vessel to structure allision	8.19×10^{-8}	9.01×10^{-8}
Total	3.24×10^{-5}	3.56×10^{-5}

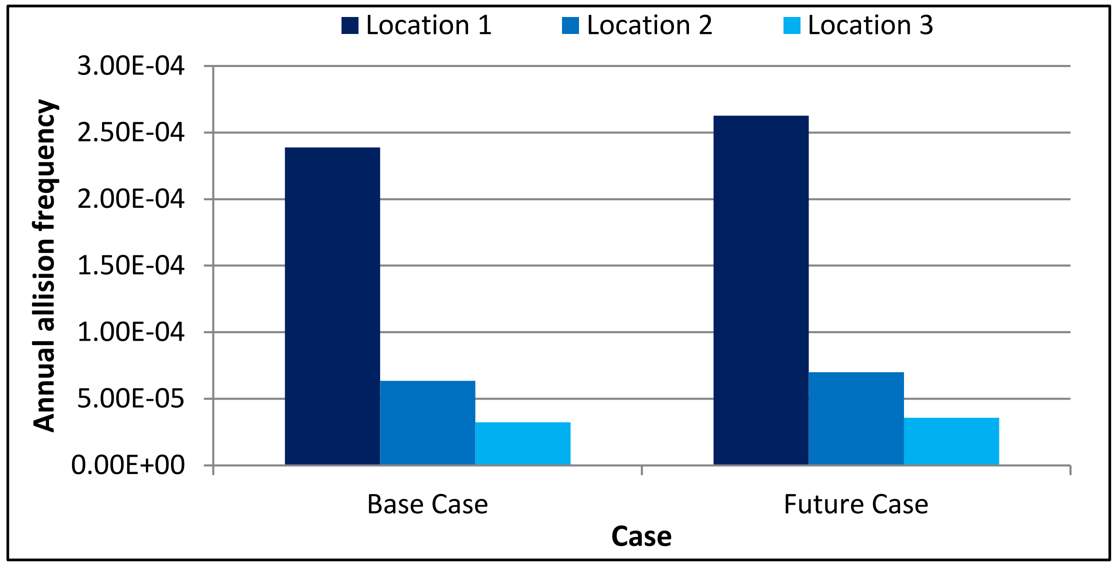


Figure 18.18: Graphical summary of risk results for Hornsea Three offshore HVAC booster stations.

18.5 Other Round Three wind farms

18.5.1.1 Table 18.11 presents the collision and allision risk modelling results (taken from their NRAs published by the planning inspectorate) for consented wind farms or wind farms that are within the consent process with MCA approval. Given the areas of build only Round Three projects have been included. Values for the maximum design scenario layouts have been shown; some results are not directly comparable given the modelling undertaken and therefore have been excluded. It should be noted that different foundation sizes were used for the modelling across the various projects.

Table 18.11: Collision and allision risk modelling results for other wind farm projects.

Round Three wind farm project	Average vessel encounters per day within 10 nm buffer		Future case external vessel to vessel collision return period	Future case external vessel to structure allision return period	Future case external NUC vessel to structure allision return period	Future case fishing vessel to structure allision return period
	Average	Maximum				
Hornsea Three *361 structures* Non Grid Planning	9	43	1 every 152 years	1 every 1,084	1 every 1,369 years	1 every 6 years
Hornsea Project Two *368 structures* One line of orientation Consented	5	14	1 every 36 years	1 every 2,089 years	1 every 878 years	1 every 7 years
Hornsea Project One *345 structures* Grid Consented	3	6	1 every 60 years	1 every 878 years	1 every 986 years	1 every 34 years
East Anglia One *325 structures* Grid Consented	55	85	Not directly comparable	1 every 197 years	1 every 434 years	1 every 6 years
East Anglia Three *182 structures* Grid Consent process	35	59	Not directly comparable	1 every 34 years	1 every 483 years	1 every 15 years
Rampion *175 structures* Grid Consented and partially constructed	42	75	1 every 1.5 years	1 every 5,100 years	1 every 1,800 years	1 every 7 years

19. Communication and Position Fixing

19.1.1.1 The following section summarises the potential impacts of the different communications and position fixing devices used in and around offshore wind farms.

19.2 Very High Frequency (VHF) communications (including digital selective calling)

19.2.1.1 As part of the 2004 SAR provider (MCA and QinetiQ, 2004) trials at North Hoyle wind farm, tests were undertaken to evaluate the operational use of typical small vessel Very High Frequency (VHF) transceivers when operated close to wind farm structures.

19.2.1.2 The wind farm structures had no noticeable effect on voice communications within the wind farm or ashore. It was noted that if small craft vessel to vessel and vessel to shore communications were not affected significantly by the presence of turbines, then it is reasonable to assume that larger vessels with higher powered and more efficient systems would also be unaffected.

19.2.1.3 During this trial a number of mobile telephone calls were made from ashore, within the wind farm, and on its seawards side. No effects were recorded using any system provider (MCA and QinetiQ, 2004).

19.2.1.4 Furthermore, as part of the SAR trials carried out at North Hoyle wind farm in 2005, radio checks were undertaken between the Sea King helicopter and both Holyhead and Liverpool coastguards. The aircraft was positioned to the seaward side of the wind farm and communications were reported as very clear, with no apparent degradation of performance. Communications with the service vessel located within the wind farm were also fully satisfactory throughout the trial (MCA, 2005).

19.2.1.5 Following consideration of these independent reports, the Hornsea Three array area is anticipated to have no significant impact upon VHF communications as demonstrated at other operational sites.

19.3 Very High Frequency (VHF) direction finding

19.3.1.1 During the 2004 trials at North Hoyle wind farm, the VHF direction finding equipment carried in the trial boats did not function correctly when very close to turbines (within approximately 50 m). This is deemed to be a relatively small scale impact due to the limited use of VHF direction finding equipment and will not impact upon operational or SAR activities, especially as the effect is not recognised by the MCA (MCA and QinetiQ, 2004).

19.3.1.2 Throughout the 2005 SAR trials carried out at North Hoyle wind farm, the Sea King radio homer system was tested. The sea king radio homer system utilises the lateral displacement of a vertical bar on an instrument to indicate the sense of a target relative to the aircraft heading. With the aircraft and the target vessel within the wind farm, at a range of approximately 1 nm, the homer system operated as expected with no apparent degradation.

19.4 Automatic Identification System (AIS)

19.4.1.1 In theory there could be interference when there is a structure located between the transmitting and receiving antennas (i.e. blocking line of sight) of the AIS. This was not evident in the trials carried out at the North Hoyle offshore wind farm site and no significant impact is anticipated for AIS signals being transmitted and received at the Hornsea Three array area. (MCA and QinetiQ, 2004).

19.5 Navigational telex (NAVTEX) systems

19.5.1.1 The Navigational Telex (NAVTEX) system is used for the automatic broadcast of localised Maritime Safety Information (MSI) and either prints it out in hard copy or displays it on an LCD screen, depending on the model.

19.5.1.2 There are two NAVTEX frequencies. All transmissions on NAVTEX 518 Kilohertz (kHz), the international channel, are in English. NAVTEX 518 kHz provides the mariner (both recreational and commercial) with weather forecasts, severe weather warnings and navigation warnings such as obstructions or buoys off station. Depending on the users' location other information options may be available such as ice warnings for high latitude sailing.

19.5.1.3 The 490 kHz national NAVTEX service may be transmitted in the local language. In the UK full use is made of this second frequency including useful information for smaller craft, such as the inshore waters forecast and actual weather observations from weather stations around the coast.

19.5.1.4 Although no specific trials have been undertaken, no significant effect has been noted at operational sites and therefore no effects are expected for the Hornsea Three array area.

19.6 Global Positioning System (GPS)

19.6.1.1 Global Positioning System (GPS) is a satellite based navigational system. GPS trials were also undertaken throughout the 2004 trials at North Hoyle wind farm and the trial report stated that "no problems with basic GPS reception or positional accuracy were reported during the trials".

19.6.1.2 The additional tests showed that "even with a very close proximity of a turbine tower to the GPS antenna, there were always enough satellites elsewhere in the sky to cover for any that might be shadowed by the turbine tower" (MCA and QinetiQ, 2004).

19.6.1.3 Therefore there are not expected to be any significant impacts associated with the use of GPS systems within or in proximity to the Hornsea Three array area.

19.7 Electromagnetic interference (from turbines or cables) on navigation equipment

19.7.1.1 A compass, magnetic compass or mariner's compass is a navigational instrument for determining direction relative to the earth's magnetic poles. It consists of a magnetised pointer (usually marked on the north end) free to align itself with the earth's magnetic field. A compass can be used to calculate heading, used with a sextant to calculate latitude, and with a marine chronometer to calculate longitude.

19.7.1.2 Like any magnetic device, compasses are affected by nearby ferrous materials as well as by strong local electromagnetic forces, such as magnetic fields emitted from power cables. As the compass still serves as an essential means of navigation in the advent of power loss or a secondary source, it should not be allowed to be affected to the extent that safe navigation is prohibited. The important factors that affect the resultant deviation are:

- Water and burial depth;
- Current (whether alternating or direct) running through the cables;
- Spacing or separation of the two cables in a pair (balanced monopole and Bipolar designs); and/or
- Cable route alignment relative to the earth's magnetic field.

19.7.1.3 Hornsea Three export and array cables could be either alternating current (AC) or direct current (DC), with studies indicating that AC does not emit an electromagnetic field significant enough to impact marine magnetic compasses (OSPAR, 2008).

19.7.1.4 It is noted that should any DC cables be used they may cause electromagnetic interference for vessels using magnetic compasses. However effects on larger vessels using inertial navigation systems and GPS as their main navigational system are expected to be limited. Smaller craft which may only carry a magnetic compass and operate within near shore waters are likely to experience the highest effects but only for the period where they are directly above an unbundled DC cable.

19.7.1.5 No problems with respect to magnetic compasses have been reported to date in any of the trials carried out (inclusive of SAR helicopters). However, small vessels with simple magnetic steering and hand bearing compasses should be wary of using these close to turbines as with any structure in which there is a large amount of ferrous material (MCA and QinetiQ, 2004).

19.8 Impact on marine Radar systems

19.8.1.1 The 2004 MCA North Hoyle wind farm trials identified areas of concern with regard to the potential impact on marine and shore based Radar systems. This is due to the large vertical extent of the turbines returning Radar responses strong enough to produce interfering side lobes, multiple and reflected echoes (ghosts). This has also been raised as a major concern by the maritime industry with further evidence of the problems being identified by the Port of London Authority (PLA) around the Kentish Flats offshore wind farm in the Thames Estuary. Based on the results of the North Hoyle trial, the MCA produced a wind farm/shipping route template to give guidance on the distances which should be established between shipping routes and offshore wind farms.

19.8.1.2 A second trial was conducted at Kentish Flats between 30 April 2006 and 27 June 2006 on behalf of the British Wind Energy Association (BWEA, 2007). The project steering group had members from the BEIS, the MCA and the PLA. This trial was conducted in pilotage waters and in an area covered by the PLA Vessel Traffic Services (VTS). It therefore had the benefit of pilot advice and experience but was also able to assess the impact of the generated effects on VTS Radars.

19.8.1.3 The trial concluded that:

- The phenomena referred to above detected on marine Radar displays in the vicinity of wind farms can be produced by other strong echoes close to the observing vessel although not necessarily to the same extent;
- Reflections and distortions by vessels' structures and fittings created many of the effects and the effects vary from vessel to vessel and Radar to Radar;
- VTS scanners static Radars can be subject to similar phenomena as above if passing vessels provide a suitable reflecting surface but the effect did not seem to present a significant problem for the PLA VTS; and
- Small vessels operating in or near the wind farm would be detectable by Radars located on vessels operating near the Hornsea Three array area but would be less detectable when the vessel was operating within the Hornsea Three array area.

19.8.1.4 Throughout the 2005 MCA SAR helicopter trials at the North Hoyle wind farm, side lobe returns were found to extend approximately 100 m to either side of each turbine, with side lobe depth estimated at less than 50 m. The Radar target, which was moving between the turbines within the wind farm, was tracked from an aircraft positioned in the 50 foot hover position between 0.25 to 0.5 nm clear of the wind farm boundary. The target could be tracked to a distance of approximately 100 m from each turbine. Beyond this point the target could be recognised at a slightly closer range to the turbine, but only if it had been previously identified at a greater separation and Radar processing continuously adjusted (MCA, 2005).

19.8.1.5 Theoretical modelling of the composite effects of the development of the Atlantic Array offshore wind farm on marine Radar systems was carried out by Ledwood Technology in October 2011 (Atlantic Array, 2012). The main outcomes of the modelling were as follows:

- *"Multipath effects (false targets) were detected under all modelled parameters. The main effects noticed were stretching of targets in azimuth and appearance of more ghost targets due to multipath energy arriving through the side lobes. However, it was concluded that there was a significant amount of clear space amongst the returns to ensure recognition of vessels moving amongst the wind farm structures and safe navigation;*
- *Even in the worst case with Radar operator settings set artificially bad there is significant clear space around each turbine that does not contain any multipath or side lobe ambiguities to ensure safe navigation and allow differentiation between false and real (both static and moving) targets;*
- *Overall it can be concluded that the amount of shadowing observed was very little. However, it should be noted that this was modelled on lattice-type base structures which are sufficiently sparse to allow Radar energy to pass through;*
- *The lower the density of structures the easier it is to interpret the Radar returns and fewer multipath ambiguities are present;*
- *In dense, target rich environments S-Band Radar scanners suffer more severely from multipath effects in comparison to X-Band scanners;*
- *It is important for passing vessels to keep a reasonable separation distance between the wind farm structures in order to minimise the effect of multipath and other ambiguities; and*
- *The potential Radar interference is mainly a problem during periods of reduced visibility when mariners may not be able to visually confirm the presence of other vessels in the vicinity (i.e. those without AIS installed which are usually fishing and recreational craft)".*

19.8.1.6 Based on the trials carried out to date, the onset range from the turbines of false returns is approximately 1.5 nm, with progressive deterioration in the Radar display as the range closes. If interfering echoes develop, the requirements of the COLREGS Rule 6 Safe speed are particularly applicable and must be observed with due regard to the prevailing circumstances. In restricted visibility, Rule 19 Conduct of vessels in restricted visibility applies and compliance with Rule 6 becomes especially relevant. In such conditions mariners are required, under Rule 5 Lookout to take into account information from other sources which may include sound signals and VHF information, for example from a VTS, or AIS (MCA, 2016).

19.8.1.7 It is noted that upon development of Hornsea Three, commercial vessels are likely to pass over 1 nm from the Hornsea Three array area, and are thereby potentially subject to minor levels of Radar interference. There is sufficient sea room around the proposed wind farm for vessels to increase their clearance further if necessary to greater than 2 nm and out with the range of Radar interference.

19.8.1.8 Figure 19.1 and Figure 19.2 show visual representations of the identified impacts.

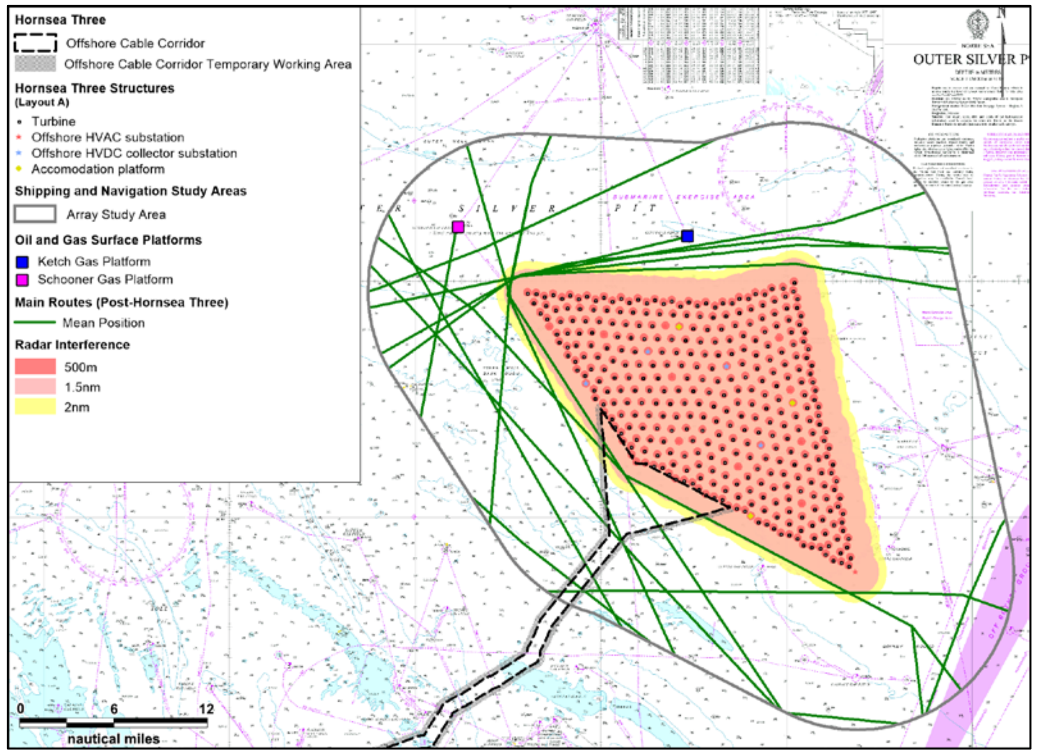


Figure 19.1: Hornsea Three array area (Layout A) Radar interference and post-Hornsea Three routeing.

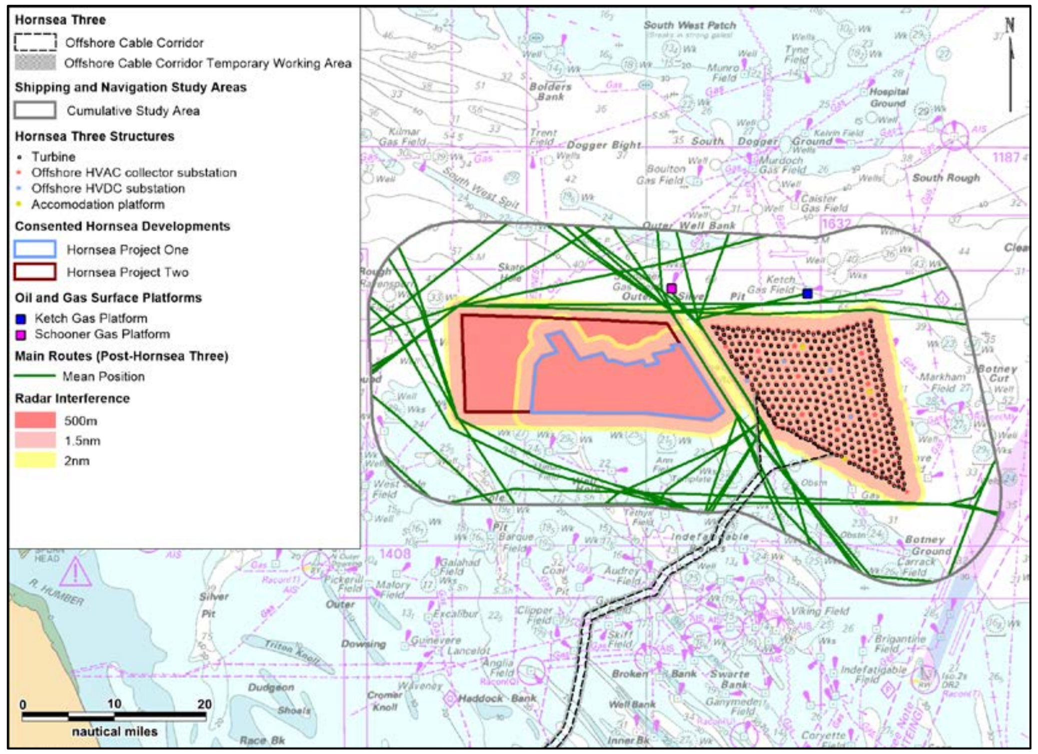


Figure 19.2: Hornsea Three array area (Layout A), Hornsea Project One and Hornsea Project Two Radar interference and post-Hornsea Three, Hornsea Project One and Hornsea Project Two routeing.

19.8.1.9 Experienced mariners should be able to suppress the observed problems to an extent and for short periods (a few sweeps) by careful adjustment of the receiver amplification (gain), sea clutter and range settings of the Radar. However, there is a consequential risk of losing targets with a small Radar cross section, which may include buoys or small craft, particularly yachts or Glass Reinforced Plastic (GRP) constructed craft, therefore due care is needed in making such adjustments. The Kentish Flats study observed that the use of an easily identifiable reference target (a small buoy) can help the operator select the optimum Radar settings.

19.8.1.10 The performance of a vessel's ARPA could also be affected when tracking targets in or near the Hornsea Three array area. However, although greater vigilance is required, it appears that during the Kentish Flats trials, false targets were quickly identified as such by the mariners and then by the equipment itself.

19.8.1.11 The evidence from mariners operating in the vicinity of existing wind farms is that they quickly learn to work with and around the effects. The MCA has produced guidance to mariners operating in the vicinity of UK Offshore Renewable Energy Installations (OREIs) which highlights Radar issues amongst others to be taken into account when planning and undertaking voyages in the vicinity of renewable energy installations off the UK coast (MCA, 2016).

19.8.1.12 AIS information can also be used to verify the targets of larger vessels (generally vessels above 300 tonnes) and fishing vessels of 18 m length and over which are required to carry AIS. Since May 2014 the carriage requirements of AIS for fishing vessels require all fishing vessels of 15 m length and over to carry AIS. It is noted that 0% of fishing vessels recorded within the Hornsea Three array area were less than 15 m, noting also that 19% of fishing vessels also did not specify a length. Furthermore an increasing number of small fishing vessels (currently not required to carry AIS) and recreational craft are voluntarily utilising Class B AIS units thus enabling verification of these small craft when in proximity to a wind farm.

19.8.2 Increased turbine size

19.8.2.1 Following analysis of Radar interference studies and general Radar principles the following impacts associated with the use of the large turbines (maximum hub height of 193 m and rotor tip of 325 m LAT) which could be used in Hornsea Three have been identified. This is specifically to identify potential impacts with the increasing size of turbines due to the operation of marine Radar beam widths and does not consider impacts associated with the total number of turbines or amount of exposure for transiting vessels passing within 2 nm.

19.8.2.2 Figure 19.3 shows an example of how Radar range is determined – the curve of the earth plus the sum of the scanner and target height. A higher target height (point B in Figure 19.3) will result in a greater range of detection (point C) of the target, especially for larger vessels with a higher antenna (point A). However the increased distance would result in a weaker Radar return and therefore the effects recorded whilst operating in close proximity to a wind farm (e.g. interfering side lobes, multiple and reflected echoes), are not likely to occur at this increased range. Therefore the increased range of detection of larger turbines will not impact on a vessels' ability to navigate safely.

19.8.2.3 Increased turbine size would mean that small craft transiting within the Hornsea Three array area would be able to identify turbine targets at a greater distance, especially if they are not in rows. Consequently, the Hornsea Three array area, ahead of the vessel, would be clear on the Radar screen.

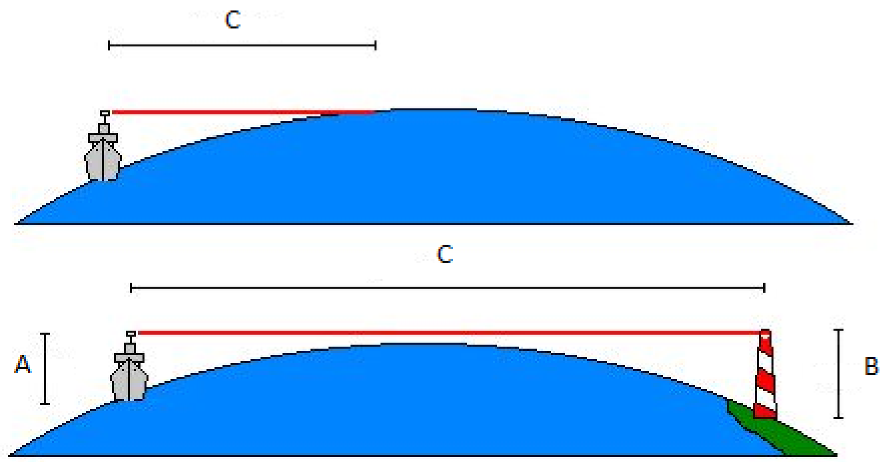


Figure 19.3: Determining Radar range.

19.8.3 Increased target returns

19.8.3.1 Beam width is the angular width, horizontal or vertical, of the path taken by the Radar pulse. Horizontal beam width ranges from 0.75 to 5°, and vertical beam width from 20 to 25°. How well an object reflects energy back towards the Radar depends on its size, shape and aspect angle.

19.8.3.2 The larger turbines (either in height or width) will return a greater target size or stronger false targets. However there is a limit to which the vertical beam width would be affected (20 to 25°) dependant on the distance from the target. Therefore the increased turbine height at the Hornsea Three array area will not create any effects in addition to those already identified from existing operational wind farms (e.g. interfering side lobes, multiple and reflected echoes).

19.8.3.3 The most likely occurrence will be a greater target return due to increased width of turbine towers and foundations resulting in similar effects to those previously described (e.g. interfering side lobes, multiple and reflected echoes). Again when taking into consideration the potential options available to marine users (e.g. reducing gain to remove false returns) and feedback from trials carried out to date that the effects of increased returns can be managed effectively, this effect is expected to be negligible and not further impact on navigational safety.

19.8.4 Floating foundations

19.8.4.1 Given that any movement associated with floating foundations and turbines will be gradual there is not expected to be any significant change in the impacts that are observed for standard fixed structures. Any need for assessment work into the impacts of floating foundations has not been identified by regulators.

19.9 Structures and turbines affecting sonar systems

19.9.1.1 No evidence has been found to date with regard to existing wind farms to suggest that they produce any kind of sonar interference which is detrimental to the fishing industry, or to military systems. No impact is therefore anticipated for the Hornsea Three array area and offshore cable corridor.

19.10 Noise impact

19.10.1.1 The concern which must be addressed under MGN 543 is whether acoustic noise from the wind farm could mask prescribed sound signals.

19.10.1.2 The sound level from a wind farm at a distance of 350 m has been predicted to be 51 (decibels) dB to 54 dB (A). Furthermore recent predictions of noise levels have been carried out throughout the consenting process of the Atlantic Array offshore wind farm. Modelling shows that the highest predicted level due to operational turbine noise (for a 125 m tall 8 megawatt (MW) turbines) is around 60 dB (Atlantic Array Offshore Wind Farm, 2012).

19.10.1.3 A vessel's whistle for a vessel of 7 m should generate in the order of 138 dB and be audible at a range of 1.5 nm (IMO, 1972/77); hence this should be heard above the background noise of the turbines. Foghorns will also be audible over the background noise of the project.

19.10.1.4 There are therefore no indications that the sound level of the wind farm will have a significant influence on marine safety.

19.10.1.5 The Scoping Opinion scoped out all airborne noise impacts and these have therefore not been considered further within the PEIR.

19.11 Underwater noise

19.11.1.1 Underwater noise radiated from 110 m tall, 2 MW capacity turbines during the operation of the Horns Rev offshore wind farm (Denmark) was measured in November 2005. The maximum levels recorded at 100 m from the turbines were a sound pressure of 122 dB re 1µ pascals (Pa) (ITAP, 2006).

19.11.1.2 During the operational phase of Hornsea Three, the subsea noise levels generated by turbines are not anticipated to have any significant impact on sonar systems as they are designed to work in pre-existing noisy environments.

19.12 Summary of communication and position fixing equipment effects

19.12.1.1 Table 19.1 summarises the impacts of Hornsea Three on communication and position fixing equipment.

Table 19.1: Summary of effects on communication and position fixing equipment.

Topic		Sensitivity	Screen in – Hornsea Three	Screen in - Cumulative
Type	Specific			
Communication	VHF	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
Communication	VHF direction finding	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
Communication	AIS	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
Communication	NAVTEX	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
Communication	GPS	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
EMF	Cables	No anticipated impacts.	Screened out	Screened out
EMF	Turbines	No anticipated impacts. Not impacted by layout design.	Screened out	Screened out
Marine Radar	Use of marine Radar	Vessels have sufficient sea room to distance themselves from the Hornsea Three array area, in line with the shipping template, to mitigate any effects as per the shipping template within MGN 543 (MCA, 2016). There are not anticipated to be any impacts with floating foundations given the slow speed at which they would move within their excursion area. Cumulatively, vessels within the navigational corridor could be sensitive but have the ability to distance themselves further from the boundary or to make manual adjustments to mitigate any temporary impacts.	Screened out	Screened out
Noise	Turbine generated noise	No anticipated impacts. Not impact by layout design.	Screened out	Screened out
Noise	SONAR	No anticipated impacts. Not impact by layout design.	Screened out	Screened out

20. Hazard Workshop Overview

20.1.1.1 A key part of the Hornsea Three consultation phase was the Hazard Workshop, which gathered local and national marine stakeholders relevant to the project in order that shipping and navigation hazards could be identified, and subsequently included in a hazard log. This ensured that expert opinion and local knowledge was incorporated into the hazard identification process, and that the final hazard log was site-specific.

20.1.1.2 The hazard log details the risks associated with each hazard, and the industry standard and additional mitigation measures required to reduce the risks to ALARP, as identified in the Hazard Workshop.

20.1.1.3 The Hazard Workshop was held at the DONG Energy office in London on Thursday 23 February 2017.

20.1.2 Hazard Workshop attendance

20.1.2.1 The organisations invited to attend the Hazard Workshop are listed in Table 20.1.

Table 20.1: Hazard Workshop invitees.

Company/organisation	Attendance
DONG Energy	Yes
Anatec Ltd	Yes
Cruising Association	Yes
Chamber of Shipping	Yes
DEME Building Materials Ltd.	Yes
MCA	Yes
DFDS Seaways	Yes
Aggregate Industries UK Ltd.	Yes
VISNED	Yes
Centrica	Yes
Vroon Offshore Services Ltd.	Yes
Poseidon	Yes
RPS	Yes
ABP	No
Aggregate Industries UK Ltd.	No
BMAPA	No
Boston Putford Offshore Safety	No
Centrica	No
Cooperative Maritime Etaploise	No
Conoco Phillips	No
CRPMEM Nord	No
Danish Shipowners' Association	No
Danish Fishermen's Association	No
DFDS Seaways	No
Department for Transport	No
Faroe Petroleum	No
From Nord	No
GloMar Shipmanagement BV	No
Lowestoft Port Authority	No
MCA	No
Nederlandse Visserbond	No
NFFO	No
P&O North Sea Ferries Ltd.	No
PD Ports	No
Peel Ports Great Yarmouth	No
Rederscentrale	No
RNLI	No
Rotterdam Harbour Master	No
Royal Association of Netherlands Shipowners	No
RYA	No
Scarborough Yacht Club	No
Shell	No
TH	No
Vroon Offshore Services Ltd.	No

20.2 Hazard Workshop process

20.2.1.1 During the Hazard Workshop, key maritime hazards associated with the construction and operation of Hornsea Three were identified and discussed. Where appropriate, hazards were considered per vessel type, to ensure risk control options could be identified on a type-specific basis (for example, risk controls for fishing vessels may differ from those considered appropriate for commercial vessels).

20.2.1.2 Post workshop, the risks associated with the identified hazards were ranked based on the discussions held during the workshop, with appropriate mitigation measures identified. The rankings were then agreed with the invitees to the hazard workshop.

20.3 Hazard Log

20.3.1.1 The Hazard Log can be found in Appendix B.

20.4 Tolerability of risks

20.4.1.1 A summary of the overall breakdown by tolerability region for the hazards identified during the Hazard Workshop is presented in Figure 20.1.

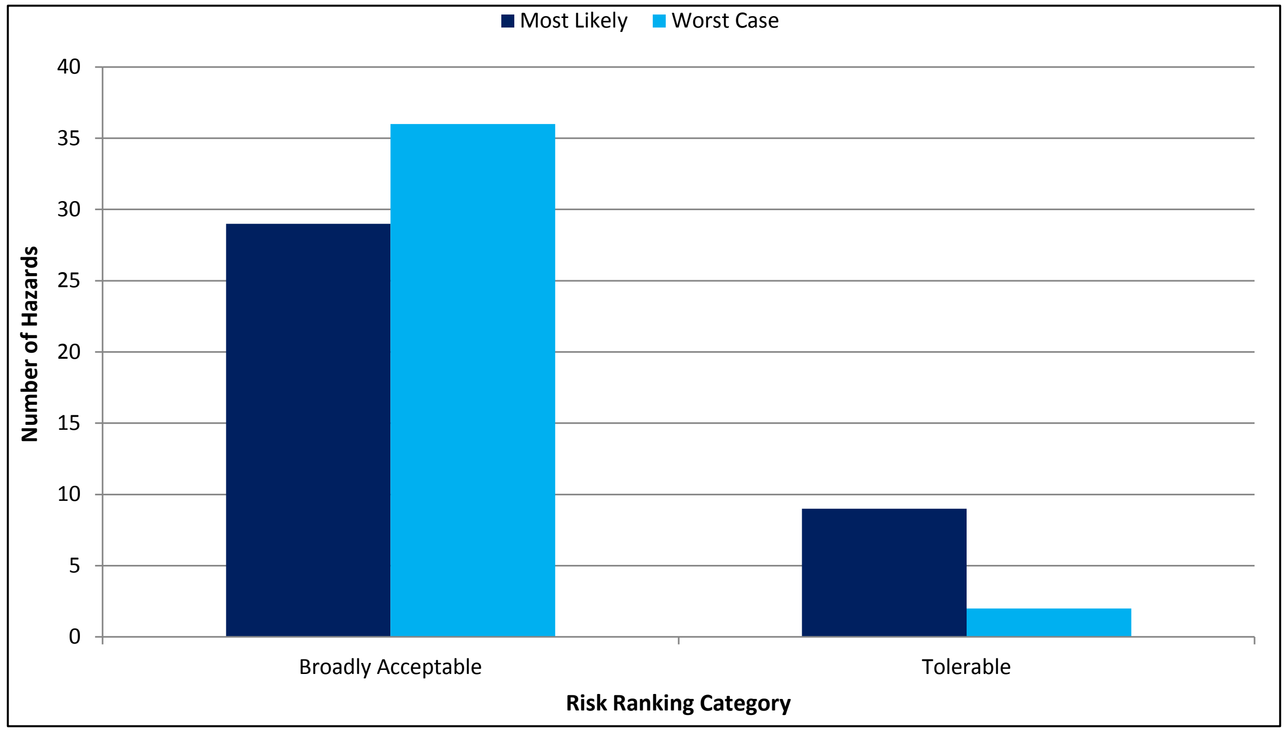


Figure 20.1: Risk ranking results.

20.4.1.2 When the most likely outcome was considered, 29 of the risks were ranked as broadly acceptable, with the remaining nine ranked as tolerable. No impacts were ranked as unacceptable. For the maximum design scenario, 36 risks were ranked as broadly acceptable, with the remaining two classed as tolerable. Again, no impacts were ranked as unacceptable.

21. Cumulative Overview

21.1 Introduction

21.1.1.1 Cumulative effects have been considered for activities in combination and cumulatively with Hornsea Three as part of the Zone Environmental Appraisal (ZEA) and ZAP to consider the cumulative effects of future offshore wind farm developments within the former Hornsea Zone and also as part of the 2013 SNSOWF report which considered routeing across the wider North Sea area.

21.1.1.2 For the Hornsea Three cumulative assessment projects and proposed developments were screened into the cumulative assessment only where a potential pathway has been identified between other activities and receptors. These were screened in or out on both a spatial and temporal basis.

21.2 Navigational corridor between Hornsea Project One, Hornsea Project Two and Hornsea Three

21.2.1.1 The proposed navigational corridor located between Hornsea Project One and Hornsea Project Two on the west and Hornsea Three on the east is considered in section 22.9.

21.3 Other offshore wind farm developments

21.3.1 Overview

21.3.1.1 In addition to Hornsea Three, Hornsea Project One and Hornsea Project Two, there are a number of offshore wind farm developments within the North Sea, both within UK waters and non-UK waters. Table 21.1 presents details of the offshore wind farms where a cumulative or in combination activity has been identified based on type of installation and the distance from Hornsea Three. Following this, Figure 21.1 presents the locations of these developments. These developments (as listed in Table 21.1).

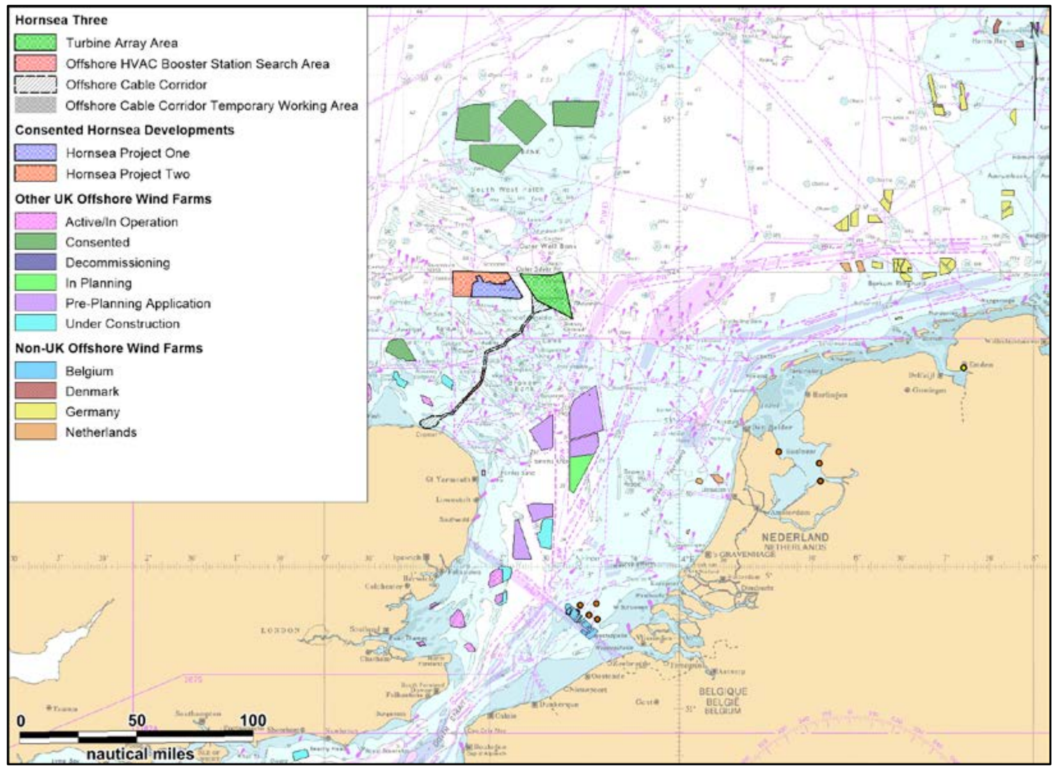


Figure 21.1: Details of offshore wind farms screened into cumulative assessment.

21.3.2 Southern North Sea Offshore Wind Forum (SNSOWF)

21.3.2.1 The SNSOWF is a group comprising representatives from the UK Round Three wind farm zones located within the southern North Sea. These are Dogger Bank, Hornsea and East Anglia.

21.3.2.2 The SNSOWF group was established at the request of TCE in order to manage wider cumulative impacts, which are likely to arise between the zones due to the scale and location of these developments. With this purpose, applicants for the Dogger Bank, former Hornsea Zone and the former East Anglia zone work together to undertake the ZAP process and address the issues arising beyond the boundaries of their respective zones. This has further been identified as part of the consultation process for the applicants and identified as an action from key stakeholders including the MCA and TH including:

- Consideration for cumulative and in combination effects;
- Re-routeing with consideration for vessels existing preferences; and
- Impacts on regular operators and timetabled routes.

21.3.2.3 Figure 21.2 shows the defined 90th percentiles from the SNSOWF study against the current cumulative scenario defined in Table 21.1. Note the routeing scenario included a larger development at the former Hornsea Zone to the east.

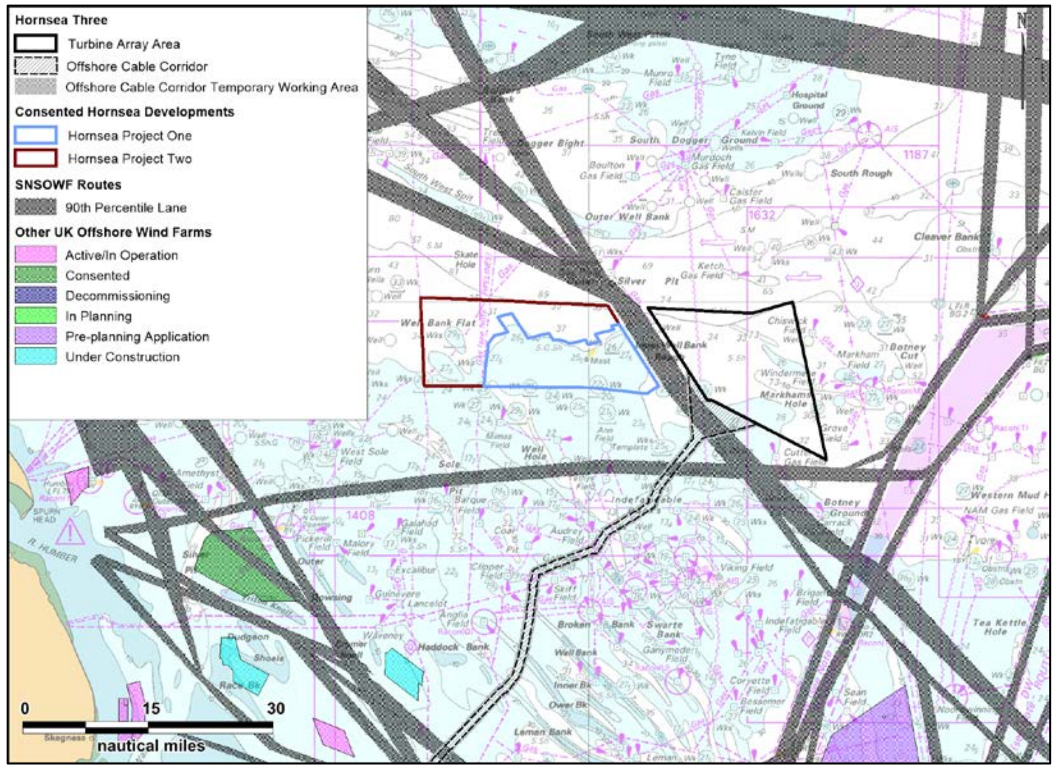


Figure 21.2: Current cumulative scenario with SNSOWF (2013) 90th percentiles.

21.4 Oil and gas infrastructure

21.4.1.1 There are no oil or gas surface platforms located within the Hornsea Three array area or offshore cable corridor. However the Schooner gas surface platform located to the north of the Hornsea Three array area has been screened into the cumulative assessment given its proximity to the Hornsea Three Array Area and its location to the north of the proposed corridor. Cumulative impacts are then considered in section 22.

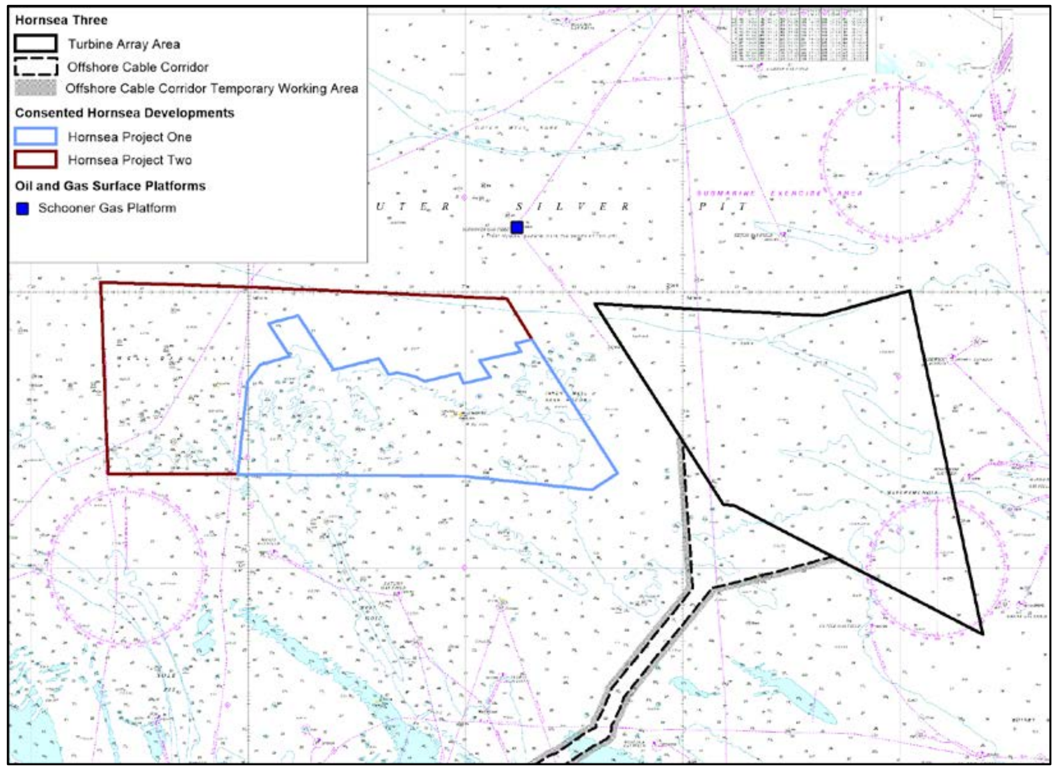


Figure 21.3: Schooner gas surface platform (screened into cumulative assessment).

21.4.1.2 The impact to the oil and gas industry is assessed in volume 2, chapter 11: Infrastructure and Other Users.

Table 21.1: Summary of offshore wind farms and oil and gas infrastructure screened-in to cumulative assessment.

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
Offshore wind farms						
Decommissioning	Blyth	270 km	4 MW (2×2 MW). One mile off the Northumberland coast, UK, within ZDE. Commissioned in December 2000. Export cables issues (cable damaged) shut it down for 3 years but operational again by 2009.	2017 decommissioning	No	No
Approved	Dogger Bank Creyke Beck A	89 km	Up to 1,200 MW. (Up to 200 turbines of up to 10 MW capacity)	2021	Yes	Yes
Approved	Dogger Bank Creyke Beck B	115 km	Up to 1,200 MW. (Up to 200 turbines of up to 10 MW turbines)	2021	Yes	Yes
Approved	Dogger Bank Teesside A & B	116 km	Up to 2,400 MW	2022	Yes	Yes
Under Construction	Dudgeon	87 km	Twenty miles off the coast of Cromer, N North Norfolk. 560 MW. 67 turbines 402 MW	N/A	No	Yes
Planned	East Anglia Four / Norfolk Vanguard	94 km	Up to 1,800 MW (between 120 – 25 seven turbines of up to 7 – 15 MW capacity)	2020	No	Yes
Approved	East Anglia ONE	53 km	714 MW (102×7 MW)	2017	No	Yes
Pre-Planning Application	East Anglia ONE North	76 km	Up to 800 MW	Unavailable	Unavailable	Unavailable
Pre-Planning Application	Norfolk Boreas	112 km	Up to 1,800 MW	N/A	No	Unknown
Planned	East Anglia THREE	110 km	Up to 1,200 MW (up to 172 turbines of up to 7 - 12 MW capacity)	2020	No	Yes
Pre-Planning Application	East Anglia TWO	112 km	Up to 800 MW	2022	Yes	Yes
Under Construction	Galloper	195 km	Up to 336 MW (56×6 MW turbines)	2017	No	Yes
Operational	Greater Gabbard	198 km	504 MW (140×3.6 MW turbines)	N/A	No	Yes
Operational	Gunfleet Sands Demo	245 km	12 MW (2×6 MW)	N/A	No	Yes
Operational	Gunfleet Sands I	240 km	108 MW (30×3.6 MW)	N/A	No	Yes
Operational	Gunfleet Sands II	239 km	64.8 MW (18×3.6 MW)	N/A	No	Yes
Approved	Hornsea Project One	14 km	Up to 240 5-8 MW turbines	2017	No	Yes
Approved	Hornsea Project Two	20 km	Up to 300 6-15 MW turbines	2017	No	Yes
In Operation	Humber Gateway	128 km	Up to 219 MW (73×3 MW turbines)	N/A	No	Yes
Consented	Hywind Scotland Pilot	438 km	30 MW (5×6 MW turbines)	2017	No	Yes

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
In Operation	Kentish Flats	272 km	90 MW (30x3 MW Vestas turbines). Fully commissioned December 2005.	N/A	No	Yes
In Operation	Kentish Flats Extension	273 km	49.5 MW (15x3.3 MW Vestas turbines)	N/A	No	Yes
Planned	Kincardine Offshore Wind Farm	422 km	48 MW (8x6 MW turbines)	2018	No	Yes
In Operation	LID6 1	143 km	6x3.6 MW Siemens turbines	N/A	No	Yes
In Operation	Lincs	139 km	270 MW (75x3.6 MW)	N/A	No	Yes
In Operation	London Array	230 km	630 MW (175x3.6 MW)	N/A	No	Yes
In Operation	Lynn and Inner Dowsing Wind Farms	147 km	194 MW (54×3.6 MW Siemens monopiles). Commissioned March 2009. Located 5 km off the coast of Skegness.	N/A	No	Yes
Pre-planning Application	Methil Demonstration Project - 2B Energy	411 km	Operated by Forthwind Limited, round/type - Demonstration/Agreement for Lease.	2018	No	Yes
Under Construction	Race Bank	114 km	Up to 580 MW	N/A	No	Yes
Under Construction	Rampion Wind Farm	388 km	400 MW (116x3.45 MW)	N/A	No	Yes
In Operation	Robin Rigg East	391 km	90 MW (30×3 MW)	N/A	No	Yes
In Operation	Robin Rigg West	392 km	90 MW (30×3 MW)	N/A	No	Yes
In Operation	Scroby Sands	132 km	60 MW (30×2 MW turbines)	N/A	No	No
In Operation	Sheringham Shoal	109 km	316.8 MW (88×3.6 MW). Sheringham, Greater Wash. 17-23 km off North Norfolk.	N/A	No	Yes
In Operation	Teesside	224 km	1.5 km northeast Teesmouth. 62.1 MW (27×2.3 MW). Commissioned July 2013.	N/A	No	Yes
In Operation	Thanet	260 km	300 MW (100×3 MW monopile turbines). UK, offshore wind, Round 2. 12 km off Foreness Point, Kent. Fully commissioned September 2010.	N/A	No	Yes
Consented	Triton Knoll	100 km	750-900 MW (113-288×8 MW turbines) Greater Wash, 20 miles off the coast of Lincolnshire and 28 miles from the coast of North Norfolk.	2017	No	Yes
In Operation	Westermost Rough	132 km	210 MW (35×6 MW)	N/A	No	Yes
In Operation	Belwind 1 (Belgium)	220 km	165 MW (55×33 MW) Belgium. Zone 3 & Bligh Bank. Developer Belwind NV (various owners). Fully Commissioned.	220	No/No	No

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
In Operation	Belwind Alstom Haliade Demonstration (Belgium)	222 km	6 MW (1×6 MW)	222	No	Yes
In Operation	Mermaid (Belgium)	217 km	288 MW (48×6 MW)	217	No	Yes
In Operation	Norther (Belgium)	236 km	Up to 370 MW (44×8 MW). Belgium. Vlaanderen region. Developer SA Norther (Air Energy sa) 100% owned by Eneco. Offshore Wind.	2017	No	Yes
Planned	Northwester 2 (Belgium)	222 km	210-296 MW (22-70 3-10 MW)	2018	No	Yes
In Operation	Northwind (Belgium)	229 km	216 MW (72×3 MW). Belgium. Developer Northwind NV (formally ELDEPASCO Ltd).	N/A	No	Yes
Consented	Rental Area A (Belgium)	231 km	309 MW (42×7.35 MW)	2017	No	Yes
Consented	Seastar (Belgium)	225 km	252 MW (42×6 MW)	2017	No	Yes
In Operation	Thornton Bank Phase I (Zone C-Power) (Belgium)	237 km	30 MW (6x5 MW). Belgium, Vlaanderen region. Developer C-Power nv. Offshore. Commissioned 2012.	N/A	No	No
In Operation	Thornton Bank Phase II (Belgium)	237 km	184.5 MW (30×6.15 MW) Belgium, Vlaanderen region. Developer C-Power nv. Offshore Wind. Commissioned 2013.	N/A	No	Yes
In Operation	Thornton Bank Phase III (Zone 1 C-Power 2) (Belgium)	235 km	110 MW (18×6.15 MW) Belgium, Vlaanderen region. Developer C-Power NV. Under Construction. Wind. Commissioned September 2013.	N/A	No	Yes
In Operation	Alpha Ventus (Formerly Borkum West I) (Germany)	252 km	60 MW Off the west coast of Germany. Developer Deutsche Offshore-Testfield-und Infrastruktur GmbH. (Owner EWE AG/ Vattenfall). Offshore wind farm. Commissioned April 2010.	N/A	No	Yes
In Operation	Amrumbank West (Germany)	328 km	288 MW (80×3.6 MW). Off the west coast of Germany. Owner E.On Climate & Renewables GmbH. Developer Amrumbank west GmbH. approved. Offshore wind farm. Scour prevention expected completion September 2013.	N/A	No	Yes
In Operation	BARD Offshore 1 (Germany)	215 km	400 MW (80×5 MW). Offshore Wind Farm off the west coast of Germany. Located some 90 km NW of the island of Borkum.SüdWestStrom Windpark GmbH & Co KG 70%, WV Energie Frankfurt 30%. Project officially inaugurated on 26 August 2013.	N/A	No	Yes
In Operation	Borkum Riffgrund 1 (Germany)	245 km	312 MW (77×4 MW)	N/A	No	Yes

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
In Operation	Trianel Windpark Bokrum Phase 1 (Bokrum West II) (Germany)	241 km	200 MW (40×5 MW)	N/A	No	Yes
Approved	Trianel Windpark Bokrum Phase 2 (Bokrum West II) (Germany)	242 km	203 MW (32×6.15 MW)	2017	No	Yes
Planned	Bokrum-Riffgrund West II (Germany)	224 km	258 MW (43×6 MW)	2019	No	Yes
In Operation	Butendiek(Germany)	346 km	288 MW (80×3.6 MW)	N/A	No	Yes
In Operation	DanTysk (Germany)	314 km	288 MW (80×3.6 MW)	N/A	No	Yes
Consented	Deutsche BuchtOffshore Wind Farm (Germany)	203 km	252 MW (30×8 MW). Off the west coast of Germany. BARD sold to Windreich who then sold to an unknown investor. Offshore wind farm.	2017	No	Yes
In Operation	Emden (Germany)	295 km	4.5 MW (1×4.5 MW)	N/A	No	No
Consented	He dreiht I (Germany)	228 km	732 MW (Up to 80 turbines) Off the west coast of Germany. Owner EnBW Energie Baden-Wurtleberg AG Offshore wind farm.	N/A	No	Yes
Consented	Hohe See (Germany)	239 km	497 MW (71×7 MW)	2018	No	Yes
Under Construction	Global Tech I (Germany)	245 km	400 MW (80×5 MW). Off the west coast of Germany. Developer Global Tech 1 Offshore Wind GmbH).	N/A	No	Yes
Under Construction	Gode Wind I (Germany)	275 km	332 MW (55×6 MW) Off the west coast of Germany. Offshore wind farm.	N/A	No	Yes
Under Construction	Gode Wind II (Germany)	276 km	252 MW (42×6 MW) Off the west coast of Germany. Owner/developer DONG Energy.	N/A	No	Yes
Under Construction	INNOGY Nordsee I (Germany)	262 km	Off the west coast of Germany. 54 turbines, capacity 332 MW. Owner / Developer RWE. Offshore wind farm.	N/A	No	Yes
In Operation	Meerwind Süd/Ost (Germany)	326 km	288 MW (80×3.6 MW) Off the west coast of Germany. Developer WindMW GmbH (Windland Energieerzeugungs GmbH) Offshore wind farm.	N/A	No	Yes
Under Construction	MEG Offshore I (now Merkur Offshore Wind Farm) (Germany)	247 km	Off the west coast of Germany. 400 MW. Developer Noordsee offshore MEG I GmbH. Offshore wind farm.	2017	No	Yes
Consented	Noerdlicher Grund (Germany)	295 km	320 MW-384 MW (64×5 MW-6 MW)	Unavailable	No	No

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
In Operation	Noerdlicher Grund Teil Sandbank (Germany)	297 km	288 MW (72×4 MW)	N/A	No	Yes
Under Construction	Nordergruende (Germany)	*353 km*	110.7 MW (18×6.15 MW)	N/A	*No*	*Yes*
In Operation	Nordsee Ost (Germany)	326 km	295.2 MW (48×6.15 MW) Off the west coast of Germany35 miles to the northeast of the island of Heligoland.	N/A	No	Yes
In Operation	Riffgat (Germany)	241 km	108 MW (30×3.6 MW)	N/A	No	Yes
Under Construction	Sandbank 24 (Germany)	298 km	288 MW (72×4 MW)	N/A	No	Yes
In Operation	Trianel Windpark Borkum Phase 1 (Germany)	242 km	200 MW (40×5 MW)	N/A	No	Yes
Under Construction	Veja Mate (Germany)	208 km	200 MW (40×5 MW)	N/A	No	Yes
Consented	Borssele 1 and 2 (Netherlands)	216 km	684 MW-760 MW (69-127×6 MW-10 MW)	2017	No	Yes
Consented	Borssele 3 and 4 (Netherlands)	217 km	664 MW-740 MW (123×6 MW-10 MW)	2018	Yes	Yes
Under Construction	Buitengaats (Netherlands)	214 km	300 MW (75×4 MW). Part of a 600 MW project called Gemini Offshore Wind Farm with the 300 MW ZeeEnergie	N/A	No	Yes
In Operation	Eneco Luchterduinen (Netherlands)	170 km	129 MW (43×3 MW)	N/A	No	Yes
In Operation	Irene Vorrink I(Netherlands)	223 km	11.4 MW (19×0.6 MW). Part of a larger 16.8 MW (28×0.6 MW) project.	N/A	No	No
In Operation	Irene Vorrink II(Netherlands)	223 km	5.4 MW (9×0.6 MW). Part of a larger 16.8 MW (28×0.6 MW) project.	N/A	No	No
In Operation	Lely(Netherlands)	184 km	2 MW. Operational. Offshore wind farm. Commissioned 1996.	N/A	No	No
In Operation	Offshore Windpark Egmond aan Zee (Netherlands)	157 km	108 MW (36×3 MW). Owner Vattenfall (AB). OffshorenWind. Commissioned 2007.	N/A	No	Yes
In Operation	Prinses Amaliapark (Netherlands)	153 km	120 MW (60×2 MW)	N/A	No	Yes
In Operation	Westermeerdijk buitendijks (Netherlands)	215 km	144 MW (48×3 MW)	N/A	No	Yes
Under Construction	ZeeEnergie (Netherlands)	203 km	300 MW (75×4 MW). Part of a 600 MW project called Gemini Offshore Wind Farm with the 300 MW Buitengaats offshore wind farm.	N/A	No	Yes

Phase	Project/Plan	Distance from Hornsea Three array area	Details	Date of construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
In Operation	Horns Rev (Denmark)	368 km	160 MW (80×2 MW).	N/A	No	No
In Operation	Horns Rev 2 (Denmark)	358 km	209.3 MW (91×2.3 MW).	N/A	No	Yes
Oil and gas infrastructure						
Producing	Schooner gas platform	2 km	Gas Field - Producing	N/A	N/A	Yes

22. Formal Safety Assessment

22.1 Introduction

22.1.1.1 This section assesses the major hazards associated with the development of Hornsea Three, considering the baseline data, assessment and consultation contained within this NRA. This assessment is carried out as per the FSA methodology as per section 3.1.

22.2 Human element

22.2.1.1 MGN 372 has been developed to provide guidance on planning and undertaking voyages in the vicinity of offshore wind farms and states that although offshore renewable energy installations present new challenges to safe navigation around the UK coast, proper voyage planning, taking into account all relevant information, should ensure a safe passage and that the safety of life and the vessel should not be compromised. To date there has only been one incident involving a third party vessel and a fixed offshore wind farm structure since offshore development began in 2000; with 76 offshore wind farms currently in operation, under construction/decommissioning or decommissioned within the UK Renewable Energy Zone (REZ) and the Southern North Sea (see section 13.4).

22.3 Deviations

22.3.1 All Phases

22.3.1.1 Marine traffic movements around the Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations have been captured through dedicated marine traffic surveys and AIS surveys as noted in section 15. When marine traffic survey data assessments are considered alongside historical analysis in the form of the Hornsea Project Two NRA and vessel route databases (Anatec ShipRoutes, 2016) a full and detailed picture of commercial vessel movement has been defined (section 15.4.5). The multiple sources used have allowed this NRA to clearly identify all key routes operating within the Hornsea Three array area shipping and navigation study area, Hornsea Three offshore cable corridor shipping and navigation study area and the Hornsea Three offshore HVAC booster station search area shipping and navigation study area using the principles defined within MGN 543 (MCA, 2016). This includes the identification of main routes, 90th percentiles and regular operators who have been consulted as part of the stakeholder process (section 14). This baseline information has then enabled the assessment to look at future case routeing (section 17).

Hornsea Three array area

22.3.1.2 Of the 16 main routes identified transiting through the Hornsea Three array area shipping and navigation study area, eight routes will be deviated from their current main route (section 15.4.5). Of these routes two were operated by commercial ferries which are also considered separately in paragraph 22.3.1.7. The shortest and therefore most likely alternative routes have been considered for the eight identified routes. Assumptions for re-routes assume the following:

- All deviated routes maintain a minimum separation of 1 nm from offshore installations and potential turbine boundaries (see paragraph 17.7.1.2); and
- All alternative routes take into account sandbanks, existing infrastructure and known routeing preferences for the vessels identified on those routes.

22.3.1.3 Average speeds for vessels on each individual route have been noted but time increases have not been considered given the minor increases to journey length. See section 17.7 for details on future case routeing.

22.3.1.4 Maximum deviations during the construction and decommissioning phase would be associated with the buoyed construction or decommissioning area. The layout consisting of 342 turbines plus associated structures spread across the entire development area (Layout A) has been considered as the maximum design scenario for deviations associated with the development of the Hornsea Three array area.

22.3.1.5 As this area for displacement cannot be increased in size given the maximum extent of the AfL, this impact can only be lower post consent; and would be caused by a significant decrease in the total number of turbines and thus development area with the results being that deviations would be reduced.

22.3.1.6 When the deviations noted in section 17 are considered against the consultation responses received there are predicted to be no significant impacts on commercial vessels and the impact is assessed to be **broadly acceptable** with measures adopted as part of Hornsea Three in place (including information promulgation in place to aid passage planning) for all phases. This is associated with the vessels not being on timetabled services, not carrying large numbers of passengers (no significant safety effects) and the small increases in length compared to the overall journey. Further examination of commercial ferry routes was also undertaken in section 22.4.

Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.3.1.7 There are expected to be very small and temporary deviations associated with the export cable installation and therefore any impact is negligible. For the Hornsea Three offshore HVAC booster stations there will be deviations required during construction, operation and maintenance, and decommissioning. The impact of this during the construction and decommissioning phases will be greater than the operational phase given the need for a buoyed construction area around the Hornsea Three offshore HVAC booster station. The Hornsea Three offshore HVAC booster stations deviations would be dictated by the construction or decommissioning buoyage put in place by TH to manage passing traffic. This impact would be temporary during the construction and decommissioning of the Hornsea Three offshore HVAC booster station(s) itself.

22.3.1.8 For operation and maintenance there will be small deviations required for the surface Hornsea Three offshore HVAC booster station(s) and the subsea HVAC booster station(s) (including any associated marker buoys) however these impacts are expected to be very low given the small deviation required against the total journey length.

22.3.1.9 Therefore for all phases the impact is assessed to be **broadly acceptable** with mitigation measures adopted as part of Hornsea Three (including information promulgation in place to aid passage planning) in place as per section 23.

22.4 Commercial ferry deviations

22.4.1 All Phases

Hornsea Three array area

22.4.1.1 Similar principles apply as per paragraph 22.2.1.1, whereby commercial ferry routes have been identified and assessed using principles defined in MGN 543. For commercial ferries although the frequency is medium given the number of transits made, however the consequences are considered low given that the ferries only carry small (less than 12) numbers of passengers minimising on board health and safety impacts for non-crew, the journey increases are small when considered against total journey length and there is available sea room for safe manoeuvring and deviations to be made.

22.4.1.2 Following consultation with DFDS Seaways, the only operator directly impacted, they noted that their main concern was with adverse weather routes (see paragraph 22.4.1.4 and section 22.6).

22.4.1.3 It is assessed that the impact for Hornsea Three is **broadly acceptable** with measures adopted as part of Hornsea Three in place.

Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.4.1.4 There are no deviations identified in association with the Hornsea Three offshore cable corridor or Hornsea Three offshore HVAC booster stations for commercial ferries.

22.5 Adverse weather routeing

22.5.1 All Phases

22.5.1.1 Adverse weather includes wind, wave and tidal conditions as well as reduced visibility due to fog that can hinder a vessel's normal route and/or speed of navigation. Adverse weather routes are assessed to be significant course adjustments to mitigate vessel movement in adverse weather conditions. When transiting in adverse weather conditions, a vessel is likely to encounter various kinds of weather and tidal phenomena, which may lead to severe roll motions, potentially causing damage to cargo, equipment and/or danger to persons on board. The sensitivity of a vessel to these phenomena will depend on the actual stability parameters, hull geometry, vessel type, vessel size and speed.

22.5.1.2 The probability of occurrence, in a particular sea state, may differ for each vessel. Adverse weather is considered most significant for passenger vessels, due to the potential health and safety risks (as well as comfort) to people on board (health and safety risk such as sea sickness and difficulty moving around the vessel). This can also have implications for regular timetabled vessels, due to increases in journey time and potential cancellations. Mitigations for vessels include adjusting their heading to position themselves 45 to the wind, altering or delaying sailing times, reducing speed and/or potentially cancelling journeys. However due to the open sea area around Hornsea Three, there is not expected to be any significant limitations to routeing options.

22.5.1.3 With regards to reduced visibility, standard mitigations are required by both the Applicant and the vessel operator. The Applicant will ensure that Hornsea Three is marked and lit in accordance with requirements defined by TH and this scheme will include fog horns to alert vessels to the position of structures when visibility is poor. Vessels are also required to take appropriate measures with regards to safe speed under the COLREGS (IMO, 1972/77), which considers determining a safe speed in conjunction with the state of visibility, the state of the wind, sea and current as well as the proximity of navigational hazards.

Hornsea Three array area

22.5.1.4 When the mitigation measures accepted as part of Hornsea Three are assessed against the probability of adverse weather including restricted visibility, the low numbers of vessels within the Hornsea Three array area and the available sea room the impact is assessed to be **broadly acceptable**.

Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.5.1.5 There are no adverse weather impacts identified in association with the Hornsea Three offshore cable corridor or Hornsea Three offshore HVAC booster stations.

22.6 Commercial ferry adverse weather routeing

22.6.1 All Phases

22.6.1.1 Commercial ferry adverse weather routeing has been identified in section 16.

Hornsea Three array area

Given the low frequency of adverse weather in the Hornsea Three array area, any increased deviations associated with weather conditions are expected to be minimal and of a limited temporal duration for both the commissioning and decommissioning phases. When assessed against the frequency of occurrence impacts on adverse weather routes are assessed to be **broadly acceptable**.

22.6.1.2 For the operation phases and following consultation with DFDS Seaways it was identified that the Hornsea Three array area was intersected by one adverse weather route for the Immingham to Cuxhaven route. However a year of AIS from 2016 was analysed, during which eight potential adverse weather transits were identified on AIS. When considered against the number of potential normal crossings this equates to less than 2% of transits (during 2016 sample) using adverse weather routeing to the north of the Hornsea Three array area. The vessels on this route are commercial ro-ro vessels that carry limited number of passengers and are therefore more able to withstand adverse weather conditions than passenger ferries (due to health and safety risks to on-board passengers). This considered against the frequency of occurrence means that the impact is considered **broadly acceptable**.

Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.6.1.3 There are no deviations identified in association with the Hornsea Three offshore cable corridor or Hornsea Three offshore HVAC booster stations for commercial ferries.

22.7 Cumulative deviations

22.7.1 All Phases

Hornsea Three array area

22.7.1.1 Cumulative deviations have been considered in line with the Hornsea Three cumulative shipping and navigation study area described in section 5.2.4 and the cumulative project list in Table 21.1.

22.7.1.2 Following work undertaken for the ZAP, including the routeing reports undertaken as part of SNSOWF; a navigation corridor was designed to mitigate impacts on cumulative deviations associated with the former Hornsea Zone.

22.7.1.3 Within the Hornsea Project Two Environmental Statement the cumulative impact of Hornsea Project One and Hornsea Project Two was considered to be a long term and continuous impact but of a low frequency. Although further deviations are now required due to the presence of the Hornsea Three array area; assessment and consultation responses do not consider this to be greater than Hornsea Project One or Hornsea Project Two and therefore Hornsea Three, Hornsea Project One and Hornsea Project Two in combination too. The cumulative impact is therefore considered broadly acceptable under the FSA given the following reasons:

- The majority of routes impacted by the cumulative developments run east to west and therefore are already deviated to the maximum extent by Hornsea Project One and Hornsea Project Two;
- Impacts were considered minor adverse within the Hornsea Project Two Environmental Statement;
- There are fewer dense and significant routes passing through Hornsea Three (than Hornsea Project One and Hornsea Project Two); and
- The proposed navigational corridor provides a useable alternative to deviating around the area.

22.7.1.4 Cumulative collision is considered further in section 22.9.

Cumulative adverse weather

22.7.1.5 It is noted that Hornsea Project One and Hornsea Project Two are consented. Therefore cumulative adverse weather scenario impacts would be the same given the routes do not intersect Hornsea Three, Hornsea Project One or Hornsea Project Two. Other offshore wind farm developments have no impact given the distance from the former Hornsea Zone and the direction of the adverse routes. The cumulative impact given the available sea room, distance from shore (giving numerous routeing options) and the preference identified for coastal passenger ferry routeing (section 16) is therefore assessed to be **broadly acceptable.** Mitigation includes marking, charting and promulgation of information to ensure that vessels are able to effectively passage plan.

Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.7.1.6 There were no cumulative deviations identified in association with the Hornsea Three offshore cable corridor or Hornsea Three offshore HVAC booster stations; based on the lack of consultation responses and also limited AIS data assessed it is assumed the impact is **negligible.**

22.8 Increased encounters and collision risk

22.8.1 Construction and decommissioning phases

Hornsea Three array area

22.8.1.1 The presence of construction (or decommissioning activities) within the Hornsea Three array area may cause low numbers of vessels to be deviated potentially increasing encounters and the risk of vessel to vessel collision. This impact can be separated into two impacts; encounters and collision between third party vessels and encounters and collision between a third party vessel and a vessel associated with Hornsea Three construction (and decommissioning). The following section details the two impacts.

<u>Encounters and collision risk between third party vessels</u>

22.8.1.2 The increased level of vessel activity required for Hornsea Three construction (or decommissioning) may lead to an increase in vessel to vessel collision risk due to displacement of third party vessels and increased encounters with construction (or decommissioning) vessels.

22.8.1.3 Mitigation measures accepted as part of Hornsea Three are in place to manage increased traffic levels and encounters between construction (or decommissioning vessels) and third party vessels.

22.8.1.4 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Compliance with Flag State regulations including International Maritime Organization Conventions including COLREGs (IMO, 1972/77) and the Safety of Life at Sea (SOLAS) (IMO, 1974);
- MGN 372 (MCA, 2008); and
- Promulgation of Information.

22.8.1.5 When considering experience at other constructing wind farms it is identified that third party vessels do consider Notice to Mariners during passage planning and avoid current constructing areas. There have not been any recorded incidents within a buoyed construction area whereby a third party vessel has collided within a construction vessel (see section 13).

22.8.1.6 As already noted under paragraph 22.2.1.1 it is likely that vessels will pass more than the 1 nm considered within this deviation assessment to keep clear from the edge of the buoyed construction area meaning that, given the sea room, the number of hot spots where vessels would be likely to meet would be reduced lowering the risk of encounter.

22.8.1.7 Considering this and given the low numbers of third party vessels in the area (compared to the other UK sea areas), when assessed with existing regulations such as COLREGS (IMO, 1972/77) and guidance such as MGN 372 (MCA, 2008) there is considered to be a low frequency of encounters. The impact is therefore assessed to be ALARP.

<u>Encounters and collision risk with construction (or decommissioning) vessels</u>

22.8.1.8 It is anticipated that up to 11,776 round trips will be made between the Hornsea Three array area and base ports during the construction of Hornsea Three. Construction could last up to eleven years in three phases (periods of activity and inactivity), however given that the mitigation measures adopted as part of Hornsea Three (section 23) will be in place until fully commissioned, the length of the construction phases or number of phases is not assessed to influence this impact.

22.8.1.9 Encounters with vessels associated with Hornsea Three are not considered likely given the mitigation measures accepted as part of Hornsea Three that will be in place to manage them and ensure that they do not encounter third party vessels, and fully comply with UK and flag state regulation.

22.8.1.10 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Compliance with Flag State regulations including International Maritime Organization Conventions including COLREGs (IMO, 1972/77);
- Buoyed construction (decommissioning) area clearly identifies the location of construction (decommissioning) works and vessels;
- 500 m construction safety zones around partially constructed offshore wind farm structures that are attended by large construction vessels;
- The Marine Coordination Centre will fully manage vessels movements associated with Hornsea Three (including between phase management); and
- Vessels will have a traffic management plan in place that may include options such as entry and exit points into the Hornsea Three array area. This will help to ensure that vessels do not exit into key vessel routes. From a cumulative impact perspective, this will also include the navigational corridor.

22.8.1.11 It is noted that collision risk frequency is also likely to increase further in reduced visibility when identification of construction vessels exiting/entering the wind farm construction area may become more difficult. However COLREGS (IMO, 1972/77) does regulate vessel movements in adverse weather and requires all vessels operating in reduced visibility to reduce speed and allow more time to react to encounters, thus minimising the risk of collision.

22.8.1.12 As already noted in section 22.2.1.1, it is likely that given the available sea room vessels will pass more than the 1 nm passing distance considered within this conservative deviation assessment to keep clear from the edge of the buoyed construction area. The frequency of vessels encountering construction (or decommissioning) vessels near the Hornsea Three array area would therefore be very low.

22.8.1.13 When considering the low numbers of third party vessels in the area (compared to the other UK areas), existing regulations such as COLREGS (IMO, 1972/77), guidance such as MGN 372 (MCA, 2008), other mitigation measures adopted as part of Hornsea Three (section 23) and mitigation in place to manage Hornsea Three's own vessel's the impact is assessed to be broadly acceptable.

Hornsea Three offshore HVAC booster stations

22.8.1.14 Any increase in collision risk associated with the Hornsea Three offshore HVAC booster station is expected to be mitigated by the mitigation measures adopted as part of Hornsea Three listed above (section 23) and the small buoyed construction area required by a Hornsea Three offshore HVAC booster station(s) in isolation or in a group.

22.8.1.15 No significant consultation response was noted from regular users in the area.

22.8.1.16 When considered with mitigation measures adopted as part of Hornsea Three included within section 23, the low density of third party vessels operating in the area (meaning low encounters and thus low collision risk) and a maximum construction duration (split over three phases) the impact is assessed to be broadly acceptable.

Hornsea Three offshore cable corridor

22.8.1.17 When considering construction (or decommissioning) within the Hornsea Three offshore cable corridor including a maximum installation of 2.5 years, there are not anticipated to be any significant impacts; given that mitigation measures adopted as part of Hornsea Three including minimum safe passing distances for installation or decommissioning vessels and notice to mariners will be in place to ensure vessels are pre warned of activity and are able to temporarily avoid areas of current activity. Therefore negligible effects have been identified for the Hornsea Three offshore cable corridor.

22.8.2 Operations and maintenance phase

Hornsea Three array area

22.8.2.1 Further details of encounter and collision modelling can be found in section 18

22.8.2.2 It is noted that collision modelling is assessed at a maximum design scenario level as it assumed that all vessels pass 1 nm from the Hornsea Three array area. In reality vessels will use all available sea room, reducing hot spots and collision risk.

<u>Encounters and collision risk between third party vessels</u>

22.8.2.3 The physical presence of the infrastructure within Hornsea Three has the potential to increase vessel to vessel collisions through displacement of vessels, when compared with the existing vessel routeing

22.8.2.4 The annual vessel to vessel collision frequency following the installation of Hornsea Three was 6.59×10^{-3}, corresponding to a major collision return period of one in 152 years based on conservative vessel routeing and Layout A.

22.8.2.5 Although not modelled beyond 10 nm, the extent of this impact will cover a large geographical area due to the start and finishing locations of the vessel routes and the early alterations to course they could be required to make, however the large extent is likely to also aid mitigation of the impact by preventing the creation of collision risk hotspots near the Hornsea Three array area by increasing the distance at which vessels will alter course to deviate around the Hornsea Three array area.

22.8.2.6 Mitigation measures adopted as part of Hornsea Three are in place to manage increased traffic levels and encounters between third party vessels; given the low levels (compared to other UK sea areas) and these mitigations; the increase in risk of encounters is expected to be ALARP.

22.8.2.7 Measures adopted as part of Hornsea Three (section 23) include:

- Compliance with Flag State regulations including International Maritime Organization Conventions including COLREGs (IMO, 1972/77);
- Marine Coordination;
- IALA (2013) Guidance and Aids to Navigation; and
- MGN 372 (MCA, 2008).

<u>Encounters with third party vessels exiting the wind farm</u>

22.8.2.8 MGN 543 (MCA, 2016) identifies the potential for visual navigation to be impaired by the location of offshore wind farm structures, decreasing vessels ability to sight each other (when hidden behind structures). Based on the Hazard Log, collision risk frequency could increase further in reduced visibility when wind farm related vessels exiting the wind farm may not be easily sighted. However COLREGS (IMO, 1972/77) should mitigate impact by regulating all vessels to operate at a safe speed and use sound signals to notify others of their presence.

22.8.2.9 A total of 40 recreational vessels were recorded through the 40 day marine traffic survey. Ten of which were identified operating on the same day and as part of a long distance yacht race – the *500 Mile North Sea Race*. Therefore recreational vessel numbers per day within the Hornsea Three array are expected to be one or less; or excluding the yacht race one every 1.5 days. On average 11 fishing vessels per day were present within the Hornsea Three array area shipping and navigation study area but were concentrated in general to the northwest of the Hornsea Three array area away from commercial routes.

22.8.2.10 Due to the low level of small craft/vessels likely to be operating within the Hornsea Three array area or in proximity to the commercial vessel routes, encounters and thus collision frequency will be low.

22.8.2.11 Hornsea Three represents an increased minimum spacing between structures when compared against existing developed and planned wind farms. One kilometre spacing is a significant distance in which targets would only be temporarily masked from other approaching vessels noting that the maximum design foundation diameter is 50 m. Considering the spacing and the size of structures it is unlikely that a small craft within or about to exit the Hornsea Three array area would be masked from passing vessels. It is also likely, as per section 22.2.1.1, that vessels would pass more than the conservative 1 nm passing distance assessed. Therefore this impact is assessed to be ALARP.

Visual interference (navigational aids and/or landmarks)

22.8.2.12 Due to the distance of Hornsea Three offshore it is predicted there will be no impacts on existing aids to navigation and/or landmarks. On the contrary it is likely to become a key navigational aid in an area previously devoid of lights and marks to assist passing vessels. This could be of particular benefit to the portion of recreational and small craft that may lack advanced navigational technology; given cost and bridge space.

Encounters and collision risk with operations and maintenance vessels

22.8.2.13 It is anticipated that up to 2,433 round trips for crew transfer vessels will be made between the Hornsea Three array area and base ports during the operation of Hornsea Three (approximately 98 per annum). Aside from personnel transfer there will also be up to four OSVs stationed on site, 312 return supply vessels trips (approximately 12-13 per annum) and up to 87 jack up return trips (approximately 3-4 per annum). As with the construction and decommissioning phase encounters between project and third party vessels are expected to be of a low frequency given the confirmed mitigation measures adopted as part of Hornsea Three (section 23) .

22.8.2.14 Operation vessel visits to the Hornsea Three offshore cable corridor are expected to be negligible and therefore no significant impacts are expected. However measures adopted as part of Hornsea Three and maritime regulations and standard industry practices (including COLREGs (IMO, 1972/77) and minimum safe passing distances) are in place to minimise encounters, near misses and thus allision.

22.8.2.15 Consultation responses from regular operators did not identify any concern for vessels operating in or near Hornsea Three, associated with collision with operations and maintenance vessels.

22.8.2.16 When considered with mitigation measures adopted as part of Hornsea Three (section 23), and the low density of third party vessels operating in the area (meaning low encounters and thus low collision risk), lessons and experience within the industry show negligible impact on encounters and collision risk, the effect for the operation and maintenance phase is assessed to be broadly acceptable.

Hornsea Three offshore HVAC booster stations

22.8.2.17 As final locations for the proposed Hornsea Three offshore HVAC booster stations (surface or subsea) have not been defined it is not yet possible to given a final ranking for a defined location. However three indicative maximum design scenario locations for shipping and navigation have been modelled (based on largest structure in the busiest shipping routes) with the results detailed in section 18. It is assumed that any other design would present a similar or lower allision risk.

22.8.2.18 Scenarios where the Hornsea Three offshore HVAC booster stations have been sited in isolation, pairs or other small groups have not been modelled and may require further consultation with the MCA and TH. It is noted that in 2016 the Hornsea Three offshore HVAC booster station search area was reduced in size to exclude a dense navigational route to the southwest.

22.8.2.19 The location of the Hornsea Three offshore HVAC booster stations will be selected with consideration of the modelling and traffic assessment but also factors influencing other identified receptors. Final agreement will be required with statutory stakeholders as to the location of the Hornsea Three offshore HVAC booster stations, however level of concern as to the location was limited to avoidance of key navigational routes. Fishing and recreational users had no concerns. If the following principles are followed then it is assessed that the risk of collision will be broadly acceptable:

- Will be placed so as to be sympathetic to shipping and within ALARP parameters;
- Aids to navigation should be installed (in consultation with TH) to identify the offshore HVAC booster stations potentially as isolated structure(s); and
- Additional buoyage (in consultation with TH) may be required depending on the number, location and type of the offshore HVAC booster stations.

22.8.2.20 It is assumed that there is no maximum spacing required by the regulators given that each structure, as with oil and gas platforms, can be marked as isolated (noting that the development principles would apply to each of the (up to) six possible locations and that significant cumulative deviations would be avoided). Significant cumulative deviations are not considered likely given that the majority of the main routes identified for the area run at 90° to the search area and with only supply/standby routes (low numbers and low risk vessels) transiting in the same orientation.

Hornsea Three offshore cable corridor

22.8.2.21 As the export cable will be buried or protected there are not anticipated to be any effects associated with increased encounters or collision risk for vessels.

22.9 Cumulative increased encounters and collision risk

22.9.1 Construction and decommissioning phases

22.9.1.1 Cumulatively during the construction and decommissioning of Hornsea Three (and assuming Hornsea Project One and Hornsea Project Two are constructed), the proposed navigational corridor should be assessed to ensure risk or inconvenience to third parties caused by buoyed construction areas is mitigated (as per further mitigation). If there is significant overlap between the Hornsea Three construction area and the proposed navigational corridor there may need to be temporary measures put in place in consultation with the MCA and TH, to ensure that any works on the western edge of the Hornsea Three array area do not adversely impact the safety of third party vessels within the proposed navigational corridor by increasing the risk of encounters.

22.9.1.2 However, it is anticipated that the proposed navigational corridor will be generally available for use by transiting vessels during construction and decommissioning and consideration (in consultation with the MCA and TH) will be given to the size and location of the buoyed construction (or decommissioning) area around the Hornsea Three array area to minimise impacts. It is also likely that marine coordination will be facilitated from a central location for all DONG Energy projects therefore ensuring effective lines of communication and information transfer during all construction, operation and decommissioning phases.

22.9.2 Operation and maintenance phase

22.9.2.1 For the operational phase a separate technical study (Anatec, 2016) was undertaken in consultation with the MCA and TH. The aim of the report was to assess whether the proposed navigational corridor width was adequate for the purposes of navigation.

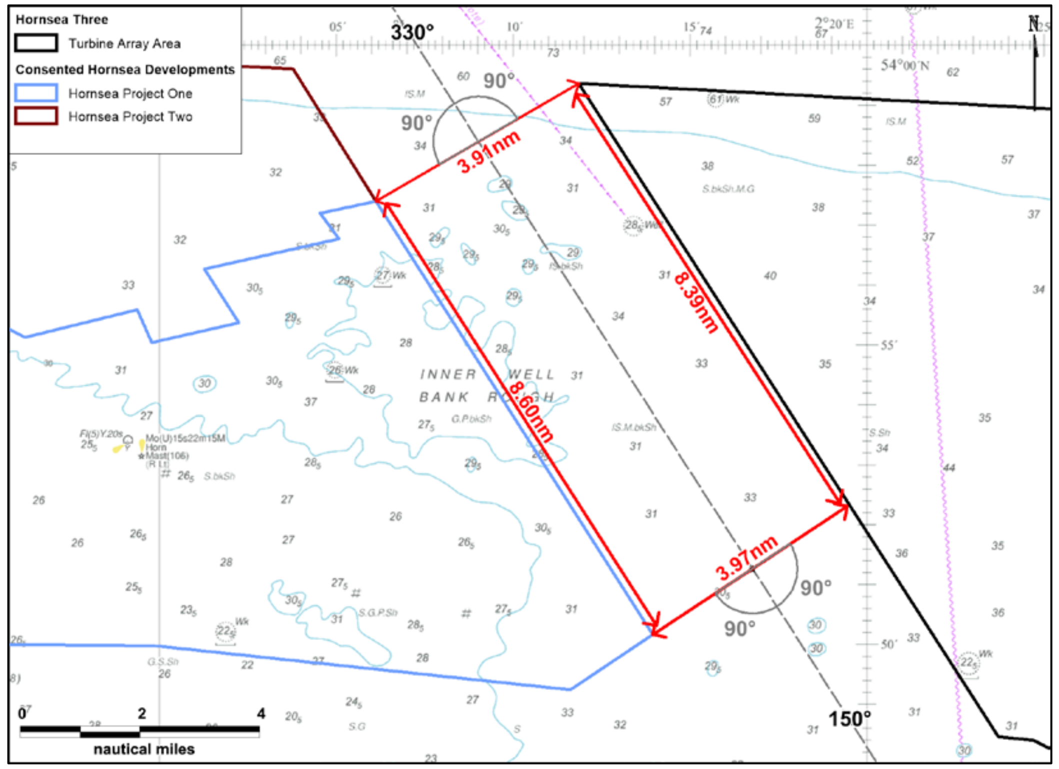


Figure 22.1: Proposed Navigational Corridor.

<u>Radar interference with the navigational corridor</u>

22.9.2.2 MGN 543 states that, dependent on the proximity to turbines and the location of Radar scanners on the super structure, some vessels may experience degradation of the Radar display by false echoes. It may be possible that this will reduce the ability of the bridge team to identify other vessels, including crossing vessels at the extremities of the proposed navigational corridor, which may require avoiding action. It is common to find that the Radar instrumentation is often adjusted to reduce the unwanted interference which can have the effect of reducing actual target acquisition. This effect has been assessed by the MCA and formed the basis of the MGN 543 (MCA, 2016) shipping template. It is noted that since operational wind farms (that were constructed up to 15 years ago) there has been no notable issues raised by mariners that have required the MCA to undertake any further assessment. See section 19.8.

22.9.2.3 Further details are contained within the technical note Assessment of Marine Traffic Corridor Design (Anatec, 2016); however following consideration of the report TH have confirmed that, given the location and indicative traffic numbers, they were content with the proposed navigational corridor (see section 14). The MCA have confirmed that they have no major reservations in relation to the conclusions of the report.

22.9.2.4 Concerns were raised at the Hazard Workshop regarding smaller vessels exiting the wind farm into the proposed navigational corridor; with no regard to Rule 9 of COLREGs (IMO, 1972/77). COLREGS notes that within narrow channels the risk of further vessel to vessel conflict will be consequently increased and therefore requires (COLREGs Rule 9 b-d (IMO, 1972/77)) the following to be adhered to:

- A vessel of less than 20 m in length or a sailing vessel shall not impede the passage of a vessel which can safely navigate only within a narrow channel or fairway; and
- A vessel engaged in fishing shall not impede the passage of any other vessel navigating within a narrow channel or fairway.

22.9.2.5 Given the concern raised, the MCA are currently considering the inclusion of a routeing measure (likely a Deep Water Route given the low number of anticipated vessels) or Fairway Buoys to clearly identify navigational priorities within the proposed navigational corridor. However given the consultation undertaken with Hornsea Three to date, and the additional technical assessment it is considered that based on the current size and orientation of the proposed navigational corridor, the associated risk is ALARP and that additional mitigation would only be required to confirm routeing priorities within its boundaries for small crossing vessels/craft. Any routeing measures would be agreed by the MCA in consultation with UK Safety of Navigation committee before requiring approval by the IMO member states.

Cumulative modelling

22.9.2.6 Based on the existing routeing in the area, Anatec's COLLRISK model has been run to estimate the existing vessel to vessel collision risks within the vicinity of the array areas for Hornsea Project One, Hornsea Project Two and Hornsea Three. The route positions and widths are based on the marine traffic survey dataset and Anatec's ShipRoutes, with the annual densities based on port logs and Anatec's ShipRoutes database, which take seasonal variations into consideration.

22.9.2.7 The annual vessel to vessel collision frequency prior to the installation of Hornsea Three, Hornsea Project One and Hornsea Project Two was 8.62×10^{-3}, corresponding to a major collision return period of one in 116 years.

22.9.2.8 Given the complexity of routeing within the cumulative area and in view of the fact that the Hornsea Project Two layout has been significantly developed, but not yet finalised, following the submission of the Hornsea Project Two Environmental Statement, allision modelling has not been undertaken. However, as part of the zone appraisal and planning process undertaken in 2010/2011, key stakeholders required that an independent assessment into cumulative routeing was undertaken by the three key developers at the time (SMart Wind, East Anglia and Forewind). A report into shipping and navigation was therefore undertaken by the Southern North Sea Offshore Wind Forum (SNSOWF) in 2011 and subsequently updated in 2013 with validated traffic plans and updated zonal plans (Anatec, 2013).

22.9.2.9 During consultation on the SNSOWF report in 2013 no significant concerns were raised in relation to collision risk for the southern North Sea; these assessments include five projects within the former Hornsea Zone development (Anatec, 2013) including a navigational corridor. Given the measures adopted as part of Hornsea Three, the three Hornsea projects considered within the cumulative assessment (Hornsea Project One, Hornsea Project Two and Hornsea Three), the low return period for cumulative collision risk related to those three projects and the results of the cumulative assessment undertaken within the Hornsea Project Two Environmental Statement (SMart Wind, 2015) which ranked the impacts as minor adverse (for a maximum design scenario) the impacts are assessed to be **tolerable with mitigation** (as detailed in section 23).

22.10 Hornsea Three allision risk (external)

22.10.1 Construction and decommissioning phases

Hornsea Three array area

22.10.1.1 Presence of infrastructure within the Hornsea Three array area may cause increased allision risk for passing vessels; however during the construction and decommissioning phase mitigation measures adopted as part of Hornsea Three will be in place to ensure that the risk is maintained within ALARP parameters.

22.10.1.2 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Buoyed construction (decommissioning) area which clearly identifies the location of construction (decommissioning) works and vessels (both for the Hornsea Three array area and the Hornsea Three offshore HVAC booster station/s);
- 500 m construction and 50 m pre commissioning safety zones;
- A Marine Coordination Centre will manage vessel movements associated with Hornsea Three (although command of each vessel remains with each individual Master);
- Extensive promulgation of information.
- Minimum safe passing distance for installation vessels promulgated by notice to mariners, VHF broadcasts and other standard marine methods of communication; and
- Increase vessel presence on site including guard vessels.

22.10.1.3 Experience in wind farm construction for developers, their contractors and the vessel operators is now extensive, with a number of wind farms having been constructed within dense shipping and development areas meaning that standard mitigation measures within the industry are tried and tested. Considering this along with consultation feedback the risk of allision with the Hornsea Three array area during construction is assessed to be **broadly acceptable** with the mitigation measures adopted as part of Hornsea Three in place.

Hornsea Three offshore cable corridor and the Hornsea Three offshore HVAC booster stations

22.10.1.4 As with construction of the Hornsea Three array area, external allision impacts for the construction (or decommissioning) of the Hornsea Three offshore HVAC booster stations are assessed to be **broadly acceptable** with the mitigation measures adopted as part of the Hornsea Three project in place.

22.10.1.5 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Buoyed construction (decommissioning) area clearly identifies the location of construction (decommissioning) works and vessels;
- 500 m construction (or decommissioning) safety zones;
- A Marine Coordination Centre will fully manage vessels movements associated with the installation of the HVACS (although command of each vessel remains with each individual Master);
- Extensive promulgation of information; and
- Minimum safe passing distance for installation and construction vessels promulgated by notice to mariners, VHF broadcasts and other standard marine methods of communication.

22.10.2 Operations and maintenance phase

Hornsea Three array area

22.10.2.1 Presence of infrastructure within the Hornsea Three array area may cause increased allision risk for passing vessels during the operation and maintenance phase.

22.10.2.2 Based on modelling of the revised routeing (see Figure 19.6 and Table 19.2), proposed layouts and local metocean data, the annual powered vessel to structure allision frequency was 9.22×10^{-4}, corresponding to an allision return period of one in 1,084 years.

22.10.2.3 The individual wind farm structure allision frequencies ranged from 5.39×10^{-4} for the turbine located on the south eastern corner of the Hornsea Three array area to negligible for a number of structures located within the centre and to the east of the Hornsea Three array area. Figure 18.8 presents the annual powered allision frequency for each structure, including turbines, offshore HVAC collector substations, offshore HVDC substations and accommodation platforms.

External lighting and marking

22.10.2.4 Layout B presents a worst case for visual navigation (external lighting and marking) externally to the Hornsea Three array area. Layout B demonstrates large internal and external spacing of structures. It is noted that there is no maximum spacing value included within the Design Envelope. This means that the preferred intervals for lighting indicated within IALA 0-139 guidance (IALA, 2013) may not be achievable noting that IALA guidance states that "*in the case of a large or extended windfarm, the distance between Significant Peripheral Structures (SPS) should not exceed 3 nm*". It is noted that an SPS light should also have a 5nm range. Therefore, following consent and once a final layout is decided additional consultation with TH may be required to identify additional lighting requirements. This will be required to ensure that lighting is fully visible around the Hornsea Three array area and may include the need for additional floating aids to navigation, increased light intensity or potential (given the future date of construction) novel technologies with regards electronic aids to navigation.

22.10.2.5 Similar consultation will also be required with the Civil Aviation Authority (CAA); noting that the CAA guidance assumes maximum spacing of 900 m. No consultation feedback has been received by the CAA on this issue (at the time of writing the NRA) but it is anticipated this can be mitigated.

22.10.2.6 Following consideration of the guidance and experience at other developments it is considered that this impact is manageable through post consent consultation to identify additional mitigations; this would mean that spacing above 1 km does not impact on operational (and peripheral) lighting and marking.

22.10.2.7 Layout A presents a worst case for the failure of navigational aids. If a SPS turbine was unexpectedly extinguished, internal or unlit turbines could be exposed to an increased allision risk. However given measures adopted as part of the Hornsea Three project including back up power supplies, Supervisory Control and Data Acquisition (SCADA) systems and Aids to Navigation Management Plans this impact is again expected to be manageable when considered against the frequency of occurrence which would be low given that SPS lights are required to have an IALA category one availability of 99.8% (IALA. 2013). This would mean that Layout A and Layout B are considered acceptable with those mitigations in place for Hornsea Three in isolation.

Offshore HVAC collector substations, accommodation platforms and offshore HVDC platforms

22.10.2.8 Maximum design scenario locations for offshore HVAC collector substations, accommodation platforms and offshore HVDC platforms have been identified within layout A and Layout B. Although these layouts are indicative these platforms may not be placed on the extreme peripheral of the Hornsea Three array area in proximity to dense traffic routes (west, north and south boundaries of the Hornsea Three array area) given the increased allision risk for vessels due to the size of the structure and potential consequences due to the resistant force of the structure compared to the energy of the impact.

22.10.2.9 When considering the maximum design scenario, shipping routes, layouts modelled and with the mitigation measures adopted as part of Hornsea Three in place the impact is assessed to be broadly acceptable.

Hornsea Three offshore HVAC booster stations

22.10.2.10 As with collision risk, allision risk associated with the offshore HVAC booster stations is considered to be acceptable assuming they are located away from key navigational routes. Fishing and recreational users had no concerns. The maximum design scenario could include up to four surface Hornsea Three offshore HVAC booster stations. If the following principles are followed then the risk is assessed to be broadly acceptable.

- Will be placed so as to be sympathetic to shipping and within ALARP parameters;
- Aids to navigation should be installed (in consultation with TH) to identify the offshore HVAC booster stations potentially as isolated structure(s); and
- Additional buoyage (in consultation with TH) may be required depending on the number, location and type of the offshore HVAC booster stations.

Surface structures

22.10.2.11 Surface allision modelling has been undertaken and shows that all selected locations were within acceptable parameters. Final consultation with the MCA, TH and any other directly impacted receptors shall be undertaken.

Subsea structures

22.10.2.12 Presence of subsea HVAC booster stations within the Hornsea Three offshore cable corridor may increase vessel to subsea structure allision risk for commercial vessels, recreational users and commercial fishing vessels; the assessment of this risk will depend on the final location of the subsea HVAC booster stations.

22.10.2.13 Following identification of both a location and layout of the (up to) six subsea HVAC booster stations, an UKC allision assessment shall be undertaken. TH have indicated that a surface buoy (likely per structure) will be required where the UKC is less than 30 m; but again as with consultation on the surface HVAC booster stations they should follow the same principles and not be located in areas of dense shipping activity.

Hornsea Three offshore cable corridor

22.10.2.14 A Cable Burial Risk Assessment shall be undertaken to ensure that any protection methods used for the Hornsea Three offshore cable corridor do not present an unacceptable UKC impact for small craft in the nearshore area or cable crossing. This was especially raised as a concern by the RYA and recreational impacts shall be considered during the Cable Burial Risk Assessment, pre-construction.

22.10.2.15 To prevent impacts on navigational equipment post installation Hornsea Three will ensure that electromagnetic interference is mitigated by cable burial, water depth or cable protection.

22.11 Hornsea Three allision risk (not under command (NUC))

22.11.1 All phases

Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.11.1.1 Presence of infrastructure within the Hornsea Three array area and Hornsea Three cable corridor including the offshore HVAC booster station(s) will increase allision risk to vessels NUC in an emergency situation (including machinery related problems or navigational system errors). However given incidents statistics (within section 13.4), lessons learnt from other offshore wind farms and modelling results which indicate 1 allision incident every 1,369 in relation to the Hornsea Three array area for a worst case weather assisted NUC vessel, this impact is considered to be of low frequency.

22.11.1.2 Given this low frequency and the increased presence of vessels (including OSVs during the operational phase) able to render assistance at Hornsea Three this impact is considered ALARP. Although not specified within the Design Envelope it is assumed that there will be vessel support on site throughout the majority of the operational phase to help ensure that all emergency response impacts can be effectively managed.

22.11.1.3 Considering this along with consultation feedback, the risk of allision within the Hornsea Three array area during operation and maintenance is assessed to be broadly acceptable with mitigation measures adopted as part of the Hornsea Three project in place.

22.12 Hornsea Three allision risk (cumulative)

22.12.1 All phases

Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.12.1.1 Following assessment of the change to baseline assessed as part of the cumulative assessment (as per section 21) it has been identified that the development of Hornsea Project One, Hornsea Project Two, Hornsea Three and the presence of the Schooner platform has the potential to cumulatively impact on navigational transits and thus allision risk. The following effects and mitigations (where required) have been identified.

Alignment either side of the proposed navigation corridor.

22.12.1.2 In order to facilitate vessel transits within the proposed navigational corridor, turbines adjacent to the proposed navigational corridor must be approximately aligned as per the indicative layouts A and B. Where feasible, options for sequences of lighting and marking (of the proposed navigational corridor) with the Hornsea Three array area and Hornsea Project One and Hornsea Project Two array areas may be considered. It is noted that significant concave or convex sections can cause negative effects on marine Radar and visual navigation by obscuring or preventing position fixing. When defining layouts the Applicant will give full consideration to cumulative issues caused by structures along the edge of the navigational corridor.

Cumulative lighting and marking within the proposed navigation corridor

22.12.1.3 As well as lighting and marking within the proposed navigational corridor, all cumulative lighting must be considered in order to minimise any potential effects and avoid confusion from the proliferation of aids to navigation in a high density development of turbines. The mariner will use SPS lights (similar to entering a port) to navigate with, including fixing their position. Following agreement on the final layout post consent a user group should be established, in consultation with TH, to identify those aids to navigation which best aid navigation within the proposed navigational corridor.

22.12.1.4 Full consideration should be given to the use of different light characters and varied light ranges. Lighting and marking will be discussed with TH in conjunction with the relevant guidance (IALA, 2013). Therefore, when defining layouts, the Applicant will give full consideration to cumulative issues caused by lighting and marking.

Vessels NUC within the proposed navigational corridor

22.12.1.5 Within the proposed navigational corridor emergency anchoring (dependent on the vessel's speed) could be used to prevent allision with a structure. Apart from a pipeline (linked to the Topaz subsea well head) within the northeast sector of the corridor, the corridor is hazard free which will generally allow safe anchoring. A vessel will have emergency anchoring procedures for areas where there might be subsea hazards (such as port approaches), and these procedures would be likely to be used within the proposed navigational corridor. It is noted that Rule 9 of COLREGs (IMO, 1972/77) prevents anchoring within a narrow channel under normal conditions. It is also noted that the operator of the Topaz subsea well head has confirmed that the well head is no longer producing and that the pipeline will be decommissioned (possibly in-situ) prior to the construction of Hornsea Three.

22.12.1.6 For other types of emergency incidents it is noted that Hornsea Project One, Hornsea Project Two and Hornsea Three will all be significant marine operations, with each including a variety of support vessels during the construction and operational phases that will be able to provide emergency support (noting potential downtime during periods of adverse weather).

Differing design envelopes

22.12.1.7 Hornsea Project One and Hornsea Project Two, given the time at which they were assessed, included different design envelopes to that proposed for Hornsea Three. Turbines on opposing sides of the proposed navigational corridor are therefore to be designed so as to be sympathetic to shipping using the proposed navigational corridor (not impacting on navigation including Radar, visual navigation and position fixing of navigating vessels).

Floating foundations

22.12.1.8 Mooring lines and/or anchors used on floating foundations shall not protrude into the agreed area (see 22.9) for the proposed navigational corridor. Following final site design, TH may require additional aids to navigation to define the edge of any subsea / under keel hazards.

22.12.1.9 Considering the mitigation measures adopted as part of Hornsea Three, the "in isolation" modelling results and the consultation responses over the various developments within the former Hornsea Zone, cumulative allision risk external (external meaning risk to passing vessels) to the wind farm arrays is assessed to be **Tolerable with Mitigations** (see section 23 for mitigation measures adopted as part of Hornsea Three).

22.13 Hornsea Three allision risk (internal)

22.13.1.1 A key concern raised during consultation with the MCA and TH is the risk posed by the irregularity of Layout A and Layout B.

22.13.1.2 MGN 543 states that "In order to minimise risks to surface vessels and/or SAR helicopters transiting through an OREI, structures (turbines, substations etc) should be aligned and in straight rows or columns. Multiple lines of orientation provide alternative options for passage planning and for vessels and aircraft to counter the environmental effects on handling i.e. sea state, tides, currents, weather, visibility etc. Developers should plan for at least two lines of orientation unless they can clearly demonstrate that fewer is acceptable" (MCA, 2016).

22.13.1.3 For the purpose of assessment of shipping and navigation impacts for the Hornsea Three EIA, surface craft and SAR helicopters impacts are being considered in two separate technical reports.

- Surface craft are considered within the main section of this NRA; and
- SAR helicopters have been considered separately by a specialist within appendix C of this NRA.

22.13.2 Construction and decommissioning phases

Hornsea Three Array Area

22.13.2.1 The presence of infrastructure within the Hornsea Three array area may cause an increase in allision risk for vessels navigating internally in the Hornsea Three array area; however during the construction and decommissioning phase measures adopted as part of Hornsea Three will ensure that the risk is within tolerable limits.

22.13.2.2 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Buoyed construction (decommissioning) area clearly identifies the location of construction (decommissioning) works and vessels;
- For areas where active platform or turbine construction (or decommissioning) activities are occurring 500 m safety zones will be in place to protect both construction and third party vessels. 50 m pre-commission safety zones will also be used to ensure users are aware of the risk associated with approaching pre-commissioned turbines;
- Marine Coordination Centre – the centre will fully manage vessels movements associated with Hornsea Three (although command of each vessel remains with each individual Master); and
- Extensive promulgation of information.

22.13.2.3 Experience of wind farm construction for developers, contractors and vessel operators is now extensive, with a number of operational wind farms located within dense shipping areas. Hornsea Three shall be monitored throughout construction by the Marine coordination Centre using VHF and AIS but also through the presence of construction (or decommissioning) vessels. Currently Hornsea Three is out with the Global Maritime Distress and Safety System (GMDSS) sea area A1, but is within sea area A2 meaning that only Medium Frequency (MF) calling or satellite communications are available (see Figure 22.2).

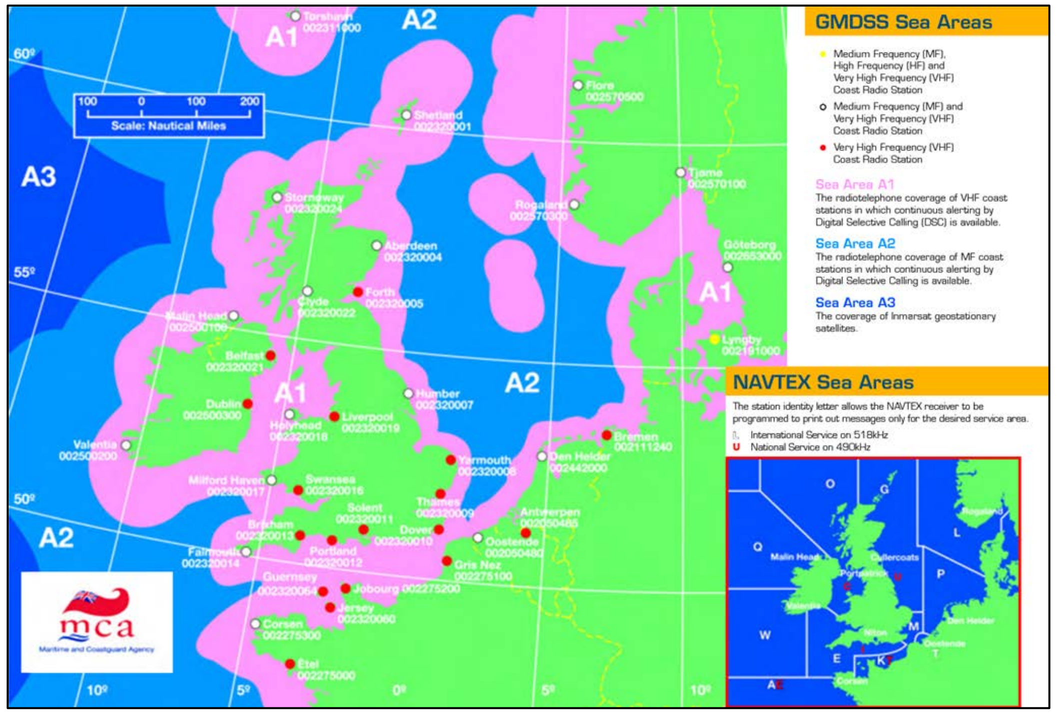


Figure 22.2: GMDSS Sea Areas.

22.13.2.4 However Medium Frequency (MF) and satellite communications are not generally carried by recreational vessels or other smaller vessels due to the high cost of equipment. Therefore the presence of the Marine Coordination Centre, offshore VHF aerials, AIS receivers and the presence of onsite construction vessels (or decommissioning vessels) will provide benefits for communication, monitoring and SAR. Should a vessel on site require assistance, then Hornsea Three vessels, including under SOLAS obligations, are beneficially placed to provide information and assets including navigational information (including weather forecasting) and safety support.

22.13.2.5 When considering the mitigation measures adopted as part of Hornsea Three, and the positive effects associated with the presence of the Hornsea Three array area, the risk of allision within the Hornsea Three array area during construction is assessed to be broadly acceptable.

22.13.3 Operation and maintenance phase

Hornsea Three Array Area

Project vessels

22.13.3.1 Any vessel and crew present within the Hornsea Three array area during the operations and maintenance phase shall have a level of competence pre determined by the Hornsea Three Safety Management Systems (SMS) and their own flag state regulations. It is noted that, given the size of vessels required for the distance offshore of the Hornsea Three array area (65.3 nm), all vessels including small crew transfer vessels will be under the command of experienced mariners, more so than previously seen at offshore wind farm developments closer to the coast given vessel certification and coding requirements. MGN 280 *Small Vessels in Commercial Use for Sport or Pleasure, Workboats and Pilot Boats – Alternative Construction Standards* (MCA, 2004) requires vessels operating over 60 nm from a safe haven to be category 1 or 0 vessels (scale is 6 to 0, with 6 being the lowest level of capability). When considering this in combination with the level of knowledge the vessel crew will have about the array design, marine coordination, and the previous low frequency of allision for internal navigation involving project vessels the impact are assessed to be ALARP.

Third party vessels

22.13.3.2 Regular operators were consulted as part of the NRA process and were asked to indicate whether they would enter the Hornsea Three array area or would navigate around it. Of those that responded, including during the Hazard Workshop, the majority indicated that they would not enter the Hornsea Three array area in part due to the small deviations that would be required in order to avoid it (as part of the entire journey and considering speed reduction they would likely make to enter the Hornsea Three array area (as with a port entrance channel)). When considering this alongside lessons learnt from other wind farms where negligible levels of commercial vessels have been recorded passing through arrays it is considered extremely unlikely that a commercial vessel would enter the Hornsea Three array area. It is noted that that in other countries (such as the Netherlands) commercial vessels are excluded from entering offshore wind farms by the regulatory authority. This option has however not been employed by the MCA, who prefer that vessels make their own risk assessment using guidance such as MGN 372 (MCA, 2008).

22.13.3.3 The maximum design scenario foundation considered for the Hornsea Three array area are floating foundations with catenary mooring lines and anchors extending up to 1,000 m from the foundation. The use of this foundation would be a factor for the Masters of vessels, with larger draughts, to consider before entering the Hornsea Three array area.

22.13.3.4 The SAR guidance annexed to MGN 543 (implemented December 2016) notes SOLAS (IMO, 1974) obligations for third party vessels and the potential need for vessels to enter wind farm array areas to render assistance. It notes "*International practice for SAR response to persons in distress at sea includes alerting and notifying the nearest vessel(s) (this includes small vessels e.g. fishing vessels and leisure craft) to an incident location, and asking them to render assistance in accordance with the SOLAS regulations"* (MCA, 2016).

22.13.3.5 The following list identifies the maximum number of accommodation platforms and vessels on site during operation:

- Up to three accommodation platforms or up to four OSVs which are likely to carry daughter craft;
- Up to 20 CTVs;
- Supply Vessels which are likely to carry daughter craft; and
- Marine Traffic Coordination 24/7.

22.13.3.6 Although not specified within the Design Envelope it is assumed that there will be vessel support on site throughout the majority of the operational phase that will help to ensure that all emergency response impacts can be effectively managed. Hornsea Three also plan to use helicopters on a regular basis and will have advanced medical provision on site.

22.13.3.7 When considering Hornsea Three resources on site against the low number of third party vessels in the area it is highly probable that Hornsea Three project vessels would be the first to render assistance in the event of an emergency. It is therefore considered extremely unlikely that a third party vessel would need to enter the Hornsea Three array area under any SOLAS (IMO, 1974) obligation. The risks associated with the requirement for third party vessels being required to render assistance are therefore considered negligible and ALARP.

22.13.3.8 Given the 1 km spacing between structures within the Hornsea Three array area, it is assessed (based on known manoeuvring and expert opinion) that navigational safety within the Hornsea Three array area will be improved compared to other consented, under-construction, or operational wind farms. The following table lists minimum spacing from consented wind farms or wind farms that are within the consent process with MCA and TH approval. It is noted that the minimum internal spacing committed to is significantly larger than other round three developments giving vessels more sea room to navigate and manoeuvre within the Hornsea Three array area (when considering turning circles and rate of turn).

Table 22.1: Minimum spacing at other projects.

Project	Minimum spacing used within the NRA (m)	Increase in spacing at Hornsea Three (minimum of 1,000 m)
Hornsea Project Two	924	8.23%
Hornsea Project One	878	13.9%
East Anglia One	675	48.15%
East Anglia Three	675	48.15%
Rampion	600	66.67%
London Array (round two wind farm)	650	53.85%

Experience at an existing offshore wind farm

22.13.3.9 London Array offshore wind farm is an example of a wind farm that was consented constructed and is currently operational with recreational and fishing activity. The following figures show a year of AIS data analysed to extract fishing and recreational vessels (carrying AIS).

22.13.3.10 Fishing and recreational data AIS was identified from AIS data collected between 1 March 2016 and 28 February 2017 (365 days) within the London Array offshore wind farm site boundary (Figure 22.3).

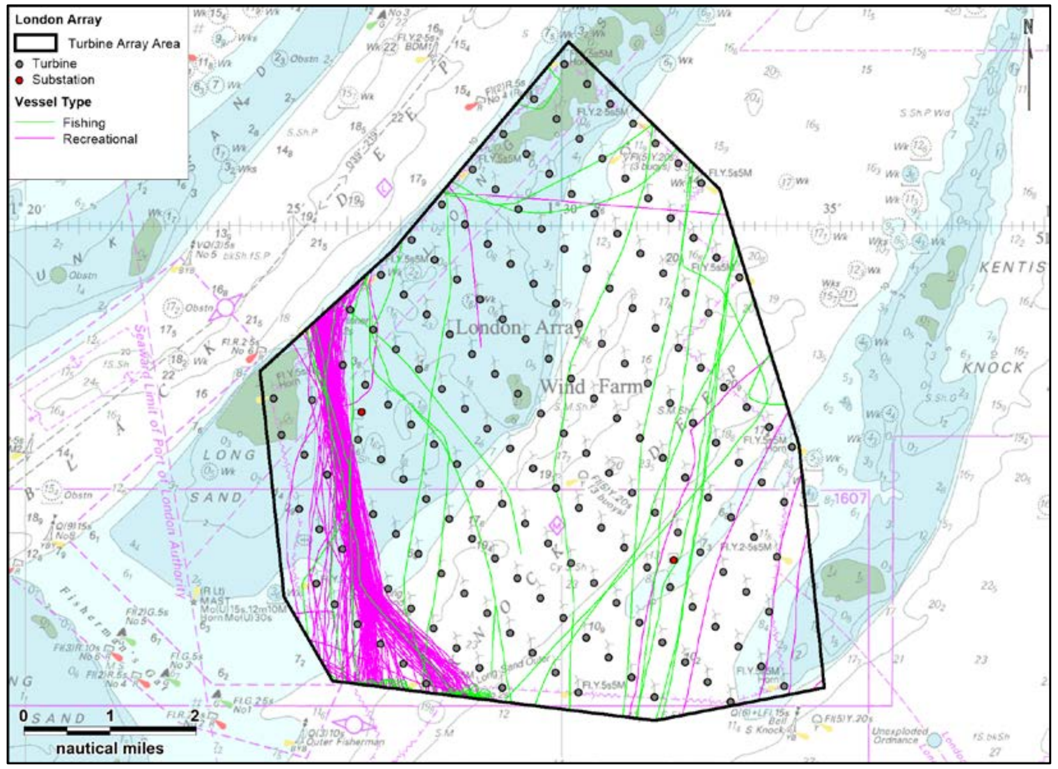


Figure 22.3: London Array offshore wind farm – fishing and recreational movements over one year (AIS only).

22.13.3.11 It is noted that London Array offshore wind farm was consented within a busy and seasonal area for small craft and a specific buoyed navigation channel (Fouglars Gat) was designed (in the position of an existing preferred route). This is illustrated in Figure 22.5 which shows recreational vessels only.

22.13.3.12 During a year 140 unique recreational transits were recorded within the London Array offshore wind farm site boundary. Only eight vessels did not use Fouglars Gat for the majority of their transit. Of those eight tracks and those that did not fully stay within Fouglars Gat it can be seen that they also do not opt to remain fully within the available straight lines of orientation.

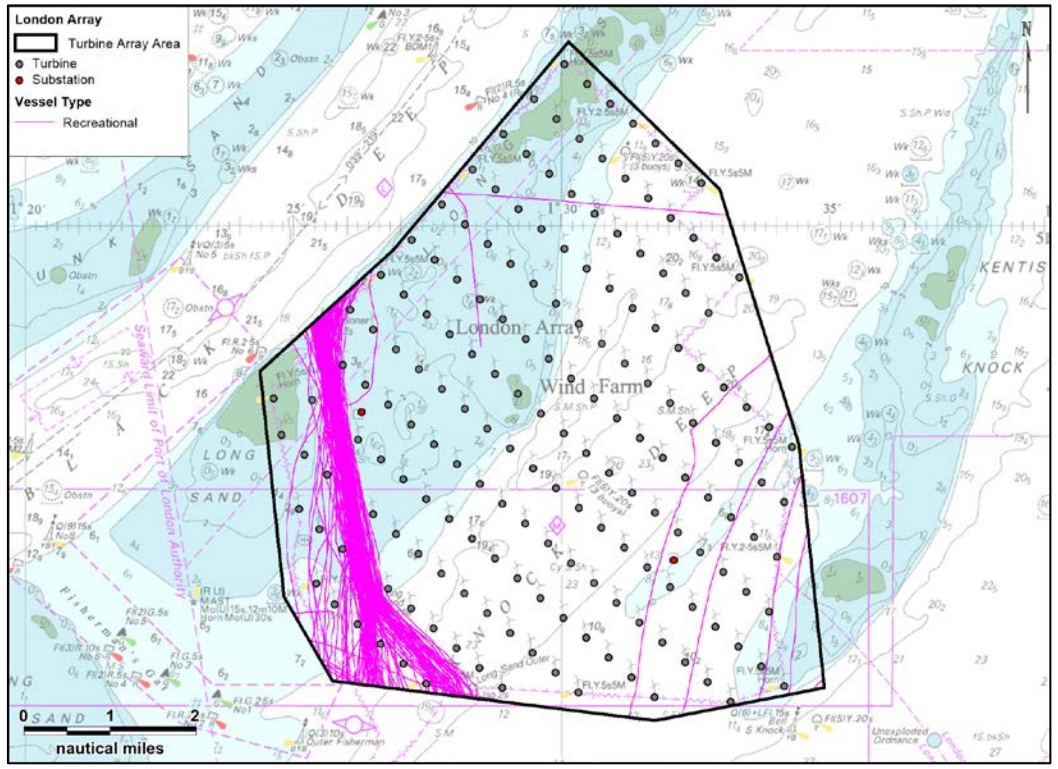


Figure 22.4: London Array offshore wind farm – recreational movements over one year (AIS only).

22.13.3.13 When looking at fishing vessels in isolation (Figure 22.6) only 32 unique fishing vessel transits were recorded within the site boundary throughout the year. Of the 49 tracks recorded, 26 were engaged in fishing near the southern boundary; the remaining 23 were passages through the London Array turbine area, with vessels not, in the majority, following the main lines of orientation. It is noted that London Array contains monopile wind turbines which do not present a UKC allision risk.

22.13.3.14 Similar buoyed channels or additional international aids to navigation for use by recreational users and other small craft could be considered at Hornsea Three in consultation with the MCA and TH, and key recreational users dependant on the final layout selected.

22.13.3.15 Turbines have the potential to affect vessels under sail when passing through the Hornsea Three array area from effects such as wind shear, masking and turbulence. From previous studies of offshore wind farms it was concluded that turbines do reduce wind velocity by an order of 10% downwind of a turbine (RYA, 2015). The limited spatial extent of the effect is not considered to be significant, and similar to that experienced when passing a large vessel or close to other large structures (e.g. bridges) or the coastline. In addition, practical experience to date from RYA members taking vessels into other offshore wind farm sites indicates that this is not likely to be a significant issue.

22.13.3.16 Given mitigation measures adopted as part of the Hornsea Three project and the potential for additional aids to navigations, the impact on internal navigation is considered **tolerable with mitigation** and ALARP.

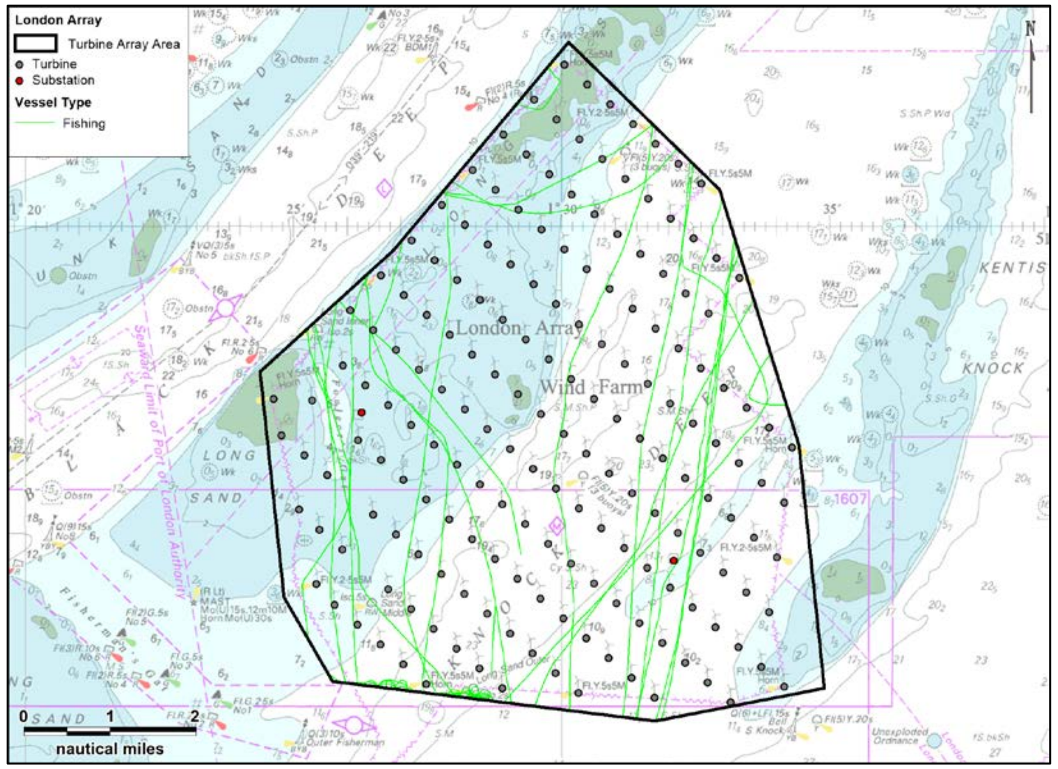


Figure 22.5: London Array offshore wind farm – fishing vessel movements over one year (AIS only).

Under keel allision risk internal to the Hornsea Three array area

22.13.3.17 Floating foundations present an under keel allision risk for vessels. The RYA requires a minimum of 4 m clearance for all subsea hazards and assumes catenary mooring systems should therefore touch down on the seabed as close as possible to the foundations. It is noted there are low levels of recreational craft and commercial vessels not anticipated to enter the array; however given the limited understanding of floating foundations, no commitment can be made at this stage to ensure that a minimum of 4 m under keel clearance is maintained and subsequently floating foundations present a significant risk to vessel navigating. Therefore under keel allision risk internally within the array is not considered to be ALARP. The issue is also considered in more detail in volume 5, chapter 6: Commercial Fisheries.

Increased internal allision for fishing and recreational craft

22.13.3.18 The presence of infrastructure within the Hornsea Three array area may increase vessel to structure allision risk internally within the Hornsea Three array area for commercial fishing vessels. Given the size of the jacket foundations used within the fishing allision modelling (25×25 m) and the density of fishing, the estimated allision frequencies are considered medium when compared to other areas of the UK and reflect the maximum target size assumed for all the structures at Hornsea Three based on jacket foundations and other structures such as accommodation platforms. The fishing allision model also assumes the fishing vessel density following development will remain the same as current levels. However, consultation with fishing representatives has indicated that they would not trawl within the Hornsea Three array area if mooring lines and anchors extending up to a 1,000 m from the floating foundation were present across the full extent of the array area, given the risk (snagging) of underwater hazards.

22.13.3.19 During consultation, the Dutch Fishing Association VISNED noted that under the following circumstances fishing, including trawling and fly-shooting would be possible in amongst the indicative Layout A: *"if the weather is ok, if the fish are still present, in areas where turbine foundations are not floating and the distance between turbines is ≥1 km. For fishing, the separation between turbines is more important than the regularity of the layout".* It is noted that Dutch fishing vessels (including those flagged in the UK) are predominant in the area. VISNED also noted that in good weather fishing vessels are likely to transit through the wind farm. Further information is contained within volume 2, Chapter 6: Commercial Fisheries. In order to reduce risk associated with fishing activity within the Hornsea Three array area, further consultation is required, but it is assumed from a navigational perspective that fishing risk would be ALARP if fishing vessels do not fish within close proximity to mooring lines used as part of the floating foundation design. However, in order to ensure vessels do not enter the Hornsea Three array area when it is not safe to do so (given underwater hazards) additional measures may need to be discussed with the MCA and the owners of fishing vessels known to be active within the area to fully mitigate. Other foundation types would be assumed ALARP based on the minimum 1 km spacing.

22.13.3.20 As noted MCA guidance states "*that in order to minimise risks to surface vessels and/or SAR helicopters transiting through an OREI [sic], structures (turbines, substations etc.) should be aligned and in straight rows or columns*" and "*the developers (the Applicant) should plan for at least two lines of orientation unless they can clearly demonstrate that fewer is acceptable*" (MCA, 2016).

22.13.3.21 Assuming that catenary floating foundations are not used and looking at the issue of surface craft navigating within the array, the following factors gathered from consultation, the Hazard Workshop and marine traffic survey results make the case that Layout A and Layout B will be tolerable with mitigation (listed within section 23).

- Predicted levels of transiting vessels (recreational and commercial fishing) will be low compared to other constructed and/or consented wind farms;
- While levels of fishing activity are high within some areas of the Hornsea Three array area, this will vary seasonally and annually. Some commercial fisheries representatives have indicated that their main concerns are over the foundation type used and the spacing rather than the alignment. Feedback from fishermen indicates that, if floating foundations were used, fishing vessels could not fish within the Hornsea Three array area. Overall, the majority of risk associated with internal navigation is related to vessels engaged in fishing, noting that in consultation the MCA stated that vessels engaged in fishing are out with their navigational safety remit;
- Demersal trawlers active within the array area are expected to target specific fishing grounds, meaning that it is unlikely that the skippers would choose to fish along fixed lines of orientation;
- Consultation indicates that commercial vessels (in transit) will not navigate through the Hornsea Three array area;
- The RYA stated that given the very low level of recreational traffic within the Hornsea Three array area, they had no express concerns with either Layout A or Layout B;
- The CA confirmed their general policy that wind farm layouts should have "straight see-through channels between the turbines" while recognising that the Hornsea Three array is in an area of very light yachting and recreational traffic. The CA confirmed that the penalty of not having straight see-through channels at Hornsea Three "may prove minimal and therefore acceptable to many". The CA also noted that the penalty of extra time and distance incurred as a result of avoiding the Hornsea Three array area would mostly be minimal and thus it is likely that yachts and recreational craft which would theoretically need to sail through may at the time of passage choose to avoid or be in a position where they should avoid the Hornsea Three array area;
- The CA stated a preference for additional aids to navigation to be provided within the array;
- Marine traffic survey data shows very low recreational vessel movements (especially when excluding the *500 Mile North Sea Race*) and those that were in the area would be well equipped and experienced (given the distance offshore);
- Aids to navigation similar to those deployed at the London Array OWF could be used at the Hornsea Three array area to assist third party internal navigation;
- Visibility is generally good or very good at the Hornsea Three array area. Appendix C of volume 5, annex 7.1: Hornsea Three Array Area, Offshore Cable Corridor and Offshore HVAC Booster Station Search Area Navigational Risk Assessment includes further detail on visibility. The total percentage of time that the visibility is below 2 km is 1.3%;
- Cumulatively no other development will border the Hornsea Three array area;
- It is unlikely that third party vessels will be required to perform SOLAS obligations within the Hornsea Three array area, given that Hornsea Three vessels are likely to be present on site;
- The Hornsea Three array area is largely out with the operational area for the RNLI and the MCA do not operate any surface craft assets within the southern North Sea.

22.13.3.22 With catenary mooring floating foundations the risk would be considered unacceptable unless under keel clearance could be guaranteed.

22.13.3.23 SAR helicopters are considered separately in Appendix C.

22.13.3.24 Given that this NRA is only able to consider indicative layouts, the following table identifies elements that should be considered when assessing site layout post consent, again excluding consideration for helicopter-based SAR operations. Table 22.2 identifies potential issues identified, risk ranking for indicative maximum design scenario Layout A and proposed mitigation for layouts to bring the effects into ALARP parameters. The information presented in this table can be used to inform post-consent layout designs.

Table 22.2: Effects associated with navigation internally within the Hornsea Three array area.

Issue	Receptor and frequency of receptor	Sources considered	Risk and proposed mitigation
Impact of 1 km minimum spacing for all structures on Internal Navigation	Recreational Craft – Low Frequency User	No negative responses were received by recreational consultees. 1 km spacing would allow recreational craft to manoeuvre between structures given the maximum size of 24 m for recreational vessels (as per EU regulations). Identification methods for structures currently required by standard guidance were considered sufficient.	No further mitigation associated with minimum spacing required, draft DCO shall state minimum of 1 km between all structures.
Impact of 1 km minimum spacing for all structures on Internal Navigation	Commercial Fishing Vessels – Medium frequency over the Hornsea Three array area	Commercial fishing favoured fewer larger turbines and noted that the separation between turbines is more important than the regularity of the layout. VISNED indicated that certain configurations of mooring lines and anchors associated with floating foundations would be spatially incompatible with ongoing demersal trawling operations.	No further mitigation associated with minimum spacing required, draft DCO shall state minimum of 1 km between all structures. It is noted that the presence of mooring lines would be spatially incompatible with demersal trawling given the high risk of gear snagging. This is considered separately in volume 2, chapter 6: Commercial Fisheries. Catenary mooring will required additional consideration and mitigation.
Impact of no maximum spacing for structures for internal navigation	Recreational Craft – Low Frequency User	At >1 km spacing recreational craft may not be able to identify low level ID lighting of the next turbine that they are approaching. Therefore additional aids should be considered. Given the increased spacing and navigational information that will be provided for Hornsea Three, recreational vessels will have greater navigational knowledge, as well as space to sail and manoeuvre. Based on the shipping template within MGN 543, the turbine will be more visible with fewer echoes on marine Radar systems. Consultation raised no concerns about maximum spacing but the CA did note that Layout B was a preference.	No further mitigation associated with maximum spacing required, draft DCO shall state no maximum spacing.
Impact of no maximum spacing for structures for internal navigation	Commercial Fishing Vessels – Medium frequency over the Hornsea Three array area	Given the large spacing and increased navigational information that will be provided for Hornsea Three commercial vessels will have access to greater knowledge about the site, space to fish and manoeuvre. Consultation noted that fishing vessels prefer the largest spacing possible.	No further mitigation associated with maximum spacing, required, draft DCO shall state no maximum spacing. It is noted that the presence of mooring lines would be spatially incompatible with demersal trawling given the high risk of gear snagging. This is considered separately in volume 2, chapter 6: Commercial Fisheries.
Impact of exposure to turbines	Recreational Craft – Low Frequency User	Exposure is defined when a vessel is on a transit with turbines on either side of it within a "row" and that will then potentially create effects as identified within the shipping template (Radar impacts within 1 nm). Time spent within the Hornsea Three array area and in proximity to structures will increase risk to vessels. At >1 km spacing exposure and thus effects will be significantly reduced compared to transits through existing wind farms with smaller spacing.	The greater the spacing and non-alignment of turbines the lower the exposure time. Layout B posed less exposure than Layout A given the increased spacing between turbines.
Impact of exposure to turbines	Commercial Fishing Vessels – Medium Frequency User over the Hornsea Three array area		
Impact of Structure (including turbine) alignment	Recreational Craft – Low Frequency User	Non-alignment within a row is considered to be a non-grid layout where turbines are converging or diverging. RYA noted no concerns regarding the misaligned turbines that comprise Layouts A and B given the low frequency. CA noted that they preferred alignment but agreed with the low frequency. CA also notes that increased spacing mitigates some of their concerns over alignment. Non-alignment can create confusion / disorientation within the Hornsea Three array area. Hornsea Three will provide navigational information via its marine coordination centre to assist. Stakeholders did not raise any concern between alignment and allison risk. It is noted that the excursion of floating turbines may change the risk ranking of any layout. Given the increased size of other structures (such as substations and accommodation platforms), there are not anticipated to be any impacts from these structures being out of alignment, given that they will provide good aids to navigation for surface craft and be visible from a greater distance.	No further mitigation required. Increased spacing inversely decreases the impact of misalignment. Recreational vessels are very low frequency within Hornsea Three and therefore the risk of a vessel becoming disorientated (when considering measures adopted as part of Hornsea Three) is negligible. There is no evidence to suggest that misalignment will directly affect allision risk but that misalignment could cause inconvenience by vessel operators becoming disorientated. Therefore if additional mitigations are in place to aid navigation the change in safety risk is assumed negligible.

Issue	Receptor and frequency of receptor	Sources considered	Risk and proposed mitigation
Impact of Structure (including turbine) alignment	Commercial Fishing Vessels – Medium frequency over the Hornsea Three array area	Fishing consultation noted that under the following circumstances fishing, including trawling and fly-shooting would be possible in amongst the indicative Layout A - "*if the weather is ok, if the fish are still present, in areas where turbine foundations are not floating and the distance between turbines is ≥1 km*". For fishing, the separation between turbines is more important than the regularity of the layout. Given the increased size of other structures, there are not anticipated to be any impacts from these structures being out of alignment, given than they will provide good aids to navigation for surface craft.	Fishing vessels are medium frequency but have a greater level of concern of floating foundations which would permanently exclude fishing from the Hornsea Three array area. Further mitigation (not yet defined) may be required depending on foundation selected. As with recreational craft increased spacing inversely decreases the impact of misalignment.

22.13.3.25 Given that Hornsea Project One and Hornsea Project Two do not directly border the Hornsea Three array area, there are not anticipated to be any impacts with cumulative internal alignment.

22.14 Gear snagging (navigational safety risk)

22.14.1 Construction and decommissioning phases

Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.14.1.1 The physical presence of partially installed cables (which may be exposed or partially buried) and other subsea infrastructure will present an increased risk of gear snagging for commercial fishing vessels with worst case consequences associated with vessel foundering, and realistic consequence of gear loss.

22.14.1.2 A foundering is considered to be when a vessel suffers structural failure and sinks. This type of incident has the potential to damage a subsea cable if the vessel sinks over the cable. It is noted that this type of incident is considered to have a very low frequency based on historical incident data for the UK (from 1994-2008 approximately 4% of all MAIB incident types were listed as flooding/foundering).

22.14.1.3 The presence of mitigation measures adopted as part of Hornsea Three mean that the risk is assessed as tolerable with mitigation; noting the issues with under keel clearance and catenary moorings in section 22.13.

22.14.1.4 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Buoyed construction (decommissioning) area clearly identifying the location of construction (decommissioning) works and vessels;
- 500 m construction and 50 m pre commissioning safety zones;
- Marine Coordination Centre – the centre will fully manage vessels movements associated with Hornsea Three (although command of each vessel remains with each individual Master);
- Extensive promulgation of information;
- Guard vessel to protect exposed cable; and
- Minimum safe passing distance for installation and construction vessels promulgated by notice to mariners, VHF broadcasts and other standard marine methods of communication.

22.14.1.5 Any areas of temporarily exposed cable or sand/gravel berms should be additionally marked and promulgated in consultation with the MCA and TH.

22.14.1.6 During decommissioning any cables that are left in situ must be risk assessed to ensure that they will not pose any continued impact on vessels engaged in fishing.

22.14.2 Operation and maintenance phase

Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.14.2.1 Presence of cables (if exposed at seabed) and other subsea infrastructure will present a gear snagging risk for fishing vessels.

22.14.2.2 Any risks associated with the Hornsea Three offshore export cable corridor shall be assessed as part of the Cable Burial Risk Assessment. Periodic follow-on monitoring will confirm whether the export cable remains buried and/or protected from fishing activity within the area.

22.14.2.3 Consultation with fishing representatives noted significant concern with floating foundation, noting that it would likely exclude fishing vessels due to high consequence.

22.14.2.4 Using site-specific marine traffic survey data as an input to Anatec's COLLRISK fishing risk model, the annual fishing vessel to structure allision frequency was estimated for Layout A. The annual fishing vessel to structure allision frequency was 1.88×10^{-1}, corresponding to an estimated allision return period of one in 5.33 years. The output of the fishing model is considered to be conservative as it assumes that fishing activity will not change post consent.

22.14.2.5 VISNED confirmed that a gear snagging incident could be far more serious if the interaction occurred with mooring lines tethering a floating foundation, rather than a monopile, noting that the chances of "un-snagging" the gear would be limited in the case of mooring lines. It is indicated that demersal trawling would not be possible between floating turbines arranged according to indicative Layout A where mooring lines extend 1 km from each floating turbine.

22.14.2.6 Gear snagging during operation is assessed to be **tolerable with mitigation** (section 23), noting that further consultation is required with respect to floating foundations in view of the fact that stakeholders have indicated that demersal trawling would be spatially incompatible with the presence of mooring lines. As this is not related to navigational safety this is considered further within the Commercial Fisheries chapter.

22.15 Anchor snagging

22.15.1 All phases

Hornsea Three array area, Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations

22.15.1.1 Floating foundations are considered the maximum design scenario foundation type for shipping and navigation receptors. The mooring lines and anchor lines pose a risk to a vessel anchoring. However, it is anticipated that anchoring during either construction or operation will be of low frequency.

22.15.1.2 There were no vessels anchoring within the Hornsea Three array area during the marine traffic surveys, therefore given that the potential for a vessel to anchor in the array area is low; impacts on vessels anchoring are expected to be negligible. Anchoring in an emergency will also be low frequency and any impacts associated with the mooring lines or anchoring arrangements within the Hornsea Three array area will be mitigated by the development and its hazards being promulgated to all mariners through the use of charted information, KIS-ORCA publications and notices to mariners.

22.15.1.3 For the Hornsea Three offshore cable corridor lessons learnt show that anchoring has the potential to damage a subsea cable if a vessel drops anchor on the cable or drags anchor over the cable. The damage caused depends on the penetration depth of the anchor (which depends on vessel size and type of anchor), the type of seabed and the cable burial depth. It is considered that anchor interaction with a subsea cable will be similar to that of fishing gear interaction, based on impact, pull over and potential snagging phases.

22.15.1.4 Anchoring can take place for a number of reasons. Most likely Adverse weather anchoring (e.g. seeking refuge in a safe haven).

Machinery failure (e.g. to slow drift speed/stop and/or to carry out repairs); and

- Subsea operations/survey vessel ;

22.15.1.5 It is noted that when the cable is installed and charted, the probability of planned anchoring in close proximity to the cable route is reduced. Only one vessel was recorded anchoring within the Hornsea Three offshore cable corridor during the marine traffic survey.

22.15.1.6 Given mitigations measures adopted as part of Hornsea Three, the low frequency of anchoring within the Hornsea Three array area, the offshore cable corridor and the near shore area the impact is assessed to be **broadly acceptable.**

22.15.1.7 Mitigation measures adopted as part of the Hornsea Three project (section 23) include:

- Cable Burial Risk Assessment;
- Guard vessel during the construction or decommissioning phase if exposed cable is identified;
- Post installation assessment;
- Effective monitoring and maintenance during operation;
- Post decommissioning survey assuming cables are left in situ;
- Effective promulgation of information; and
- Charting of cables on UKHO charts (in consultation with the UKHO).

23. Measures Adopted as Part of Hornsea Three

23.1.1.1 As part of the Hornsea Three design process, a number of mitigation measures adopted by Hornsea Three have been proposed to reduce the potential for impacts on shipping and navigation. These measures are considered standard industry practice for this type of development.

Table 23.1: Mitigation adopted as part of Hornsea Three with respect to shipping and navigation.

Industry Standard Mitigation Measure	Description
Aid to Navigation Management Plan	An Aid to Navigation Management Plan is required to mitigate risk associated with extinguished lights and sound signals through all phases.
Application and use of Safety Zones of up to 500 m during construction/ maintenance and decommissioning.	With regard to the application for and use of safety zones to protect the development site, Section 95 of the Energy Act 2004 states that where there is a proposal to construct or operate a renewable energy installation such as wind turbines and associated infrastructure, a notice may be issued declaring specific areas around the installation to be safety zones in order to secure the safety of, in the case of Hornsea Three, the turbines, offshore HVDC substations, offshore HVAC collector substations, accommodation platforms and HVAC booster stations. Schedule 16 of the Energy Act 2004 and The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007 provide details of the application process. 500 m safety zones for the construction, major maintenance and eventual decommissioning phases of a wind turbine, offshore HVDC substation, offshore HVAC collector substation, accommodation platform and HVAC booster stations life will be applied for. These will cover only those parts of the total site in which such activities are actually taking place at a given time in order to reduce the amount of time that mariners and other users of the sea will be required to deviate around the safety zones. Once the activity has been completed in that specific location, the 500 m safety zone will then be removed (or reduced to 50 m in the case of partially complete works) at that location . During the operational and maintenance phase, it is unlikely that adjacent wind turbines will undergo major maintenance at the same time, and therefore that safety zones may be present around adjacent turbines, however this may be required in exceptional circumstances. As above, safety zones with a radius of up to 50 m around turbines, substations and platforms where installation has finished but other work is on-going (pre commissioning) may also be applied for.
Application and use of Safety Zones of up to 500 m during operation for manned platforms.	Operational safety zones of 500 m will be applied for around accommodation platforms. Given that these would be required over the life of the project, these safety zone applications will need to include a safety case.
Blade clearance	Wind turbines will be constructed to ensure that the minimum rotor blade clearance is 34.97 m above LAT.
Bridge links	Consideration will be given to navigational safety when designing the height and location of bridge links within the Hornsea Three array area (e.g., avoiding higher risk locations such as at the periphery of the array) and the bridge links will be designed in line with MCA and TH requirements as per experience within the oil and gas industry.
Buoyed construction area	Buoyed construction areas will be deployed around construction work in line with TH requirements. These will include a combination of cardinal and/or safe water marks.
Cable Burial Risk Assessment and periodic surveys	Cables will be buried where seabed conditions allow, and cable protection measures will be employed to mitigate risks associated with anchor interaction. The subsea cables will be subject to periodic inspection in order to confirm they remain buried/protected and do not become a hazard to marine navigation. This will include ad hoc inspections after any reported actual anchor interactions. A cable specification and installation plan, and a scour protection management and cable armouring plan, including details on any cable protection, will be submitted to the MMO at least four months prior to the construction of the wind farm, along with a Cable Burial Risk Assessment.
Compliance with UK and Flag State regulations including International Maritime Organization Conventions including COLREGs and SOLAS	Compliance to ensure that standard levels of navigation and vessel safety continue to be adhered to by all project related vessels during all phases.
Electromagnetic Interference minimisation	A cable specification and installation plan will be prepared as part of the Code of Construction Practice. This will include the technical specification of offshore electrical circuits, and a desk-based assessment of attenuation of electro-magnetic field strengths, shielding and cable burial depth in accordance with industry good practice.
Emergency Response and Cooperation Plan (ERCoP)	This will be developed and implemented for the construction, operation/maintenance and decommissioning phases of the project.
Export cable, interconnector and array charting	Cables will be marked on nautical charts in line with the UK Hydrographic Office (UKHO) standards. Note that depending on the scale of the chart, array cabling may not be shown and it may only be the export cable that is visible.
Guard vessels	Guard vessel(s) will be present within the Hornsea Three array area and along the export cable route during key periods of construction and potentially during certain operational-phase activities.
IALA Guidance and Aids to Navigation	Structures within the wind farm will be marked and lit in accordance with International Association of Lighthouse Authorities (IALA) Recommendation O-139 on the Marking of Man-Made Offshore Structures (IALA, 2013). Other visual and auditory aids to navigation may also be implemented. Under a requirement of the DCO, the placement and standard of aids to navigation will be agreed with TH prior to the construction of the wind farm. See section 23.2 for more detail.
Marine coordination	Appropriate marine coordination will be in place to ensure that project vessels do not present an unacceptable risk to each other or to transiting vessels.

Industry Standard Mitigation Measure	Description
Marine Pollution Contingency Planning	Creation of an ERCoP in line with guidance, from the construction phase onwards is proposed. This will include interfaces with the UK National Contingency Plan. Measures will be adopted to ensure that the potential for release of pollutants from construction and operation and maintenance activities is minimised, which will include planning for accidental spills and responding to all potential contaminant releases.
MGN 543	The individual wind turbine structures will be designed in accordance with MGN 543 (MCA, 2016) and procedures put in place for generator shut down and other operational requirements in emergency situations.
Monitoring by AIS	Vessel traffic monitoring by AIS for the duration of the construction period. A report will be submitted to the MMO and the MCA at the end of each year of the construction period (28 day period per year). Monitoring during the operational phase will also be required for a minimum of one year. This is as per the relevant DCO condition.
Personal protective equipment (PPE)	All personnel will wear the correct PPE suitable for the location and role at all times, as defined by the relevant Quality, Health, Safety and Environment (QHSE) documentation. This will include the use of Personnel Locator Beacons.
Promulgation of information	Information and warnings will be distributed via Notices to Mariners and other appropriate media (e.g. Admiralty Charts and fishermen's awareness charts) to enable vessels to effectively and safely navigate around the Hornsea Three array area and Hornsea Three offshore cable corridor. This may include additional consultation above and beyond the minimum standard required.
QHSE documentation	Marine QHSE documentation will ensure safe operation on a daily basis, including work vessel operations.
Advisory distances	A 1,000 m advisory safe passing distance around work areas during construction and decommissioning phases, and up to 1,000 m advisory safety distances around cable installation/removal or maintenance vessels. These are advisory and not enforceable.
Self Help capabilities	Provision of self-help capabilities to deal with wind farm associated emergencies. Consideration shall be given to towage, pollution response and man over board.
Temporary Aids to Navigation	Consultation with TH on the implementation of temporary Aids to Navigation for construction activities.
Vessel health and safety requirements	As industry standard mitigation, the Applicant will ensure that all vessels meet both IMO conventions for safe operation as well as HSE requirements, where applicable. This shall include the following good practice: • Wind farm associated vessels will comply with International Maritime Regulations; • All vessels, regardless of size, will be required to carry AIS equipment on board; • All vessels engaged in activities will comply with relevant regulations for their size and class of operation and will be assessed on whether they are "fit for purpose" for activities they are required to carry out; and • All marine operations will be governed by operational limits, tidal conditions, weather conditions and vessel traffic information. • Walk to work solutions will be utilised.

Industry Standard Mitigation Measure	Description
Wind Farm and offshore HVAC booster stations – charting	The wind farm will be marked on relevant UKHO admiralty charts. These areas have generally been marked as "submarine power cable area" as well as with wind farm symbology. The offshore HVAC booster stations shall also be charted.

23.1.1.2 The following section details marine aids to navigation.

23.2 Marine aids to navigation

23.2.1.1 Throughout the construction, operation and maintenance of Hornsea Three, aids to navigation will be provided in accordance with TH and MCA requirements, with consideration being given to IALA standard O-139 on the Marking of Offshore Wind Farms (IALA, 2013),the BEIS Standard Marking Schedule for Offshore Installations (2011) and MGN 543 (MCA, 2016).

23.2.2 Construction and decommissioning markings

23.2.2.1 During the construction/decommissioning of Hornsea Three, buoyed construction areas will be established and marked, where required, in accordance with TH requirements based on the IALA Maritime Buoyage System. In addition to this, where advised by TH additional temporary marking on structures may also be applied.

23.2.2.2 Notices to Mariners (including local), Radio Navigational Warnings, NAVTEX and/or broadcast warnings as well as Notices to Airmen will be promulgated in advance of any proposed works, where required.

23.2.3 IALA guidance of the marking of groups of structures (wind farms)

23.2.3.1 It is noted that the IALA 0-139 guidance does not have to be followed and that TH may request additional or alternative mitigations; however it is assumed that the peripheral lighting will consist of Significant Peripheral Structures (SPS) and Intermediate Peripheral Structures (IPS). Given the distance offshore and the minimum spacing, variations to the standard guidance may be required in consultation with the statutory stakeholders.

23.2.3.2 No lighting or marking will be required during the operational phase for the export cable.

23.2.3.3 The surface Hornsea Three offshore HVAC booster stations will be marked as isolated structures; regardless of how far apart they are located. Subsea HVAC booster stations will be marked by a surface navigational aid (following consultation by TH) where clearance is less than 30 m.

23.2.3.4 Relevant guidance from the MCA and CAA will also be considered during the operational phase. This is likely to include:

- Red aviation lighting synchronised Morse W;

- Search and rescue helicopter lights;
- Heli-hoist lights for day to day operation; and
- Audible warnings.

23.3 Other lighting and marking considerations

23.3.1.1 The following section identifies additional measures that are requirements or are currently being considered by Hornsea Three but will require final consultation post consent.

23.3.2 Low level lighting on foundations

23.3.2.1 Use of low level lighting and retro reflective areas on signage, access platforms and ladders.

23.3.3 Day marks

23.3.3.1 The tower of every turbine (or relevant components) should be painted yellow all-round from the level of Highest Astronomical Tide (HAT) to 15 m or the height of the Aid to Navigation, if fitted, whichever is greater. Alternative marking may include horizontal yellow bands of not less than 2 m in height and separation.

23.3.4 Location of lights

23.3.4.1 The Aids to Navigation on the structure of a wind generator should be mounted below the lowest point of the arc of the rotor blades. They should be exhibited at a height of at least 6 m above the level of the Highest Astronomical Tide (HAT).

23.3.5 Use of AIS transmitters, virtual buoys or Racons

23.3.5.1 The use of AIS transmitters, virtual buoys or Racons may be used following consultation with TH. These will be placed on the periphery of the array to assist safe navigation particularly in reduced visibility and could provide a modern mitigation for the proposed navigational corridor. AIS transmitters or virtual buoys could also be considered internally to assist with navigation within the Hornsea Three array area.

23.3.6 Sound signals

23.3.6.1 Provision of sound signals where appropriate, taking into account the prevailing visibility and vessel traffic conditions. The typical range of such a sound signal should not be less than 2 nm.

23.3.7 Spurious white lights

23.3.7.1 Additional white lights should be kept to a minimum and Hornsea Three should ensure that regular checks are undertaken to identify any lights which should not be visible are extinguished after use.

23.3.8 Aviation lighting

23.3.8.1 Aviation lighting will be as per CAA requirements, however will be synchronised to Morse "W" at the request of TH.

23.3.9 Remote monitoring and sensors

23.3.9.1 Remote monitoring and sensors (SCADA) should be included as part of the lighting and marking scope to ensure high level availability for all aids to navigation.

23.3.10 Numbering of structures

23.3.10.1 The MCA will advise during the consent process on the specific requirements for Hornsea Three however a logical pattern with potential for additional visual marks may be considered by statutory stakeholders.

23.4 OREI design specifications noted as per Marine Guidance Note 543 (MGN 543)

23.4.1.1 The turbines and other structures will be designed to satisfy the control requirements within MGN 543 and annexes (MCA, 2016).

24. Additional Mitigation Measures Required to Bring Risks to ALARP Parameters

24.1.1.1 As part of the Hornsea Three design process a number of additional mitigation measures have been proposed to reduce the potential for impacts on shipping and navigation.

Table 24.1: Additional mitigation measures to be adopted as part of Hornsea Three with respect to shipping and navigation.

Additional Mitigation Measure	Description
Additional aids to navigation to assist internal navigation.	Following consultation with recreational users the Applicant will consult with TH and MCA to consider internal aids to navigation.
Additional means of communication to assist third parties.	Marine coordination facilities, offshore VHF aerials, AIS transceivers/receivers and the onsite vessels shall be used to mitigate risk to third party vessels transiting internally within the array area.
Additional peripheral Hornsea Three array area aids to navigation.	Given the potential for increased maximum spacing on the periphery of the Hornsea Three array area TH and CAA may require additional aids or increased intensity of lights.
IMO routeing measures.	MCA will consider the use of an IMO deep water route or Fairway buoys to ensure routeing priorities within the proposed navigational corridor are managed.
Consultation with commercial fisheries – Hornsea Three array area	In order to reduce risk associated with fishing activity within the Hornsea Three array area, further consultation is required, but it is assumed from a navigational perspective that fishing risk would be ALARP if trawlers avoided the mooring lines and anchors associated with floating foundation design. However, in order to ensure vessels do not enter the Hornsea Three array area when it is not safe to do (given underwater hazards) additional mitigation may need to be discussed with the MCA and known fishing vessels within the area to fully mitigate. Other foundation types would be assumed ALARP based on the minimum 1 km spacing.
Cumulative lighting on the western periphery.	Full consideration should be given to the use of lighting sequences such as different light characters and varied light ranges. Lighting and marking will be discussed with TH in conjunction with the relevant guidance (IALA, 2013). The applicant may be required to liaise directly with the developers of Hornsea Project one and Hornsea Project Two.
Floating foundation placement on the western periphery.	Floating foundation mooring lines shall not extend outside of the AfL.
Minimisation of buoyed construction area for the Hornsea Three array area.	The placement of cardinal buoys during the construction of the western extent of Hornsea Three will give rise to consideration of the long term usability of the proposed navigational corridor, i.e. buoy placements should not adversely impact the usability of the proposed navigational corridor for significant periods.
Peripheral navigational aids within the corridor.	Following agreement on the final layout post consent a user group should be established to identify aids to navigation, in consultation with TH, that best aid navigation within the proposed navigational corridor.
Placement of turbine on western peripheral edge in cumulative scenario.	In order to facilitate vessel transits within the proposed navigational corridor, turbines adjacent to the proposed navigational corridor must be approximately aligned as per the indicative layouts A and B. Where feasible, options for sequences lighting and marking (of the proposed navigational corridor) with the Hornsea Three array area and Hornsea Project One and Hornsea Project Two array areas may be considered. It is noted that significant concave or convex sections can cause negative effects on marine Radar and visual navigation by obscuring or preventing position fixing. When defining layouts the Applicant will give full consideration to cumulative issues caused by structures along the edge of the navigational corridor.
Placement of Hornsea Three offshore HVAC booster stations.	Following assessment of worst case locations further consultation will be required with the MCA and TH to agree final area/location post consent.
Siting consideration for the placement of the Hornsea Three offshore HVAC booster stations.	• Will be placed so as to be sympathetic to shipping and within ALARP parameters; • Following this assessment of maximum design scenario locations further consultation will be required with the MCA and TH to agree final location; and • The subsea HVAC booster stations will require marker buoys (in consultation with TH) in water depths giving less than 30 m UKC. This is noted as likely given the water depths but will be dependent on the final dimensions.
Subsea HVAC booster station marker buoys.	Subsea offshore HVAC booster stations will require marker buoys (in consultation with TH) in water depths giving less than 30 m UKC. This is noted as likely given the water depths but will be dependent on the final dimensions.
Temporary restrictions on shipping using the proposed navigational corridor during construction and decommissioning phases.	If there is significant overlap from construction in the Hornsea Three array area into the proposed navigational corridor there may need to be temporary restrictions on shipping, in consultation with the MCA and TH, to ensure that any works do not adversely impact the safety of third party vessels by increasing the risk of encounters.
Catenary Floating Foundations	If catenary floating foundations are selected and under keel clearance of cannot be guaranteed additional mitigation and consultation will be required.

24.2 Cost benefit analysis

24.2.1.1 The FSA Guidelines require a process of Cost Benefit Assessment (CBA) to rank the proposed mitigation (risk control) options in terms of risk benefit related to life cycle costs. This will be considered in terms of gross cost of averting a fatality (GCAF). This is a cost effectiveness measure in terms of ratio of marginal (additional) cost of the risk control option to the reduction in risk to personnel in terms of the fatalities averted.

24.2.1.2 Until layout and associated mitigation measures are defined, a review of cost benefit analysis cannot be undertaken; however, Hornsea Three is committed to implementing mitigation measures that show a positive impact and a reduction in worst case Potential Loss of Life (PLL) value in conjunction with the frequency of occurrence.

24.2.1.3 Further work will be undertaken pre- and post-consent.

25. Through Life Safety Management

25.1 Quality, Health, Safety and Environment (QHSE)

25.1.1.1 QHSE documentation including a Safety Management System will be in place for the project and will be continually updated throughout the development process. The following sections provide an overview of documentation and how it will be maintained and reviewed with reference, where required, to specific marine documentation.

25.1.1.2 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.

25.2 Incident reporting

25.2.1.1 After any incidents, including near misses, an incident report form will be completed in line with the Hornsea Three QHSE documentation. This will then be assessed for relevant outcomes and reviewed for possible changes required to operations.

25.2.1.2 Hornsea Three shall maintain records of investigations and analyse incidents in order to:

- Determine underlying deficiencies and other factors that might be causing or contributing to the occurrence of incidents;
- Identify the need for corrective action;
- Identify opportunities for preventive action;
- Identify opportunities for continual improvement; and
- Communicate the results of such investigations.

25.2.1.3 All investigations shall be performed in a timely manner.

25.2.1.4 A database (lessons learnt) of all marine incidents will be developed. It will include the outcomes of investigations and any resulting actions. Hornsea Three will promote awareness of their potential occurrence and provide information to assist monitoring, inspection and auditing of documentation.

25.2.1.5 When appropriate, the designated person (noted within the ERCoP) should inform the MCA of any exercise or incidents including any implications on emergency response. If required, the MCA should be invited to take part in incident debriefs.

25.3 Review of documentation

25.3.1.1 Hornsea Three will be responsible for reviewing and updating all documentation including the risk assessments, ERCoP, Safety Management System and, if required, Hornsea Three will convene a review panel of stakeholders to quantify risk.

25.3.1.2 Reviews of the risk register should be made after any of the following occurrences:

- Changes to the project, conditions of operation and prior to decommissioning;
- Planned reviews; and
- Following an incident or exercise.

25.3.1.3 A review of potential risks should be carried out annually. A review of the response charts should be carried out annually to ensure that response procedures are up to date and should include any amendments from audits/incident reports/deficiencies.

25.4 Inspection of resources

25.4.1.1 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. This will include monitoring and inspection of all Aids to Navigation to determine compliance with the performance standards specified by TH.

25.5 Audit performance

25.5.1.1 Auditing and performance review are the final steps in QHSE management systems. The feedback loop enables an organisation to reinforce, maintain and develop its ability to reduce risks to the fullest extent and to ensure the continued effectiveness of the system. Hornsea Three will carry out audits and periodically evaluate the efficiency of the marine safety documentation.

25.5.1.2 The audits and possible corrective actions should be carried out in accordance with standard procedures and results of the audits and reviews should be brought to the attention of all personnel having responsibility in the area involved.

25.6 Future monitoring

25.6.1.1 Hornsea Three has a commitment to manage the risks associated with the activities undertaken at the Hornsea Three array area, offshore cable corridor and the offshore HVAC booster stations. It shall establish an integrated management system which ensures that the safety and environmental impacts of those activities are ALARP. This includes the use of remote monitoring and switching for Aids to Navigation to ensure that if a light is faulty a quick fix can be instigated from the Marine Coordination Centre.

25.7 Future monitoring of marine traffic

25.7.1.1 Whilst no Radar monitoring of vessel movements has been proposed for the array area, AIS monitoring will be available from a vessel (during construction) and site location (during operation) to record the movements of vessels around the Hornsea Three array area.

25.8 Decommissioning plan

25.8.1.1 A decommissioning plan will be developed. With regards to impacts on shipping and navigation this will also include consideration of the scenario where on decommissioning and on completion of removal operations, an obstruction is left on site (attributable to the wind farm) which is considered to be a danger to navigation and which it has not proved possible to remove. Such an obstruction may require to be marked until such time as it is either removed or no longer considered a danger to navigation, the continuing cost of which would need to be met by Hornsea Three.

26. Impact Assessment for the Environmental Statement

26.1.1.1 The requirement for an EIA is set out in the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009. The Infrastructure Planning (Environmental Impact Assessment Regulations 2009 have been superseded in some cases by the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017, but Hornsea Three is subject to the transition provisions in these regulations which stipulate that the earlier regulations continue to apply. Following identification of both future case impacts and the outcomes of the FSA an impact assessment is undertaken in line with EIA guidance (volume 5, chapter 7: shipping and navigation). This impact assessment assesses the identified impacts screened from the NRA with effective pathways.

26.1.1.2 The likely significant effects of the construction, operation and maintenance, and decommissioning stages of Hornsea Three will be assessed and reported in the Environmental Statement to be prepared and submitted with the application for the DCO. This will include an assessment of the effects on Navigation. The Environmental Statement will take into account any measures adopted as part of Hornsea Three and include a conclusion on the assessed likely significant environmental effects of Hornsea Three. It will include mitigation measures in order to avoid, prevent, reduce and, where possible, offset any significant adverse effects on the environment. Following this is the identification of any residual effects be required.

27. Summary

27.1.1.1 Following a review of the base case environment, an NRA for Hornsea Three has been undertaken. The assessment has included collision and allision risk modelling and a formal safety assessment for all phases of the development (construction, operation and decommissioning) as well as an assessment of cumulative effects.

27.2 Consultation

27.2.1.1 Throughout the NRA process, consultation has been undertaken with regulators and stakeholders, including:

- MCA,
- TH,
- CA,
- CoS,
- RYA,
- Hazard Workshop attendees; and

- Extensive regular operator consultation.

27.2.1.2 Responses to the consultation effort were low based on experience at other offshore wind farms; however the majority of responses focused on the cumulative scenario, the use of floating foundations and layouts.

27.3 Marine traffic

27.3.1.1 The Hornsea Three array area marine traffic survey consists of 40 days AIS, Radar and visual observation data recorded during surveys between 6 June and 4 July 2016 (26 days summer) and 10 November and 3 December 2016 (14 days winter). The surveys were carried out by the *Neptune* (summer only) and *RV Aora* (winter only).

27.3.1.2 The offshore cable corridor marine traffic survey consists of 40 days AIS data recorded during the same periods as for the Hornsea Three array area marine traffic survey. The survey consists of shore based AIS survey data combined with Hornsea Three array area marine traffic survey data.

27.3.1.3 The Hornsea Three offshore HVAC booster station marine traffic survey consists of 28 days AIS, Radar and visual observation data recorded during surveys between 16 and 29 September 2016 (14 days summer) and 17 November and 15 December 2016 (14 days winter). The surveys were carried out by the *Willing Lad* (summer only) and *RV Aora* (winter only).

27.3.1.4 The data was assessed to identify the main user types and operators' within the Hornsea Three array area shipping and navigation study area.

27.3.1.5 For the 26 days analysed in summer 2016, there were an average of 42 unique vessels per day passing within the Hornsea Three array area shipping and navigation study area, recorded on AIS, visual and Radar. In terms of vessels intersecting the Hornsea Three array area, there was an average of 15 unique vessels per day. Throughout the summer period, the majority of tracks were cargo vessels (33% within Hornsea Three) and fishing (30%). Throughout the winter period the majority of tracks were cargo vessels (45% in Hornsea Three) and tankers (21%).

27.3.1.6 Throughout the combined summer and winter survey period, five regular commercial ferry routes were identified. The most frequently transited route was a DFDS Seaways ferry route between Immingham and Esbjerg, with the *Ark Dania*, *Primula Seaways* and *Ark Germania* making 74 transits between them within the Hornsea Three array area shipping and navigation study area throughout the summer and winter survey periods. Two other DFDS Seaways ferry routes were also relatively prominent, with these both being between Immingham and Cuxhaven (the *Hafnia Seaways* and *Jutlandia Seaways* each made 18 transits within the Hornsea Three array area shipping and navigation study area throughout the summer and winter survey periods).

27.3.1.7 For the purposes of the NRA, recreational activity includes sailing and motor craft (including those undertaking dive / fish excursions) of between 2.4 and 24 m. Throughout the combined summer and winter survey period, an average of one unique recreational craft passed within the Hornsea Three study area per day. A medium level of fishing vessel activity was recorded within and in proximity to the Hornsea Three array area, with vessels tracked transiting through the area as well as actively engaged in fishing.

27.3.1.8 For the 14 days analysed in summer 2016, there were an average of 28 unique vessels per day passing within the offshore HVAC booster station shipping and navigation study area, recorded on AIS, visual and Radar. In terms of vessels intersecting the Hornsea Three offshore HVAC booster station search area, there was an average of five unique vessels per day.

27.3.1.9 Throughout the survey periods the majority of tracks were cargo vessels (38% within the Hornsea Three offshore HVAC booster station search area) and tankers (18%). However, 36% of tracks intersecting the Hornsea Three offshore HVAC booster station search area were wind farm support vessels transiting to and from Dudgeon Offshore Wind Farm.

27.3.1.10 Throughout the survey periods the levels of recreational and fishing vessel activity within the Hornsea Three offshore HVAC booster station search area shipping and navigation study area was low, with only a small number of tracks recorded.

27.3.1.11 AIS data collected for the Hornsea Three offshore cable corridor between 6 June to 4 July and between 10 November and 15 December have been analysed. The Hornsea Three offshore cable corridor is crossed by a number of dense traffic routes.

27.3.1.12 Throughout June and July 2016 (summer) the majority of tracks were cargo vessels (approximately 50%) and tankers (20%). Throughout November and December 2016 (winter) the majority of tracks were also cargo vessels (56%) and tankers (21%).

27.3.1.13 Throughout the combined summer and winter survey period, an average of one to two unique recreational craft passed within the Hornsea Three offshore cable corridor shipping and navigation study area per day. The majority of fishing vessels recorded within the Hornsea Three offshore cable corridor shipping and navigation study area were either on passage in a north south direction or actively engaged in fishing activities in the vicinity of the Hornsea Three array area or the shore.

27.3.1.14 Throughout the 40 day period analysed, only one vessel was recorded broadcasting "at anchor" with this being a wind farm support vessel.

27.4 Collision and allision risk modelling

27.4.1.1 Deviations would be required, due to the presence of Hornsea Three, for eight of the 16 main routes identified, with the level of deviation required varying between 5.59 nm for route 15 (eastbound) and 0.2 nm for route 2 (eastbound). For the deviated routes, the maximum increased distance was 5.48% of the total length of route 15, whilst the increased distance of the total length of route 16 was 2.69%. The increased distance of the total length of all others routes was less than 2% of the total journey length.

27.4.1.2 An assessment of current vessel to vessel encounters was carried out by replaying at high speed 40 days of AIS, visual and Radar data from the marine traffic surveys. There were 365 encounters observed throughout the 40 day period, corresponding to an average of nine encounters per day. The day with the most vessel encounters was 7 June with 43 unique encounters observed. In contrast there were three days during the winter period with just one vessel encounter.

27.4.1.3 The annual vessel to vessel collision frequency following the installation of Hornsea Three was 6.59×10^{-3}, corresponding to a major collision return period of one in 152 years. This represents a 21.4% increase in collision frequency compared to the pre-wind farm result.

27.4.1.4 Based on modelling of the revised routeing proposed layouts and local metocean data, the annual powered vessel to structure allision frequency was 9.22×10^{-4}, corresponding to an allision return period of one in 1,084 years.

27.4.1.5 After modelling each of the drift scenarios it was established that wind-dominated drift produced the worst case results. The annual NUC vessel to structure allision frequency for the wind-dominated drift was 7.31×10^{-4}, corresponding to an allision return period of one in 1,369 years. The majority of the annual NUC vessel allision frequency is associated with those structures located on the western and southern boundary of the Hornsea Three array area since the prevalent wind direction in the region is from the southwest.

27.4.1.6 Three indicative locations were modelled for the Hornsea Three offshore HVAC booster stations. Based on the vessel routeing identified for the region, the anticipated change in routeing due to the Hornsea Three offshore HVAC booster stations, and assumptions that effective mitigation measures are in place, the frequency of an errant vessel under power deviating from its route (to the extent that it comes into proximity with a Hornsea Three offshore HVAC booster station) is not considered to be a probable occurrence. The worst case was identified as Location 1 in Figure 18.14. At Location 1, the annual powered vessel to structure allision frequency was 2.15×10^{-4}, corresponding to an allision return period of one in 4,653 years, and the annual NUC vessel to structure allision frequency was 2.38×10^{-5}, corresponding to an allision return period of one in 42,058 years.

27.4.1.7 Using site-specific data as an input, the annual fishing vessel to structure allision frequency was estimated for Layout A. The annual fishing vessel to structure allision frequency was 1.88×10^{-1}, corresponding to an estimated allision return period of one in 5.33 years.

27.4.1.8 Mitigation and safety measures have been identified as suitable for application within Hornsea Three appropriate to the level and type of risk determined within the EIA process. The specified measures to be employed will be selected in consultation with the MCA, TH and other relevant statutory stakeholders.

27.4.1.9 Following this assessment it is noted that surface navigational safety impacts associated with the development of Hornsea Three can meet ALARP principles through identified mitigation measures and continual consultation with navigational stakeholders.

27.4.1.10 Impacts associated with helicopter SAR operations have been assessed by a separate specialist consultancy within appendix C of this NRA.

27.5 Summary of impacts for the Environmental Impact Assessment (EIA)

27.5.1.1 The following table shows which impacts identified as part of this NRA will be assessed within the EIA.

Table 27.1: Impacts to be assessed within the EIA.

Impact Identified	Formal Safety Assessment Ranking	Assessed within EIA
Deviations due to Hornsea Three array area (excluding commercial ferries) – all phases	Broadly acceptable	No – broadly acceptable and no safety implications
Deviations due to the Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations (excluding commercial ferries) – all phases	Broadly acceptable	No – broadly acceptable and no safety implications
Deviations due to Hornsea Three array area (commercial ferries) – all phases	Broadly acceptable	No – broadly acceptable and no safety implications
Deviations due to the Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations (commercial ferries)– all phases	No impact identified	No
Adverse weather route impacts Hornsea Three array area (excluding commercial ferries) – all phases	Broadly acceptable	Yes
Adverse weather route impacts due to the Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations (excluding commercial ferries) – all phases	No impact identified	Yes
Adverse weather route impacts Hornsea Three array area (commercial ferries) – all phases	Broadly acceptable	Yes
Adverse weather route impacts due to the Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations	No impact identified	No

Impact Identified	Formal Safety Assessment Ranking	Assessed within EIA
(commercial ferries) – all phases		
Adverse weather route impacts – cumulative	Broadly acceptable	Yes
Cumulative deviations due to Hornsea Three array area – all phases	Tolerable with mitigation	Yes
Cumulative deviations due to the Hornsea Three offshore cable corridor and Hornsea Three offshore HVAC booster stations – all phases	Negligible impact	No
Increased encounters and collision risk due to Hornsea Three array area– construction and decommissioning	Broadly acceptable	No – broadly acceptable and effective measures adopted as part of Hornsea Three
Increased encounters and collision risk due to Hornsea Three offshore HVAC booster stations - construction and decommissioning	Broadly acceptable	No – broadly acceptable and effective measures adopted as part of Hornsea Three
Increased encounters and collision risk due to the Hornsea Three offshore cable corridor – construction and decommissioning	Negligible impact	No
Increased encounters and collision risk due to Hornsea Three array area – operation and maintenance	Broadly acceptable	Yes
Increased encounters and collision risk due to the Hornsea Three offshore cable corridor – operation and maintenance	Negligible impact	No
Increased encounters and collision risk due to Hornsea Three offshore HVAC booster stations – operation and maintenance	Broadly acceptable	Yes
Increased encounters and collision risk – cumulative	Tolerable with mitigation	Yes
Increased external allision due to Hornsea Three array area – construction and decommissioning	Broadly acceptable	Yes
Increased external allision due to Hornsea Three array area – operation and maintenance	Broadly acceptable	Yes
Increased external NUC allision risk – all phases	Broadly acceptable	Yes
Increased allision risk due to Hornsea Three offshore HVAC booster stations – construction and decommissioning	Broadly acceptable	Yes
Increased allision risk due to Hornsea Three offshore HVAC booster stations – operation and maintenance	Broadly acceptable	Yes
Increased external allision risk – cumulative	Tolerable with mitigation	Yes
Increased internal Hornsea Three array area allision risk – construction and decommissioning (excluding large commercial vessels)	Broadly acceptable	Yes

Impact Identified	Formal Safety Assessment Ranking	Assessed within EIA
Increased internal Hornsea Three array area allision risk – operations and maintenance (excluding large commercial vessels)	Tolerable with mitigation; unacceptable with catenary moorings	Yes
Increased internal Hornsea Three array allision risk – cumulative	No identified impact	No
Increased risk of gear snagging – construction and decommissioning	Tolerable with mitigation	Yes
Increased risk of gear snagging – operation and maintenance	Tolerable with mitigation	Yes
Increased risk of anchor snagging – all phase	Broadly acceptable	No – broadly acceptable, low frequency and effective measures adopted as part of Hornsea Three

28. References

Anatec (2013). *Cumulative Navigational Issues in the Southern North Sea*. Aberdeen: Anatec.

Anatec (2016). *Assessment of Marine Traffic and Corridor Design Hornsea Project 3*. Aberdeen: Anatec.

Atlantic Array (2012). *Atlantic Array Offshore Wind Farm, Draft Environmental Statement* (2012). Annex 18.3: Noise and Vibration (Anthropogenic Receptors): Predictions of Operational Wind Turbine Noise Affecting Fishing Vessel Crews. RWE npower renewables, Channel Energy Limited 2012.

BBC (2016). Three rescued after Cumbria fishing boat hits wind turbine. http://www.bbc.co.uk/news/uk-england-cumbria-36386583 [Accessed December 2016].

BEIS (2011). *Standard Marking Schedule for Offshore Installations.* London: BEIS.

BWEA (2007). *Investigation of Technical and Operational Effects on Marine Radar Close to Kentish Flats Offshore Wind Farm*. London: BWEA (now RUK), DECC, MCA & PLA.

CAA (2016). *Policy and Guidelines on Wind Turbines CAP 764 6th Edition. London: CAA.*

CHIRP (2016). *Aviation and Maritime Confidential Incident Reporting.* https://www.chirpmaritime.org [Accessed December 2016].

DfT (2001). *Identification of Marine Environmental High Risk Areas (MEHRAs) in the UK*. Southampton: DfT.

DfT (2004). *Department for Transport maritime statistics*. Southampton: DfT.

DfT (2004). *Results of the electromagnetic investigations*. 2nd ed. Southampton: MCA and QinetiQ.

DfT (2009-2015). *Port Freight statistics*. Available at: https://www.gov.uk/government/publications/maritime-and-shipping-statistics-guidance [accessed 10/04/2017].

Holland R, 2008). Wind Turbines Wake Turbulence and Separation.
http://www.arising.com.au/aviation/windturbines/wind-turbine.pdf [Accessed 2017].

HSE (2001). *Wind and wave frequency distributions for sites around the British Isles*. London: HSE.

IALA (2013). *0-139 the Marking of Man-Made Offshore Structures*. Edition 2. Saint Germain en Laye, France: IALA.

IMO (1972/77). *Convention on the International regulations for Preventing Collisions at Sea – Annex 3*. London: IMO.

IMO (1974). *Convention on the Safety of Life at Sea*. London: IMO.

IMO (2001): *Maritime Safety Committee, 72nd session, Agenda item 16 (MSC 72/16), Decision Parameters Including Risk Acceptance Criteria for Safety*. Norway: IMO.

IMO (2002). *Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule Making Process*. London: IMO.

ILO (2001). *The Impact on Seafarers' Living and Working Conditions of Changes in the Structure of the Shipping Industry*. Geneva: ILO.

IAMSAR (IMO, 2016). International Aeronautical and Maritime Search and Rescue Manual. London:IMO.

ITAP (2006). *Measurement of underwater noise emitted by an offshore wind turbine at Horns Rev. Germany*. Institut für technische und angewandte Physik GmbH 2006.

Lee, AJ and Ramster, JW (1981) Atlas of the Seas around the British Isles. Ministry of Agriculture, Fisheries and Food, London.

MCA and QinetiQ (2004). *Results of the electromagnetic investigations and assessments of marine radar, communications and positioning systems undertaken at the North Hoyle wind farm by QinetiQ and the Maritime and Coastguard Agency*. Southampton: MCA and QinetiQ Ltd 2004.

MCA (2004). *Marine Guidance Notice 280, Small Vessels in Commercial Use for Sport or Pleasure, Workboats and Pilot Boats – Alternative Construction Standards*. Southampton: MCA.

MCA (2005). *Offshore Wind Farm Helicopter Search and Rescue – Trials Undertaken at the North Hoyle Wind Farm Report of helicopter SAR trials undertaken with Royal Air Force Valley "C" Flight 22 Squadron on March 22nd 2005*. Southampton: MCA.

MCA (2008). *Marine Guidance Notice 372, Guidance to Mariners Operating in the Vicinity of UK OREIs*. London: MCA.

MCA (2015). *Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind farms.* Southampton: MCA.

MCA (2016). *Marine Guidance Notice 543 (Merchant and Fishing), Safety of Navigation Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response*. Southampton: MCA.

MCA (2017). *Safety Information*. Available at https://www.gov.uk/government/publications/maritime-and-coastguard-agency-mca-safety-bulletins [accessed 19th April 2017].

MOD (2016). The Ministry of Defence has confirmed the deal to purchase nine P-8A Poseidon Maritime Patrol Aircraft (MPA) for the Royal Air Force (RAF). [accessed 2017].

MOD (2017). Statistical annual of search and rescue (SAR) by military units in the UK, Falklands and Cyprus. https://www.gov.uk/government/collections/military-search-and-rescue-annual-statistics-index [Accessed 2017].

Nautical Institute (2013). The shipping industry and marine spatial planning. NautInst:London.

NOREL. (Unknown). *A Report compiled by the Port of London Authority based on experience of the Kentish Flats Wind Farm Development*. Norel Work Paper. WP4 (2nd).

OSPAR (2008). *Background Document on Potential Problems Associated with Power Cables Other Than Those for Oil and Gas activities*. Paris: OSPAR Convention.

Robertson, DH and Simpson, ME (1996) Review of Probable Survival Times for Immersion in the North Sea. UK Health and Safety Executive, Abingdon.

RUK (2014). *Guidelines for Health & Safety in the Wind Energy - Industry British Wind Energy Association*. Issue 2. London: RUK.

RYA (2009). *UK Coastal Atlas of Recreational Boating*. Updated 2008. Southampton: RYA. GIS shapes files dated 2016.

RYA & CA (2004). *Identification of recreational boating interests in the Thames Estuary, Greater Wash and North West (Liverpool Bay).* Southampton: RYA.

RYA (2015). *The RYA's Position on Offshore Renewable Energy Developments Paper 1 – Wind Energy*. Southampton: RYA.

SMartWind (2015). *Environment Statement. Volume 2, Chapter 7: Shipping and Navigation.* London:SMW.

SNSOWF (2013). *SNSOWF Cumulative Navigational Issues in the Southern North Sea.* Aberdeen: Anatec.

TCE and Anatec (2012). *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*. London. TCE.

UKHO (2016). *Admiralty Sailing Directions – North Sea (West) Pilot NP54*. Taunton: UKHO.

Appendix A Consequences Assessment

A.1 Introduction

A.1.1.1 This appendix presents an assessment of the consequences of collision and allision incidents, in terms of people and the environment, due to the impact of the wind farm structures.

A.1.1.2 The significance of the impact of the Hornsea Three array area is also assessed based on risk evaluation criteria and comparison with historical accident data in UK waters.

A.2 Risk evaluation

A.2.1 Risk to people

A.2.1.1 With regard to the assessment of risk to people, two measures are considered, namely:

- Individual risk; and
- Societal risk.

Individual risk (per year)

A.2.1.2 This measure considers whether the risk from an accident to a particular individual changes significantly due to the presence of the wind farm structures. Individual risk considers not only the frequency of the accident and the consequence (likelihood of death), but also the individual's fractional exposure to that risk, (the probability of the individual being in the given location at the time of the accident).

A.2.1.3 The purpose of estimating the individual risk is to ensure that individuals who may be affected by the presence of the wind farm structures are not exposed to excessive risks. This is achieved by considering the significance of the change in individual risk resulting from the presence of the wind farm relative to the background individual risk levels.

A.2.1.4 Annual individual risk levels to crew (the annual fatality risk of an average crew member) for different vessel types are presented in Figure A.1. This figure also highlights the upper and lower bounds for risk acceptance criteria as suggested in IMO Maritime Safety Committee (MSC) 72/16. The annual individual risk level to crew falls within the ALARP region for each of the vessel types presented.

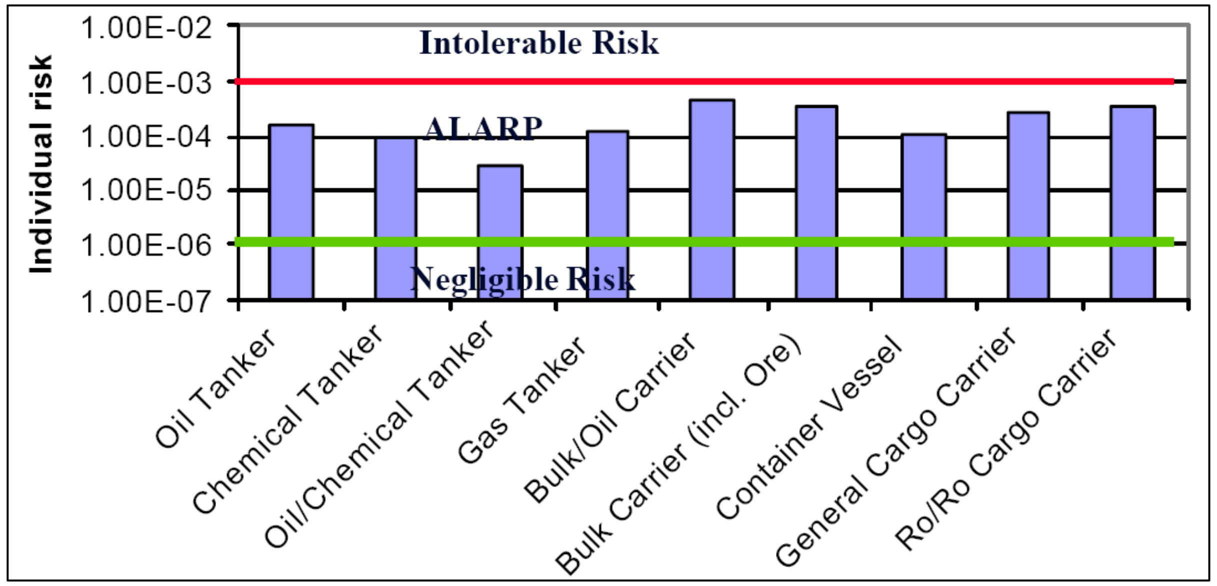


Figure A.1: Individual risk levels and risk acceptance criteria per vessel type.

A.2.1.5 Typical bounds defining the ALARP regions for decision making within shipping are presented in Table A.1.

Table A.1: Individual risk ALARP criteria.

Individual	Lower bound for ALARP	Upper bound for ALARP
To crew member	10^{-6}	10^{-3}
To passenger	10^{-6}	10^{-4}
3rd party	10^{-6}	10^{-4}
New Vessel target	10^{-6}	Above values reduced by one order of magnitude

A.2.1.6 On a UK basis, the MCA website presents individual risks for various UK industries based on HSE data for 1987 to 1991. The risks for different industries are presented in Figure A.2.

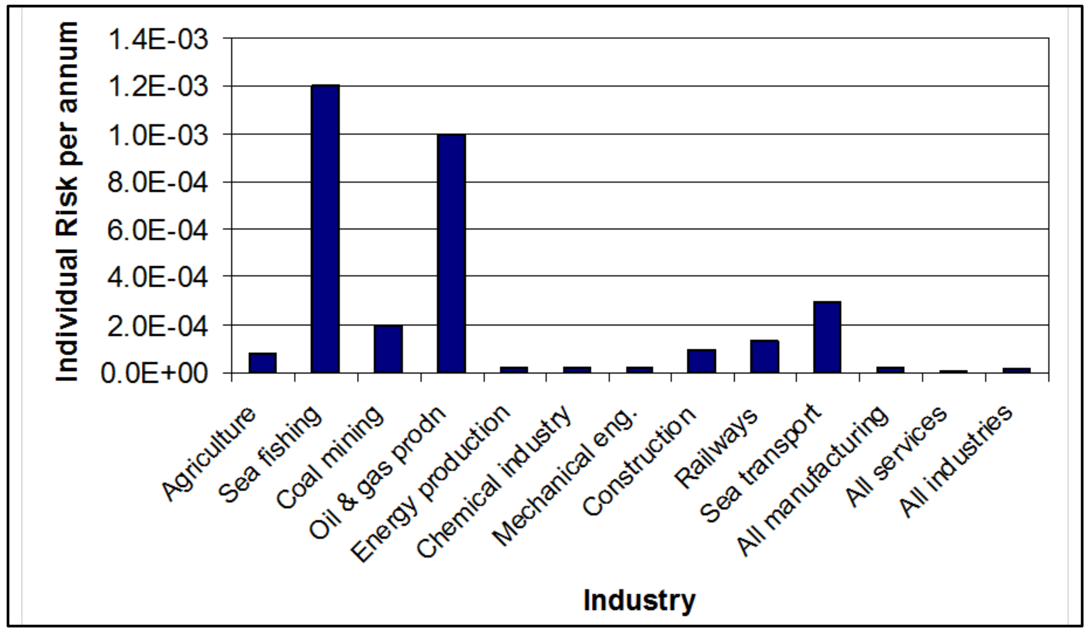


Figure A.2: Individual risk per year for various UK industries.

A.2.1.7 The individual risk for sea transport of 2.9×10^{-4} per year is consistent with the worldwide data presented in Figure A.1, whilst the individual risk for sea fishing of 1.2×10^{-3} per year is the highest across all of the industries included.

Societal risk

A.2.1.8 Societal risk is used to estimate risks of accidents affecting many persons (catastrophes), and acknowledging risk averse or neutral attitudes. Societal risk includes the risk to every person, even if a person is only exposed on one brief occasion to that risk. For assessing the risk to a large number of affected people, societal risk is desirable because individual risk is insufficient in evaluating risks imposed on large numbers of people.

A.2.1.9 Within this assessment societal risk (navigational based) can be assessed for the Hornsea Three array area, giving account to the change in risk associated with each accident scenario caused by the installation of the wind farm structures. Societal risk may be expressed as:

- Annual fatality rate where frequency and fatality are combined into a convenient one-dimensional measure of societal risk. This is also known as Potential Loss of Life (PLL); and
- FN-diagrams showing explicitly the relationship between the cumulative frequency of an accident and the number of fatalities in a multi-dimensional diagram.

A.2.1.10 When assessing societal risk this study focuses on PLL, which takes into account the number of people likely to be involved in an incident (which is higher for certain vessel types), and assesses the significance of the change in risk compared to background risk levels for the UK.

A.2.2 Risk to environment

A.2.2.1 For risk to the environment the key criteria considered in terms of the effect of the wind farm is the potential amount of oil spilled from a vessel involved in an incident.

A.2.2.2 It is recognised there will be other potential pollution (such as hazardous containerised cargoes) but oil is considered the most likely pollutant and the extent of predicted oil spills will provide an indication of the significance of pollution risk due to the wind farm compared to background pollution risk levels for the UK.

A.3 MAIB incident analysis

A.3.1 All incidents

A.3.1.1 All UK commercial vessels are required to report accidents to the MAIB. Non-UK vessels do not have to report unless they are in a UK port or are within 12 nm territorial waters and carrying passengers to a UK port. There are no requirements for non-commercial recreational craft to report accidents to the MAIB; however a significant proportion of these incidents are reported and investigated by the MAIB.

A.3.1.2 A total of 19,130 accidents, injuries and hazardous incidents were reported to the MAIB between 1 January 1994 and 27 September 2005 involving 21,140 vessels (some incidents such as collisions involved more than one vessel). Overall 72% of incidents were in UK waters with the remaining 28% reported in foreign waters.

A.3.1.3 The locations of incidents reported in the vicinity of the UK are presented in Figure A.3, colour-coded by type. It is noted that the MAIB aim for 97% accuracy in reporting the locations of incidents.

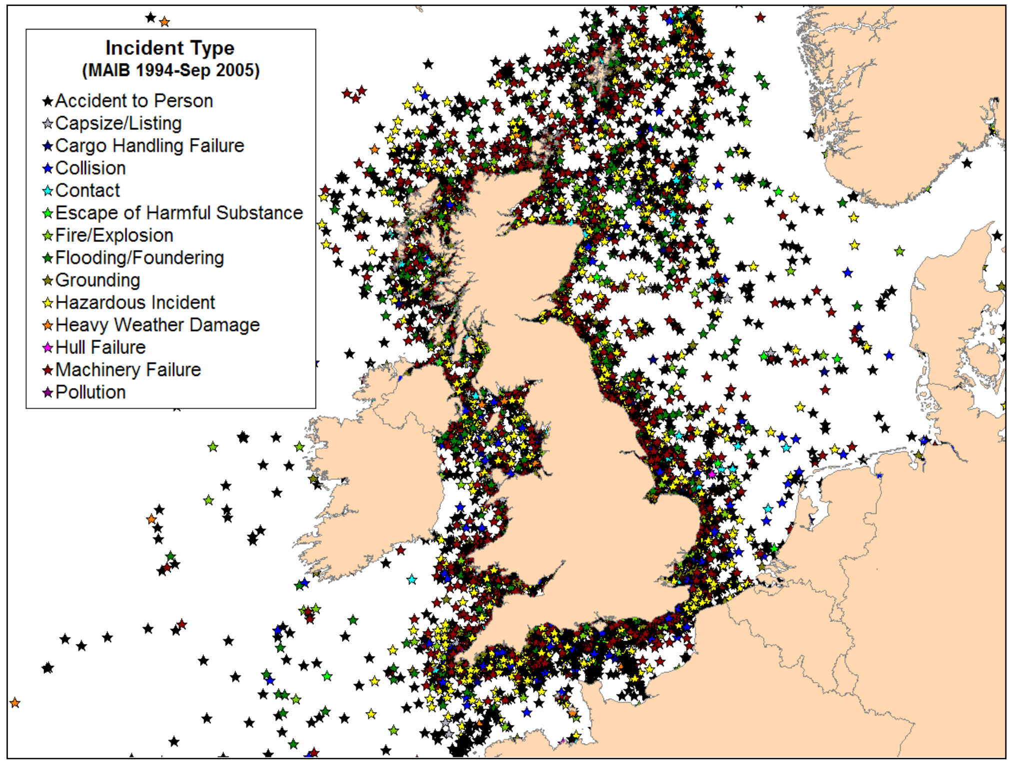


Figure A.3: MAIB incidents by type within vicinity of the UK (1994–2005).

A.3.1.4 The distribution of incidents by year is presented in Figure A.4.

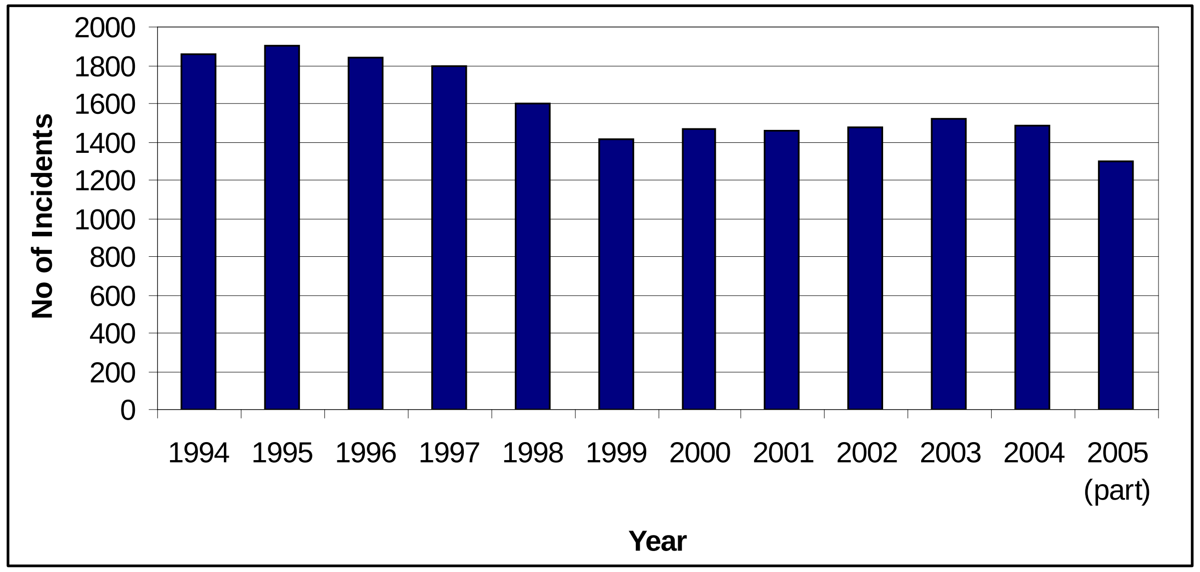


Figure A.4: MAIB incidents per year (1994–2005).

28.1.1.1 The average number of incidents per year, excluding 2005 which is a part-year, was 1,621. It can be seen that generally there is a declining trend in incidents.

28.1.1.2 The distribution of incidents by incident type is presented in Figure A.5.

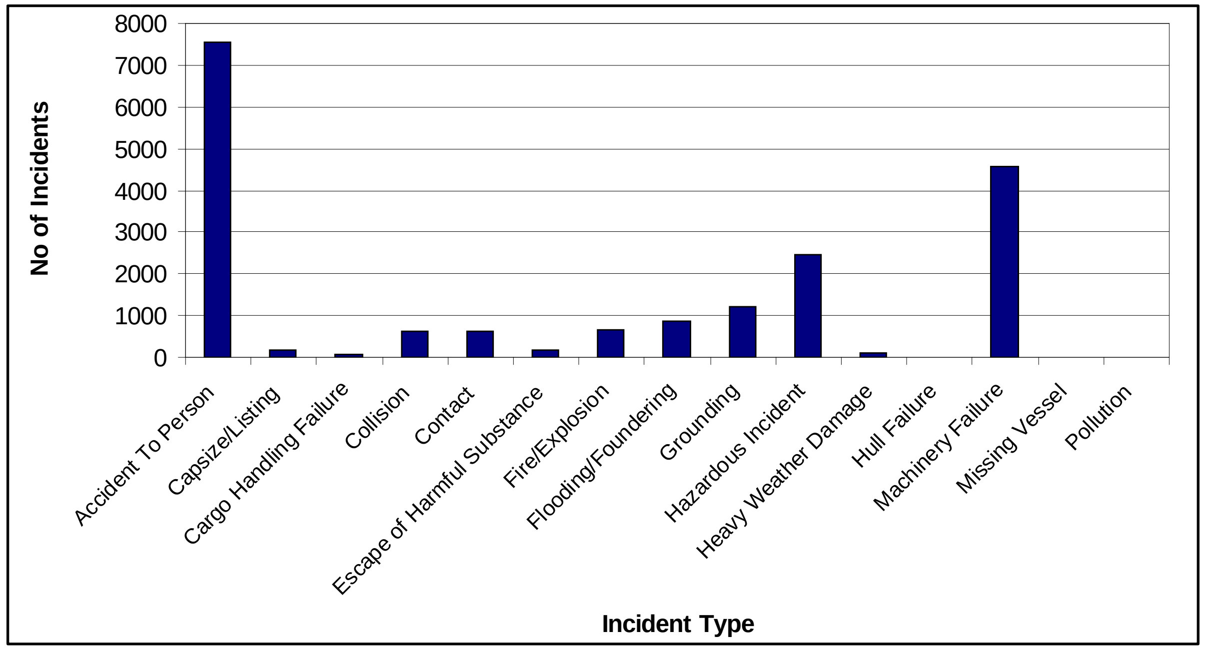


Figure A.5: MAIB incidents by type (1994–2005).

A.3.1.5 The most common incident types were “Accident to Person” (40%), “Machinery Failure” (24%) and “Hazardous Incident” (13%). “Collisions” and “Contacts” each represented 3% of total incidents.

A.3.1.6 The distribution of incidents by casualty type is presented in Figure A.6.

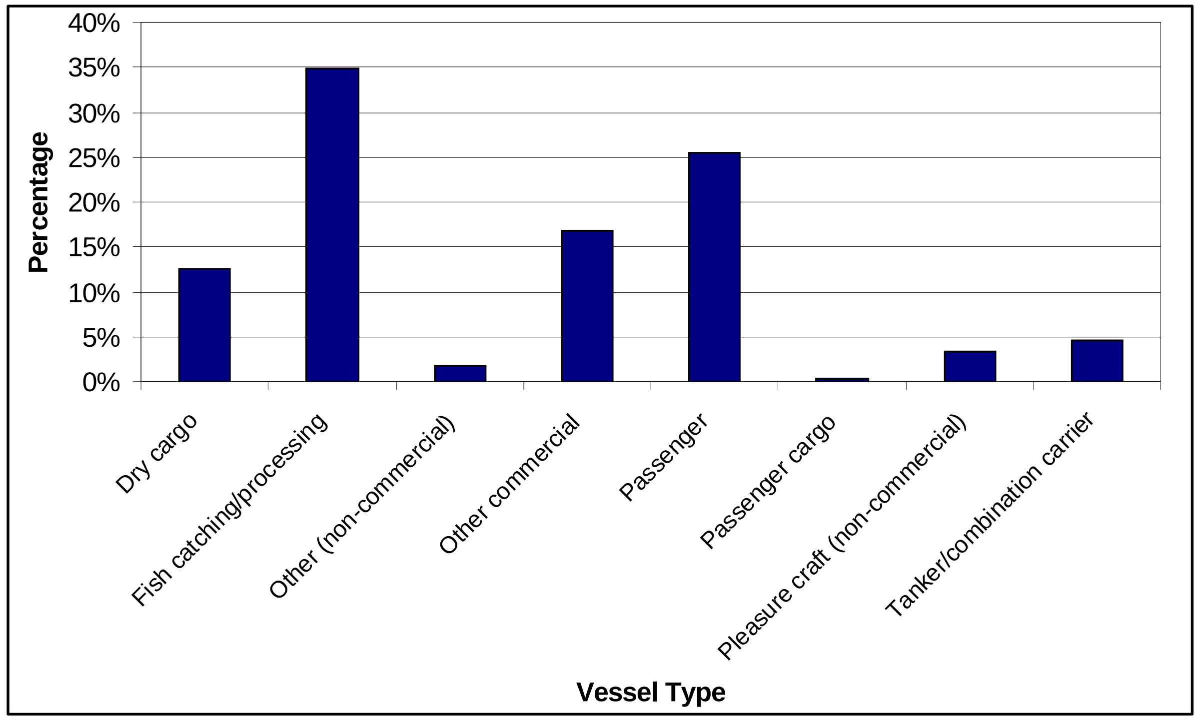


Figure A.6: MAIB incidents by casualty type (1994–2005).

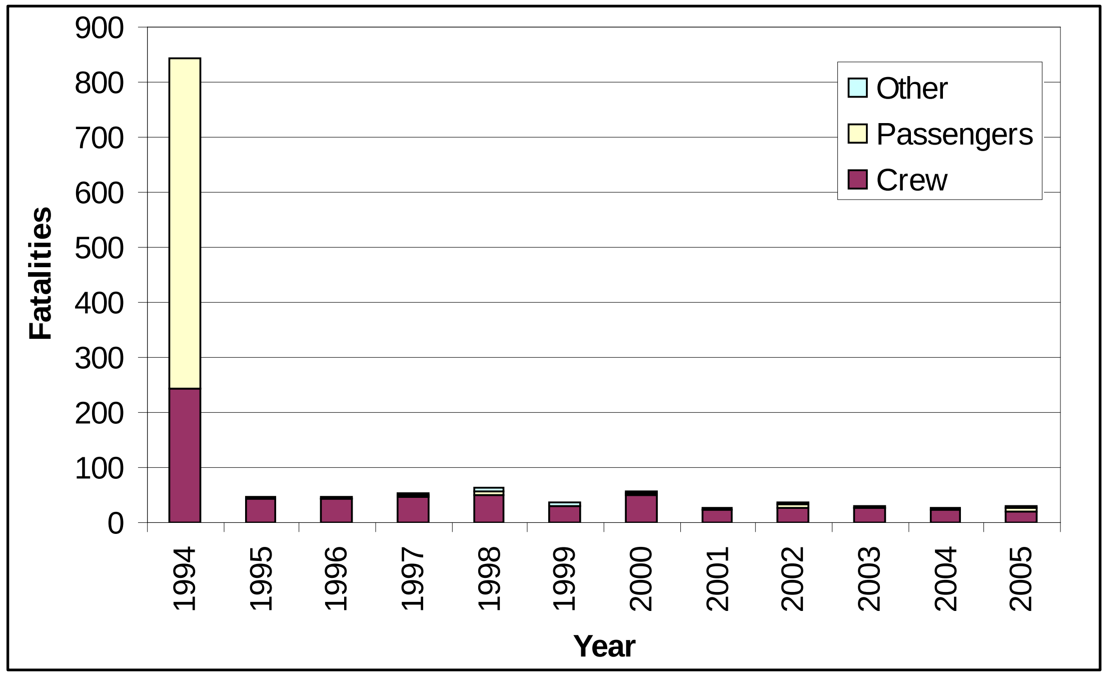


Figure A.7: Number of fatalities per year for MAIB incidents (1994–2005).

A.3.1.7 The most common casualty types were fishing vessels (35%), passenger vessels (25%) and other commercial vessels (17%), which includes oil and gas affiliated vessels, tugs, workboats and pilot vessels.

A.3.1.8 The total number of fatalities per year (divided into crew, passenger and other) reported in MAIB incidents are presented in Figure A.7.

A.3.1.9 The average number of fatalities per year, excluding 2005 which is a part-year, was 115. The sinking of the *Estonia* passenger ferry in the Baltic Sea in 1994, which resulted in a reported 852 fatalities, dominates the figures. Excluding 1994, and thus the sinking of the *Estonia*, the average number of fatalities per year would drop to 42.

A.3.1.10 Considering only those incidents reported to have occurred in UK territorial waters, the number of fatalities per year is presented in Figure A.8.

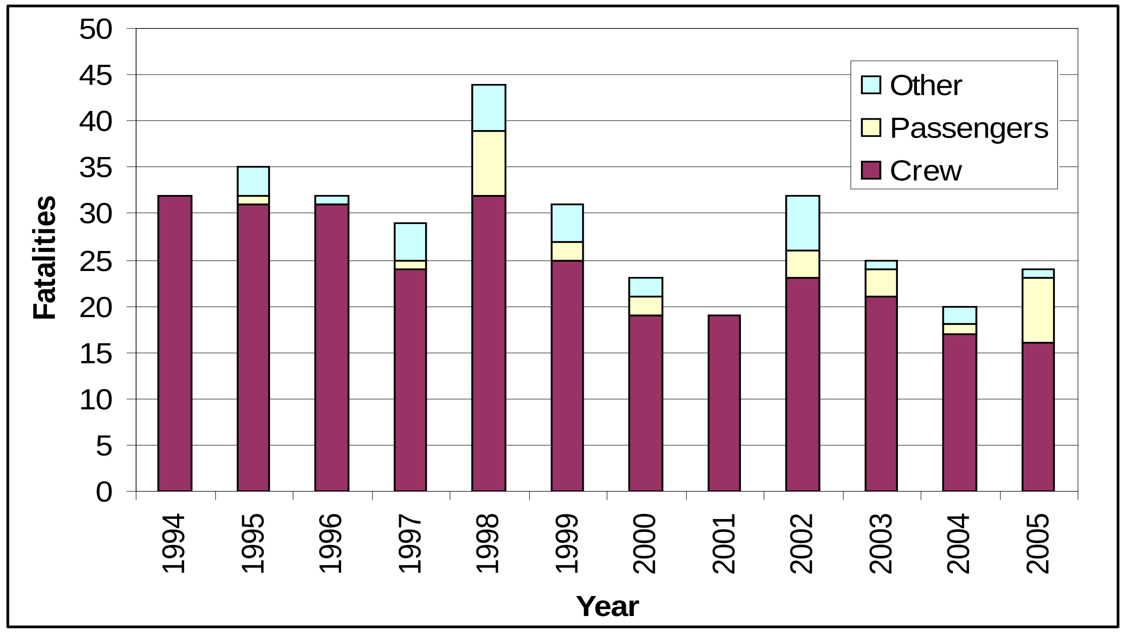


Figure A.8: Number of fatalities per year for MAIB incidents within UK waters (1994–2005).

A.3.1.11 The average number of fatalities per year in UK territorial waters between 1994 and 2004 was 29.

A.3.1.12 The distribution of fatalities in UK waters by vessel type and person category is presented in Figure A.9.

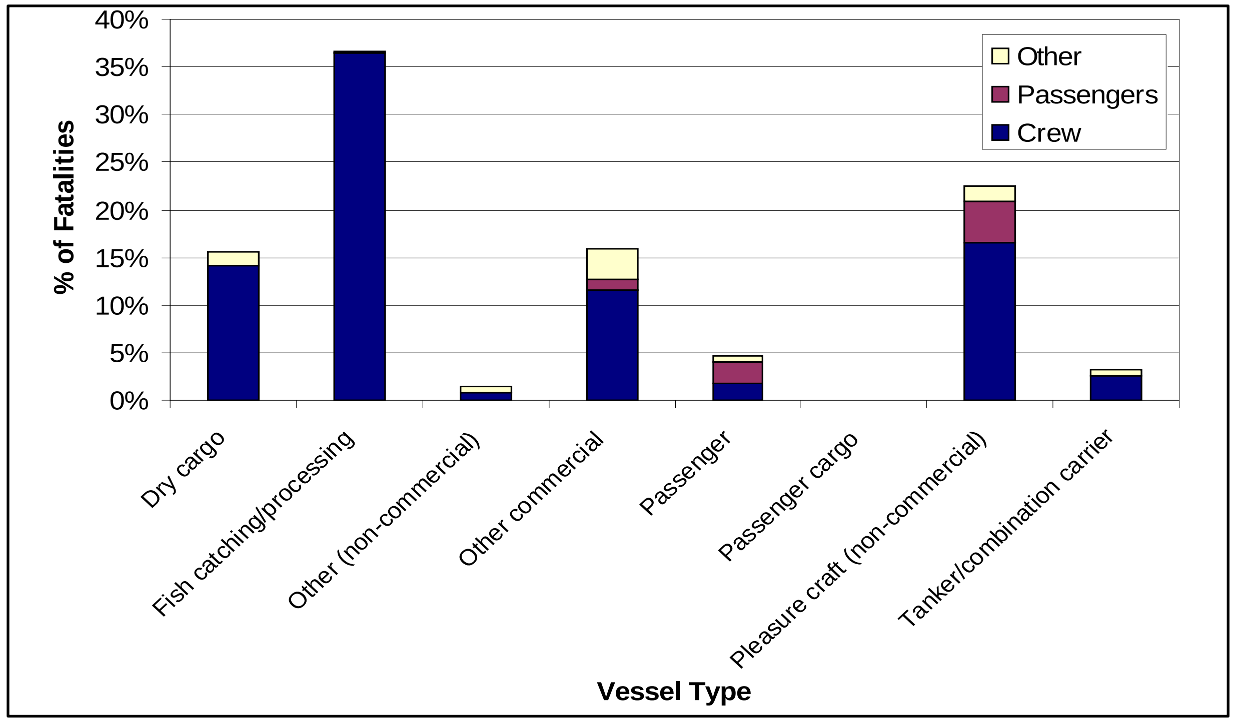


Figure A.9: Fatalities by casualty type for MAIB incidents within UK waters (1994–2005).

A.3.1.13 It can be seen that the majority of fatalities in the UK occurred to fishing vessels and pleasure craft, with crew members the main people involved.

A.3.2 Collision incidents

A.3.2.1 The MAIB define a collision incident as when "a vessel hits another vessel that is floating freely or is anchored (as opposed to being tied up alongside)".

A.3.2.2 A total of 623 collisions were reported to the MAIB between 1 January 1994 and 27 September 2005 involving 1,241 vessels (in a handful of cases the other vessel involved was not logged).

A.3.2.3 The locations of collisions reported in the vicinity of the UK are presented in Figure A.10.

A.3.2.4 The distribution of all collision incidents by year is presented in Figure A.11.

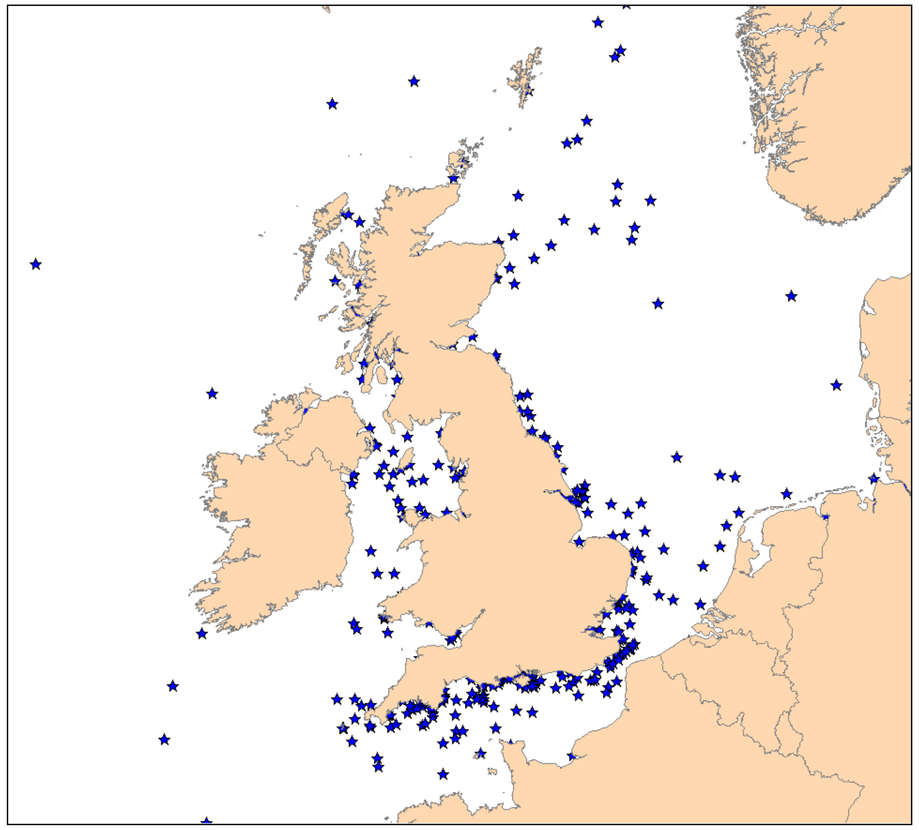


Figure A.10: MAIB collision incident locations (1994–2005).

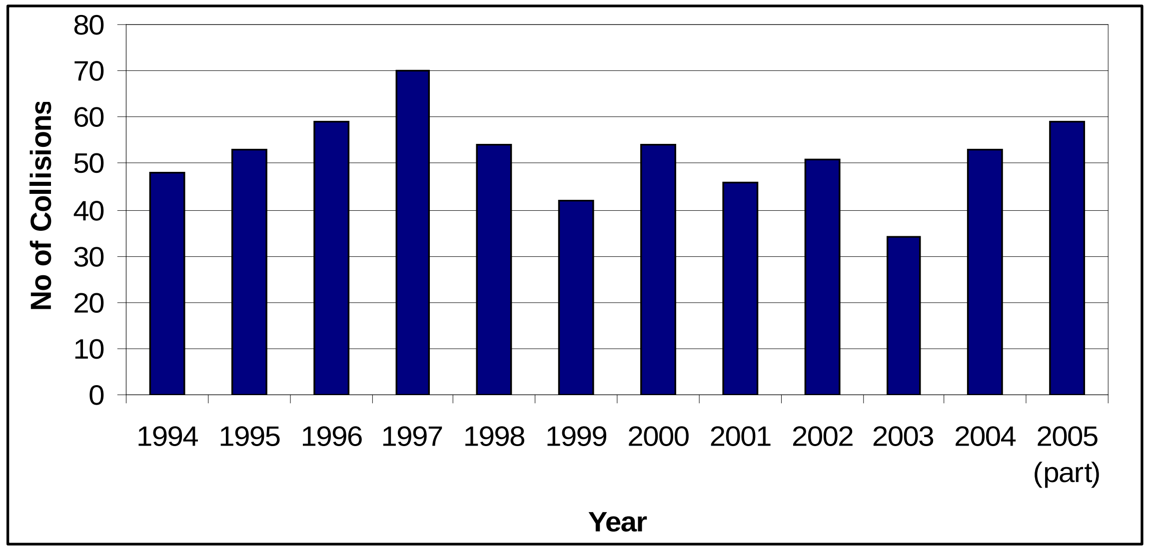


Figure A.11: MAIB collisions per year (1994–2005).

A.3.2.5 The average number of collisions per year, excluding 2005 which is a part-year, was 51.

A.3.2.6 The distribution of collisions by casualty type is presented in Figure A.12.

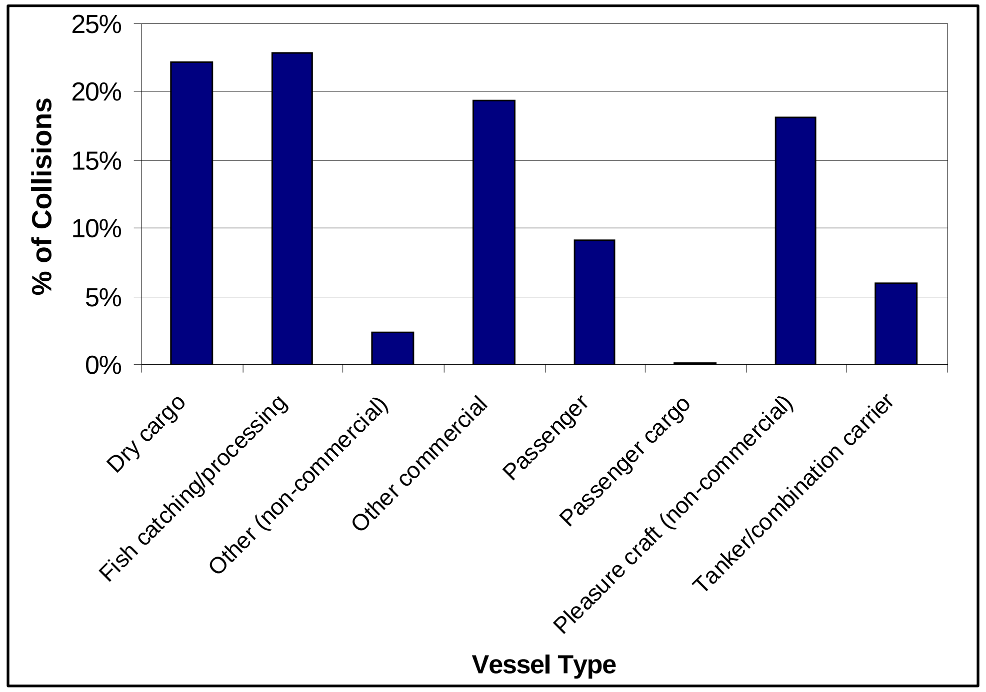


Figure A.12: MAIB collisions by casualty type (1994–2005).

A.3.2.7 The most common collision incident casualty types were fishing vessels (25%), dry cargo vessels (22%), other commercial vessels (19%) and non-commercial pleasure craft (18%).

A.3.2.8 Finally, the total number of fatalities per year reported in MAIB collisions between 1994 and 2005 is presented in Table A.2. MAIB statistics include UK flagged vessels or foreign flags within territorial waters.

Table A.2: Summary of MAIB collisions resulting in fatalities (1994–2005).

Date	Description	Fatalities
November 1994	Beam trawler collision with bulk carrier on high seas in foreign waters with moderate visibility and sea state.	6
February 1995	Stern trawler collision with supply Vessel within a river/canal in foreign waters with good visibility and moderate seas.	1
March 1997	Stern trawler collision with another fishing vessel in foreign waters with good visibility and calm seas.	1
June 1998	Rigid-hulled inflatable (RIB) collision with another RIB in a river/canal within UK territorial waters.	1
June 1998	Seine netter collision with containership on high seas in foreign waters, with good visibility and moderate seas.	5
March 1999	Fishing vessel collision with containership in coastal water within non UK waters with good visibility.	1
August 2001	Pleasure craft collision with small commercial motor vessel within UK territorial waters.	1
October 2001	General cargo vessel collision with chemical tanker in coastal waters within UK territorial waters with good visibility.	1
August 2002	Speed craft collision with another speed boat in an unspecified location within UK waters with good visibility and calm seas.	1
May 2004	Port services tug collision with passenger ferry (during towing) in non UK coastal waters.	1
June 2004	Pleasure craft collision with another pleasure craft in a river/canal within non UK waters.	1
July 2005	Pleasure craft collision resulting in one passenger fatality in coastal waters within UK territorial waters with good visibility and calm seas.	1

A.3.2.9 A more detailed description of the two incidents which resulted in multiple fatalities is provided below:

- **Collision between a bulk carrier and beam trawler in the eastward lane of the Terschelling German Bight TSS.** Both vessels were on passage. Visibility was about five miles. The collision caused extensive damage to the beam trawler with the vessel rapidly flooded and sinking with the loss of her six crew, all of whom were Dutch nationals. The collision was primarily caused by the Master of the bulk carrier failing to take early and substantial action when complying with his obligation to keep out of the way; and
- **Collision between a seine netter and containership on passage between the Firth of Forth and Esbjerg and Hamburg and Gothenburg respectively.** The fishing vessel was on an easterly course while the containership was on a northwesterly course. The fishing vessel was the give-way vessel but did not alter course and speed, the cause of which could not be established. The chief officer of the containership did not alter course until it was too late and the two vessels collided. The fishing vessel foundered so quickly that all hands were trapped inside the accommodation and the containership was so badly damaged that she had to use Esbjerg as a port of refuge.

A.3.3 Contact incidents

A.3.3.1 The MAIB define a contact incident as "a vessel hits an object that is immobile and is not subject to the collision regulations e.g. buoy, post, dock (too hard), etc. Also, another vessel if it is tied up alongside. Also floating logs, containers etc."

A.3.3.2 A total of 609 contacts were reported to the MAIB between 1 January 1994 and 27 September 2005 involving 663 vessels.

A.3.3.3 The locations of contacts reported in the vicinity of the UK are presented in Figure A.13.

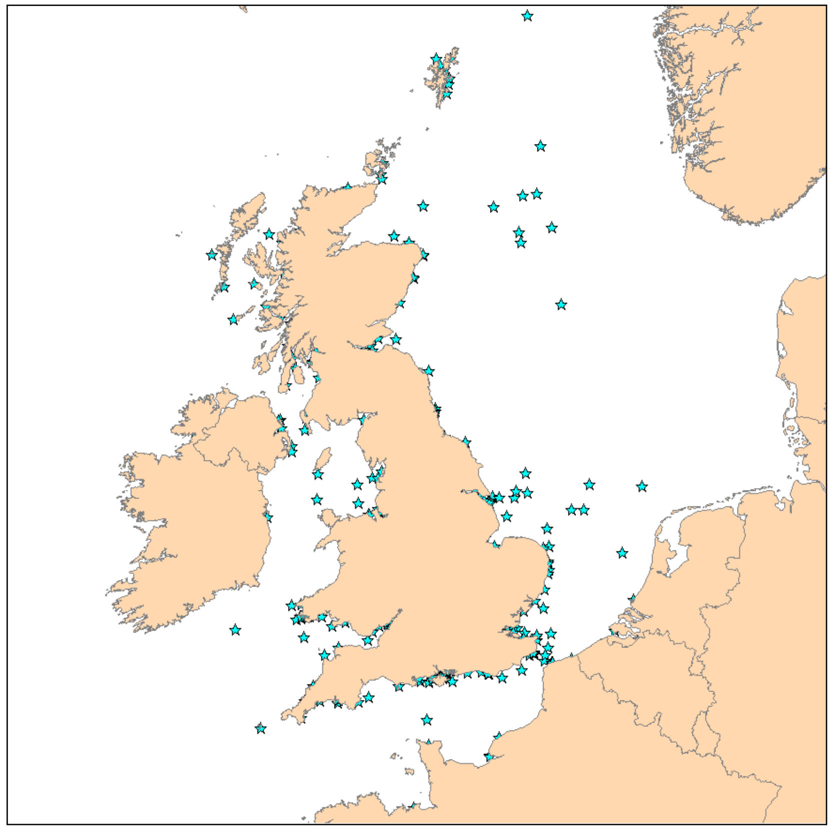


Figure A.13: MAIB contact incident locations (1994–2005).

A.3.3.4 The distribution of contact incidents by year is presented in Figure A.14.

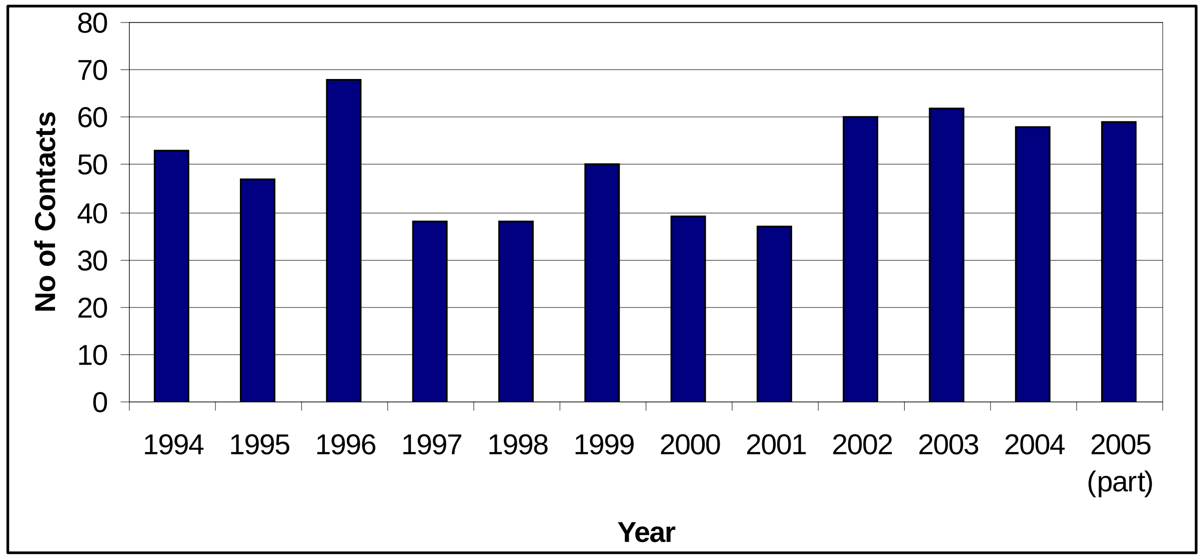


Figure A.14: MAIB contact incidents per year (1994–2005).

A.3.3.5 The average number of contacts per year, excluding 2005 which is a part-year, was 50.

A.3.3.6 The distribution of contacts by casualty type is presented in Figure A.15.

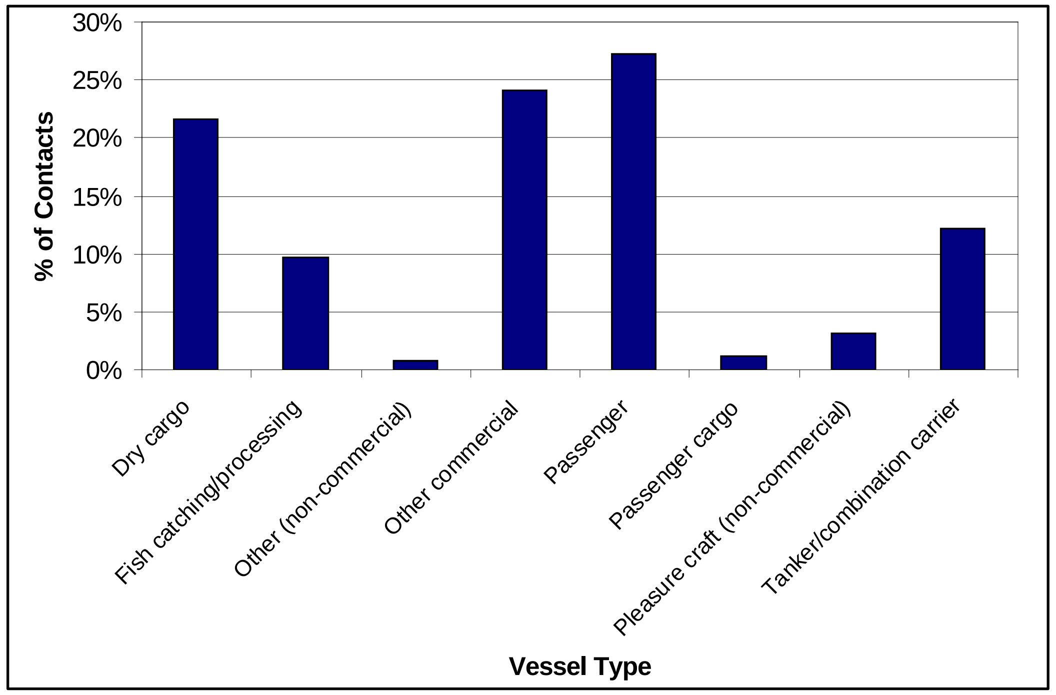


Figure A.15: MAIB contact incidents by casualty type (1994–2005).

A.3.3.7 The most common contact incident casualty types were passenger ferries (27%), other commercial vessels (24%) and dry cargo vessels (22%).

A.3.3.8 There were no fatalities in any of the contact incidents recorded by the MAIB.

A.4 Fatality risk

A.4.1 Overview

A.4.1.1 This section uses the MAIB incident data reported in section A.3 along with information on average manning levels per vessel type to estimate the probability of fatality in a marine incident associated with Hornsea Three.

A.4.1.2 The wind farm structures are assessed to have the potential to affect the following incidents:

- Vessel to vessel collision;
- Powered vessel to structure allision;
- NUC vessel to structure allision; and
- Fishing vessel to structure allision.

A.4.1.3 Of these incidents, only vessel to vessel collisions match the MAIB definition of collisions and hence the fatality analysis presented in section A.3.2 is considered to be directly applicable to these types of incidents.

A.4.1.4 The other scenarios of powered vessel to structure allision, NUC vessel to structure allision and fishing vessel to structure allision are technically contacts since they involve a vessel hitting an immobile object in the form of a turbine or other wind farm structure. From section A.3.3 it can be seen that none of the 609 contact incidents reported by the MAIB between 1994 and 2005 resulted in fatalities.

A.4.1.5 However, as the mechanics involved in a vessel contacting a turbine may differ in severity from hitting, for example, a buoy, quayside or moored vessel, the MAIB collision fatality risk rate has also been conservatively applied for these incidents.

A.4.2 Fatality probability

A.4.2.1 Twelve of the 623 collision incidents reported by the MAIB between 1 January 1994 and 27 September 2005 resulted in one or more fatalities. This gives a 2% probability that a collision will lead to a fatal accident. A total of 21 fatalities resulted from the collision incidents.

A.4.2.2 To assess the fatality risk for personnel on-board a vessel (crew, passenger or other) the number of persons involved in the incidents needs to be estimated. From an ILO survey of seafarers during 1998-99 (ILO, 2001), the average commercial vessel had a crew of 17. For other (non-commercial vessels) such as naval craft and RNLI lifeboats the average crew was estimated to be 20. On-board fishing vessels the average crew was estimated to be five.

A.4.2.3 It is recognised these numbers can be substantially higher or lower on an individual vessel basis depending on the likes of size and subtype, but applying reasonable averages is considered sufficient for this analysis.

A.4.2.4 Using the average number of persons carried along with the vessel type information involved in collisions reported by the MAIB (see section A.3.2), there were an estimated 50,000 personnel on-board the ships involved in the collisions.

A.4.2.5 Based on 21 fatalities, the overall fatality probability in a collision for any individual on-board is approximately 4.3×10^{-4} per collision (0.04%).

A.4.2.6 It is considered inappropriate to apply this rate uniformly as the statistics clearly show that the majority of fatalities tend to be associated with smaller craft, such as fishing vessels and recreational vessels. Therefore, the fatality probability has been subdivided into two categories of vessel as presented in Table A.3.

Table A.3: Fatality probability per incident per vessel category.

Vessel Category	Sub Categories	Fatalities	People Involved	Fatality Probability
Commercial	Dry cargo vessels, passenger vessels, tankers, etc.	3	46,200	6.5×10^{-5}
Non-Commercial	Fishing vessels, pleasure craft, etc.	18	3,120	5.8×10^{-3}

A.4.2.7 It can be seen that the risk is approximately two orders of magnitude higher for people on-board non-commercial vessels.

A.4.3 Fatality risk due to Hornsea Three array area

A.4.3.1 The base case and future case annual collision and allision frequency levels without the wind farm and with the wind farm are summarised in Table A.4.

Table A.4: Summary of annual collision and allision frequency levels at Hornsea Three array area.

Allision and collision scenario	Base case			Future case		
	Without Hornsea Three array area	With Hornsea Three array area	Change	Without Hornsea Three array area	With Hornsea Three array area	Change
Vessel to vessel collision	5.18×10^{-3}	6.59×10^{-3}	1.41×10^{-3}	5.70×10^{-3}	7.25×10^{-3}	1.55×10^{-3}
Powered vessel to structure allision	0.00×10^{0}	9.22×10^{-4}	9.22×10^{-4}	0.00×10^{0}	1.01×10^{-3}	1.01×10^{-3}
NUC vessel to structure allision	0.00×10^{0}	7.31×10^{-4}	7.31×10^{-4}	0.00×10^{0}	8.04×10^{-4}	8.04×10^{-4}
Fishing vessel to structure allision	0.00×10^{0}	1.88×10^{-1}	1.88×10^{-1}	0.00×10^{0}	2.06×10^{-1}	2.06×10^{-1}
Total	5.18×10^{-3}	1.96×10^{-1}	1.91×10^{-1}	5.70×10^{-3}	2.15×10^{-1}	2.10×10^{-1}

A.4.3.2 Table A.5 presents the estimated average number of persons on board (POB) for the local vessels operating in the vicinity of the Hornsea Three array area.

Table A.5: Number of POB by vessel type and collision.

Vessel Type	Collision and allision incidents	Average POB
Cargo/Offshore	Vessel to vessel collision, powered vessel to structure allision, NUC vessel to structure allision.	25
Tanker	Vessel to vessel collision, powered vessel to structure allision, NUC vessel to structure allision.	20
Passenger	Vessel to vessel collision, powered vessel to structure allision, NUC vessel to structure allision.	2,700
Fishing	Vessel to vessel collision, fishing vessel to structure allision.	6
Recreational Vessel	Vessel to vessel collision.	4

A.4.3.3 From the detailed results of the collision and allision frequency modelling, the distribution of the predicted change in annual collision frequency by vessel type due to the wind farm for the base and future cases are presented in Figure A.16. For clarity, the same distribution is presented in Figure A.17 with the proportion of the change annual collision frequency attributed to fishing vessels excluded.

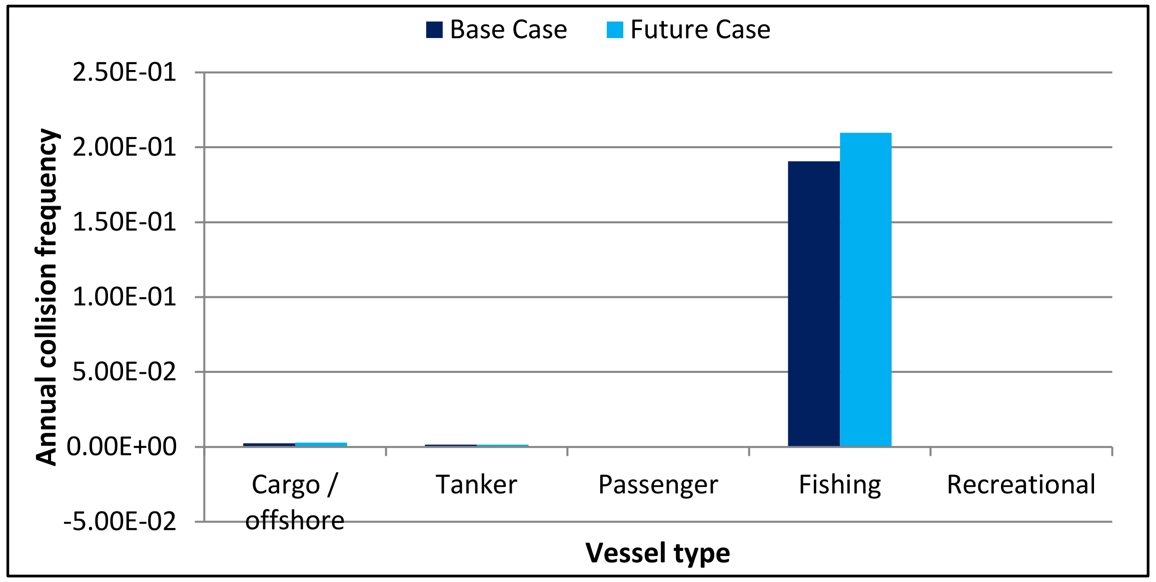


Figure A.16: Change in annual collision frequency by vessel type.

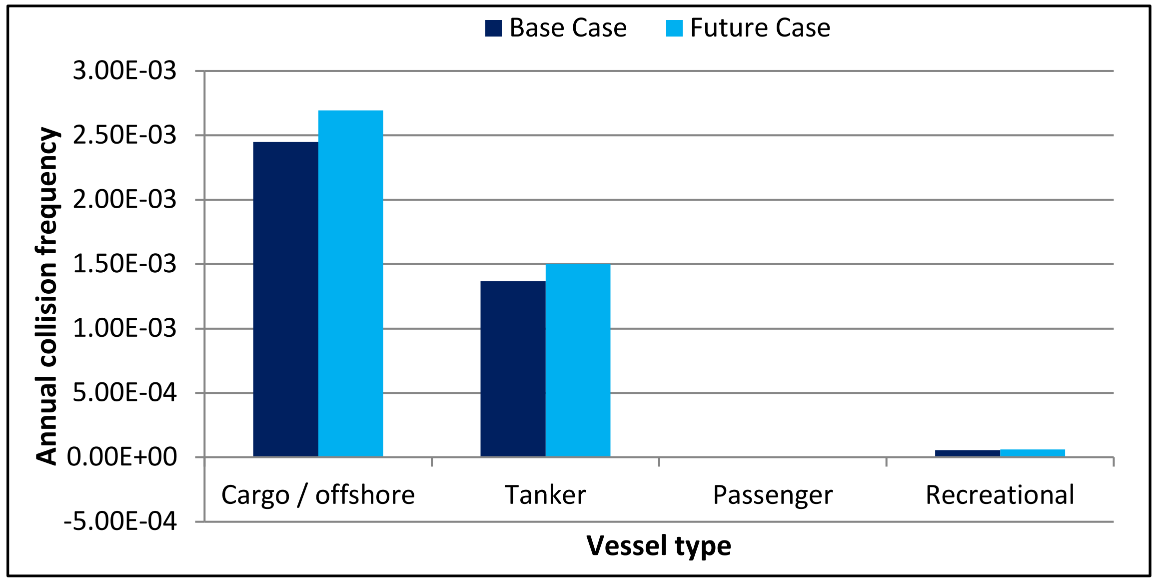


Figure A.17: Change in annual collision frequency by vessel type excluding fishing vessels.

A.4.3.4 It can be seen that the change in annual collision frequency is dominated by fishing vessels. The change in frequency is lowest for passenger vessels for which the change in annual collision frequency was negative. This is due to the majority of passenger vessel traffic within the vicinity of the Hornsea Three array area transiting the Off Botney Ground TSS which is located approximately 6.5 nm from the Hornsea Three array area. Therefore the impact of vessel to structure allision (both powered and NUC vessels) for passenger vessels is low. In addition, the re-routeing of non-TSS commercial traffic in the vicinity of the TSS which was affected by the installation of the wind farm resulted in the duration of such traffic in the vicinity of the TSS being lower; hence the decrease in annual collision frequency for traffic using the TSS, including passenger vessels.

A.4.3.5 Combining the annual collision frequency, the estimated number of persons on board each vessel type (see section A.4.3) and the estimated fatality probability for each vessel category (see section A.4.2), the annual increase in Potential Loss of Life (PLL) due to the impact of the wind farm for the base case is 6.72×10^{-3}, which equates to one additional fatality in 149 years. The annual increase in PLL due to the impact of the wind farm for the future case is 7.39×10^{-3}, which equates to one additional fatality in 139 years. In comparison to MAIB statistics, which indicate an average of 28 fatalities per year in UK territorial waters, this is a small change. It is noted that these values are based on maximum design scenarios for Hornsea Three as well as indicative parameters for vessel type and personnel on board.

A.4.3.6 The estimated incremental increases in PLL due to the wind farm, distributed by vessel type for the base and future cases, are presented in Figure A.18. For clarity, the same incremental increases in PLL are presented in Figure A.19 with the proportion of the PLL attributed to fishing vessels excluded.

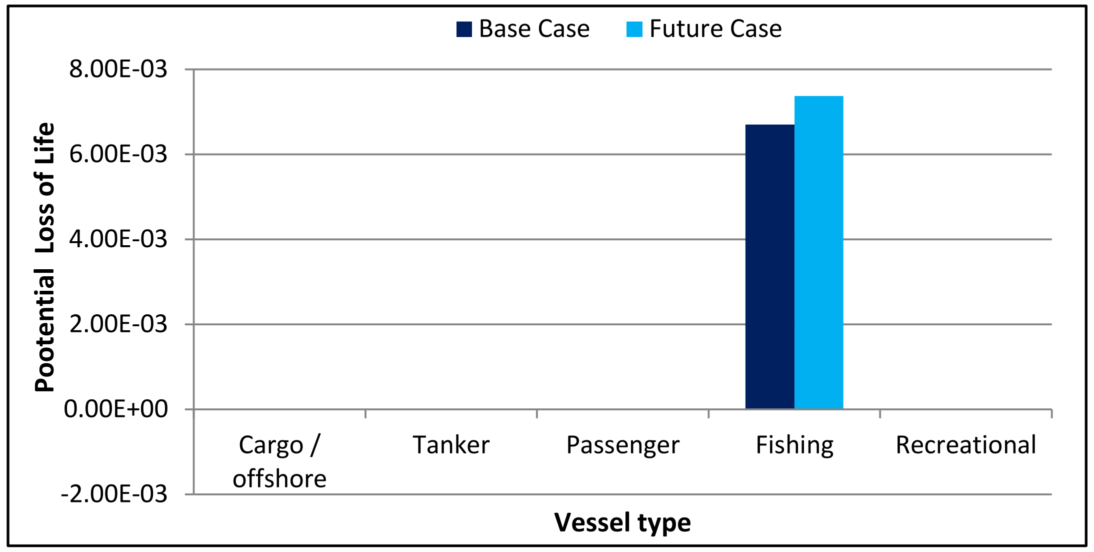


Figure A.18: Estimated change in annual PLL by vessel type.

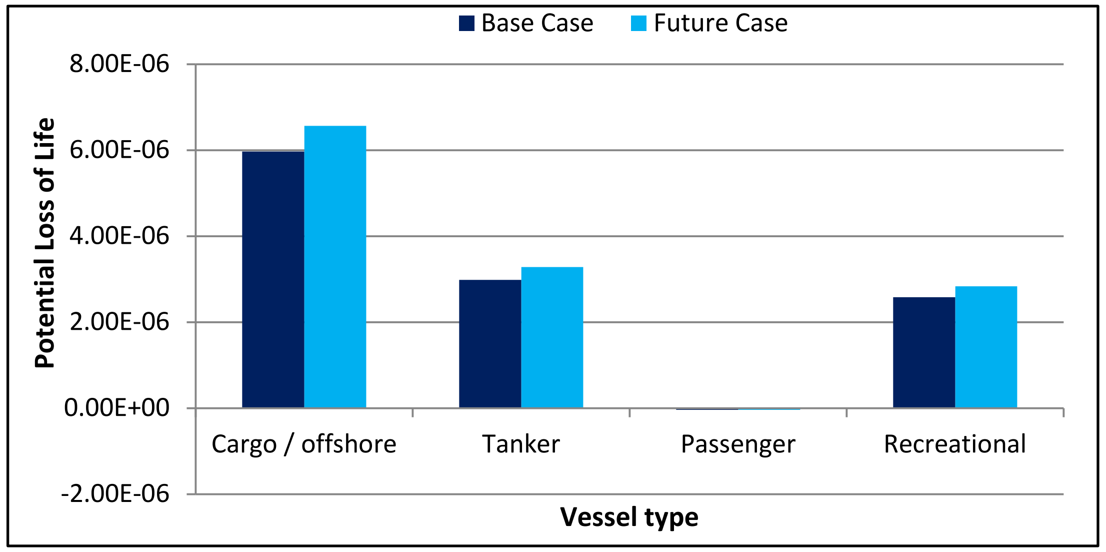


Figure A.19: Estimated change in annual PLL by vessel type excluding fishing vessels.

A.4.3.7 As with the change in annual collision frequency, it can be seen that the change in annual PLL is dominated by fishing vessels, which historically have a higher fatality probability than commercial vessels.

A.4.3.8 Converting the PLL to individual risk based on the average number of people exposed by vessel type, the results are presented in Figure A.20. For clarity, the same changes in individual risk are presented in Figure A.21 with the proportion of the individual risk attributed to fishing vessels excluded.

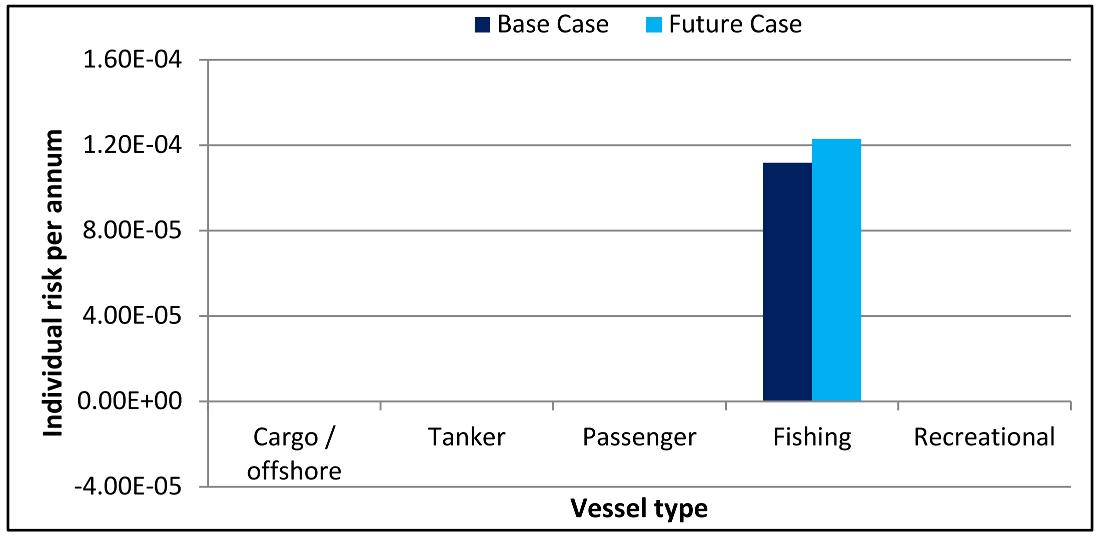


Figure A.20: Estimated change in individual risk by vessel type.

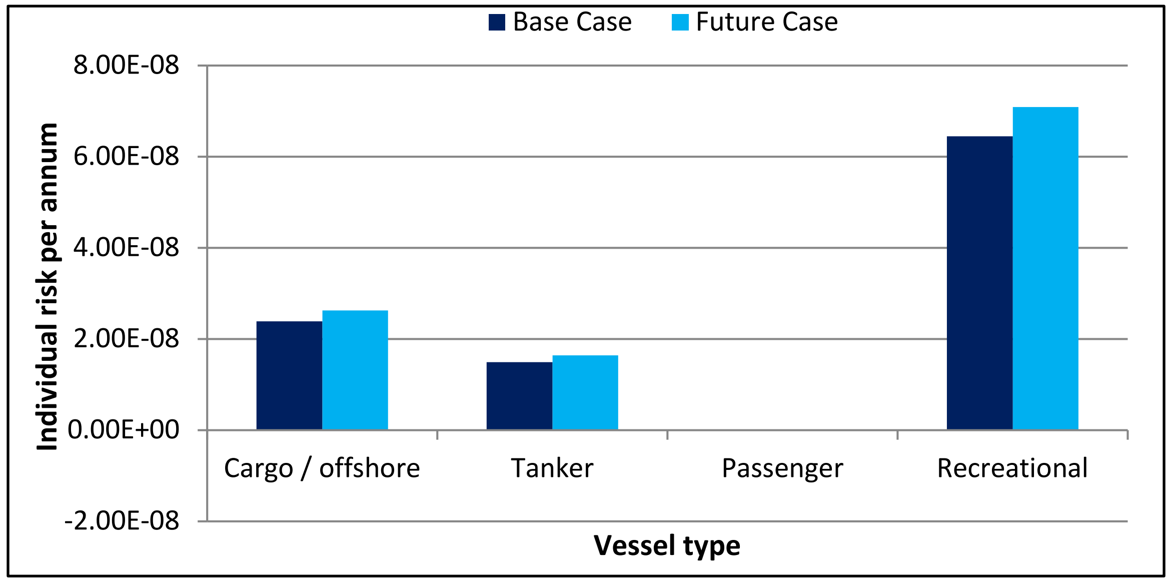


Figure A.21: Estimated change in individual risk by vessel type excluding fishing vessels.

A.4.3.9 It can be seen that the individual risk is highest for people on fishing vessels, which is related to the higher probability of fatalities occurring in the event of an incident.

A.4.4 Significance of increase in fatality risk due to Hornsea Three array area

A.4.4.1 The overall increase in PLL estimated due to the wind farm is 6.71×10^{-3} fatalities per year (base case), which equates to one additional fatality in 149 years. This is a small change compared to MAIB statistics which indicate an average of 29 fatalities per year in UK territorial waters.

A.4.4.2 In terms of individual risk to people, the incremental increase for commercial vessels (approximately 3.88×10^{-8} for the base case) is low compared to the background risk level for the UK sea transport industry of 2.9×10^{-4} per year.

A.4.4.3 Similarly for fishing vessels, whilst the change in individual risk attributed to the development is significantly higher than for commercial vessels (approximately 1.12×10^{-4} for the base case), it is low compared to the background risk level for the UK sea fishing industry of 1.2×10^{-3} per year.

A.5 Pollution risk

A.5.1 Historical analysis

A.5.1.1 The pollution consequences of a collision in terms of oil spill depend on the following:

- Spill probability (likelihood of outflow following an accident); and
- Spill size (amount of oil).

A.5.1.2 Two types of oil spill are considered:

- Fuel oil spills from bunkers (all vessel types); and
- Cargo oil spills (laden tankers).

A.5.1.3 The research undertaken as part of the DfT's MEHRAs project (DfT, 2001) has been used as it was comprehensive and based on worldwide marine spill data analysis.

A.5.1.4 From this research, the overall probability of a spill per accident was calculated based on historical accident data for each accident type as presented in Figure A.22.

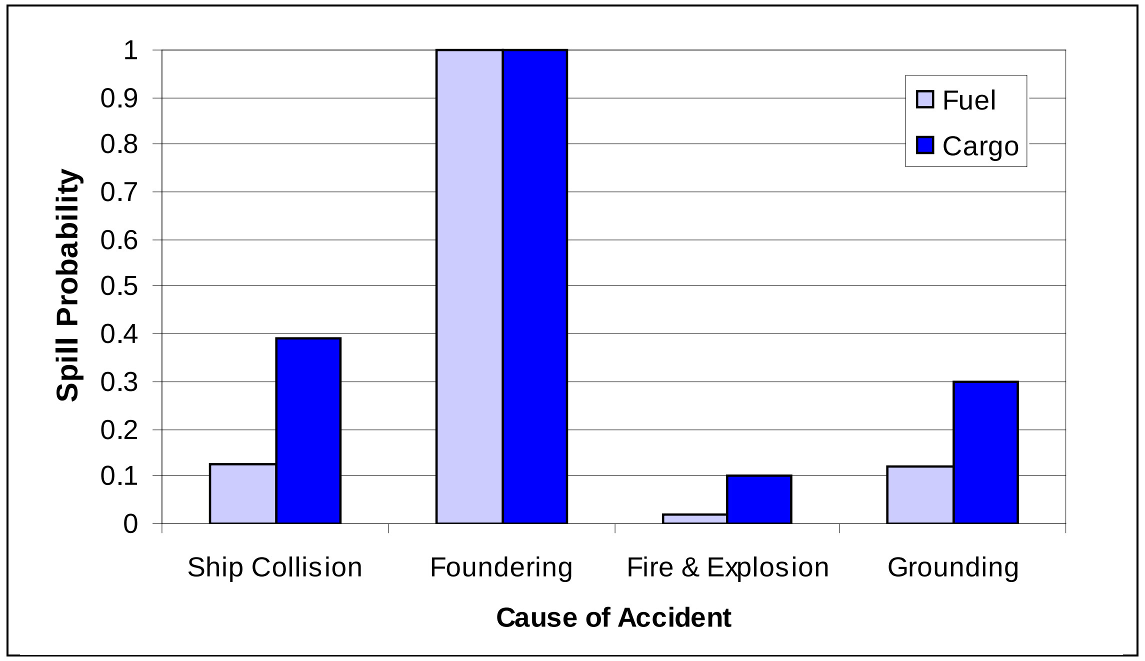


Figure A.22: Probability of an oil spill resulting from an accident.

A.5.1.5 Therefore, 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.

A.5.1.6 In the event of a bunker spill, the potential outflow of oil depends on the bunker capacity of the vessel. Historical bunker spills from vessels have generally been limited to a size below 50% of the bunker capacity, and in most incidents much lower. For the types and sizes of ships exposed to the wind farm, an average spill size of 100 tonnes of fuel oil is considered to be a conservative assumption.

A.5.1.7 For cargo spills from laden tankers, the spill size can vary significantly. International Tanker Owners Pollution Federation limited (ITOPF) report the following spill size distribution for tanker collisions between 1974 and 2004.

- 31% of spills below seven tonnes;
- 52% of spills between seven and 700 tonnes; and
- 17% of spills greater than 700 tonnes.

A.5.1.8 Based on this data and the tankers transiting the area in proximity to the Hornsea Three array area, an average spill size of 400 tonnes is considered conservative.

A.5.1.9 For fishing vessel collisions, comprehensive statistical data is not available. Consequently it is conservatively assumed that 50% of all collisions involving fishing vessels will lead to an oil spill with the quantity spilled being an average of five tonnes.

A.5.2 Pollution risk due to Hornsea Three array area

A.5.2.1 Applying the above probabilities to the annual collision frequency by vessel type and the average spill size per vessel, the estimated amount of oil spilled per year due to the impact of the wind farm would equate to 0.72 tonnes of oil per year for the base case and 0.79 tonnes of oil per year for the future case. It is noted that these values do not indicate that 0.72 tonnes of oil would consistently be spilt each year but rather that 0.72 tonnes of oil would be the average amount of oil spilled per year if the estimated annual collision frequency materialised. The breakdown of the estimated change in pollution by vessel type is presented in Figure A.19. It is noted that this pollution risk assessment is based on conservative parameters and in reality the amount indicated would be negligible. The conservative assumptions assume that particular elements occur i.e. a vessel is involved in an allision, that the allision contains enough energy to puncture the hull and a tank containing an oil or fuel substance. The model inputs are also based on real incidents and are influenced by severe spills within UK waters notably the Sea Empress.

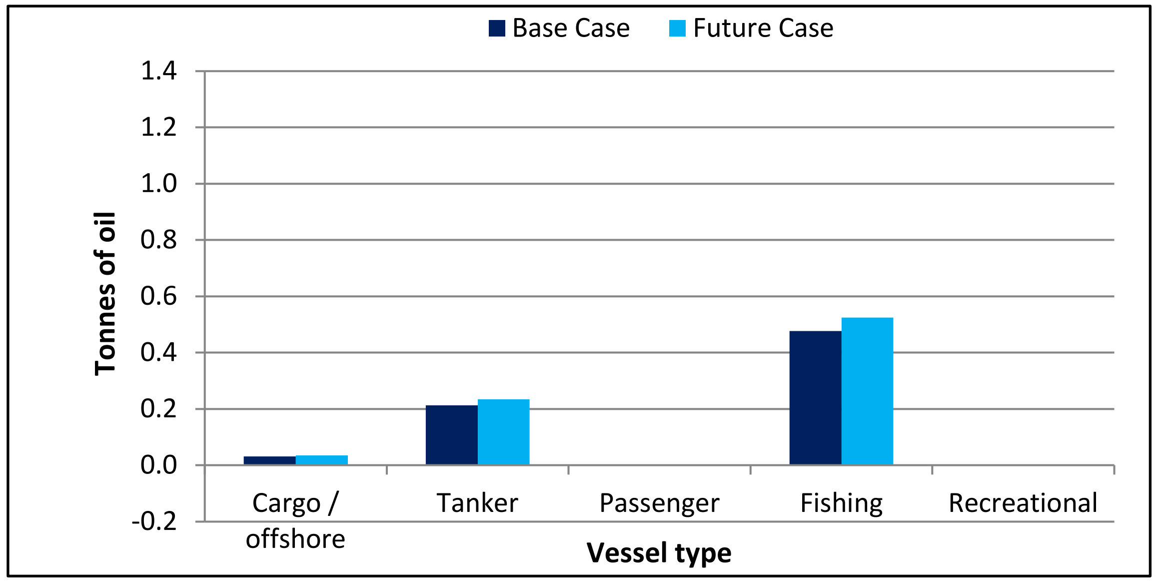


Figure A.23: Estimated change in pollution by vessel type.

A.5.2.2 It can be seen that fishing vessels contribute the majority of the overall risk of oil spills despite tankers having the potential to spill both fuel and cargo oils. However tankers do make up a greater proportion of the overall risk of oil spills than they do with regards to the fatality risk (see section A.4).

A.5.3 Significance of increase in pollution risk due to Hornsea Three array area

A.5.3.1 To assess the significance of the increased pollution risk from marine vessels caused by the wind farm, historical oil spill data for the UK has been used as a benchmark.

A.5.3.2 From the MEHRAs research (DfT, 2001); the annual average tonnes of oil spilled in the waters around the British Isles due to marine accidents in the ten year period from 1989 to 1998 was 16,111. This is based on a total of 146 reported oil pollution incidents of greater than one tonne (smaller spills are excluded as are incidents which occurred within port and harbour areas or as a result of operational errors or equipment failure). Commercial vessel spills accounted for approximately 99% of the total while fishing vessel incidents accounted for less than 1%.

A.5.3.3 The overall increase in pollution estimated due to the wind farm of 0.004% for the base case is very low compared to the historical average pollution quantities from marine accidents in UK waters.

A.6 Conclusions

A.6.1.1 The quantitative risk assessment indicates that the impact of the wind farm on people and the environment is relatively low compared to the existing background risk levels in UK waters.

A.6.1.2 However, it is recognised that there is a degree of uncertainty associated with numerical modelling. For example, the model does not consider the potential Radar interference from turbines which may have an influence on the risk of vessel to vessel collisions, especially in reduced visibility where one or both of the vessels involved is not carrying AIS. Therefore, conservative assumptions have been applied in this analysis and the overall project is being carried out based on the principle of ALARP to ensure the risks to people and the environment are managed to a level that is as low as reasonably practicable.

A.6.1.3 It should also be noted that this is the localised impact of a single project and there will be additional maritime risks associated with other offshore wind farm projects in the southern North Sea and the UK as a whole.

Appendix B Hazard Log

B.1.1.1 The complete Hazard Log for Hornsea Three can be seen below.

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Commercial Vessels																							
Deviation	Activities within the Hornsea Three array area and export cable route could cause commercial vessels to be deviated.	Commercial Vessels	C/D	Promulgation of Information. Consultation with vessel operators.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial vessels to be displaced from historical routes.	Increased journey time and distance.	5	1	1	1	2	1.3	Tolerable	Increased journey time and distance affecting operational schedules.	3	1	1	1	2	1.3	Broadly Acceptable	Ensure buoyed construction areas are appropriate to the size of the development. Construction safety zones must roll with the activity.	From a cumulative perspective it was noted that the construction buoys must take account of the presences of Project One and Two i.e. Do not significantly narrow the proposed corridor for an extended period of time.
Deviation	Activities within the Hornsea Three array area and export cable route cause commercial vessels to be deviated during adverse weather.	Commercial Vessels	C/D	Promulgation of Information. Consultation with vessel operators.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial vessels to be displaced from historical adverse weather routes.	Increased journey time and distance in adverse weather.	3	1	1	1	2	1.3	Broadly Acceptable	Inability to transit during adverse weather as a safe alternative cannot be found.	1	1	1	1	3	3.0	Broadly Acceptable	Additional consultation with users to identify adverse weather routes.	Commercial vessel operators noted that adverse weather routes were not important for them given they did not carry passengers or sensitive cargoes.
Collision	Activities within the Hornsea Three array area and export cable route cause commercial vessels to be deviated, increasing encounters and thus the risk of vessel to vessel collision.	Commercial Vessels including Commercial Ferries	C/D	Compliance with international and flag state regulations, MGN 372, promulgation of information.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial vessels to be deviated creating new areas of high density traffic or congestion points for third party vessels. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	5	1	1	1	1	1.0	Tolerable	Collision between vessels due to deviations associated with the Hornsea Three array area and export cable area during construction or decommissioning.	2	4	3	3	3	3.3	Broadly Acceptable	Ensure buoyed construction areas is appropriate to the size of the development. Construction safety zones must roll with the activity. Increased level of promulgation of information on the development so that all vessels can effectively passage plan.	From a cumulative perspective it was noted that vessel to vessel encounters would increase within the proposed navigational corridor during the construction of Hornsea Three (assuming that Project One and Two are constructed or under construction) and that additional mitigation such as routeing measures or fairway buoys may be required. A particular risk associated with small craft crossing the channel was noted, whom may not be fully aware of or be compliant with rule 9 of COLREGS.
Interaction	Activities within the Hornsea Three array area and export cable route corridor may create interactions between a third party commercial vessel and a project construction vessel.	Commercial Vessels including Commercial Ferries	C/D	Compliance with international and flag state regulations, MGN 372 and 543, promulgation of information, marine coordination, monitoring by AIS.	Presence of additional vessels within the area associated with Hornsea Three activities will increase the potential for encounters and therefore the potential for collisions. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters with Hornsea Three construction or decommissioning vessels and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	5	1	1	1	1	1.0	Tolerable	Collision between a Hornsea Three construction or decommissioning vessel and a third party vessel.	1	4	3	3	3	3.3	Broadly Acceptable	Project standard vessel health and safety requirements including competency assessments and audits.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Allision	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause increased allision risk for commercial vessels.	Commercial Vessels	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss or entrance into safety zone by third party vessel.	3	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a newly installed structure.	2	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	
Allision (NUC)	Presence of infrastructure within the Hornsea Three array area and export cable route corridor will increase allision risk to commercial vessels Not Under Command (NUC) in an emergency situation (including machinery related problems or navigational system errors).	Commercial Vessels	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses a risk specifically to a vessel NUC (likely due to mechanical failure).	Vessel NUC is on a closing point of approach with a structure but no allision occurs due to the vessel regaining power or other evasive action.	2	1	1	1	1	1.0	Broadly Acceptable	NUC vessel is on a closing point of approach with a structure and an allision occurs.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	
Deviation	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may displace commercial vessels leading to increased journey times or distances for commercial vessels.	Commercial Vessels	O	Promulgation of Information. Consultation with vessel operators.	Presence of the Hornsea Three array area and export cable route will cause commercial vessels to be displaced from historical routes.	Increased journey time and distance.	5	1	1	1	2	1.3	Tolerable	Increased Journey time and distance affecting operational schedules.	3	1	1	1	2	1.3	Broadly Acceptable	Continued promulgation of information noting when maintenance activities are occurring.	
Deviation	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may displace commercial vessels leading to increased journey times or distances for commercial vessels during adverse weather.	Commercial Vessels	O	Promulgation of Information. Consultation with vessel operators.	Presence of the Hornsea Three array area and export cable route will cause commercial vessels to be displaced from historical adverse weather routes.	Increased journey time and distance in adverse weather.	3	1	1	1	2	1.3	Broadly Acceptable	Inability to transit during adverse weather as a safe alternative can not be found.	1	1	1	1	3	1.5	Broadly Acceptable	No further mitigation required.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Collision	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause commercial vessels to be deviated, increasing encounters and thus the risk of vessel to vessel collision.	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, Promulgation of information.	Structures will cause commercial vessels to be deviated creating new areas of high density traffic or congestion points for third party vessels. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	4	1	1	1	1	1.0	Broadly Acceptable	Collision between vessels due to deviations associated with the Hornsea Three array area and export cable area during operations and maintenance.	1	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	From a cumulative perspective it was noted that vessel to vessel encounters would increase within in the proposed navigational corridor during the operation of Hornsea Three (assuming that Project One and Two are constructed) and that additional mitigation such as routeing measures or fairway buoys may be required. A particular risk associated with small craft crossing the channel was noted, whom may not be fully aware of or be compliant with rule 9 of COLREGS.
Interaction	O&M activities within the Hornsea Three array area and export cable route corridor may create interactions between third party vessel and project O&M vessels.	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, marine pollution contingency planning.	Presence of additional vessels within the area associated with Hornsea Three activities will increase the potential for encounters and therefore the potential for collisions. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters with Hornsea Three operations and maintenance vessels and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	3	1	1	1	1	1.0	Broadly Acceptable	Collision between a Hornsea Three operations and maintenance vessel and a third party vessel.	1	4	3	3	3	3.3	Broadly Acceptable	Vessel Health and Safety Requirements including competency assessments and audits.	
Allision	Presence of infrastructure located within the Hornsea Three array area may increase vessel to structure allision risk external to the array for commercial vessels.	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of infrastructure within the Hornsea Three array area and export cable route poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss of structure by third party vessel on the periphery of the site.	4	1	1	1	1	1.0	Broadly Acceptable	Allision with structure by third party vessel on the peripahry of the site.	2	4	3	3	3	3.3	Broadly Acceptable	Consideration for peripheral site design to ensure aids to navigation are effective. Additional aids to navigation including the potential for permanent floating aids.	It was noted in the workshop that large non turbine structures should not be placed on the periphery. Also, it was agreed that generally the array area would not be used for transiting by commercial vessels.
Allision (NUC)	Presence of infrastructure within the Hornsea Three array area may increase vessel to structure allision risk external to the array for NUC vessels in an emergency situation (including machinery related problems or navigational system errors).	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses a risk specifically to a vessel NUC (likely due to mechanical failure).	Vessel NUC is on a closing point of approach with a structure but no allision occurs due to the vessel regaining power or other evasive action.	3	1	1	1	1	1.0	Broadly Acceptable	NUC vessel is on a closing point of approach with a structure and an allision occurs.	2	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Allision	Presence of offshore HVAC booster stations within the export cable route corridor may increase vessel to structure allision risk for commercial vessels.	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of surface HVAC booster station poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss by third party vessel.	2	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a structure.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	
UKC	Presence of cable/scour protection, floating foundation moorings and subsea HVAC booster stations may reduce navigable water depth for commercial vessels.	Commercial Vessels including Commercial Ferries	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of subsurface HVAC booster station or mooring associated with a foundation poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss by third party vessel and under keel hazard.	2	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a structure causing damage to the keel.	1	1	3	3	4	2.8	Broadly Acceptable	Further mitigation will be required to mark the mooring lines associated with floating foundations.	
Specific Impacts for Commercial Ferries																							
Deviation	Activities within the Hornsea Three array area and export cable route cause commercial ferries to be deviated.	Commercial Ferries	C/D	Promulgation of Information. Consultation with vessel operators.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial ferries to be displaced from historical routes.	Increased journey time and distance within manageable parameters for vessels on a timetabled service.	5	1	1	1	3	1.5	Tolerable	Increased journey time and distance out with manageable parameters for vessels on a timetabled service.	3	1	1	1	3	1.5	Broadly Acceptable	Further consultation with vessel operators to ensure that both their normal and adverse weather routes are considered. Ensure buoyed construction areas is appropriate to the size of the development. Construction safety zones must roll with the activity.	Noted that Project One and Two, both consented, already displace the same routes as Project Three.
Deviation	Activities within the Hornsea Three array area and export cable route cause commercial ferries to be deviated during adverse weather.	Commercial Ferries	C/D	Promulgation of Information. Consultation with vessel operators.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial ferries to be displaced from historical adverse weather routes.	Increased journey time and distance.	4	1	1	1	3	1.5	Broadly Acceptable	Inability to transit during adverse weather as a safe alternative cannot be found.	2	1	1	1	4	1.8	Broadly Acceptable	Additional consultation with users to identify adverse weather routes.	DFDS agreed to provide further information on adverse weather routes used. Noted the additional sensitivity due to the carriage of passengers and roll-on roll-off cargoes.

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences							Worst Case Consequences	Realistic Worst Case Consequences							Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
								Consequences								Consequences							
							Frequency	People	Environment	Property	Business	Average Consequence	Risk		Frequency	People	Environment	Property	Business	Average Consequence	Risk		
Deviation	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may displace commercial ferries leading to increased journey times or distances for commercial ferries.	Commercial Ferries	O	Promulgation of Information. Consultation with vessel operators.	Presence of Hornsea Three Array will cause commercial ferries to be displaced from historical routes.	Increased journey time and distance within manageable parameters for vessels on a timetabled service.	4	1	1	1	3	1.5	Broadly Acceptable	Increased journey time and distance out with manageable parameters for vessels on a timetabled service.	4	1	1	1	4	1.8	Broadly Acceptable	No further mitigation required.	
Deviation	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may displace commercial vessels leading to increased journey times or distances for commercial ferries during adverse weather.	Commercial Ferries	O	Promulgation of Information. Consultation with vessel operators.	Presence of Hornsea Three Array will cause commercial ferries to be displaced from historical adverse weather routes.	Increased journey time and distance.	3	1	1	1	3	1.5	Broadly Acceptable	Inability to transit during adverse weather as a safe alternative can not be found.	3	1	1	1	4	1.8	Broadly Acceptable	No further mitigation required.	
Recreational Vessels																							
Collision	Activities within the Hornsea Three array area and export cable route may cause recreational vessels to be deviated, increasing encounters and thus the risk of vessel to vessel collision.	Recreational Vessels	C/D	Promulgation of Information.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause recreational vessels to be displaced from historical routes.	Increased encounters and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	5	1	1	1	1	1.0	Tolerable	Collision involving recreational vessel due to deviations associated with the Hornsea Three array area and export cable route during construction or decommissioning.	2	5	3	3	3	3.5	Broadly Acceptable	Safety zones should roll with the activity and information on construction phasing should be clearly promulgated.	It was agreed by recreational representatives at the workshop that recreational traffic was low and likely that mariners were highly skilled with better equipped vessels.
Interaction	Activities within the Hornsea Three array area and export cable route corridor may create interactions between a third party recreational vessel and project construction vessels.	Recreational Vessels	C/D	Compliance with international regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS.	Presence of additional vessels within the area associated with Hornsea Three activities will increase the potential for encounters and therefore the potential for collisions. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters with Hornsea Three construction or decommissioning vessels and therefore more collision avoidance action required by recreational vessels as per COLREGS but does not result in a collision.	4	1	1	1	1	1.0	Broadly Acceptable	Collision between a Hornsea Three construction or decommissioning vessel and a third party recreational vessel.	1	5	3	3	3	3.5	Broadly Acceptable	No further mitigation required.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Allision	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause increased allision risk for recreational vessels external to the array.	Recreational Vessels	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss or entrance into safety zone by third party recreational vessel..	3	1	1	1	1	1.0	Broadly Acceptable	Recreational vessel allides with a newly installed structure.	2	5	3	3	3	3.5	Broadly Acceptable	No further mitigation required.	
Allision (NUC)	Presence of infrastructure within the Hornsea Three array area and export cable route corridor will increase allision risk to recreational vessels NUC in an emergency situation (including machinery related problems or navigational system errors).	Recreational Vessels	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses a risk specifically to a recreational vessel NUC (likely due to mechanical failure).	Recreational vessel NUC is on a closing point of approach with a structure but no allision occurs due to the vessel regaining power or other evasive action.	2	1	1	1	1	1.0	Broadly Acceptable	NUC recreational vessel is on a closing point of approach with a structure and an allision occurs.	1	5	3	3	4	3.8	Broadly Acceptable	No further mitigation required.	
Collision (internal)	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause recreational vessels to be deviated, increasing encounters and thus the risk of a vessel to vessel collision internally within the array.	Recreational Vessels	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation.	Recreational vessels navigating internally within the array may become disorientated or confused leading to potential collisions. This could also be caused by vessels being obscured from one another due to structures and turbines. This could be associated with turbine layout, human error, navigational equipment error or adverse weather.	Near miss between a recreational vessel and another vessel internally within the array.	2	1	1	1	1	1.0	Broadly Acceptable	Collision between a recreational vessel and another vessel internally within the array.	1	5	3	3	3	3.5	Broadly Acceptable	No further mitigation required.	
Allision (internal)	Presence of infrastructure within the Hornsea Three array area may increase vessel to structure allision risk internally within the array for recreational users.	Recreational Vessels	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Recreational vessels navigating internally within the array may become disorientated or confused leading to potential allisions This could be associated with turbine layout, failure of navigational aids, human error, navigational equipment error or adverse weather.	Near miss with a structure by third party recreational vessel.	2	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a structure	1	5	3	3	3	3.5	Broadly Acceptable	No further mitigation required.	It is possible to become disorientated within the array area, particularly at low speeds where tidal streams can affect a vessel's course. This is more relevant as spacing becomes larger, however it was agreed that the larger the spacing the less need for alignment.

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences							Worst Case Consequences	Realistic Worst Case Consequences							Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
							Frequency	Consequences: People	Environment	Property	Business	Average Consequence	Risk		Frequency	Consequences: People	Environment	Property	Business	Average Consequence	Risk		
Allision	Presence of offshore HVAC booster stations within the export cable route corridor may increase vessel to structure allision risk for recreational users.	Recreational Vessels	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of surface HVAC booster station poses an allision risk to recreational vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss by recreational vessel.	2	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a structure	1	5	3	3	4	3.8	Broadly Acceptable	No further mitigation required.	
UKC	Presence of cable/scour protection, floating foundation moorings and subsea HVAC booster stations may reduce navigable water depth for recreational vessels.	Recreational Vessels	O	Compliance with international and flag state regulations, MGN 372, Promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of subsurface HVAC booster station or mooring associated with a foundation poses an allision risk to recreational vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss by recreational vessel.	2	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a structure causing significant damage to the keel/founder.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	Recreational representative in the workshop stated that subsurface HVAC booster stations would be preferable to surface.
Commercial Fishing Vessels																							
Collision	Activities within the Hornsea Three array area and export cable route could cause commercial fishing vessels to be deviated, increasing encounters and this risk of vessel to vessel collision.	Commercial Fishing Vessels (in transit/mobile gear)	C/D	Promulgation of Information. Consultation with vessel operators.	Presence of construction or decommissioning activities, buoyed construction areas and safety zones will cause commercial vessels to be displaced from historical routes.	Increased encounters and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	5	1	1	1	1	1.0	Tolerable	Collision involving commercial fishing vessel due to deviations associated with the Hornsea Three array area and export cable route during construction or decommissioning.	1	5	3	3	3	3.5	Broadly Acceptable	No further mitigation required.	
Interaction	Activities within the Hornsea Three array area and export cable route corridor may create interactions between a third party commercial fishing vessel and a project construction vessel.	Commercial Fishing Vessels (in transit/mobile gear)	C/D	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS.	Presence of additional vessels within the area, associated with Hornsea Three activities will increase the potential for encounters and therefore the potential for collision. This impact could also include causes associated with navigational error, human error or adverse weather.	Increased encounters with Hornsea Three construction or decommissioning vessels and therefore more collision avoidance action required by vessels as per COLREGS but does not result in a collision.	5	1	1	1	1	1.0	Tolerable	Collision between a Hornsea Three construction or decommissioning vessel and a third party commercial fishing vessel.	1	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences							Worst Case Consequences	Realistic Worst Case Consequences							Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
								Consequences								Consequences							
							Frequency	People	Environment	Property	Business	Average Consequence	Risk		Frequency	People	Environment	Property	Business	Average Consequence	Risk		
Allision	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause increased allision risk for commercial fishing vessels.	Commercial Fishing Vessels (in transit/mobile gear)	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses an allision risk to fishing vessels (including gear snagging). The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss or entrance into safety zone by third party commercial fishing vessel.	3	1	1	1	1	1.0	Broadly Acceptable	Vessel allides with a newly installed structure.	2	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	
Allision (NUC)	Presence of infrastructure within the Hornsea Three array area and export cable route corridor will increase allision risk to commercial fishing vessels NUC in an emergency situation (including machinery related problems or navigational system errors).	Commercial Fishing Vessels (in transit/mobile gear)	C/D	Buoyed construction areas, safety zones, temporary navigational marks, marine coordination, monitoring by AIS, promulgation of information.	Presence of newly installed infrastructure within the Hornsea Three array area and export cable route poses a risk specifically to a fishing vessel NUC (likely due to mechanical failure).	Commercial fishing vessel NUC is on a closing point of approach with a structure but no allision occurs due to the vessel regain power or other evasive action.	2	1	1	1	1	1.0	Broadly Acceptable	NUC commercial fishing vessel is on a closing point of approach with a structure and an allision occurs.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	
Collision (Internal)	Presence of infrastructure within the Hornsea Three array area and export cable route corridor may cause commercial fishing vessels to be deviated, increasing encounters and thus the risk of a vessel to vessel collision internally within the array.	Commercial Fishing Vessels (in transit/mobile gear)	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Fishing vessels navigating internally within the array may become disorientated or confused leading to potential collisions. This could also be caused by vessels being obscured from one another due to structures and turbines. This could be associated with turbine layout, human error, navigational equipment error or adverse weather.	Near miss between a commercial fishing vessel and another vessel internally within the array.	4	1	1	1	1	1.0	Broadly Acceptable	Collision between a commercial fishing vessel and another vessel internally within the array.	1	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences							Worst Case Consequences	Realistic Worst Case Consequences							Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
							Frequency	Consequences: People	Environment	Property	Business	Average Consequence	Risk		Frequency	Consequences: People	Environment	Property	Business	Average Consequence	Risk		
Allision (Internal)	Presence of infrastructure within the Hornsea Three array area may increase vessel to structure allision risk internally within the array for commercial fishing vessels.	Commercial Fishing Vessels (in transit/mobile gear)	O	Compliance with international and flag state regulations, MGN 372, Promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Fishing vessels navigating internally within the array may become disorientated or confused leading to potential allisions. This could be associated with turbine layout, failure of navigational aids, human error, navigational equipment error or adverse weather.	Near miss with a structure by third party commercial fishing vessel.	3	1	1	1	1	1.0	Broadly Acceptable	Commercial fishing vessel allides with a structure.	1	4	3	3	3	3.3	Broadly Acceptable	No further mitigation required.	
Allision	Presence of offshore HVAC booster stations within the export cable route corridor may increase vessel to structure allision risk for commercial fishing vessels.	Commercial Fishing Vessels (in transit/mobile gear)	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of surface HVAC booster station poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational error.	Near miss by third party commercial fishing vessel.	2	1	1	1	1	1	Broadly Acceptable	Commercial fishing vessel allides with a structure.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	
UKC	Presence of cable/scour protection, floating foundation moorings and subsea HVAC booster stations may reduce navigable water depth for commercial fishing vessels.	Commercial Fishing Vessels (in transit/mobile gear)	O	Compliance with international and flag state regulations, MGN 372, promulgation of information, marine coordination, monitoring by AIS, permanent aids to navigation, marine pollution contingency planning.	Presence of subsurface HVAC booster station or mooring associated with a foundation poses an allision risk to vessels. The risk could be associated with lack of or failure of navigational marking, human error, adverse weather, navigational equipment error.	Near miss by third party commercial fishing vessel.	2	1	1	1	1	1.0	Broadly Acceptable	Commercial fishing vessel allides with a structure causing significant damage to the keel.	1	4	3	3	4	3.5	Broadly Acceptable	No further mitigation required.	
Snagging	Physical presence of partially installed cables (which may be exposed or partially buried/protected) and other subsea infrastructure (including foundations and mooring lines) will present an increased risk of gear snagging for commercial fishing vessels.	Commercial Fishing Vessels (mobile gear)	C/D	Cable burial risk assessment, compliance with international and flag state regulations, use of guard vessels or temporary marks, promulgation of information (charting and KISORCA).	Presence of partially installed cables or structures could pose a risk to vessels fishing in proximity or near to current areas of operation. This could be associated with human error or navigational equipment error.	A vessel fishes (trawls) on an area of exposed /partially buried cable or partially completed structure but no interaction occurs.	3	1	1	1	1	1.0	Broadly Acceptable	A vessel fishes (trawls) on an area of exposed /partially buried cable or partially completed structure. This results in damage to the cable, gear or foundering of vessel.	2	5	4	3	4	4.0	Tolerable	A fishing plotter app developed for the O&G industry was mooted. Such software is viable as a mitigation for the HVAC booster stations.	It was noted during the workshop that the type of foundation will significantly impact the risk.

Hazard Type	Hazard Title	Receptor	Phase (C/O/D)	Industry Standard Risk Reduction Measures (Assumed In Place)	Possible Causes	Most Likely Consequences	Realistic Most Likely Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Worst Case Consequences	Realistic Worst Case Consequences: Frequency	Consequences: People	Consequences: Environment	Consequences: Property	Consequences: Business	Average Consequence	Risk	Risk Reduction Measures (Initial risk assessment was undertaken assuming industry standard mitigation is in place, therefore this column highlights mitigations above that level)	Additional Comments
Snagging	Presence of cables and other subsea infrastructure (including foundations and mooring lines) will present an increased gear snagging risk for commercial fishing vessels.	Commercial Fishing Vessels (mobile gear)	O	Cable burial risk assessment, compliance with international and flag state regulations, promulgation of information (charting).	Presence of exposed cables or subsurface structures could pose a risk to vessels fishing in proximity or near to current areas of operation. This could be associated with human error or navigational equipment error.	A vessel fishes (trawls) close to an area of exposed cable or subsurface structure but no snagging interaction occurs.	5	1	1	1	1	1.0	Tolerable	A vessel fishes (trawls) on an area of exposed or partially buried cable or subsurface structure. This results in damage to the cable, gear or foundering of vessel.	2	5	4	3	4	4.0	Tolerable	A fishing plotter app developed for the O&G industry was mooted. Such software is viable as a mitigation for the HVAC booster stations.	During the workshop it was noted that the design of the HVAC booster stations was important with regards to the risk of gear snagging. It was also noted that floating foundations represented the highest snagging risk followed by jackets, monopiles and gravity base.
Anchored Vessels																							
Snagging	Physical presence of partially installed cables (which may be exposed or partially buried/protected) and other subsea infrastructure (including mooring lines) will present an increased risk of anchor snagging for commercial vessels and commercial fishing vessels.	All vessels including Commercial Fishing Vessels (not engaged in fishing).	C/D	Cable burial risk assessment, compliance with international and flag state regulations, use of guard vessels or temporary marks, promulgation of information (charting).	Presence of partially installed cables or structures could pose a risk to vessels anchoring in proximity or near to current areas of operation. This could be associated with human error or navigational equipment error.	A vessel anchors on an area of exposed /partially buried cable or partially completed structure but no interaction occurs.	3	1	1	1	1	1.0	Broadly Acceptable	A vessel anchors on an area of exposed /partially buried cable or partially completed structure. This results in damage to the cable and/or anchor.	2	2	3	3	2	2.5	Broadly Acceptable	No further mitigation required.	
Snagging	Presence of cables and other subsea infrastructure will present an anchor snagging risk for commercial vessels and commercial fishing vessels.	All vessels including Commercial Fishing Vessels (not engaged in fishing).	O	Cable burial risk assessment, compliance with international and flag state regulations, promulgation of information (charting).	Presence of installed cables could pose a risk to vessels anchoring. This could be associated with human error, navigational equipment error or adverse weather.	A vessel anchors on an area of buried / protected cable but no interaction occurs.	4	1	1	1	1	1.0	Broadly Acceptable	A vessel anchors on an area of exposed or partially buried cable or subsurface structure resulting in damage to the cable and/or anchor.	3	2	3	3	2	2.5	Broadly Acceptable	Monitoring and maintenance of cable burial.	Although not identified as a shipping and navigation impact it was noted by marine aggregate dredger representatives in the workshop that potential for gear interaction with export cables should be mitigated against.

Appendix C Helicopter Search and Rescue Operations in Offshore Windfarms

C.1.1.1 This section of the NRA has been produced by Aviation Safety Consulting Limited.

C.2 Introduction

C.2.1.1 This report is intended to explain the basic principles, capabilities and limitations of offshore helicopter search and rescue (SAR) operations in the UK. It will assess the effects of the design, location and layout of wind turbines on such operations and, where necessary, provide recommendations on how any potentially significant adverse impacts may be mitigated or avoided.

C.2.1.2 While this report discusses design options and other measures that are potentially available to mitigate significant adverse effects, the scope of this report does not extend to a Cost Benefit Analysis that establishes whether, or not, the costs associated with these are grossly disproportionate to the benefits gained.

C.3 Background

C.3.1 Helicopter assets

C.3.1.1 Search and rescue operations (SAROPS) in offshore wind farms that are any significant distance from the coast are likely to be conducted principally by helicopters, due to the relatively long distances and the longer response and transit times of surface vessels unless they happen to be on-site. In the case of the Hornsea Three array area, the closest SAR helicopter base is Humberside Airport. This base is operated by Bristow Helicopters on behalf of the Maritime and Coastguard Agency (MCA), using the Sikorsky S92A SAR helicopter. Other bases in the UK are currently using either the S92A or the Leonardo AW139, which is an interim type due to be replaced by the Leonardo AW189, over the course of the next two years.The capability of the S92A will be used as the basis for this analysis, as it is considered to currently be the most likely machine to be used for SAROPS in the Hornsea Three array area: an AW189 would have a similar capability and constraints.

C.3.2 SAR helicopter equipment

C.3.2.1 The Sikorsky S92A is fitted with highly specialised equipment for the SAR role. This includes:

- A 4-axis flight control system with autopilot;
  - Amongst other capabilities, this allows the aircraft to fly pre-programmed search patterns and descend to the hover for a recovery.
  - This can be coupled to an airfield's instrument landing system (ILS) equipment which allows the helicopter to make an approach to the runway in poor weather.
- A weather radar system;
  - This radar can also be used to search for vessels and other contacts.
  - It can be used for obstacle clearance allowing the helicopter to descend safely when offshore.
- A combined forward looking infra-red (FLIR) and thermal imaging (TI) sensor;
  - This system has four camera sensors: mid-range infra-red (IR), high IR, Television (TV) and low light TV. It has a 30x optical zoom and digital image enhancement.
- A Chelton radio homer incorporating six independent receivers;
  - This allows the SAR helicopter to home onto beacons transmitting on emergency frequencies such as 406 MHz, 243.0 MHz or 121.5MHz, as well as vessels transmitting on marine DSC frequencies or any manually selected frequency.
- A dual rescue hoist;
- Ultra High Frequency (UHF), VHF Amplitude Modulation (AM), VHF Frequency Modultation (FM) and High Frequency (HF) radios and a satellite telephone;
- A lightweight stretcher; and
- Medical facilities including oxygen, entonox and a defibrillator.

C.3.3 SAR helicopter crew

C.3.3.1 A typical crew consists of two pilots, a winchman and a winch operator. The winchman is always a fully trained paramedic.

C.3.4 Capabilities and limitations

C.3.4.1 The S92A typically flies at a cruise speed of 145 knots (kn) and has an effective radius of action of about 200 nm, with sufficient fuel for 30 minutes on station at the limit of this range. This can be extended if refuelling facilities are available en route (for example, at a suitable offshore platform). The helicopter is equipped to fly in both Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC), by day and night. It has a clearance to fly in icing conditions up to 10,000 ft pressure altitude, but cannot fly in freezing rain or drizzle, which occur very rarely in the UK.

C.3.4.2 Its sensors and equipment are tailored to the SAR role, the key limitations of these are as follows:

- Weather radar;
  - 120-degree forward sweep sector;
  - Maximum range – 300 miles (mi.) (at altitude); and
  - Minimum blind range – 150 yards (yds) (240 yds in normal operation).
- Hoist cables – 290 feet (ft) long;
- ILS – When conducting an instrument approach to an airfield in poor weather, the lowest permitted approach to a suitable runway before transferring to a visual approach is 200 ft;
- MCA guidance and Bristow's internal procedures do not allow a SAR helicopter to enter a wind turbine lane that is less than 500 m wide (measured between blade tips, that are transverse to the turbine lanes, unless the blades can be rotated away from the lane to increase the spacing to 500 m or more) in Instrument Meteorological Conditions (IMC) or at night (MCA, 2016).

C.3.5 SAR helicopter response times

C.3.5.1 UK helicopter SAR crews are typically at 15 minutes notice to launch during the day and 45 minutes at night. The centre of the Hornsea Three array area is almost exactly 120 nm to the east of Humberside Airport.

C.3.5.2 The typical speed of an S92 is 145 kn, so the expected time on scene for a SAR helicopter in the area would be:

- Day: 15 minutes + (120 / 145) x 60 = 65 minutes; and
- Night: 45 minutes + (120 / 145) x 60 = 95 minutes.

C.3.6 Fixed wing assets

C.3.6.1 Since the Nimrod was withdrawn from service by the UK MOD in 2011, there has been no reliable source of fixed wing aircraft available for the SAR role. The MOD has recently committed to procure nine P8-A Poseidon Maritime Patrol Aircraft which will be introduced in 2019 to 2020. One of the roles of the aircraft type will be Search and Rescue. It will have the advantages of a suite of highly sophisticated sensors, a high search speed (approximately 440 knots), a long endurance and highly trained crews. The aircraft will be based at Royal Air Force (RAF) Lossiemouth, approximately 300 nm from the Hornsea Three array area, about a 40 minute transit time from take-off.

C.3.6.2 The MOD state (MOD, 2016) that:

"The P-8A can operate at long range from its operating base without refuelling and has the endurance to carry out high and low-level airborne maritime and overland surveillance for extended periods. This cutting-edge aircraft will also be able to conduct wide-area search of open ocean to locate small boats and drop rescue life-rafts and equipment to vessels and people in distress".

C.3.7 Surface vessel assets

C.3.7.1 The distance of the wind farm from the coast means that shore-based vessels such as RNLI lifeboats would take a considerable time to reach the scene in the event of an incident. It is also possible that third party vessels could be involved, as they can be requisitioned by the search and rescue authorities. The International Convention SOLAS (IMO, 1974) regulation 33 requires that:

"The Master of a vessel at sea which is in a position to be able to provide assistance on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance, if possible informing them or the search and rescue service that the vessel is doing so."

C.3.7.2 Depending on the construction, operation and maintenance strategies that are developed, there is likely to be a OSV on site in the wind farm, which will have a search and recovery capability. A typical operating cycle for this type of vessel will be to spend 14 days offshore followed by five days in transit/alongside in port.

C.3.7.3 The response time for an OSV on site to an incident within the wind farm would be relatively short, but in comparison with a SAR helicopter, it will travel at a much lower speed, have a limited visual detection range due to the height of the bridge and will lack the helicopter's sophisticated sensors and crews with specialist training. It would, however, likely be equipped with daughter craft which can travel at over 30 kn in suitable sea conditions.

C.4 SAROPS

C.4.1.1 SAROPS can be divided into four distinct phases, each of which can be affected differently by the presence of wind turbines and their layout. These are:

1. The planning and search phase;
2. The detection and identification of a target;
3. The casualty recovery; and
4. Helicopter emergencies.

C.4.2 The search phase

C.4.2.1 The initial tasking will be based upon the information available at the time of the dispatch. It will typically include the nature of the emergency, details of the casualty or casualties (which may be vessels, aircraft or personnel), the source and time of the first alert. It will invariably include some location information, though details are often very scarce at this stage. The location information may simply be an area containing all possible survivor locations. This is usually done by estimating the maximum distance that the survivors could have travelled since the time of their last known position (LKP) and the known or assumed time of the distress incident and drawing a circle of that radius around the LKP. The accuracy of the datum will vary: an initial detection by a Cospas-Sarsat satellite of an Emergency Position Indicating Radio Beacon (EPIRB) or PLB will give an accuracy within five nautical miles, a second pass (usually within an hour) will reduce this to about one nautical mile, if the emergency locator transmitter (ELT) is a GPS-enabled the position may be accurate to within 30 m, rendering any search unnecessary. In many cases, however, the exact location of the casualty will not be available and a search will therefore be required before assistance can be rendered. A search will therefore always be based upon a datum point, which is defined in the International Aeronautical and Maritime Search and Rescue (IAMSAR) (IMO, 2016) Manual as:

C.4.2.2 A point, such as a reported or estimated position, at the centre of the area where it is estimated that the search object is most likely to be located.

C.4.2.3 The principal types of search, which may be used singly or in any combination, are as follows:

- Visual search;
  - Day – Using the naked eye.
  - Night – Night vision goggles (NVG).
- Radar search;
- Electro-optical search; and
  - FLIR.
  - TI.
- Radio search.
  - Homing to 121.5MHz PLB or ELT

C.4.2.4 The type of search pattern, altitude flown and track spacing used will depend on a number of factors which all affect the probability of detection (POD). These include:

- Search type (visual/radar/radio/TII/FLIR);
- Size/colour/lighting of target (including radar cross section);
- Meteorological conditions, including:
  - Cloud base (a low cloud base may mean a low search altitude and thus a small track spacing).
  - Visibility (affects visual/FLIR/TI) - mist, fog, rain and snow may all affect visibility and the POD.
- Time of day
  - Visual detection may be more difficult looking towards the sun when it is low in the sky.
- Sea conditions (wind/swell/waves)
  - A high sea state will reduce the POD by all sensors
- Sensitivity of equipment (Radar/FLIR/TI).
  - This will depend on the type of aircraft involved (fixed wing or helicopter)

C.5 Typical search patterns

C.5.1.1 The type of search pattern used will depend upon the accuracy of the datum (i.e. the most probable location of a search object) and the time it was established, as well as the probability that the target may have drifted before SAR assets arrive on scene.

C.5.1.2 In open water, the most common search patterns used by UK SAR helicopters are:

- Expanding square search;
- Sector search;
- Track line search;
- Creeping line ahead search; and
- Contour search (onshore only).

C.5.1.3 These searches may have to be modified due to local circumstances, such as the presence of land or obstacles in poor weather. An explanation of each search type is provided in the following sections.

C.5.2 Expanding square search

C.5.2.1 This search pattern is often used when searching for persons in the water or other search objects with little or no leeway caused by wind, tide or current. It is most effective when the location of the target is known within relatively close limits.

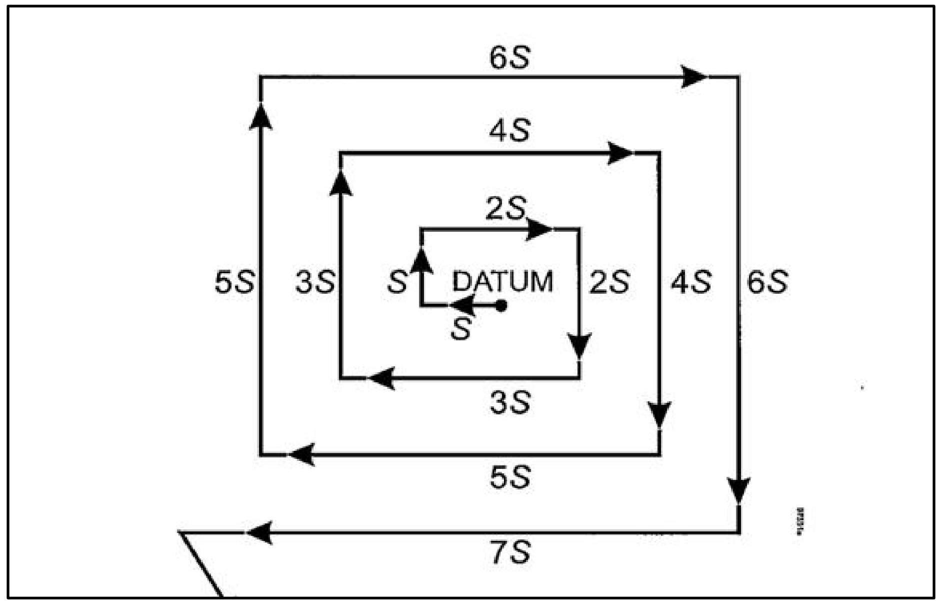


Figure C.1: Expanding square search.

C.5.3 Sector search

C.5.3.1 This pattern is most effective when the position of the search object is accurately known and the search area is small.

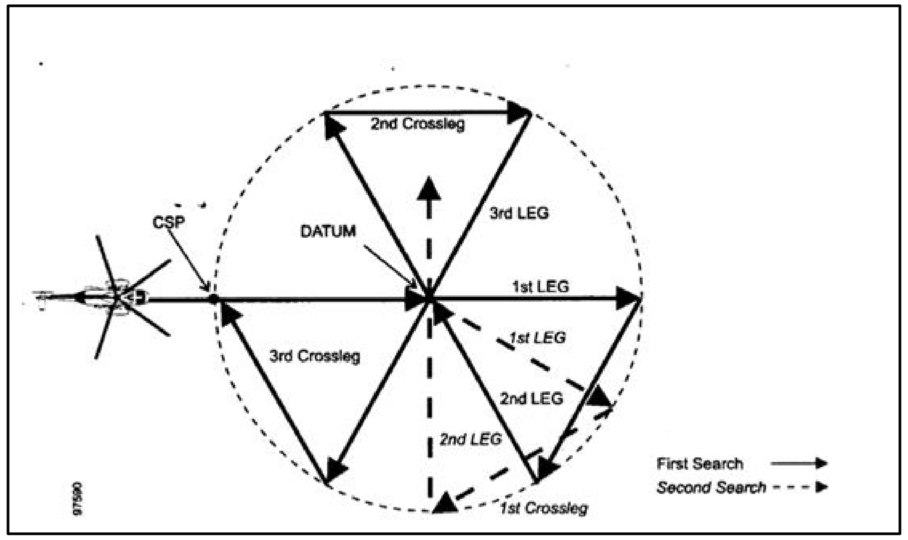


Figure C.2: Sector search.

C.5.4 Track line search

C.5.4.1 The track line search pattern is normally employed when an aircraft or vessel has disappeared without a trace while en-route from one point to another.

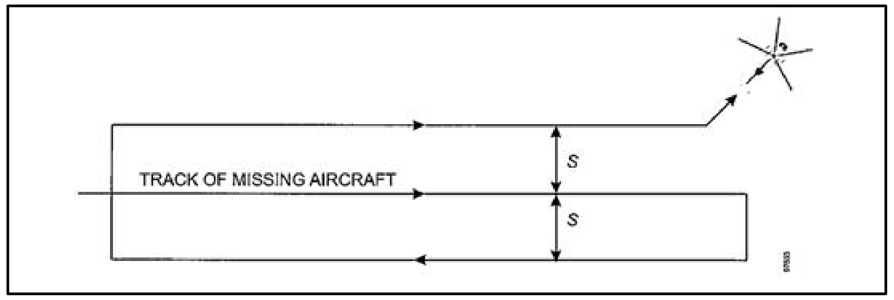


Figure C.3: Track line search.

C.5.5 Creeping line ahead search

C.5.5.1 This pattern is often used when the target may have drifted from the datum due to wind/tide.

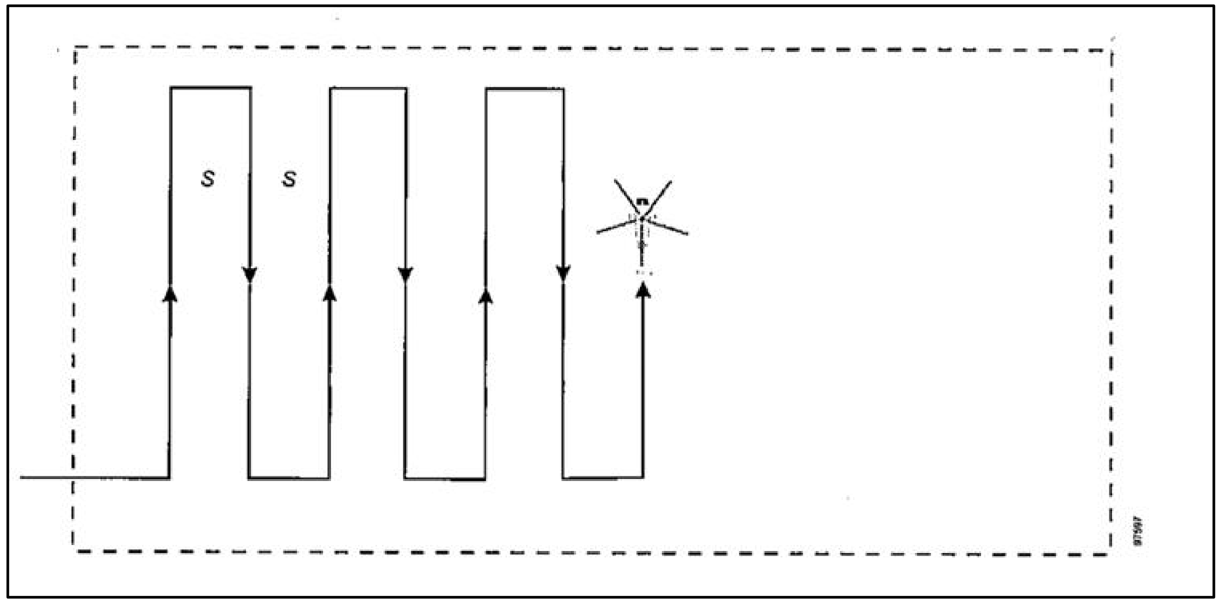


Figure C.4: Creeping line ahead search.

C.6 Search altitudes

C.6.1.1 Search altitude is a key consideration in search planning. As shown in Table C.1, a higher altitude provides a greater distance to the horizon, but a correspondingly reduced POD for a small object.

Table C.1: Horizon range table.

Altitude in ft	Distance in nm	Altitude in m	Distance in km
500	26	150	47
1000	37	300	66

C.6.1.2 The altitude at which a SAR helicopter will conduct a radar, visual and/or electro-optical search will depend upon a variety of factors. These include:

- The number, size, colour and lights (if any) of a target;
  - The larger and more brightly coloured or lit a target is, the more easily it will be visually detected.
- The time of day;
  - The POD by the naked eye will vary with the amount of ambient light.
  - Night vision goggles depend upon ambient light from the moon and stars. A small unlit target on a dark night will require reduced track spacing.
- The radar cross-section of any target(s);
  - Most surface vessels will have a radar signature.
  - High sea state will increase radar clutter and make discriminating a target more difficult.
- The sea state;
  - The POD of a small target will reduce with increasing sea state.
- Visibility;
  - Reduced visibility in mist, fog or precipitation will mean a lower optimum search altitude.
- The cloud base;
  - Radar/radio searches can be conducted while the helicopter is in cloud, but visual/FLIR/TI searches cannot. A low cloud base means a lower search altitude than the optimum may be necessary.
- The radar/radio horizon.
  - VHF radio transmissions on 121.5 MHz from a PLB or EPIRB are 'line of sight', therefore the distance at which a transmission can be detected will vary with altitude. The optimum altitude for homing to an EPIRB/PLB is typically 1000 ft because this gives a distance to the horizon of about 38 mi. (since the EPIRB/PLB transmitter will be at sea level) and beyond this range the VHF signal may be too weak to be detected. At higher altitudes, the signal will still be detected but the probability of a visual detection reduces.
- Similarly, the maximum effective radar range will vary with altitude.

C.6.1.3 SAR crews will have access to tables which provide guidance on optimum search altitudes and track spacing's. Table C.2 illustrates example sweep widths for a visual search for a variety of targets at different altitudes, assuming a visibility of ten. In ideal conditions, the sweep width could be up to 55 km for a large vessel.

Table C.2: Sweep widths in km (nm in brackets) vs altitude for various targets in 10 nm visibility.

Altitude Search Object	150 m (500 ft)	300 m (1000 ft)	600 m (2000 ft)
Person In water	0.2 (0.1)	0.2 (0.1)	0.0 (0.0)
4-person life raft	4.1 (2.2)	4.3 (2.3)	4.3 (2.3)
8-person life raft	5.2 (2.8)	5.4 (2.9)	5.6 (3.0)
15-person life raft	6.1 (3.3)	6.5 (3.5)	6.7 (3.6)
Power Boat 6 m (20 ft)	8.0 (4.3)	8.1 (4.4)	8.3 (4.5)
Sailing Boat 15 m (49 ft)	17.6 (9.5)	17.6 (9.5)	17.8 (9.6)
Vessel 27 to 46m (90-150ft)	22.6 (12.2)	22.6 (12.2)	22.6 (12.2)
Vessel >91m (>300ft)	26.5 (14.3)	26.5 (14.3)	26.5 (14.3)

C.6.1.4 Note: For search altitudes of 150 m (500 ft) only, the sweep width values for a person in the water may be multiplied by 4 if it is known that the person is wearing a personal flotation device.

C.6.1.5 In practical terms, if the cloud base and obstacles permit, most radar or radio homing searches are likely to be conducted at about 1000 ft altitude, where the superstructure of a vessel may be detected at ranges beyond those in Table C.2. This is also the optimum altitude for the detection of VHF signals from an EPIRB or PLB. The optimum altitude for visual and electro-optical searches is between 200 and 500 ft.

C.6.1.6 It should also be noted that the data in Table C.2 (IMO, 2016) was developed before the advent of electro-optical search aids such as TI and FLIR (nevertheless, the table is still relevant for searching for a life raft, which may have no thermal signature). Current guidance is for SAR crews to search for a man overboard (typically the smallest target and the most difficult to detect) using a combination of visual and thermal imaging from 500 feet altitude and a sweep width of 0.5 nm.

C.7 Sweep width or track spacing

C.7.1.1 The sweep width (which determines the track spacing for a search) will depend upon the sensor(s), the target and the environmental conditions.

C.7.1.2 The sweep width will depend upon all the factors listed above which affect the optimum search altitude, as well as:

- The elevation of the sun or moon, which may affect visual detection ranges;
- The wind strength, which is allied to sea state;
  - SAR crews will apply a "white cap correction factor" to determine the optimum sweep width.
- The field of view (FOV) of electro-optical equipment; and
  - The 'footprint' observed by FLIR/TV equipment will depend upon the search altitude and the angle of depression of the sensor.
- Radar 'blind' ranges (the radar uses the same antenna for transmitting and receiving. During the transmission of a pulse, the radar cannot receive and thus there is a minimum range inside which the radar cannot detect a target. The shorter the pulse length, the smaller the minimum range).
  - Can be 150 -240 m depending upon radar mode.
  - Bristow crews are currently prohibited from entering wind farms with spacing of <500 m between blade tips in IMC or fog. Even with wider spacing, it will take longer to search a congested area with an adequate probability of detection.

C.7.1.3 The diagram (Figure C.5) below shows the probability of detection against the sweep width. It is worth noting that the area of 100% POD is very small, and that it is also possible to detect a target beyond the sweep width.

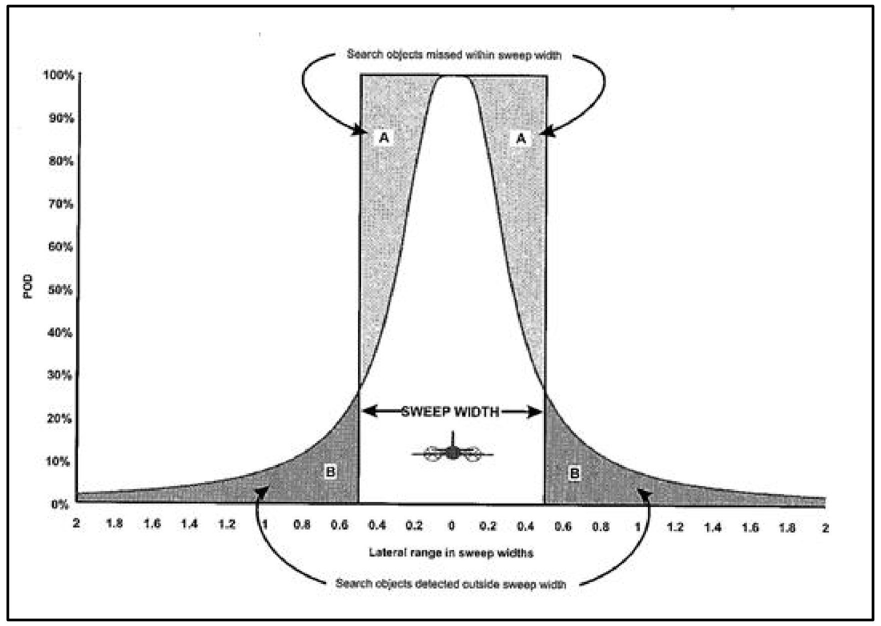


Figure C.5: Sweep width versus probability of detection.

C.8 Detection and identification

C.8.1.1 Sensors typically detect targets long before they are positively identified, either as a casualty or one that can be discounted. Positive identification is almost always achieved visually when the SAR helicopter has arrived on scene. The systems in the SAR helicopter allow for a degree of integration to expedite the process of identifying 'targets of interest' before approaching to conduct a positive identification. For example, the FLIR/TI camera can be slewed to radar targets which allow them to be processed quickly using the high optical magnification of the TV camera. That said, there may be multiple false targets which will have to be eliminated, depending upon the environment and the sensor. A high density of shipping will make it more difficult to identify a particular vessel visually or by using FLIR/TI, and the very presence of turbines in a wind farm will generate radar returns as well as thermal signatures, which may mask the presence of a casualty within the area.

C.8.2 Impact of weather on probability of detection

C.8.2.1 There are three key weather factors which will affect the probability of detection during a search. These are:

- Cloud base;
  - A low cloud base may force the SAR helicopter to search from a lower altitude than is ideal. This will lead to a smaller track spacing and an increase in the time taken to search an area.

- Visibility; and
  - Poor visibility will reduce the range at which a target can be detected (and it adversely affect the performance of thermal imaging equipment). This can also lead to reduced track spacing and a corresponding increase in the time taken to conduct a search.
- Wind / Sea state.
  - Strong winds are normally associated with a high sea state, though this may persist for some time after the wind has dropped
  - A high sea state will increase 'clutter' on the radar returns making small objects much more difficult to detect.
  - A high sea state (known as the 'white cap effect') will make it more difficult to detect and identify an object in the water, either visually or using TI.
  - The 'white cap' effect in strong winds may require a correction factor to the sweep width, reducing it by as much as 90% in gale force winds if a reasonable POD is to be achieved.

C.9 Potential positive impacts of Hornsea Three on SAROPS

C.9.1 General

C.9.1.1 The presence of a wind farm could have several beneficial effects during a SAROP; some of the possibilities are outlined below.

C.9.2 Location information

C.9.2.1 A casualty within the wind farm might be able to provide a rapid and accurate position report by referring to the turbine identification numbers described in MGN 543 (MCA, 2016).

C.9.2.2 The CGOC might be able to tap into AIS, VHF, and radar information from facilities installed in the wind farm.

C.9.3 SAROPS

C.9.3.1 An OSV, which will be on site most of the time, equipped with fast rescue craft may be on scene before a SAR helicopter arrives. If the position of a casualty is known, it could recover survivors quickly and it could commence a search if necessary, although it is a less effective platform for this than a helicopter.

C.9.4 Communications

C.9.4.1 Communications between the CGOC and helicopter operating at low level could be enhanced by relaying communications to shore via wind farm assets.

C.9.5 Fuel

C.9.5.1 If fuel were available on a suitable platform within the array, the SAR helicopter might be able to land, refuel and extend its endurance

C.10 Wind turbines and search patterns

C.10.1 General

C.10.1.1 The search patterns which are used in open water may have to be modified if a search area includes all or part of an offshore wind farm, though it is highly unlikely that in a large wind farm, such as Hornsea Three, the search would need to include the entire layout. If the turbine spacing permits, a SAR helicopter should be able to turn safely within the wind farm, even in poor visibility or at night, if the turbine locations are correctly mapped in the helicopter's flight management system (FMS), as the layout and tracks will be visible on the moving map display. To conduct an effective search within an offshore wind farm, the SAR crew will need to be able to plan a route which gives an adequate POD over the entire area to be searched. The variables which will need to be taken into account are discussed below.

C.10.2 Altitude

C.10.2.1 If the cloud base and visibility permit, in most cases a SAR helicopter will initially follow the planned track search by overflying the wind turbines, and then descending to investigate any targets of interest. The increased altitude may result in a lower POD if the target is small and if the cloud base is low and the search will then have to be conducted following a track between the turbines.

C.10.3 Track spacing

C.10.3.1 If the cloud base is lower and the turbine spacing adequate, it will be possible to fly between the turbines, even in poor visibility and at night, but the track may have to be modified and the presence of the turbines may mean that the optimal track spacing cannot be achieved. Overall, this may result in a lower POD or an increase in the time required to search an area.

C.10.4 Orientation

C.10.4.1 The orientation of a search pattern will depend upon the type of search (whether it is based on a datum point or a track) and the anticipated movement of a target due to wind, tide or current. If the wind is strong, this is likely to be a predominant factor. The IAMSAR Manual contains tables which indicate that a life raft without a drogue can move downwind at over 2 kn in a strong wind, whereas a single person in the water is likely to move at less than 0.5 kn.

C.10.4.2 Given the option, the helicopter pilot will aim to have the wind on the beam during a search, and the FMS/autopilot combination will offset the heading into wind to maintain the correct track. This helps to maintain the optimum groundspeed (typically around 55-60 kn) and allows a more effective search (in a strong wind, it is difficult to maintain the desired groundspeed with the wind from behind.).

C.10.5 Helicopter navigation within a wind farm

C.10.5.1 The SAR helicopter will be equipped with an FMS which contains a comprehensive database of obstruction information. If accurate positions of the wind turbines are provided to the compiler of the database as required by Section 26.4 of Annex 5 MGN 543 (MCA, 2016), the crew will be able to navigate between the turbines by entering the appropriate waypoints and using the autopilot system to reduce the pilot workload. Individual turbines will be visually identifiable by markings on the base of the tower and the nacelle as outlined in Section 20.1 of Annex 5MGN 543.

C.10.5.2 Section 23.2 of Annex 5 MGN 543 introduces the concept of SAR access lanes:

"For wind farms, the SAR access requirement is so that a SAR helicopter can fly from one side of a wind farm to the other, entering from outside the wind farm at altitudes below 500 ft, to either conduct searches amongst turbines or to access a location or turbine within the field, from low altitude e.g. in bad weather where cloud base and/or visibility is poor."

C.10.5.3 A SAR helicopter crew conducting a search in a large wind farm, however, may find it neither necessary nor desirable to transit through the entire wind farm to conduct a search, especially if the turbine spacing is such that turns can safely be made within the wind farm. It is likely to be much more efficient to search by sections; thus, SAR lanes may not necessarily have to be in the same direction all the way through the wind farm; a change in direction of up to 60 degrees could be catered for by entering waypoints in the helicopter's FMS during the search planning. As explained in C9.4.2 above, if SAR access lanes are orientated approximately perpendicular to the prevailing wind this may increase the probability of conducting an effective search. Some examples of such partial searches in an indicative layout for Hornsea Three are included at Figure C.7, with an approximate track spacing of 1 km.

C.10.6 Visual or electro-optical searches within a wind farm

C.10.6.1 In fine weather, the helicopter could search from above the wind farm, but the altitude may reduce the POD for a small target. It is more likely, therefore, that a visual/electro-optical search would be conducted at 500 ft when searching for a small target such as a person in the water, with tracks between the turbines. The spacing between the centre point of turbines in the Hornsea Three array area will be at least 1 km. This spacing, together with a typical minimum track spacing of 800 m for a person in the water with a buoyancy aid, means that the helicopter will be able to turn safely within the wind farm and will not have to transit all the way through from one side to the other. This will be an important capability given that it is highly unlikely that all the wind farm will be included in the search area.

C.11 Impact of wind turbines on POD

C.11.1.1 In a wind farm, the ability of a SAR crew to distinguish a target of interest from a false target by radar or thermal imaging is likely to be affected, at least to some extent, by the layout. In a regular layout, it should be relatively easy to recognise a target which does not conform to the pattern, but this will become increasingly difficult as a pattern becomes less regular and, depending on a number of factors that are yet to be tested, potentially very difficult in a completely random layout.

C.11.1.2 The presence of wind turbines could also reduce the POD, depending on the primary sensor used, by creating false targets or by enforcing a higher search altitude than optimal. The types of search affected and the degree of potential impact are as follows:

- Visual Search;
  - The effect is likely to be minor unless the search altitude is significantly raised.
- Radar Search;
  - Turbines will create false targets which may make the identification of targets of interest difficult if the layout is irregular.
  - Turbines will generate blind sectors behind the turbines, though these arcs will be cleared as the helicopter moves; this effect is considered likely to be minimal.
- Electro-optical Search; and
  - FLIR. Turbines will show up on the FLIR equipment and possibly mask a target of interest behind; the motion of the helicopter will clear the arcs, so the impact is considered to be minimal.
  - TI. Turbine nacelles generate significant heat which will show up on thermal imaging equipment. This may mask the presence of a smaller heat source such as a person in the water. There is currently little data available on this possibility and a trial to assess this effect will be considered as part of ongoing discussions with the MCA.
- Radio homing to PLB to ELT. Turbines will cause little or no impact on this type of search as they will not interfere with radio transmission or reception.

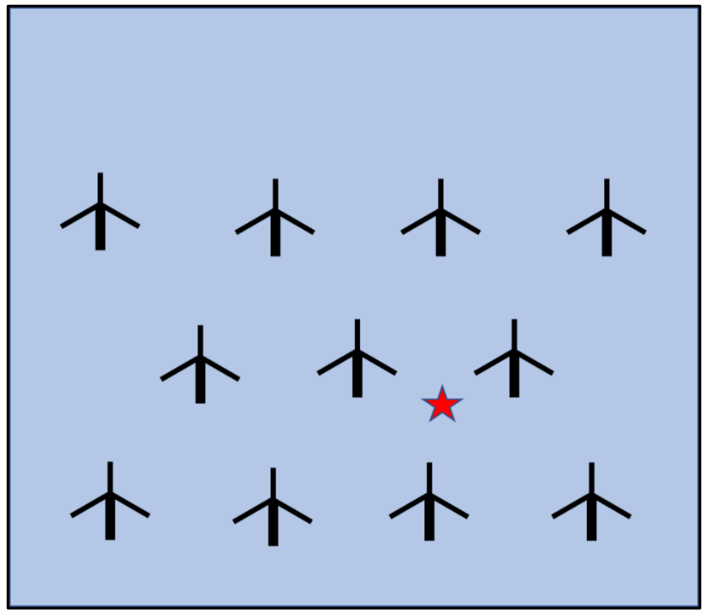


Figure C.6: Improved POD in regular pattern.

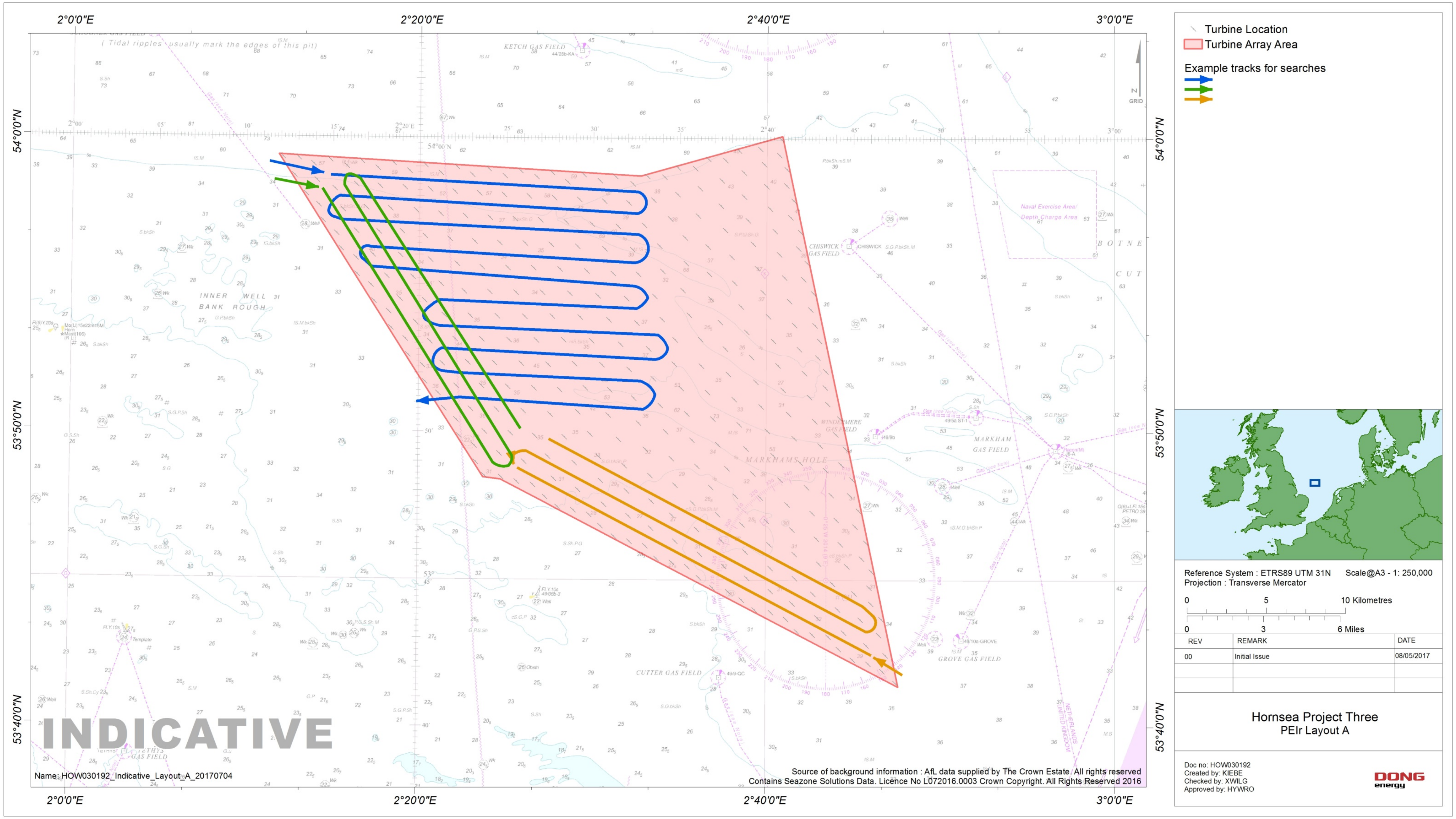


Figure C.7: Inidcative search pattern for Layout A

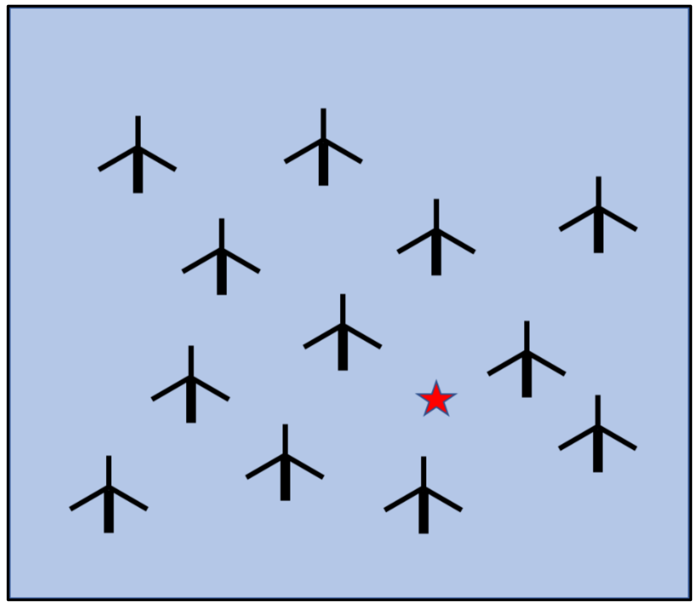


Figure C.8: Degraded POD in irregular pattern.

C.12 Impact of wind turbines on recovery

C.12.1.1 Once a target has been positively identified and the situation assessed by the crew, they will develop a strategy to recover any casualties. If the casualty is in the water, winching should be fairly straightforward, using a 'double lift' technique, where the winchman is lowered into the water to put the casualty into a strop and both are then lifted into the helicopter. If the casualty is on a vessel, it will be directed to steer a suitable course; the winchman will then be lowered onto the vessel and perform a double lift, with a stretcher being used if necessary. The winchman has communication to the pilots via radio throughout, and the helicopter crew can also communicate with the vessel on marine VHF. If the vessel is pitching or rolling violently and/or has dangerous obstructions such as masts or radio antennae that interfere with normal winching, the 'high line transfer' technique will be used.

C.12.1.2 It is possible that the presence of a wind turbine will constrain the choice of suitable courses for a vessel, but with at least 1 km spacing between the turbines, this should not be a significant problem. There may be some turbulence directly downwind of a turbine that is turning; a study (Holland R, 2008) has shown that "the near-field wake turbulence behind a horizontal axis turbine extends downstream to three to seven blade diameters."

C.12.1.3 The UK CAA publication CAP 764 states that "The CAA has so far investigated the effects of small wind turbine wakes on GA aircraft. The results of this study show that wind turbines of rotor diameter (RD) of less than 30 m should be treated like an obstacle and GA aircraft should maintain a 500 ft clearance. Regarding wind turbines of larger RD than 30 m; these are subject to further investigations. Until the results of these investigations are available, discussions between aerodrome managers and wind farm developers are encouraged, taking note of existing CAA safeguarding guidance. As the results of this research become available the CAA Wind Energy web pages will be updated" (CAA, 2016).

C.12.1.4 If turbulence during a recovery becomes a significant problem, it should be possible to stop one or more turbines remotely to eliminate the problem.

C.12.1.5 If the casualty is actually in the turbine itself, it may be necessary to winch from the nacelle as described in MGN 543 (MCA, 2016). In this case, the nacelle can be turned across the wind and the blades stopped, ideally in the 'Retreating Blade Horizontal' position.

C.12.1.6 A casualty close to the base of the turbine may be more difficult to extract, as the length of the winch wire may well be insufficient. In the case of a Siemens 8 MW turbine (which may be used in Hornsea Three array area), the nacelle height will be around 120 m (394 ft), well in excess of the S92's ft cable. In this case, the casualty might need to be moved away from the turbine or a 'high line transfer' technique employed.

C.13 The role of flight simulation

C.13.1.1 Most SAR helicopter crews currently have little practical experience of operating within an offshore wind farm and thus the true impact of its effects on search patterns, POD and recovery have not been fully assessed. Flight simulators are used extensively to train crews in normal and emergency procedures, as well as Line Oriented Flying Training (LOFT). LOFT allows crews to train under realistic environments and includes scenarios which require good decision making, intercommunication and leadership capabilities.

C.13.1.2 If the database of a Flight Simulator were to contain a realistic representation of a wind farm (including accurate geographic, visual, thermal and radar characteristics), crews could be trained to operate in wind farms in a safe, cost-effective and mission-specific environment. It would also be possible to quantify the effects of wind farms on SAROPs and to develop new procedures if necessary.

C.14 Helicopter emergencies

C.14.1.1 As in any aviation activity, there is a small risk of equipment failure during SAR helicopter operations. In most cases, technical malfunctions will not affect the safety of the helicopter, though it may be necessary to abort the mission and return to base. In more serious cases, the crew may opt to land at the nearest suitable site, which might be an offshore platform or the nearest point of land. To achieve either of these outcomes, the helicopter will usually be able to climb safely out of a wind farm and transit to its destination at a safe altitude.

C.14.1.2 In the event of an engine failure in transit at low speed or in the hover, the helicopter will need to accelerate to a safe speed to deal with the problem (as helicopters require less power to maintain height at 60-70 kn than at low or high airspeeds). An engine failure will also limit the helicopter's rate of climb; thus, it may be preferable for a SAR helicopter experiencing an engine failure within a wind farm to exit while remaining at low level before climbing and returning to land. This is the rationale for the helicopter 'refuge areas' mentioned in MGN 543 (MCA, 2016).

C.14.2 Probability of an engine failure

C.14.2.1 The Sikorsky S92A helicopter and its engines (General Electric CT-7) have been certified to civil standards by the European Aviation Safety Agency (EASA). While there are no quantifiable reliability requirements for certification, EASA issued a Certification Memorandum in November 2016 which requires the Type Certificate holders of a rotorcraft (in this case, The Sikorsky Aircraft Corporation) and engine (General Electric) to perform a risk assessment by:

- Assessing the rates of engine in flight shut down (IFSD) or power loss for the in-service fleet(s);
- Evaluating the potential consequences of the engine IFSD and power losses; and
- Proposing rate limits above which a potential unsafe condition may exist.

C.14.2.2 The rate limits over which a potentially unsafe condition may exist are known a 'watch rates': focussed attention is typically applied when they are reached or exceeded. 'Global Rates' (which are the actual rates of IFSD and power loss across the whole fleet, or sub-fleets if appropriate) are set at one event in 100,000 flying hours. 'Individual Rates' (which are the rates or probabilities of IFSD and power loss caused by an identified engine or rotorcraft defect) are set at 1 in 1,000,000 flying hours for

C.14.2.3 It is reasonable to assume, therefore, that in the absence of an Airworthiness Directive, which would be EASA's response to watch rates above those being set, the anticipated rate of engine power loss or IFSD should be no more than one in 100,000 flying hours. The probability of this occurring while a helicopter is conducting a search and rescue operation within a wind farm is therefore extremely remote.

C.15 Weather in the Hornsea Three area

C.15.1.1 The nearest comprehensive weather data available to the Met Office is that from Platform 62145 located at 53.102 north 2.800 east (decimal degrees), some 40 mi. south south east of the centre of the Hornsea Three array area. On behalf of DONG Energy, Aviation Safety Consulting Limited commissioned an analysis of key weather data parameters available between January 2010 and December 2016. The full report, consisting of frequency tables of low cloud height versus visibility and measured wave height versus measured wind speed is attached as Appendix A to this document. It is important to note that the Met Office records are based upon the use of an automatic ceilometer, which measures the presence of any cloud at all, rather than a defined cloud base. Thus, the assessments of the frequency with which low cloud may interfere with SAROPS shown in the table below are conservative.

C.15.1.2 For the purposes of this analysis, the maximum blade tip height of any turbine in the Hornsea Three array area of 325 m (approximately 1066 ft) has been used. A SAR helicopter could safely perform a visual, radio radar and electro-optical search while maintaining a safe distance above the turbines if the cloud base were at 460 m (approximately 1500 ft) or above, though it might be necessary to descend below this height if the target and track spacing were small. The table below (Table C.3) shows that between January and December, the average percentage of time (measured hourly) with any cloud detected below 460 m is 28.1%. The total percentage of time that the visibility is below 2 km is 1.3%.

Table C.3: Percentage cloud below 460 m visbility.

Cloud height (m) / Visibility (m)	Lower limit = 0	Lower limit = 470	Total
	Upper limit = 460		
0 - 40	0	0	0.0
50 - 190	0.2	0	0.2
200 -490	0.4	0	0.4
500 - 990	0.3	0	0.3
1000 -1990	0.4	0.1	0.4
2000 - 3990	1.2	0.6	1.7
4000 - 9990	8.7	12.8	21.6
10000 - 19990	12.2	40.5	52.7

Cloud height (m)	Lower limit = 0	Lower limit = 470	Total
20000 - 49990	4.4	15.3	19.7
50000 or more	0.4	2.5	2.9
Total	*28.1*	*71.9*	*100.0*

C.15.1.3 The table below (Table C.4) gives more detail on cloud heights. It shows that the frequency of cloud occurring below 200 m (just over 650 ft) is 12.0%. Cloud above this height would not restrict a SAR helicopter in the conduct of a visual/electro-optical search at 500 ft.

Table C.4: Percentage cloud height versus visibility.

Cloud height (m) / Visibility (m)	Lower limit = 0	50	100	200	300	600	1000	1500	2000	2500	Total
	Upper limit = 40	90	190	290	590	990	1490	1990	2490		
0 – 40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50 – 190	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
200 – 490	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
500 – 990	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
1000 –1990	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
2000 – 3990	0.2	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.4	1.7
4000 – 9990	0.3	1.1	1.9	1.9	3.5	1.9	1.6	1.0	0.7	7.6	21.6
10000 – 19990	0.2	0.4	1.1	2.0	8.6	9.4	5.2	3.3	2.1	20.4	52.7
20000 – 49990	0.1	0.0	0.2	0.5	3.6	4.7	2.2	0.9	0.5	7.0	19.7
50000 or more	0.0	0.0	0.0	0.0	0.3	0.7	0.5	0.2	0.1	1.2	2.9
Total	*1.5*	*2.5*	*3.5*	*4.5*	*16.1*	*16.7*	*9.6*	*5.4*	*3.5*	*36.7*	*100*

C.15.1.4 The other key parameters which will affect a search are wind and sea state. These are usually closely related, unless the wind speed is in the process of increasing or decreasing rapidly. The table below gives a breakdown of the annual percentages of wind speed vs wave height. It shows that the percentage of time that the wind speed is over 21 kn (Beaufort Force 5) is 14.3% and the percentage of time that the wave height exceeds 2.5 m (Moderate) is 8.4%.

Table C.5: Percentage wind speed versus wave height.

Wind Speed (kn) / Wave Height (m)	Lower limit = 0	1	4	7	11	17	22	28	34	41	48	56	64	Total
	Upper limit =0	3	6	10	16	21	27	33	40	47	55	63		
0.1 – 0.5	0.1	1.9	3.6	4.1	3.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
0.6 – 1.0	0.2	2.3	5.9	9.2	10.6	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	31.4
1.1 - 1.5	0.0	0.8	2.6	5.0	9.4	4.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	24.1
1.6 – 2.0	0.0	0.1	0.5	1.6	4.8	4.8	2.7	0.2	0.0	0.0	0.0	0.0	0.0	14.8
2.1 – 2.5	0.0	0.0	0.1	0.4	1.6	2.4	2.9	0.6	0.0	0.0	0.0	0.0	0.0	8.0
2.6 – 3.0	0.0	0.0	0.0	0.1	0.5	0.9	1.6	1.1	0.1	0.0	0.0	0.0	0.0	4.3
3.1 – 4.0	0.0	0.0	0.0	0.0	0.2	0.3	1.0	1.3	0.4	0.0	0.0	0.0	0.0	3.3
4.1 – 5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.7
5.1 – 6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Total	*0.3*	*5.1*	*12.7*	*20.5*	*30.4*	*16.7*	*9.9*	*3.5*	*0.8*	*0.1*	*0.0*	*0.0*	*0.0*	*100.0*

C.15.2 Prevailing wind direction

C.15.2.1 There will be natural variation in wind direction and speed, but strong winds will have most effect on SAR operations because they will affect the ability to maintain the desired groundspeed for searches and the 'white cap' effect in winds of more than 21 kn, which may obscure a small target. The figure below is taken from the Hornsea Project One Design Basis Part A, MetOcean Site Assessment for WTG and Support Structures. It shows that the typical extreme wind speed for the area is predominantly from the western sector.

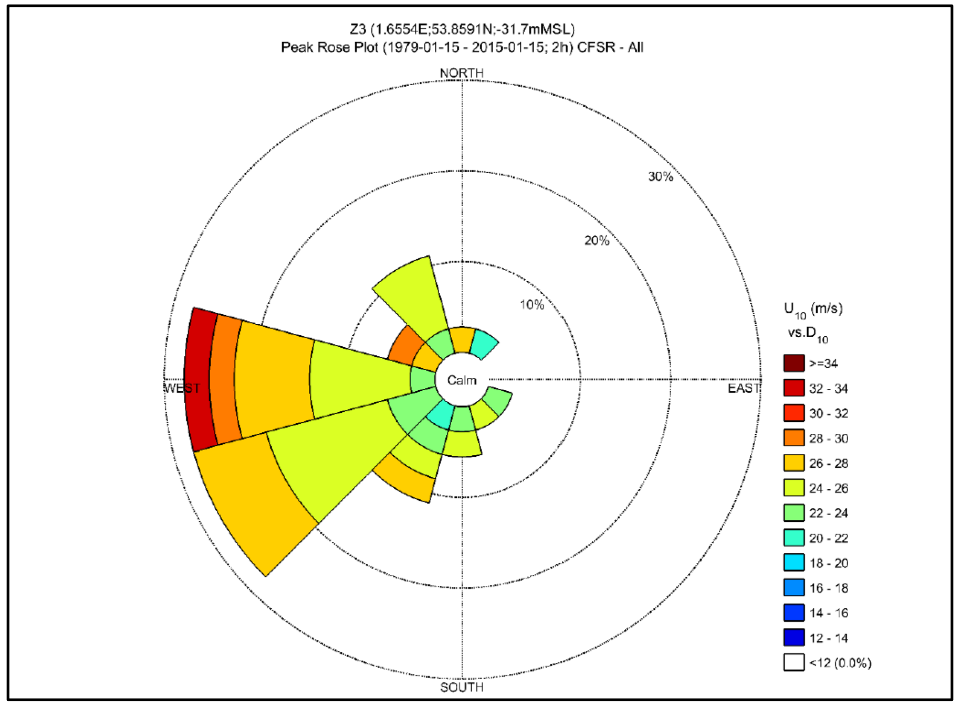


Figure C.9: Extreme wind rose – Hornsea Project One.

C.16 SAR incidents in the Hornsea Three array area

C.16.1.1 There is limited historical data available on the frequency and type of SAR operations in the Hornsea Three aray area. The best source of information was the MOD statistics published on the Government website (MOD, 2017), which contains detailed data for SAROPs around the UK between 2011 and 2015. SAROPs location data is not currently available for the years prior to 2011 and the MCA, which has been responsible for publishing UK SAROPs statistics since February 2016, does not currently publish detailed location data. The published information was analysed to identify any SAR incidents which occurred in the 5-year period between 2011 and 2015 in a study area extending 10 nm beyond the Hornsea Three array area.

C.16.1.2 Over the five year period, there was only one SAROP in the Hornsea Three wind farm area and a total of nine within the 10 nm study area. All of these were medrescues conducted in the daytime and none involved a search. It appears that several of the incidents are centred on oil and gas fields in the area (Schooner, Ketch and Chiswick), but this could not be confirmed from the information available. The figure below shows the locations of the incidents and the Hornsea Three 10 nm Study Area.

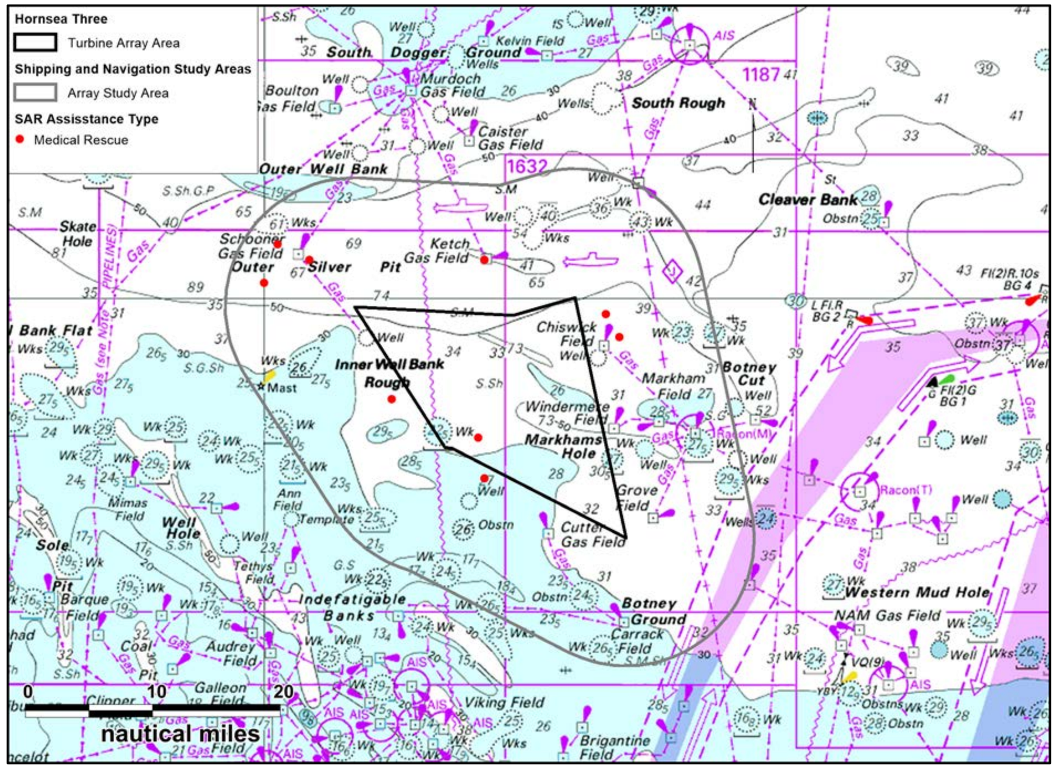


Figure C.10: Historic SAR incidents in the Hornsea Three array area shipping and navigation study area.

C.16.1.3 Table C.6 contains the details of the incidents recorded.

Table C.6: SAROPS in the Hornsea Three array area study area.

Incident date	Departure time	Incident position	Unit name	Assistance	Persons moved	Unit type	Latitude decimal degrees	Longitude decimal degrees
12/06/2012	10:50	5346North (N) 00229 East€	RAF Wattisham	Medrescue	1	SEA KING	53.77	2.47
15/07/2012	11:21	5403N 0229E	RAF Leconfield	Medrescue	1	SEA KING	54.05	2.48
13/03/2013	09:14	5352N 00217E	RAF Wattisham	Medrescue	1	SEA KING	53.87	2.28
08/07/2013	11:58	5401N 00200E	RAF Wattisham	Medrescue	1	SEA KING	54.02	2.00
16/08/2013	13:41	5349N 00228E	RAF Wattisham	Medrescue	1	SEA KING	53.82	2.47
26/09/2013	05:40	5403N 00206E	RAF Leconfield	Medrescue	1	SEA KING	54.05	2.10
08/11/2013	14:20	5357N 00247E	RAF Leconfield	Medrescue	1	SEA KING	53.95	2.78
24/05/2014	13:35	5359N 00245E	RAF Leconfield	Medrescue	2	SEA KING	53.98	2.75
20/11/2014	15:44	5404N 00202E	H RAF Leconfield	Medrescue	1	SEA KING	54.07	2.03

C.16.1.4 Note that a Medrescue involving a search is classified as Search – Medrescue.

C.16.2 Frequency of searches

C.16.2.1 The MOD (2017) data lists 9,000 SAR incidents over the 5-year period in the UK. This data was analysed to establish the number of occasions that a helicopter was engaged in a search as part of the response and it was found that a total of 1,659 incidents (18.5% of the total launches) involved a search. Historically, however, a higher proportion of incidents over land or in coastal areas involve a search than those offshore. The data was further analysed to identify how many incidents located more than ten nautical miles offshore included an element of search. The table (Table C.7) below shows the breakdown of the data.

Table C.7: SAROPS over 10 nm offshore 2011-2015.

Assistance Type	> 10 nm
Aborted	6
Assist	4
False Alarm	4
Medrescue	572
Medtransfer	9
Not Required	4
Precaution	3
Recalled	38
Recovery	1
Rescue	17
Search	30
Search and Assist	4
Search and Medrescue	5
Search and Recovery	1
Search and Rescue	6
Top Cover	12
Transfer	8
Total	*724*

C.16.2.2 Overall, 46 of the total of 724 offshore operations involved a search, approximately 6.4% of the total.

C.17 Survival times

C.17.1.1 The typical sea surface temperature in the Southern North Sea ranges between 5 degrees celsius in the winter and 16 degrees Celsius in the summer (Lee, AJ and Ramster, JW , 1981) . Even in the summer, predicted survival times for an unprotected casualty immersed in the North Sea are short: in the order of an hour and a half. The table below (Robertson, DH and Simpson, ME, 1996) shows that without a survival suit, the estimated survival time in calm water can be less than an hour if the water temperature is below 10 degrees celsius, which is common in winter

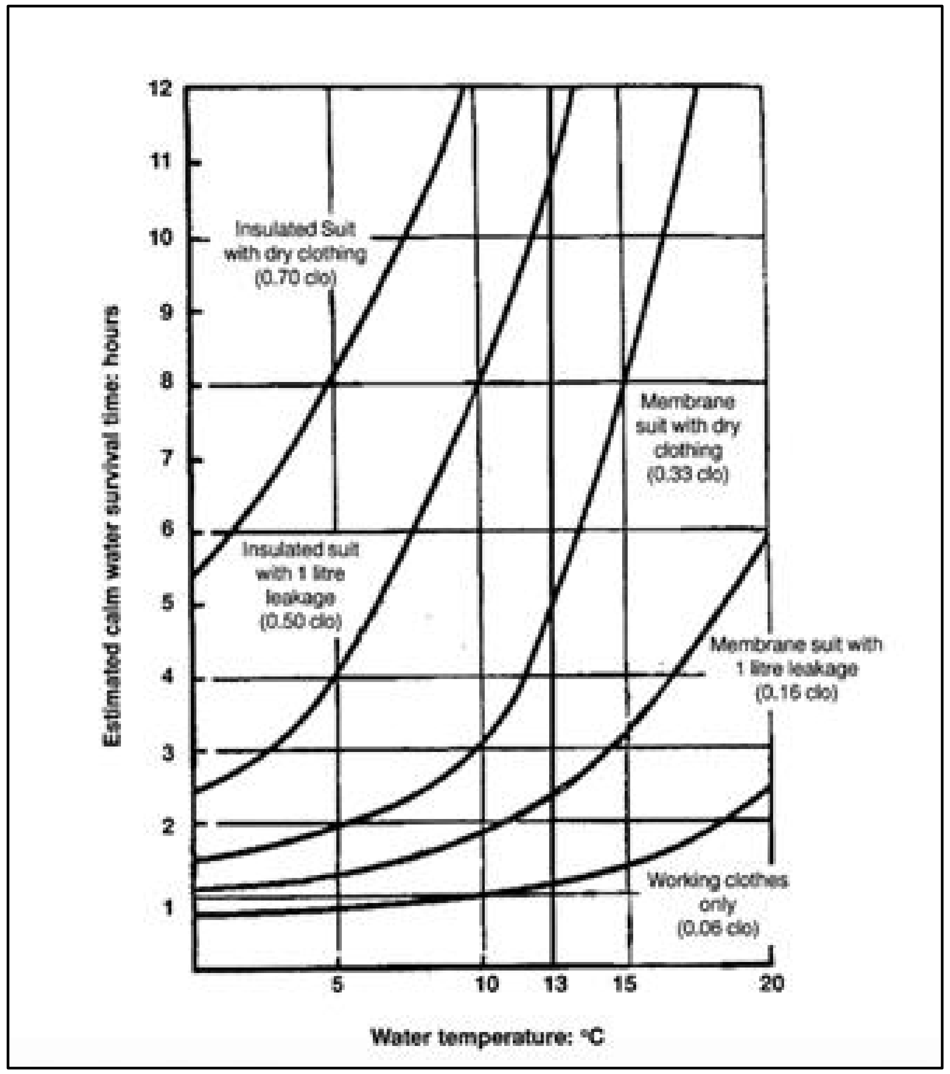


Figure C.11: Estimated survival time.

C.18 The plausible 'worst case' incident scenario

C.18.1.1 There are a wide variety of scenarios that might result in a SAR operation within an offshore wind farm, but in many cases, particularly if the weather is good, the impact of the presence of turbines would be considered to be negligible. However, for the purposes of this paper, it is considered prudent and necessary to establish a plausible 'worst case' incident scenario and derive an estimate of its probability using historic SAR and weather data.

C.18.1.2 Any SAR operation which has an accurate location provided by electronic means, such as an ELT, GPS-based navigation equipment, AIS or an on-scene vessel, reduce or negate the requirement for a search. The SAR helicopter will be able to navigate directly to the scene, though it may need to enter the wind farm at low level to safely reach the casualty.

C.18.1.3 The plausible worst case incident scenario considered herein involves:

- One or more persons in the water;
- No accurate datum or electronic location aids;
- A significant time lapse between the occurrence and initiation of SAR action.

C.18.1.4 Since the Hornsea Three array area is located at a significant distance offshore, it is highly unlikely that any casualty will have no survival aids at all. Offshore yachtsmen and fishermen who may have gone overboard are likely to be at least wearing a life jacket.

C.18.1.5 The plausible 'worst case', therefore, might be a yachtsman or fisherman gone overboard but the absence not being immediately noticed or reported. This would entail a degree of uncertainty about the position of the casualty and a small target to detect. For the best chance of detection, the SAR helicopter would need to operate at 500 ft or below to conduct its search, and the presence of SAR access lanes would expedite this process, noting that a prescriptive definition of a SAR access lane is not currently available. It should be noted that, at this level, the electro-optical sensor will be deflected downward, so false thermal targets from turbine nacelles detected by the TI equipment are likely to be eliminated.

C.19 Probability of a SAR incident in the Hornsea Three wind farm

C.19.1.1 The very existence of a wind farm means that there is scope for accidents to happen, as visits to platforms and turbines will be necessary for both scheduled and unplanned operations and maintenance. During routine operations, and on the occasions when unscheduled visits will have to be made, such as in response to a technical fault, any increase in the risks to personnel will be significantly mitigated by the use of a documented adverse weather policy. Additionally, all wind farm personnel will have defined procedures, be equipped with the appropriate personal protection equipment (including a PLB - Since all Hornsea Three personnel present within the array area will be wearing PLB's, it is considered that the presence of wind farm personnel will not significantly impact the search aspect of SAROPS), be accompanied by at least one other person at all times, and will have in-field resources to locate and extract them from the wind farm to a place of safety if necessary. It is also possible that interaction with third party surface vessels will occur and that there might be an incident involving a helicopter used for transferring operations and maintenance personnel to and from a turbine.

C.19.1.2 Given the historic data on SAR incidents in the Hornsea Three array area shipping and navigation study area, it appears that there might be about ten incidents every five years, though from the available data, relatively few (perhaps one or two) would be in the Hornsea Three array area itself. Over the projected 25-year life of the wind farm, this might result in five to ten incidents within the wind farm, and the historic data on the frequency of searches (6.4% of typical offshore SAROPS) suggests that the likelihood of a search being conducted in the wind farm over the period is between 30-64% This gives a mean probability of 47%. This falls into the 'Remote' category (one event per 10 – 100 years) in the Risk Tolerability matrix presented in section 3.2.

C.19.1.3 Overall, therefore, the probability that the presence of the Hornsea Three array area will have a significant adverse impact on the outcome of a SAR operation is relatively small, though it cannot be discounted.

C.20 Regular vs irregular layouts

C.20.1.1 As the layout in a wind farm becomes less regular, it could have the following impact on SAROPS:

- An increase in the time taken to search an area, caused by:
  - A degradation in the helicopter's ability to navigate through a wind farm at low level.
  - A degradation in the ability to detect a casualty using radar/visual, or electro-optical sensors.
  - A degradation in the ability of the SAR helicopter to exit the wind farm at low level in the event of an engine failure or IFSD, though this is extremely unlikely to occur and can be considered as negligible for the purposes of this assessment.

C.20.1.2 As outlined in the bullet points above, a more regular pattern will permit crews to plan and execute searches more quickly, and will increase the probability that a target that does not conform to the pattern will be rapidly identified.

C.20.1.3 If a search were necessary in the event of the 'plausible worst case', i.e. a person in the water wearing a lifejacket, the following analysis has been undertaken to quantify the impact of an irregular layout.

C.20.1.4 In open water, a SAR helicopter would typically search at 500 ft and 60 kn, using an expanding square or creeping line ahead search, with the datum based on the best information available. The track spacing would typically be 800-900 m (approximately 0.5 nm) which should achieve a coverage factor of one. The figure below (taken from the IAMSAR Manual) shows that the POD would be about 80% in ideal conditions and 64% in normal conditions.

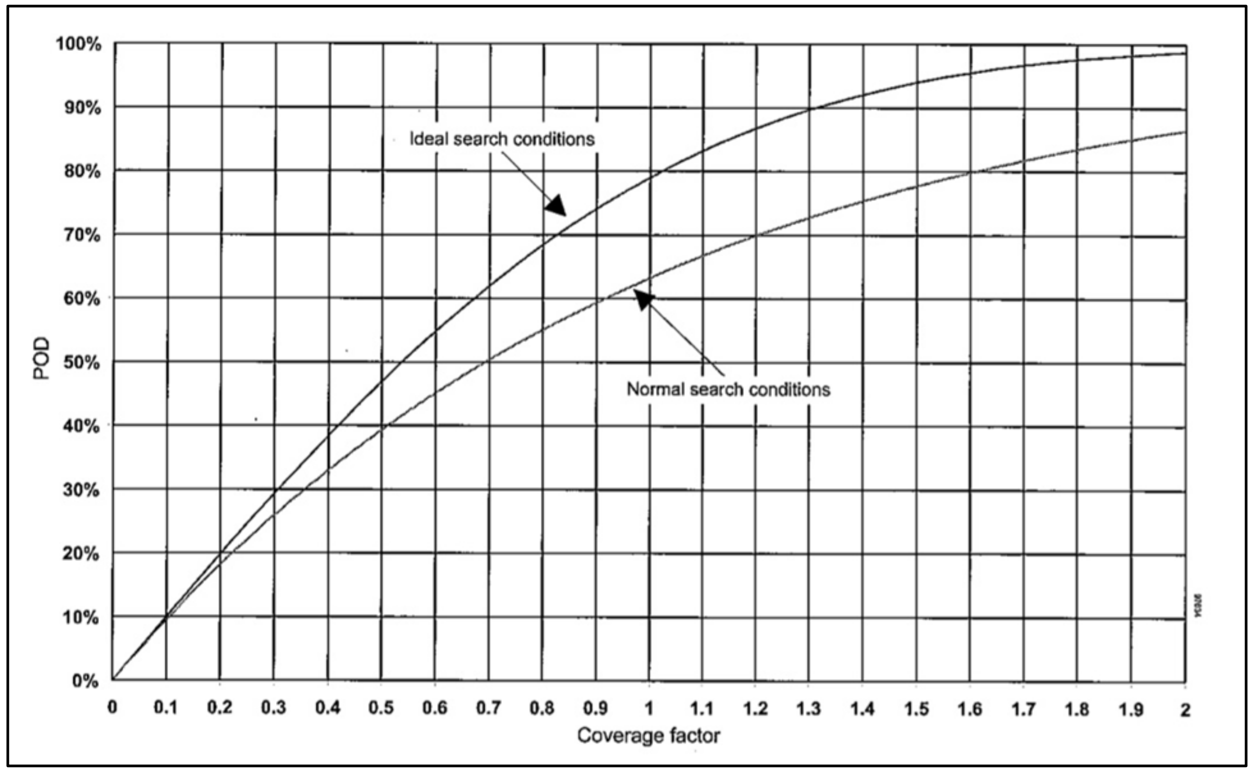


Figure C.12: POD graph.

C.20.1.5 Figure C.13 to this paper shows how a SAR helicopter might search an area of 6 nm by 6 nm in open water or in a wind farm with a turbine spacing of 1km and straight lines of orientation, compared with an indicative less regular layout (Layout A). The blue lines show the planned tracks and the yellow bands show the effective detection range of 450 m. The regular layout entails a ground track of about 70nm, which would take a helicopter travelling at 60 kn about 70 minutes to achieve. The representative search in the irregular layout has a ground track of 85-90 nm, an increase of about 25% in time, and a noticeably lower coverage factor, in the order of 0.75. It would also be more difficult for the crew to plan and execute, as they would have to expend more attention on navigating through the turbines, which would detract from the search effort. A coverage factor of 75% would reduce the POD from 80% to 65% in ideal conditions, and from 64% to 53% in normal conditions. Any potential higher workload for the crew while navigating through the wind farm has been conservatively assessed as reducing the POD by a further 25%. This results in a POD of 39% in normal conditions; a total reduction of 25%.

C.21 Conclusions

C.21.1.1 It is estimated that there might be between five and ten SAR incidents inside the wind farm during its projected 25-year life, of which there is an estimated probability of 47% that a SAR incident might involve a search.

C.21.1.2 Given the projected survival times in the North Sea for the plausible 'worst case' incident scenario, a significant delay in the execution of a search could result in a single fatality (a 'Serious' severity of consequence).

C.21.1.3 The existence of SAR access lanes, ideally orientated perpendicularly to the prevailing wind, will expedite search planning and execution, and will significantly increase the probability that a target that does not conform to the pattern will be rapidly identified.

C.21.1.4 SAR access lanes should not necessarily run in a straight line throughout the entire wind farm.

C.21.1.5 It is highly unlikely that it will be necessary or desirable to search an entire wind farm during a SAROP.

C.21.1.6 SAR helicopters will be able to turn within a wind farm during a search when the turbine spacing is at least 1 km.

C.21.1.7 An irregular layout has the potential to increase search time by approximately 25% and reduce the coverage factor to approximately 0.75, compared to scenarios for open water or for a wind farms with straight lines of orientation. This might result in a reduction of the POD for a single person in the water from 62% to 39%; a total reduction of 25%.

C.21.1.8 The probability of a SAR helicopter experiencing a single engine failure or IFSD while operating within the wind farm in poor weather or at night is considered to be extremely unlikely.

C.21.1.9 There is little or no authoritative data on the impact of wind turbines on the planning and execution of a search conducted by a modern SAR helicopter.

C.21.1.10 The use of flight simulation could be used to:

- Model the effects of wind turbines on searches and the probability of detection for various targets and sensors.
- Train SAR crews in wind farm operations as part of a LOFT programme.

C.21.1.11 Modelling the effect of wind farms on SAROPS, ideally using an appropriately equipped helicopter flight simulator and current SAR helicopter crews, may help to develop new techniques and mitigate the influence of layout on the likely success of SAR operations.

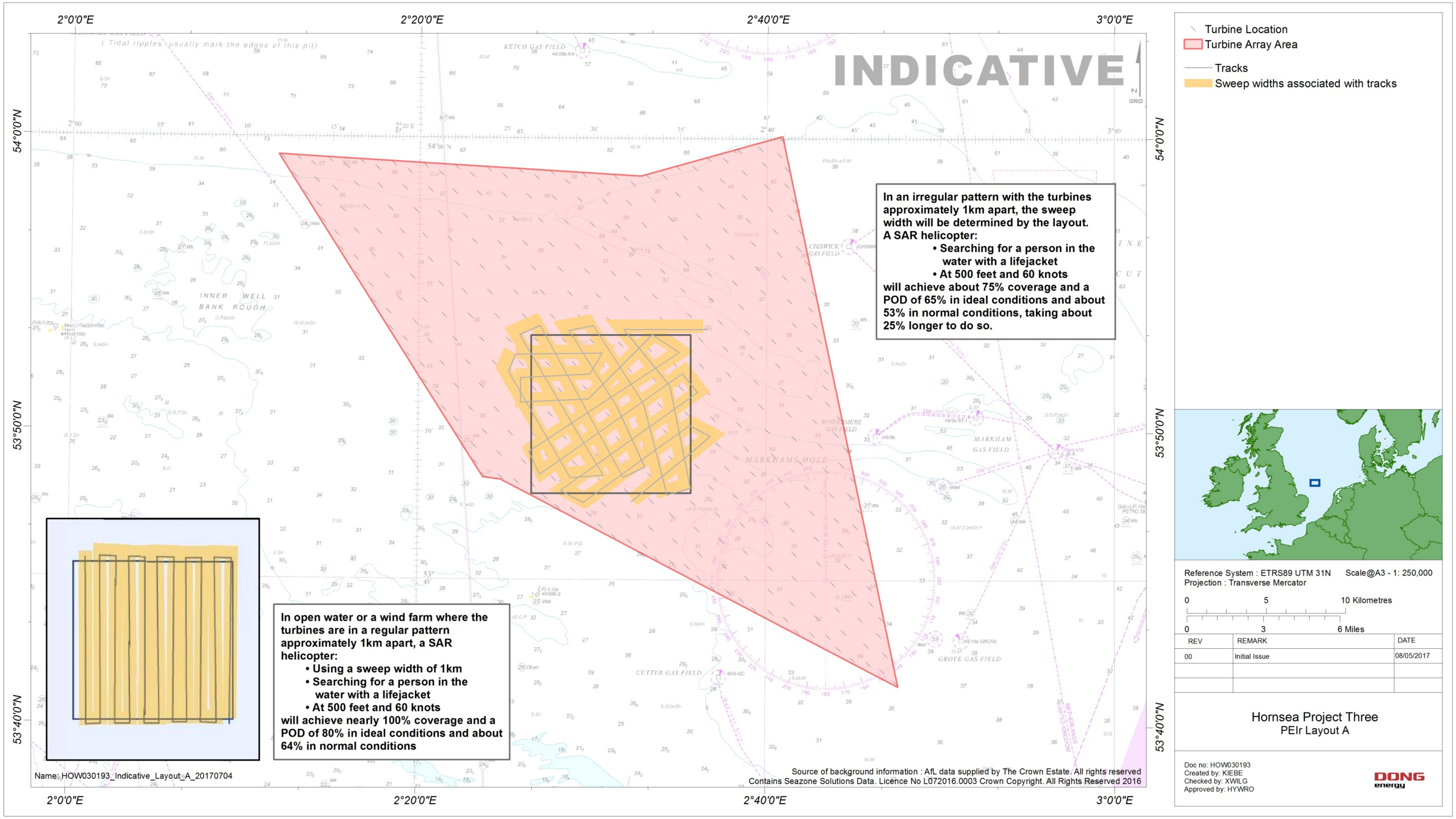


Figure C.13: Probability of section within Layout A

Appendix D MGN 543 Checklist

D.1 MGN 543 compliance checklist

Issue	Compliant (Yes/No)	Reference notes/remarks
Annex 1: Considerations on Site Position, Structures and Safety Zones		
1. Site and Installation Co-ordinates. Developers are responsible for ensuring that formally agreed co-ordinates 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 Geographical Information System (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 (ETRS89) datum.		
2. Traffic Survey. Includes the following:		
All vessel types	✓	Section 15: Marine Traffic Surveys All vessel types are considered, with section 15.2.3 providing specific breakdowns by vessel type for the Hornsea Three array area marine traffic survey and section 15.4.3 providing specific breakdowns by vessel type for the Hornsea Three offshore HVAC booster station search area. Section 17: Future Case Marine Traffic The predicted growth in future shipping densities is provided by vessel type. Section 18: Collision and Allision Risk Modelling and Assessment Appendix A: Consequences Assessment Modelling considers collision and allision risk by vessel type including both commercial and non-commercial vessels.
At least 28 days duration, within either 12 or 24 months prior to submission of the Environmental Statement	✓	Section 7: Marine Traffic Survey Methodology For the Hornsea Three array area, 40 days of AIS, visual and Radar data (26 days in June and July 2016 and 14 days in November and December 2016) was recorded. The same period of data was collected for the offshore cable corridor. For the Hornsea Three offshore HVAC booster station search area, 28 days of AIS, visual and Radar data (14 days in September 2016 and 14 days in November and December 2016) was recorded.
Multiple data sources	✓	Section 7: Marine Traffic Survey Methodology Section 15: Marine Traffic Surveys The marine traffic surveys include AIS, visual and Radar data.
Seasonal variations	✓	Section 7: Marine Traffic Survey Methodology Section 15: Marine Traffic Surveys Marine traffic surveys were carried out in summer and winter periods to take account of seasonal variations in traffic patterns. Section 18: Collision and Allision Risk Modelling and Assessment Anatec's ShipRoutes database (which is used as modelling input) is compiled using marine traffic survey data which takes account of seasonal variations in traffic patterns.
MCA consultation	✓	Section 4: Consultation The MCA have been consulted as part of the NRA process. Section 14: Overview of Key Consultation Table 14.2 includes issues raised by the MCA relevant to shipping and navigation during consultation for Hornsea Project One and Hornsea Project which is applicable to Hornsea Three. Table 14.3 includes issues raised by the MCA relevant to shipping and navigation during consultation for Hornsea Three. Section 20: Hazard Workshop Overview The MCA attended the Hazard Workshop.

Issue	Compliant (Yes/No)	Reference notes/remarks
General Lighthouse Authority (TH) consultation	✓	Section 4: Consultation TH have been consulted as part of the NRA process. Section 14: Overview of Key Consultation Table 15.2 includes issues raised by TH relevant to shipping and navigation during consultation for Hornsea Project One and Hornsea Project which is applicable to Hornsea Three. Table 15.3 includes issues raised by TH relevant to shipping and navigation during consultation for Hornsea Three.
CoS consultation	✓	Section 4: Consultation The CoS have been consulted as part of the NRA process. Section 14: Overview of Key Consultation Table 15.2 includes issues raised by the CoS relevant to shipping and navigation during consultation for Hornsea Project One and Hornsea Project which is applicable to Hornsea Three. Table 15.3 includes issues raised by the CoS relevant to shipping and navigation during consultation for Hornsea Three. Section 20: Hazard Workshop Overview As shown in Table 21.1, the CoS attended the Hazard Workshop.
Recreational and fishing vessel organisations consultations	✓	Section 4: Consultation The RYA and CA have been consulted as part of the NRA process. Section 14: Overview of Key Consultation Table 15.2 includes issues raised by the RYA and CA relevant to shipping and navigation during consultation for Hornsea Project One and Hornsea Project which is applicable to Hornsea Three. Table 15.3 includes issues raised by the RYA and CA relevant to shipping and navigation during consultation for Hornsea Three. Section 20: Hazard Workshop Overview As shown in Table 21.1, the CA attended the Hazard Workshop.
Port and navigation authorities consultation, as appropriate	✓	Section 20: Hazard Workshop Overview As shown in Table 21.1, the Lowestoft Port Authority, Peel Ports Great Yarmouth and Rotterdam Harbour Master were invited to 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 15: Marine Traffic Surveys Summarises the results of the marine traffic surveys, including commercial and non-commercial traffic. Section 18: Collision and Allision Risk Modelling and Assessment Section 18.2.2 and section 18.4.1 consider the effects on vessel routeing of the Hornsea Three array area and Hornsea Three offshore HVAC booster stations respectively. Section 18.3.1 considers the cumulative effect on vessel routeing of the Hornsea Three array area.

Issue	Compliant (Yes/No)	Reference notes/remarks
ii. Numbers, types and sizes of vessels presently using such areas.	✓	Section 15: Marine Traffic Surveys Summarises the results of the marine traffic surveys, including specific breakdowns by vessel numbers, types and sizes, for the Hornsea Three array area (section 15.2), Hornsea Three offshore cable corridor (section 15.3) and the Hornsea Three offshore HVAC booster station search area (section 15.4). Section 15.2.9 provides an overview of recreational vessel activity in the southern North Sea based on RYA cruising routes in addition to marine traffic survey data. Section 15.2.10 and section 15.4.6 provide an overview of fishing vessel activity based on MMO sightings and satellite data in addition to marine traffic survey data for the Hornsea Three array area and Hornsea Three offshore HVAC booster station search area respectively.
iii. Non-transit uses of the areas, e.g. fishing, day cruising of leisure craft, racing, aggregate dredging, etc.	✓	Section 10: Existing Environment Section 10.6 provides an overview of aggregate dredging activity in the southern North Sea based on BMAPA transit routes. Section 21: Cumulative Assessment Section 21.5 provides an overview of the cumulative effect of Hornsea Three on dredging. Section 15: Marine Traffic Surveys Section 15.2.9 provides an overview of recreational vessel activity in the southern North Sea based on RYA cruising routes in addition to marine traffic survey data. Section 15.2.10 and section 15.4.6 provide an overview of fishing vessel activity based on MMO sightings and satellite data in addition to marine traffic survey data for the Hornsea Three array area and Hornsea Three offshore HVAC booster station search area respectively.
iv. Whether these areas contain transit routes used by coastal or deep draught vessels on passage.	✓	Section 10: Existing Environment Section 10.4 provides an overview of IMO routeing measures used by deep draught vessels located within the vicinity of Hornsea Three. Section 15: Marine Traffic Surveys Summarises the results of the marine traffic surveys, including current vessel routeing for the Hornsea Three array area (section 15.2.7) and Hornsea Three offshore HVAC booster station search area (section 15.4.5) which includes transit routes used by deep draught vessels on passage. Specific breakdowns by draught are also included within this section for both areas. Section 18: Collision and Allision Risk Modelling and Assessment Section 18.2.2 and section 18.4.1 consider the effects on vessel routeing of the Hornsea Three array area and Hornsea Three offshore HVAC booster stations respectively, including transit routes used by deep draught vessels on passage. Section 18.3.1 considers the cumulative effect on vessel routeing of the Hornsea Three array area, including transit routes used by deep draught vessels on passage.

Issue	Compliant (Yes/No)	Reference notes/remarks
v. Alignment and proximity of the site relative to adjacent shipping lanes.	✓	Section 15: Marine Traffic Surveys Summarises the results of the marine traffic surveys, including current vessel routeing for the Hornsea Three array area (section 15.2.7) and Hornsea Three offshore HVAC booster station search area (section 15.4.5). Section 16: Adverse Weather Impacts Summarises alternative routeing used by regular operators during periods of adverse weather. Section 18: Collision and Allision Risk Modelling and Assessment Section 18.2.2 and section 18.4.1 consider the effects on vessel routeing of the Hornsea Three array area and Hornsea Three offshore HVAC booster stations respectively. Section 18.3.1 considers the cumulative effect on vessel routeing of the Hornsea Three array area
vi. Whether the nearby area contains prescribed routeing schemes or precautionary areas.	✓	Section 10: Existing Environment Section 10.4 provides an overview of IMO routeing measures and existing aids to navigation within the vicinity of Hornsea Three.
vii. Whether the site lies on or near a prescribed or conventionally accepted separation zone between two opposing routes	✓	Section 10: Existing Environment Section 10.4 provides an overview of IMO routeing measures within the vicinity of Hornsea Three.
viii. Proximity of the site to areas used for anchorage, safe haven, port approaches and pilot boarding or landing areas.	✓	Section 10: Existing Environment Section 10.2 provides an overview of ports within the vicinity of Hornsea Three. Section 10.3 provides an overview of anchorage areas within the vicinity of Hornsea Three. The Hornsea Three array area is not located in proximity to any safe havens, port approaches or pilot boarding/landing areas.
ix. Whether the site lies within the jurisdiction of a port and/or navigation authority.	✓	Section 10: Existing Environment Section 10.2 provides an overview of ports within the vicinity of Hornsea Three. The Hornsea Three array area does not lie within the jurisdiction of a port and/or navigation authority.
x. Proximity of the site to existing fishing grounds, or to routes used by fishing vessels to such grounds.	✓	Section 15: Marine Traffic Surveys Section 15.2.10 and section 15.4.6 provide an overview of fishing vessel activity based on MMO sightings and satellite data in addition to marine traffic survey data for the Hornsea Three array area and Hornsea Three offshore HVAC booster station search area respectively.
xi. Proximity of the site to offshore firing/bombing ranges and areas used for any marine military purposes.	✓	Section 10: Existing Environment Section 10.8 provides an overview of military exercise areas within the vicinity of Hornsea Three.
xii. Proximity of the site to existing or proposed offshore oil / gas platform, marine aggregate dredging, marine archaeological sites or wrecks, Marine Protected Area or other exploration/exploitation sites.	✓	Section 10: Existing Environment Section 10.5 provides an overview of oil and gas infrastructure within the vicinity of Hornsea Three. Section 10.6 provides an overview of aggregate dredging areas within the vicinity of Hornsea Three. Section 10.9 provides an overview of MEHRAs within the vicinity of Hornsea Three. Section 10.10 provides an overview of charted wrecks within the vicinity of Hornsea Three.
xiii. Proximity of the site to existing or proposed OREI developments, in co-operation with other relevant developers, within each round of lease awards.	✓	Section 21: Cumulative Assessment Section 21.3.1 provides an overview of offshore wind farm developments within the North Sea, with Table 22.1 summarising developments screened into the cumulative assessment. Section 21.3.2 provides details of the SNSOWF involving representatives from the UK Round Three wind farm zones located within the southern North Sea.
xiv. Proximity of the site relative to any designated areas for the disposal of dredging spoil or other dumping ground.	✓	N/A
xv. Proximity of the site to aids to navigation and/or Vessel Traffic Services (VTS) in or adjacent to the area and any impact thereon.	✓	Section 10: Existing Environment Section 10.4 provides an overview of existing aids to navigation within the vicinity of Hornsea Three.

Issue	Compliant (Yes/No)	Reference notes/remarks
xvi. 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 18: Collision and Allision Risk Modelling and Assessment Section 18.2.2 and section 18.4.1 consider the effects on vessel routeing of the Hornsea Three array area and Hornsea Three offshore HVAC booster stations respectively. Section 18.3.1 considers the cumulative effect on vessel routeing of the Hornsea Three array area.
xvii. With reference to xvi. 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 13: Maritime Incidents MAIB (section 13.2) and RNLI incidents (section 13.3) in the vicinity of the Hornsea Three array area and Hornsea Three offshore HVAC booster station search area is analysed by incident type and vessel type. Table 14.1 summaries historical collision and allision incidents involving wind farm sites.
3. 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 9: Design Envelope Summarises the Design Envelope including the number of structures. Section 17: Future Case Marine Traffic The predicted growth in future shipping densities is provided. Section 18: Collision and Allision Risk Modelling and Assessment Assesses the impact of the Hornsea Three array area on vessel to vessel collisions, vessel to structure allision (powered and NUC vessels), fishing vessel to structure allision and recreational vessel allisions. Assesses the impact of the Hornsea Three offshore HVAC booster stations on vessel to structure allision (powered and NUC vessels). Appendix A: Consequences Assessment Provides an assessment of the consequences of collision and allision incidents, in terms of people and the environment, due to the impact of the structures.
b. Clearances of wind turbine blades above the sea surface are not less than 22 metres above MHWS.	✓	Section 9: Design Envelope Table 10.2 includes minimum blade tip height of 34.97 m above LAT.
c. Underwater devices: Changes to charted depth; Maximum height above seabed; and UKC.	✓	Section 22: Formal Safety Assessment Assesses impacts relevant to under keel clearance are in section 22.10.2.
d. The burial depth of cabling and changes to charted depths associated with any protection measures.	✓	Section 9: Design Envelope A Cable Burial Risk Assessment will be carried out with the extent of cable burial dependent on the results (see section 9.6.5).
4. 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:		

Issue	Compliant (Yes/No)	Reference notes/remarks
a. Navigation within or close to the site would be safe: by all vessels, or by specified vessel types, operations and/or sizes; in specified directions or areas; and in specified tidal, weather or other conditions.	✓	Section 14: Overview of Key Consultation Table 15.1 summarises responses from regular operators identified during the marine traffic surveys. Table 15.2 includes issues raised by stakeholders regarding navigation during consultation for Hornsea Project One and Hornsea Project which is applicable to Hornsea Three. Table 15.3 includes issues raised by stakeholders regarding navigation during consultation for Hornsea Three. Section 16: Adverse Weather Impacts Summarises alternative routeing used by regular operators during periods of adverse weather. Section 18: Collision and Allision Risk Modelling and Assessment Assesses the impact of the Hornsea Three array area on vessel movement using a number of collision and allision models which take into account tidal and weather conditions. Assesses the impact of the Hornsea Three offshore HVAC booster stations on movement using allision models which take into account tidal and weather conditions. Section 19: Communication and Position Fixing Summarises the potential impacts on navigation of the different communications and position fixing devices used in and around offshore wind farms. Section 22: Formal Safety Assessment Assesses impacts relevant to navigation, including adverse weather (section 22.5).
b. Navigation in and/or near the site should be: Prohibited by specified vessel types, operations and/or sizes; Prohibited in respect of specific activities; Prohibited in all areas or directions, or Prohibited in specific areas or directions, or Prohibited specified tidal or weather conditions, or simply Recommended to be avoided.	✓	Section 18: Collision and Allision Risk Modelling and Assessment Assesses the impact of the Hornsea Three array area on vessel movement using a number of collision and allision models to determine the level of risk for vessels. Assesses the impact of the Hornsea Three offshore HVAC booster stations on movement using allision models to determine the level of risk to vessels. Section 19: Communication and Position Fixing Summarises the potential impacts on navigation of the different communications and position fixing devices used in and around offshore wind farms. Section 22: Formal Safety Assessment Assesses impacts relevant to navigation, including the navigational corridor. Section 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 summarises the application and use of safety zones during construction, operation and maintenance and decommissioning phases. Section 24: Additional Mitigation Measures Required to Bring Risks to ALARP Parameters Table 25.1 summarises consultation with commercial fisheries regarding the circumstances under which fishing vessels or fishing activity may be excluded from the Hornsea Three array area.
c. Exclusion from the site 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 18: Collision and Allision Risk Modelling and Assessment Assesses the impact of the Hornsea Three array area on vessel movement using a number of collision and allision models to determine the level of risk for vessels. Assesses the impact of the Hornsea Three offshore HVAC booster stations on movement using allision models to determine the level of risk to vessels.

Issue	Compliant (Yes/No)	Reference notes/remarks
d. Relevant information concerning a decision to seek a safety zone for a particular site during any point in its construction, extension, operation or decommissioning should be specified in the Environmental Statement accompanying the development application.	✓	Section 23: Mitigation Measures Adopted as part of Hornsea Three Table 24.1 summarises the application and use of safety zones during construction, operation and maintenance and decommissioning phases.
Annex 2: Navigation, Collision Avoidance and Communications		
1. The Effect of Tides and Tidal Streams. 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 9: Design Envelope Section 9.2 provides the water depths within the Hornsea Three array area. Section 11: Metocean Data Presents meteorological and oceanographic statistics for the Hornsea Three array area. Section 15: Marine Traffic Surveys Summarises the results of the marine traffic surveys, which account for a range of tidal conditions. Section 18: Collision and Allision Risk Modelling and Assessment Collision and allision models take into account tidal conditions.
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 11: Metocean Data Table 12.1 provides details of the various states of the tide within the area. Section 18: Collision and Allision Risk Modelling and Assessment Collision and allision models take into account tidal conditions.
c. The maximum rate tidal stream runs parallel to the major axis of the proposed site layout, and, if so, its effect.	✓	Section 11: Metocean Data Table 12.1 provides details of the various states of the tide within the area.
d. The set is across the major axis of the layout at any time, and, if so, at what rate.	✓	Section 11: Metocean Data Table 12.1 provides details of the various states of the tide within the area.
e. In general, whether engine failure or other circumstance could cause vessels to be set into danger by the tidal stream.	✓	Section 11: Metocean Data Table 12.1 provides details of the various states of the tide within the area. Section 18: Collision and Allision Risk Modelling and Assessment NUC vessel to structure allision model takes into account tidal conditions within the area and assesses whether machinery failure could cause recreational vessels to be set into danger.
f. The structures themselves could cause changes in the set and rate of the tidal stream.	✓	No effect found.
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 23: Mitigation Measures Adopted as part of Hornsea Three Table 24.1 summarises the need for a scour protection management and cable armouring plan along with a Cable Burial Risk Assessment in order to mitigate the risk of scouring.
2. Weather. It should be determined whether:		
a. 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 11: Metocean Data Presents meteorological and oceanographic statistics for the Hornsea Three array area. Section 15: Marine Traffic Surveys Assesses vessel routeing in close proximity to Hornsea Three array area and Hornsea Three offshore HVAC booster station search area. Section 16: Adverse Weather Impacts Summarises alternative routeing used by regular operators during periods of adverse weather. Section 22: Formal Safety Assessment Assesses impacts relevant to navigation, including adverse weather (section 22.5).
b. The structures could create problems in the area for vessels under sail, such as wind masking, turbulence or sheer.	✓	Section 22: Formal Safety Assessment Wind masking, turbulence and sheer is discussed in section 22.12.3.

Issue	Compliant (Yes/No)	Reference notes/remarks
c. 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 18: Collision and Allision Risk Modelling and Assessment NUC vessel to structure allision model assesses whether vessels could drift into danger.
3. Collision Avoidance and Visual Navigation. It should be determined whether:		
a. The layout design will allow safe transit through the OREI by SAR helicopters and vessels.	✓	Appendix C: Helicopter Search and Rescue Operations in Offshore Windfarms
b. The MCA's Navigation Safety Branch and Maritime Operations branch will be consulted on the layout design and agreement will be sought.	✓	Section 14: Overview of Key Consultation As seen in Table 15.2 and Table 15.3, consultation has already taken place with the MCA regarding the layout design and will continue.
c. The layout design has been or will be determined with due regard to safety of navigation and Search and Rescue.	✓	Appendix C: Helicopter Search and Rescue Operations in Offshore Windfarms Section 22: Formal Safety Assessment Surface navigation is considered within section 22.13.
d.i. The structures could block or hinder the view of other vessels under way on any route.	✓	Section 18: Collision and Allision Risk Modelling and Assessment Section 18.2.2 and section 18.4.1 consider the effects on vessel routeing of the Hornsea Three array area and Hornsea Three offshore HVAC booster stations respectively.
d.ii. The structures could block or hinder the view of the coastline or of any other navigational feature such as aids to navigation, landmarks, promontories, etc	✓	Section 10: Existing Environment Section 10.4 provides an overview of existing aids to navigation within the vicinity of Hornsea Three.
4. Communications, Radar and Positioning Systems. To provide researched opinion of a generic and, where appropriate, site specific nature concerning whether:		

Issue	Compliant (Yes/No)	Reference notes/remarks
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 GMDSS and AIS, whether vessel borne, ashore or fitted to any of the proposed structures, to: Vessels operating at a safe navigational distance; 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; and Vessels by the nature of their work necessarily operating within the OREI.	✓	Section 19: Communication and Position Fixing Summarises the potential impacts on navigation of the different communications and position fixing devices used in and around offshore wind farms.
b. The structures could produce radar reflections, blind spots, shadow areas or other adverse effects: Vessel to vessel; Vessel to shore; VTS radar to vessel; Racon to/from vessel.	✓	Section 19: Communication and Position Fixing Summarises the potential impacts on navigation of the different communications and position fixing devices used in and around offshore wind farms.
c. The structures and generators might produce sonar interference affecting fishing, industrial or military systems used in the area.	✓	Section 19: Communication and Position Fixing Section 19.9 discusses sonar interference and related impacts.
d. The site might produce acoustic noise which could mask prescribed sound signals.	✓	Section 19: Communication and Position Fixing Section 19.10 discusses noise and related impacts.
e. Generators and the seabed cabling within the site and onshore might produce electro-magnetic fields affecting compasses and other navigation systems.	✓	Section 19: Communication and Position Fixing Section 19.7 discusses electromagnetic and related impacts.
5. Marine Navigational Marking. It should be determined:		

Issue	Compliant (Yes/No)	Reference notes/remarks
a. How the overall site would be marked by day and by night throughout construction, operation and decommissioning phases, taking into account that there may be an ongoing requirement for marking on completion of decommissioning, depending on individual circumstances.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Summarises mitigation measures adopted as part of the Project, including how the Hornsea Three array area will be marked during the construction, operation and maintenance and decommissioning phases.
b. How individual structures on the perimeter of and within the site, both above and below the sea surface, would be marked by day and by night.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Summarises mitigation measures adopted as part of the Project, including how the Hornsea Three array area will be marked during the construction, operation and maintenance and decommissioning phases
c. If the specific OREI structure would be inherently radar conspicuous from all seaward directions (and for SAR and maritime surveillance aviation purposes) or would require passive enhancers.	✓	n/a
d. If the site would be marked by additional electronic means e.g. Racons	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.3.5 states that AIS transmitters, virtual buoys and Racons may be used following consultation with TH.
e. If the site would be marked by an AIS transceiver, and if so, the data it would transmit.	✓	Section 24: Additional Mitigation Measures Required to Bring Risks to ALARP Parameters Table 25.1 summarises additional means of communication to third parties which are proposed, including AIS transceivers.
f. If the site would be fitted with audible hazard warning in accordance with IALA recommendations	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.2.3 states that audible warnings are among the features under consideration for the operation and maintenance phase, as part of relevant guidance from the MCA and CAA.
g. If the structure(s) would be fitted with aviation lighting, and if so, how these would be screened from mariners or guarded against potential confusion with other navigational marks and lights.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.2.3 states that aviation lighting will be used as per CAA requirements.

Issue	Compliant (Yes/No)	Reference notes/remarks
h. Whether the proposed site and/or its individual generators complies in general with markings for such structures, as required by the relevant GLA in consideration of IALA guidelines and recommendations.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.2.3 states that variation from the standard IALA guidance may be required given the distance offshore, but any variation would be made at the request of TH.
i. The aids to navigation specified by the GLAs are being maintained such that the “availability criteria”, as laid down and applied by the GLAs, is met at all times.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.2 states that throughout the construction, operation and maintenance and decommissioning phases, aids to navigation will be provided in accordance with both TH and MCA requirements.
j. The procedures that need to be put in place to respond to casualties to the aids to navigation specified by the GLA, within the timescales laid down and specified by the GLA.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Includes an Aid to Navigation Management Plan
k. The ID marking will conform to a spreadsheet layout, sequential, aligned with SAR lanes and avoid the letters O and I.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.3.10 states that the MCA will advise during the consent process on the specific requirements for Hornsea Three.
l. Working lights will not interfere with AtoN or create confusion for the Mariner navigating in or near the OREI.	✓	Section 22: Formal Safety Assessment Visual navigation is considered within 22.10.
6. 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		
i. Pre-consent: the site and its immediate environment extending to 500 m outside of the development area shall be undertaken as part of the licence and/or consent application. The survey shall include all proposed cable route(s).	✓	Will be provided by the Applicant.
ii. Post-construction: cable route(s).	✓	Will be provided by the Applicant.
iii. Post-decommissioning of all or part of the development: cable route(s) and the area extending to 500 m from the installed generating assets area.	✓	Will be provided by the Applicant.
Annex 3: MCA template for assessing distances between wind farm boundaries and shipping routes		
“Shipping route” template and interactive boundaries. Where appropriate, the following should be determined:		

Issue	Compliant (Yes/No)	Reference notes/remarks
a. The safe distance between a shipping route and turbine boundaries.	✓	Section 17: Future Case Marine Traffic Section 17.7 summarises that alternative routes following construction of Hornsea Three is assumed to maintain a minimum 1 nm distance from structures. This section also outlines details of evidence suggesting that vessels can and do pass consistently and safely within 1 nm of established wind farms.
b. The width of a corridor between sites or OREIs to allow safe passage of shipping.	✓	Section 22: Formal Safety Assessment Section 22.10 includes information regarding the navigational corridor between Hornsea Project One, Hornsea Project Two and Hornsea Three.
Annex 4: Safety and mitigation measures recommended for OREI 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 Environmental Impact Assessment (EIA). The specific measures to be employed will be selected in consultation with the Maritime and Coastguard Agency and will be listed in the developer's Environmental Statement. These will be consistent with international standards contained in, for example, the Safety of Life at Sea (SOLAS) Convention - Chapter V, IMO Resolution A.572 (14) and Resolution A.671(16) 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 23: Mitigation Measures Adopted as Part of Hornsea Three Table 14.1 includes details on the promulgation of Information as a mitigation measure adopted for Hornsea Three.
ii. Continuous watch by multi-channel VHF, including DSC.	✓	Section 19: Communication and Position Fixing Screen out based on lessons learnt at existing developments.
iii. Safety zones of appropriate configuration, extent and application to specified vessels	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 summarises the application and use of safety zones during construction, operation and maintenance and decommissioning phases as a mitigation measure adopted for Hornsea Three.
iv. Designation of the site as an area to be avoided (ATBA).	✓	n/a
v. Provision of AtoN as determined by the GLA	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.2 provides details of AtoN as required by TH and MCA, and in line with IALA requirements.

Issue	Compliant (Yes/No)	Reference notes/remarks
vi. Implementation of routeing measures within or near to the development.	✓	Section 22: Formal Safety Assessment Section 22.10 states that the MCA are currently considering the inclusion of a routeing measure for the navigational corridor between Hornsea Project One, Hornsea Project Two and Hornsea Three.
vii. Monitoring by Radar, AIS, CCTV or other agreed means	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Section 23.3.5 states that AIS transmitters may be used following consultation with TH. CCTV and Radar are not considered as mitigation.
viii. Appropriate means for OREI operators to notify, and provide evidence of, the infringement of safety zones.	✓	n/a
ix. Creation of an ERCoP with the MCA's SAR Branch for the construction phase onwards.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 summarises the development of an ERCoP for the construction, operation and maintenance and decommissioning phases as a mitigation measure adopted for Hornsea Three.
x. Use of guard vessels, where appropriate	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 summarises the use of guard vessels during the deployment of safety zones and other key periods of the construction phase as a mitigation measure adopted for Hornsea Three.
xi. Any other measures and procedures considered appropriate in consultation with other stakeholders.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 includes further mitigation measures adopted as part of Hornsea Three. Section 24: Additional Mitigation Measures Required to Bring Risks to ALARP Parameters Table 25.1 includes additional mitigation measures proposed for Hornsea Three.
Annex 5: Standards procedures and operational requirements in the event of search and rescue, maritime assistance service counter pollution or salvage incident in or around an OREI, including generator/installation control and shutdown		

Issue	Compliant (Yes/No)	Reference notes/remarks
The MCA, through HM Coastguard, is required to provide Search and Rescue and emergency response within the sea area occupied by all offshore renewable energy installations 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 23: Mitigation Measures Adopted as Part of Hornsea Three Table 24.1 summarises the development of an ERCoP for the construction, operation and maintenance and decommissioning phases as a mitigation measure adopted for Hornsea Three.
b. The MCA's guidance document Offshore Renewable Energy Installation: Requirements, Advice and Guidance for Search and Rescue and Emergency Response for the design, equipment and operation requirements will be followed.	✓	Section 23: Mitigation Measures Adopted as Part of Hornsea Three The applicant will consider guidance within MGN 543.

D.2 MGN 543 general comments checklist

Issue	Compliant (Yes/No)	Reference notes/remarks
A1: Reference Sources - Lessons learned.	✓	Section 6: Lessons Learnt
B1: Base case traffic densities and types.	✓	Section 15: Marine Traffic Surveys
B2: Future traffic densities and types.	✓	Section 17: Future Case Marine Traffic Section 18: Collision and Allision Risk Modelling and Assessment
B3: The marine environment :		
B3.1 Technical & operational analysis	✓	Section 9: Design Envelope
B3.2 Generic Technical and Operational Analysis (TOA)	✓	Section 18: Collision and Allision Risk Modelling and Assessment Section 22: Formal Safety Assessment
B3.3 Potential accidents	✓	Section 18: Collision and Allision Risk Modelling and Assessment Section 22: Formal Safety Assessment
B3.4 Affected navigational activities	✓	Section 22: Formal Safety Assessment
B3.5 Effects of OREI structures	✓	Section 18: Collision and Allision Risk Modelling and Assessment
B3.6 Development phases	✓	Section 9: Design Envelope
B3.7 Other structures and features	✓	Section 10: Existing Environment Section 21: Cumulative Assessment
B3.8 Vessel types involved	✓	Section 15: Marine Traffic Surveys
B3.9 Conditions affecting navigation	✓	Section 11: Metocean Data Section 19: Communication and Position Fixing
B3.10 Human actions	✓	Section 22: Formal Safety Assessment
C1: Hazard Identification	✓	Section 22: Formal Safety Assessment Appendix B: Hazard Log
C2: Risk Assessment	✓	Section 22: Formal Safety Assessment Appendix B: Hazard Log
C3: Influences on level of risk	✓	Section 9: Design Envelope Section 10: Existing Environment Section 15: Marine Traffic Surveys Section 19: Communication and Position Fixing
C4: Tolerability of risk	✓	Section 22: Formal Safety Assessment Appendix B: Hazard Log
D1 : Appropriate risk assessment	✓	Section 11: Metocean Data Section 13: Maritime Incidents Section 15: Marine Traffic Surveys Section 18: Collision and Allision Risk Modelling and Assessment Section 19: Communication and Position Fixing Section 22: Formal Safety Assessment Section 23: Mitigation Measures Adopted as Part of Hornsea Three
D2 : MCA acceptance for assessment techniques and tools	✓	Section 22: Formal Safety Assessment
D3: Demonstration of results	✓	Appendix B: Hazard Log

Issue	Compliant (Yes/No)	Reference notes/remarks
D4 : Area traffic assessment	✓	Section 9: Design Envelope Section 15: Marine Traffic Surveys Section 18: Collision and Allision Risk Modelling and Assessment Section 19: Communication and Position Fixing Section 21: Cumulative Assessment Section 22: Formal Safety Assessment Appendix B: Hazard Log
D5 : Specific traffic assessment	✓	Section 4: Consultation Section 9: Design Envelope Section 12: Emergency Response Overview and Assessment Section 18: Collision and Allision Risk Modelling and Assessment Section 22: Formal Safety Assessment Section 23: Mitigation Measures Adopted as Part of Hornsea Three Appendix B: Hazard Log
E1 : Risk control log	✓	Appendix B: Hazard Log
E2 : Marine stakeholders	✓	Section 24: Additional Mitigation Measures Required to Bring Risks to ALARP Parameters
F1 : Hazard identification checklist	✓	Assessment of equity to stakeholders will be carried out if required.
F2 : Risk control checklist	✓	Appendix B: Hazard Log

Appendix E Regular Operators Consultation

E.1 Sample regular operator consultation letter – Hornsea Three array area

anatec

DFDS Seaways
[redacted]

Anatec Ltd.,
Cain House
10 Exchange Street,
Aberdeen AB11 6PH
Tel: [redacted]
Fax: [redacted]
Email: [redacted]
Web: www.anatec.com

Date: Thursday 26th January 2017

Doc Ref: [redacted]

Stakeholder Consultation on Navigation Impacts for the Proposed Hornsea Project Three Offshore Wind Farm

Dear Stakeholder,

As you may be aware, DONG Energy UK Limited (DONG Energy) is the developer of the Hornsea offshore wind farms located off the East Riding of Yorkshire coast, having purchased control of the Hornsea Zone from SMartWind Limited in 2015.

The third offshore wind farm site being developed is called ‘Hornsea Project Three’ and consists of offshore wind turbines and associated infrastructure located in a defined area to the east of Hornsea Projects One and Two, as well as export cables to shore, and an onshore grid connection. The proposed Hornsea Project Three has an installed capacity of up to 2.4GW and covers an area of 203nm^2 (695km^2), with the closest point of the proposed offshore wind farm area from shore being 140km (76nm). Offshore construction is intended to commence in 2023 at the earliest. The location of the Hornsea Project Three offshore wind farm is presented in Figure E.1 alongside the soon to be under construction Hornsea Project One, and the recently consented Hornsea Project Two.

Anatec has been contracted by DONG Energy to provide technical support on navigation during the consenting process, and to coordinate the stakeholder consultations. Therefore, we are writing to you on behalf of DONG Energy to provide you with an outline of their proposals for developing Hornsea Project Three.

The Environmental Impact Assessment process requires DONG Energy to identify impacts that the development could potentially have on shipping and navigation, and to ensure that consultation is carried out in a comprehensive and consistent manner. In order to analyse shipping and navigation movements in the area, AIS and Radar data has been collected from vessel-based surveys which will feed into the Navigational Risk Assessment (NRA).

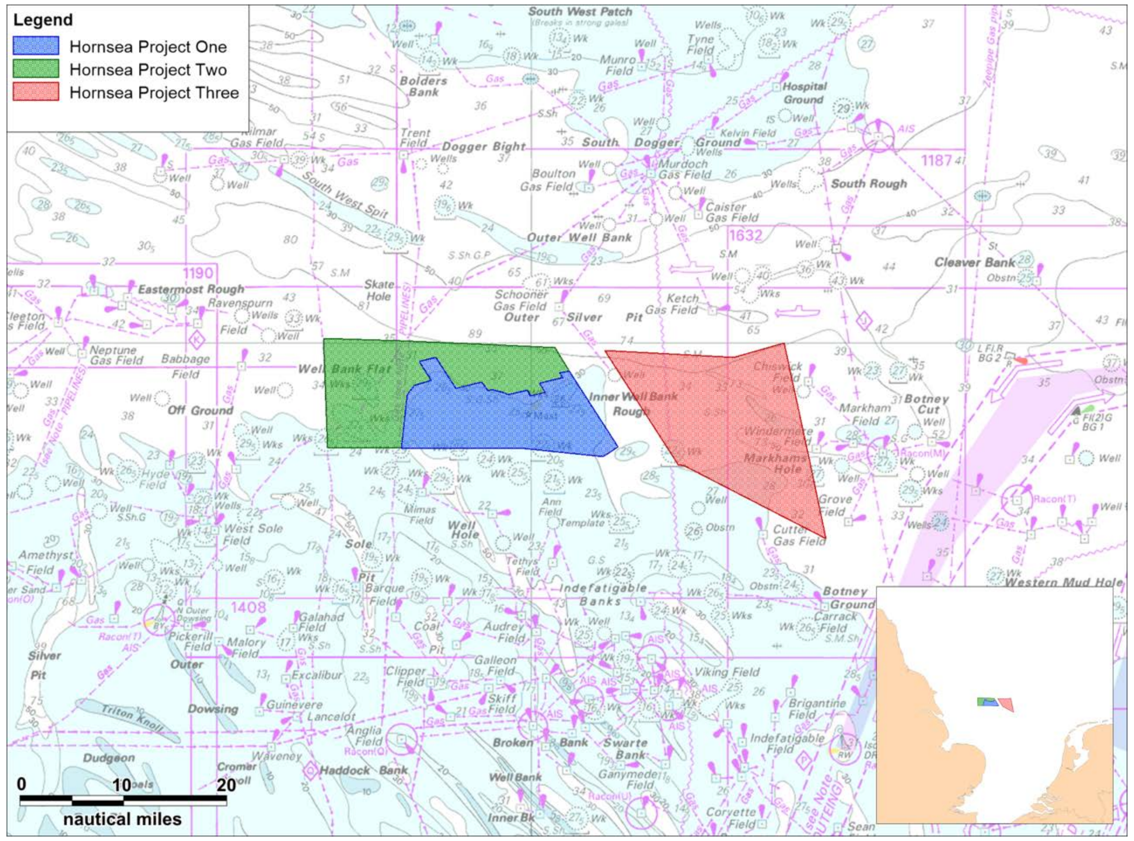


Figure E.1: Hornsea Offshore Wind Farm Projects.

Figure E 2 illustrates the dimensions of the corridor that exists between Hornsea Project Three on the east and the consented Hornsea Projects One and Two on the west. This corridor is intended as a route option that may enable shorter deviations for vessels travelling north – south.

Anatec has analysed the aforementioned AIS and Radar data and has observed that your organisation’s vessel(s) have regularly navigated in the sea area shown in Figure E.3. As a result, your company has been identified as a potential Marine Stakeholder for Hornsea Project Three. We therefore invite your feedback on the potential development including any impact it may have on the navigation of vessels. To assist your review, Figure E.3 shows AIS plots of your vessels’ movements over a period of 40 days in 2016 (26 days in June / July and 14 days in November / December). A 10nm buffer has been placed around the wind farm boundary for context.

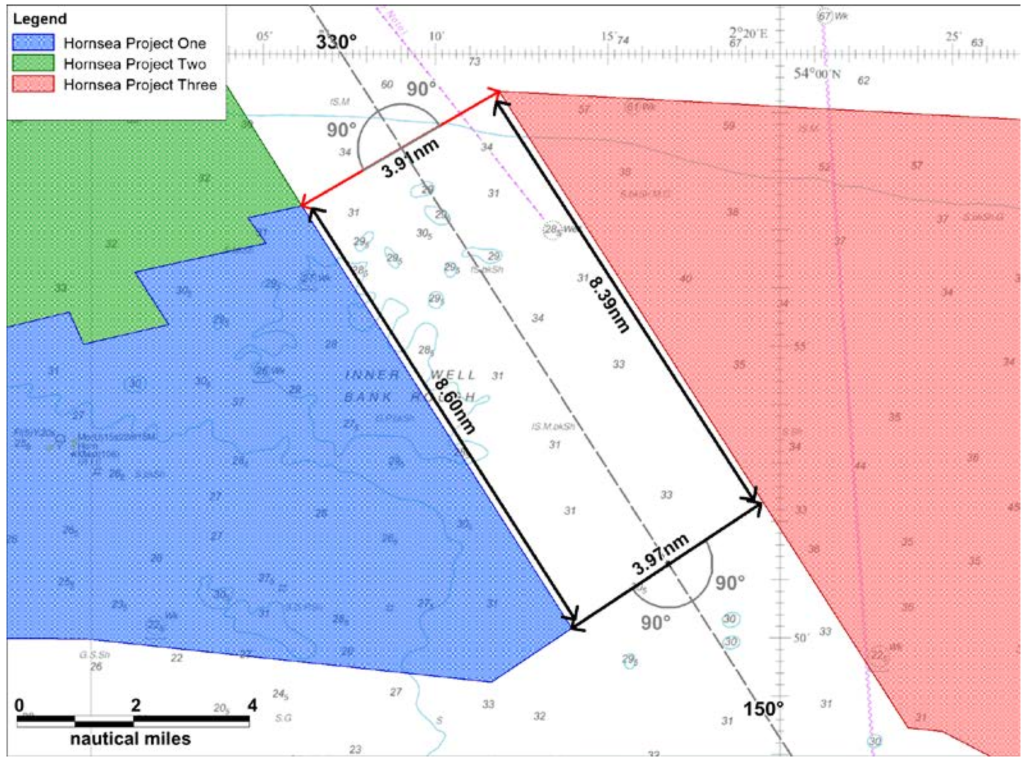


Figure E 2: Corridor Dimensions.

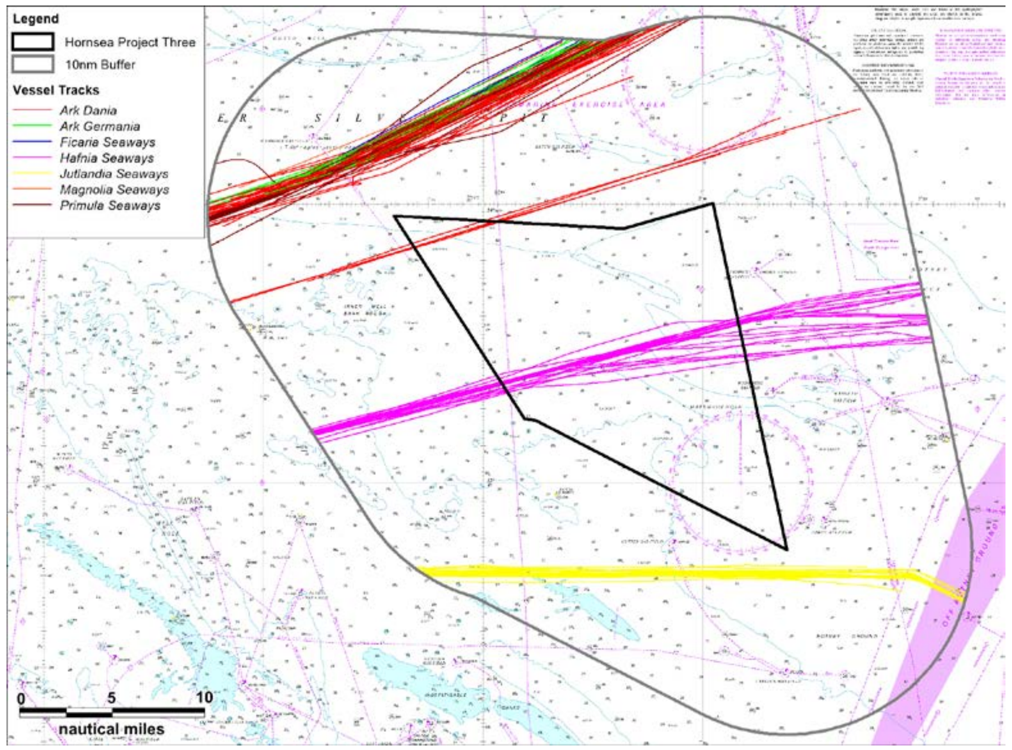


Figure E.3: 40 Days AIS & Radar Data for DFDS Seaways Vessels (June – December 2016).

Further project information is available at:
http://www.dongenergy.co.uk/uk-business-activities/wind-power/offshore-wind-farms-in-the-uk/hornsea-project-three-development

We would be grateful if you could review this letter and provide us with any comments or feedback that you may have by February 17th. This will allow us to assess your feedback as part of the NRA which is currently being undertaken. We would also be grateful if you could forward a copy of this information on to any vessel operators / owners you feel may be interested in commenting.

In particular, we are keen to receive comments on:

1. Whether the proposal to construct wind turbines and associated infrastructure within the Hornsea Project Three offshore wind farm area is likely to impact the routeing of any specific vessels;
2. Whether the development could pose any safety concerns for your organisation or members, including any adverse weather routeing;
3. The extent to which you would route through the corridor;
4. Whether you would like to be retained on our list of Marine Stakeholders and consulted throughout the NRA process: and
5. Whether you would like to attend a hazard workshop being held in central London on the 23rd February 2017.

Should you require any further information to support your review or additional information on the navigational consenting process in general, please do not hesitate to contact us. We look forward to receiving your response by February 17th.

Yours sincerely,

Anatec Ltd

Please send all responses and / or requests for further information via email [redacted] or in writing to:

Hornsea Project Three Stakeholder Feedback
Anatec Ltd