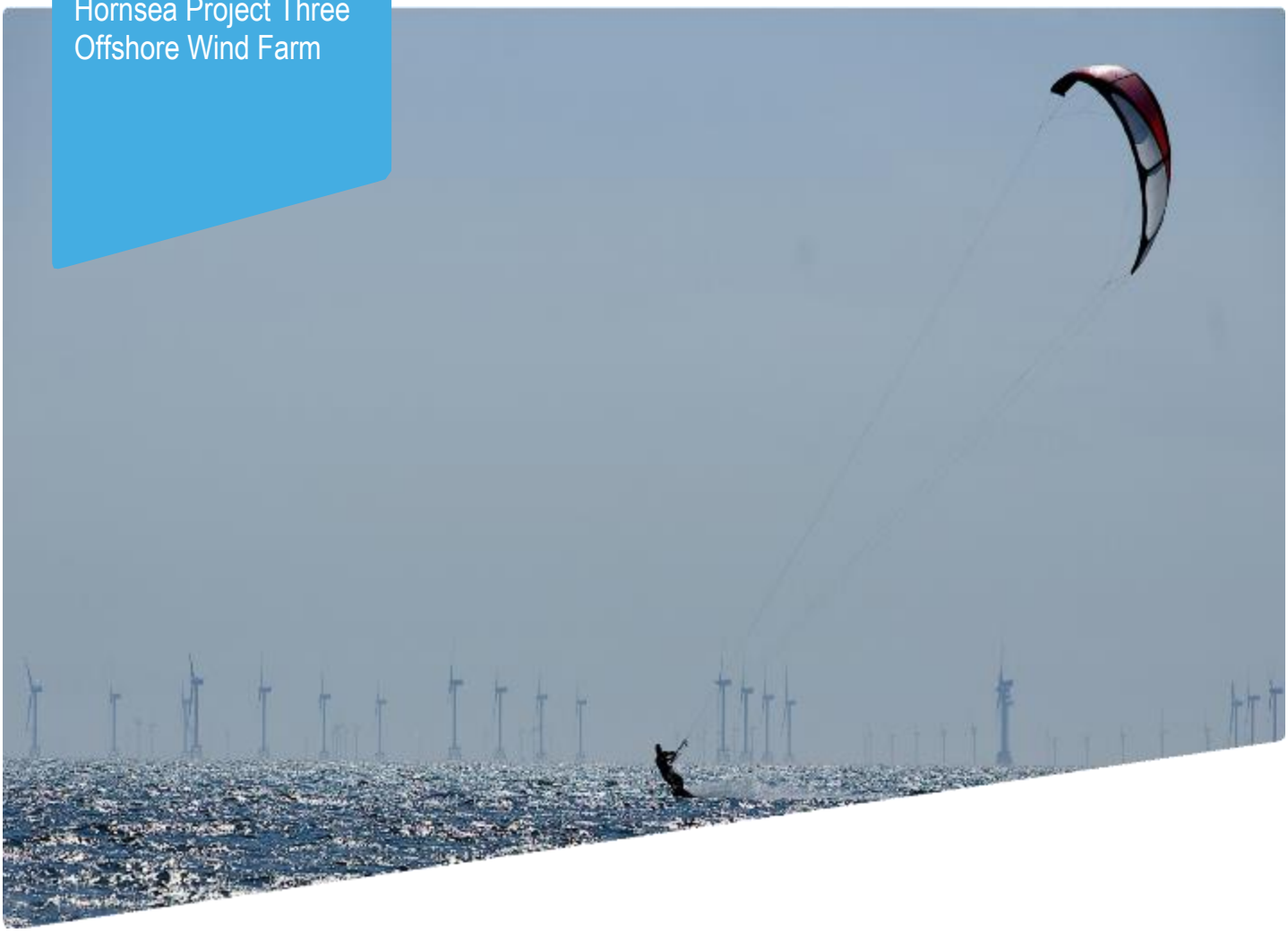
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Appendix 26 to Deadline 9 submission - Safety Justification for Single Line of Orientation Layout

Date: 26th March 2019

Hornsea 3
Offshore Wind Farm

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Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2019.

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1. Introduction

Background

1.1 Guidance provided in the Maritime and Coastguard Agency's (MCA) Marine Guidance Note (MGN) 543 states *'Developers should plan for at least two lines of orientation unless they can clearly demonstrate that fewer is acceptable'.* Using this guidance as a basis, the Applicant has been assessing layouts and layout strategies for over two years as part of the Environmental Impact Assessment (EIA) process. Following the Preliminary Environmental Impact Assessment (PEIR) and responses received as part of the Section 42 consultation, the Applicant moved, in consultation with the MCA and Trinity House (TH), to firstly develop a set of Layout Development Principles to provide a framework for post consent layout approval and secondly to base the Navigational Risk Assessment (NRA) and the Environmental Statement on a layout with a single line of orientation (SLoO).

1.2 As reflected at Deadline 4 responses, as part of the Hornsea Three Examination phase both the MCA and TH agreed that a single line of orientation would be acceptable if a suitable safety justification was presented and agreed. The Applicant clarified that its safety justification was presented in the Navigational Risk Assessment (NRA) dated May 2018, as supplemented with information requested by the MCA and TH during the examination. At the Issue Specific Hearing (ISH) on the 7th March 2019 submissions made by TH indicated that it would be helpful to have the safety justification in one document. In response the Applicant agreed to represent the work undertaken as part of the NRA and also the technical submissions into the examination process from the Search and Rescue (SAR) Helicopter Specialist into one document comprising the safety justification for a SLoO. This document serves that purpose and demonstrates how fewer than two lines of orientation is '*acceptable'* (as defined in accordance with MGN 543) for Hornsea Three.

Purpose of this Report

1.3 This report serves as the safety justification which the MCA have requested in line with Principle 3 of the Layout Development Principles. The report shows that a SLoO incorporated into the Hornsea Three array layout is '*acceptable and safe'* (as defined in accordance with MGN 543) by summarising relevant information given in Volume 5, Annex 7.1: Navigational Risk Assessment of the Environmental Statement (hereafter referred to as the "NRA") and materials produced since the NRA was submitted as part of the examination process.

2. Project Details

2.1 The layout considered in the NRA is shown in Figure 2.1. The symbology used in Figure 2.1 for turbine locations has been designed to give a clearer idea of the size of the turbines in relation to the Hornsea Three array area as a whole.

2.2 The layout consisted of the following 319 structures:

- 300 turbines;
- 12 offshore High Voltage Alternating Current (HVAC) transformer substations;
- Four offshore High Voltage Direct Current (HVDC) converter substations; and
- Three accommodation platforms.

2.3 The minimum structure spacing in the NRA layout is 1,000 m. Key project parameters provided in the NRA are summarised in Table 2.1.

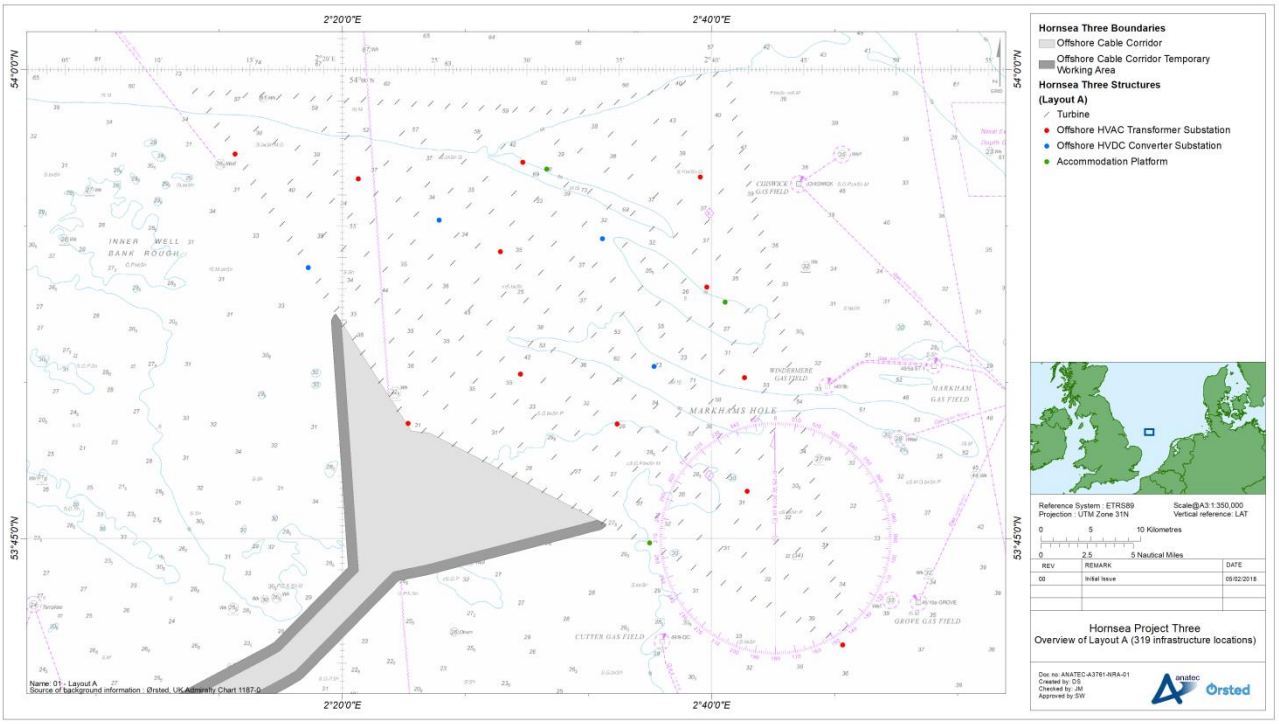

Figure 2.1 Overview of NRA layout

Table 2.1 Key project parameters

Parameter	Updated Application Value
Maximum number of turbines	300
Maximum number of other structures	19 (see above for breakdown)
Maximum blade tip height (above Lowest Astronomical Tide (LAT))	250 m
Maximum hub height (above LAT)	153 m
Maximum rotor diameter	195 m
Minimum spacing	1,000 m
Minimum blade clearance (above LAT)	34.97 m
Worst case foundation for shipping and navigation	Jacket

3. Guidance

3.1 Section 2 of the NRA outlines the guidance and legislation used to inform the assessment. This includes MGN 543 which, as noted in Section 1, advises that a SLoO layout will be agreed if demonstrated to be acceptable. However, there are no parameters within the guidance to identify what is acceptable and so this has been assumed based on both early consultation and the MCA's remit that the developer must demonstrate that the risk is As Low As Reasonably Practicable (ALARP) in line with the MCAs own methodologies[1] which the MCA require to be a template when preparing NRAs. For clarity this methodology has been used for the NRA for Hornsea Three.

3.2 Although not referenced by either guidance document, the MCA have recently noted during examination that geotechnical constraints may be used to aid the justification for a SLoO, i.e. demonstrating that it is not physically possible to apply two lines of orientation[2].

3.3 As demonstrated in section 4, this safety justification has been built upon the safety of both surface craft and SAR aircraft and is therefore in accordance with MGN 543.

4. Consultation

4.1 Throughout the consenting process for Hornsea Three consultation has been undertaken with relevant shipping and navigation stakeholders including the MCA. This section provides detail of consultation undertaken relevant to the topic of the array layout, including consultation summarised in the NRA.

Maritime and Coastguard Agency

4.2 During a consultation meeting in February 2017, both the MCA and Trinity House (TH) were clear that MGN 543 states that developers should plan for two lines of orientation in the Hornsea Three array layout unless they can clearly demonstrate that fewer is acceptable and safe for SAR helicopter operations. In consultation with the MCA, the Applicant subsequently took the decision to progress the final NRA based upon a SLoO layout.

4.3 During a consultation meeting in December 2017, the key points of the safety justification for a SLoO were discussed. These key points are listed below alongside where they are addressed in greater detail within this report.

- Agreement between Hornsea Three and the MCA that vessel traffic levels were low within the array area (section 5 – traffic density at Hornsea developments);
- Fishing stakeholders are more concerned with minimum spacing and foundation types than array layout (section 4 – regular operators);

[1] *Methodology for Assessing the Marine Navigational Safety Risk & Emergency Response Risks of Offshore Renewable Energy Installations (OREI)* (MCA, 2016).
[2] MCA's Responses to the Examining Authority's request for further information (Rule 17) (REP7-102)

- Hornsea Three resources will be on site and most likely to respond to an incident (section 8 – International Convention for the Safety of Life at Sea (SOLAS) obligations); and
- No other project borders the Hornsea Three array area (section 8 – Hornsea Three as a standalone development).

Trinity House

4.4 During a consultation meeting in December 2017, TH viewed the change to a SLoO as "a positive step forward" compared to the irregular layout assessed in the Preliminary Environmental Information Report (PEIR) and did not express a need for further refinement to two lines of orientation. At this meeting TH agreed that commercial vessels will not navigate within the array. The Applicant noted their commitment to a SLoO and added that a safety justification supporting a SLoO would be included within the NRA.

Cruising Association

4.5 During consultation the Cruising Association (CA) has stated that they have no major issues with the development of Hornsea Three and noted that many yachtsman will choose not to transit through an offshore wind farm. Furthermore, the CA felt that the additional time and distance incurred as a result of avoiding the array would mostly be minimal and it is likely that yachts and recreational craft may at the time of passage choose to avoid or be in a position where they should avoid the array.

4.6 The CA commented that Hornsea Three is located in an area of very light yachting and recreational traffic. This is in agreement with the vessel traffic data assessed in the NRA which provides very low numbers of recreational vessel movements. Although "straight see-through channels between the turbines" are preferable, the CA confirmed that any disadvantage for not doing so "may prove minimal and therefore acceptable to many".

4.7 In their Section 42 response the CA noted that the layout of structures should be in straight lines following a rectangular or similar pattern, although their view was eased by the adoption of a minimum spacing of 1,000 metres (m) or greater. Any consequent disorientation of helmsman can be mitigated to an extent by additional marking and lighting. As per the NRA, structures in the array will be marked and lit in accordance with *IALA Recommendation O-139 on The Marking of Man-Made Offshore Structures* (IALA, 2013) and TH and the MCA will be consulted in relation to the need for additional internal aids to navigation.

4.8 In the SoCG between Hornsea Three and the CA the CA agree that Hornsea Three has minimal impacts on recreational craft and are therefore in agreement with the Layout Development Principles approach being developed in conjunction with the MCA and TH.

Royal Yachting Association

4.9 During consultation the Royal Yachting Association (RYA) expressed no concerns given that the level of recreational activity at the distance offshore of the Hornsea Three array area is very low. The RYA added that at the distance offshore any recreational user would be very experienced and well-equipped. It is noted that the RYA had no concerns with the indicative layouts which were presented at the PEIR stage. The PEIR layouts included no lines of orientation (irregular).

4.10 The RYA were provided but had no comments with regard to the Environmental Statement and NRA.

Regular Operators

4.11 Regular operators were identified in the NRA using the Automatic Identification System (AIS) traffic data and were invited to comment on the development and attend a Hazard Workshop held at the Ørsted offices in London in February 2017.

4.12 Regular operators whose representatives attended the Hazard Workshop included the following:

- DFDS Seaways;
- Aggregate Industries UK;
- DEME Building Materials;
- Centrica (now Spirit Energy);
- Vroon Offshore Services; and
- Dutch Fishing Association VISNED.

4.13 It is also noted that a representative from the MCA was present at the Hazard Workshop.

4.14 During the meeting, all commercial operators present agreed that commercial vessels (non-fishing) would not use the array area for transiting. Specifically, both DFDS Seaways and marine aggregate dredger representatives confirmed that the array layout is a non-issue since their vessels would not enter the array area. Oil & Gas representatives stated that their support vessels would choose to use the navigational corridor between the Hornsea developments rather than transit through the array area, noting that this would not significantly increase routeing distances.

4.15 Although not in attendance at the Hazard Workshop, commercial ferry operator KESS expressed similar views, noting a slight impact on routeing but that vessels can avoid the area and therefore there are no notable safety concerns.

4.16 VISNED noted that fishing activity would be possible within the indicative layout presented at the PEIR stage (an irregular layout with no lines of orientation) and commented that “for fishing, the separation between turbines is more important than the regularity of the layout”. Demersal trawlers active within the array are expected to target specific fishing grounds meaning that it is unlikely that the skippers would choose to fish along a fixed line of orientation in the array layout.

4.17 VISNED also noted that in good weather fishing vessel are likely to transit through the array. It is noted that Dutch fishing vessels (represented by VISNED) are predominant in the area.

4.18 Regular operator consultation clearly indicates that, with the exception of fishing vessels, commercial traffic would be unlikely to transit through the array and therefore there is no, or minimal, additional benefit to safe surface navigation by including two lines of orientation in the array layout. In the case of fishing vessels the NRA remarks that the majority of risk associated with internal navigation is related to vessels engaged in fishing rather than transiting.

4.19 In summary, it is clear that no consultee expressed concerns from a safety perspective or otherwise in relation to a SLoO.

5. Vessel Traffic

Data Overview

5.1 The NRA included a baseline navigation review of the Hornsea Three array area using marine traffic data. The dataset analysed consisted of a combined dataset of 40 days of AIS, visual and Radar data recorded within 10 nautical miles (nm) of the array area (the "study area") from survey vessels working at the Hornsea Three array area during summer (26 days) and winter (14 days) 2016. This data satisfied MCA requirements as set out in MGN 543 and was approved by the MCA in April 2017.

All Vessels

5.2 Plots of the vessel tracks recorded during each survey period, colour-coded by vessel type, and excluding temporary traffic (such as the survey vessels and traffic associated with temporary drilling rigs) is presented in Figure 5.1 (Panels A and B). Figure 5.1 also presents the corresponding density grid for each survey period (Panels C and D).

5.3 For the 26 days analysed in summer 2016, there was an average of 42 unique vessels per day passing within the study area. In terms of vessels intersecting the Hornsea Three array area, there was an average of 15 unique vessels per day. The majority of tracks were cargo vessels (33% of traffic within the Hornsea Three array area) and fishing vessels (30%).

5.4 For the 14 days analysed in winter 2016, there was an average of 28 unique vessels per day passing within the Hornsea Three array area study area. In terms of vessels intersecting the Hornsea Three array area, there was an average of 13 unique vessels per day. The majority of tracks were cargo vessels (45% of traffic within the Hornsea Three array area) and tankers (21%).

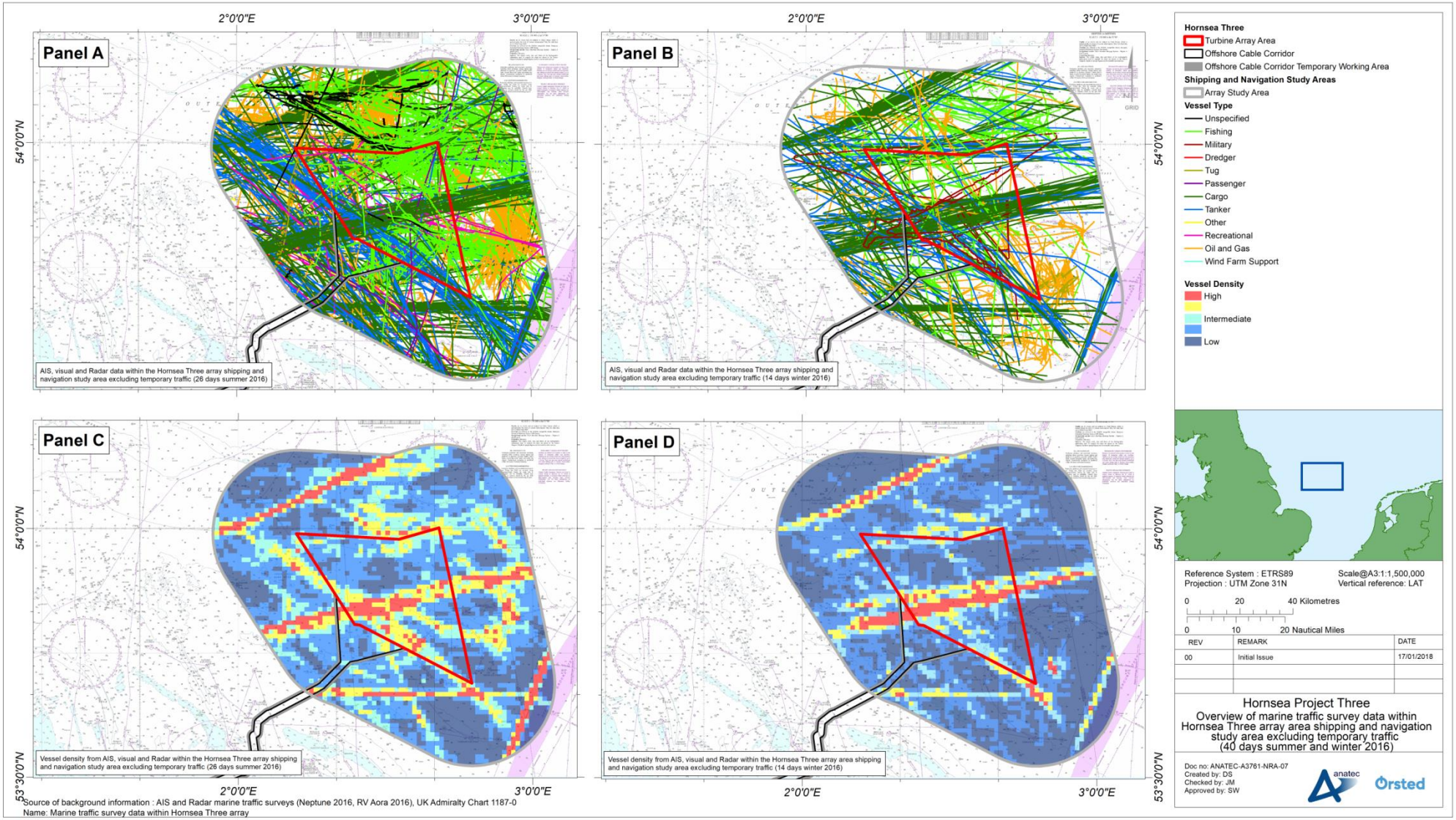

Figure 5.1 Overview of vessel traffic data within 10 nm of Hornsea Three array area (40 days summer and winter 2016)

Recreational Vessels

5.5 A plot of the recreational vessel tracks recorded throughout the survey period is presented in Figure 5.2. It is noted that 45% of all recreational activity was recorded over a period of two days when an annual sailing race passed through the Hornsea Three array area.

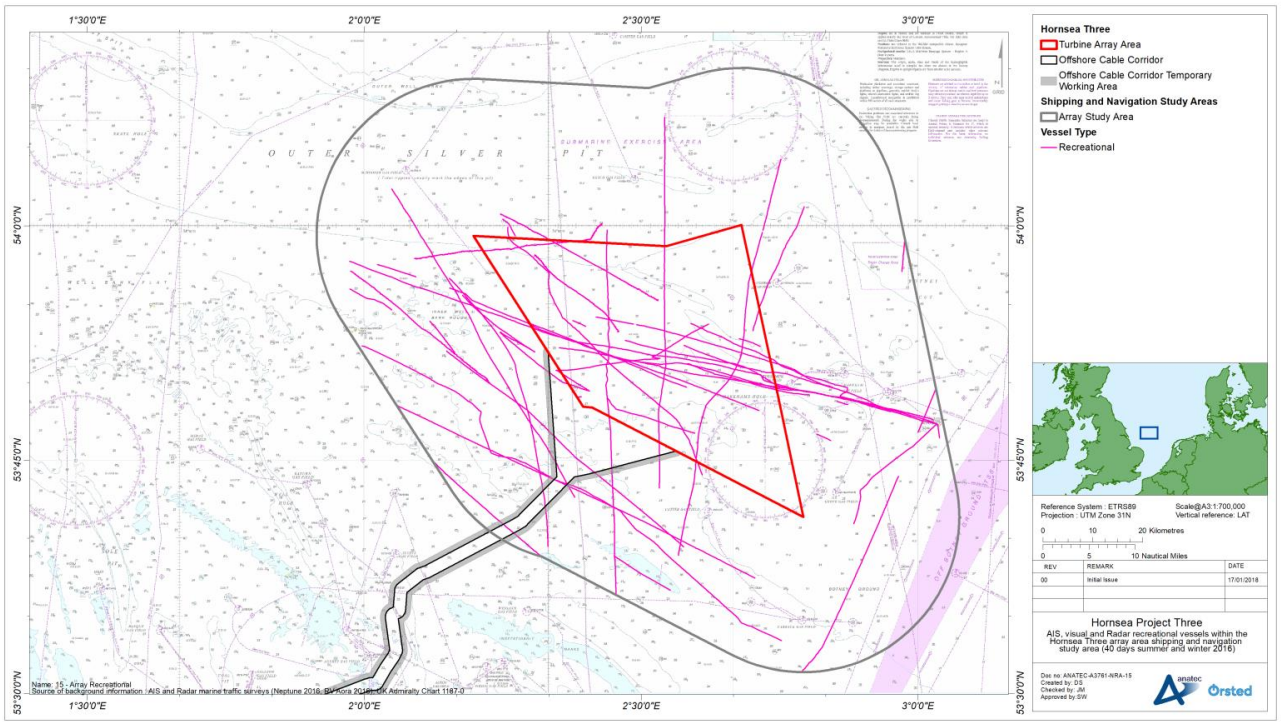

Figure 5.2 Recreational vessels within 10 nm of Hornsea Three array area (40 days summer and winter)

Fishing Vessels

5.6 A plot of the fishing vessel tracks recorded throughout the survey period is presented in Figure 5.3. It can be seen that fishing vessels were tracked transiting through the Hornsea Three array area as well as actively engaged in fishing activity.

5.7 Fishing vessel sightings (over flight and/or vessel-based) and satellite data (from the MMO) was used to validate the AIS, visual and Radar dataset and showed good correlation.

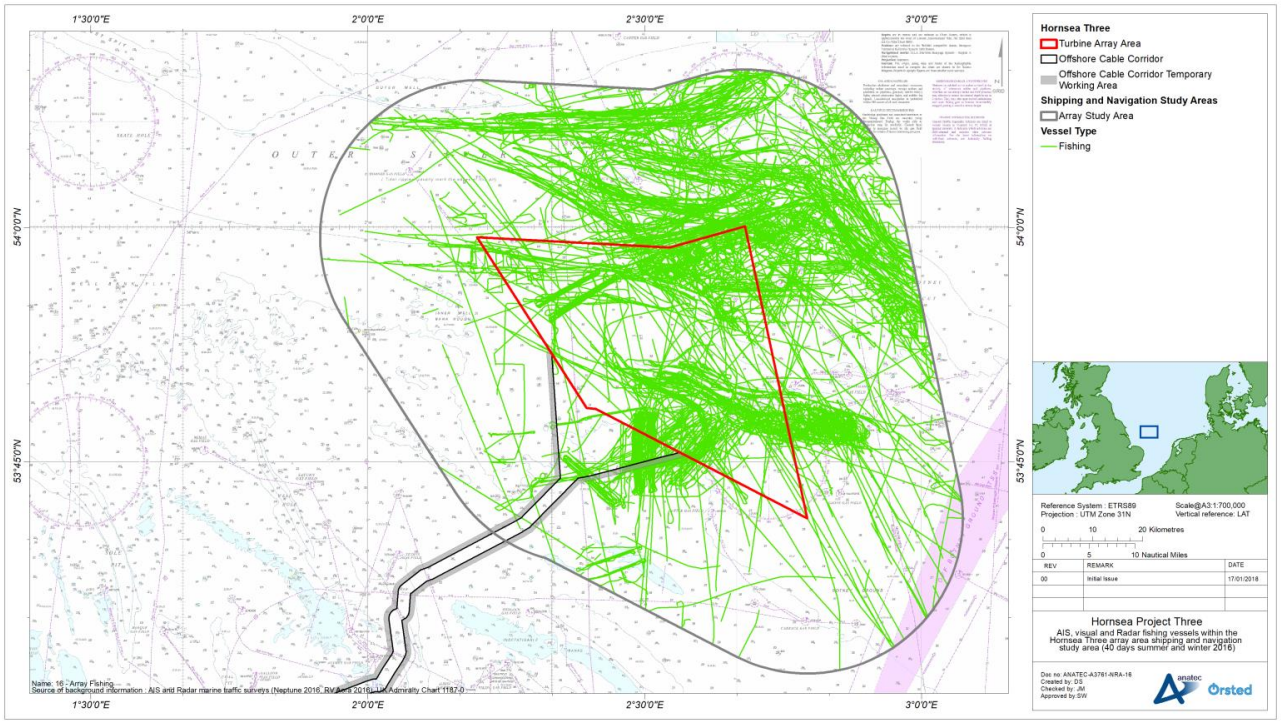

Figure 5.3 Fishing vessels within 10 nm of Hornsea Three array area (40 days summer and winter)

Traffic Density at Hornsea Developments

5.8 Table 5.1 summarises the density of vessel traffic recorded on AIS, visual and Radar during the NRA surveys undertaken for each Hornsea development, noting that the data for each NRA was approved by the MCA.

Table 5.1: Traffic density within each Hornsea development array area

Development	Surface Area of Array Area (nm^2)	Average Unique Vessels per Day Within Array Area			Traffic Density (Daily Vessels per nm^2)
		Summer	Winter	All	
Hornsea Project One	118	12	13	12	0.10
Hornsea Project Two	134	12	12	12	0.09
Hornsea Three	202	15	13	14	0.07

5.9 It can be seen that the levels of vessel traffic for each Hornsea development was similar with Hornsea Three giving the highest average number of unique vessels per day by a small margin. However, when accounting for the significantly greater surface area covered by the Hornsea Three array area (71% greater than Hornsea Project One and 51% greater than Hornsea Project Two), the vessel density is lower at Hornsea Three than at the other Hornsea developments.

5.10 Moreover, it is noted that the AIS data used for Hornsea Three was collected in 2016 at which point all fishing vessels of length greater than 15 m were required to carry AIS equipment as per Annex II of European Union (EU) Directive 2002/59/EC. This compares with length thresholds of 45 m and 24 m at the time of data collection for Hornsea Project One (2011) and Hornsea Project Two (2012), respectively. Therefore, given the significant presence of fishing vessels in all three Hornsea developments, in reality the traffic density for Hornsea Project One and Hornsea Project Two may be significantly higher than that of Hornsea Three.

5.11 With increasing experience and knowledge of navigation by SAR assets within offshore wind farms, the Applicant understands that precedence should not be set with respect to the number of lines of orientation in a layout. However, both Hornsea Project One and Hornsea Project Two had layouts approved by the MMO in consultation with the MCA with a SLoO (noting vessel density being greater than that of Hornsea Three). Therefore, from the perspective of local vessel traffic and impacts on surface navigation, it is considered reasonable for Hornsea Three to also be consented with a SLoO.

Anchoring Activity within Array Area

5.12 As part of the vessel analysis undertaken in the NRA, an assessment was undertaken to identify anchoring activity within a 10 nm buffer of the Hornsea Three array area. Considering both vessels broadcasting an “at anchor” status and vessels travelling at speeds of less than one knot (kt) for more than 30 minutes no vessels were deemed to be at anchor. This may be attributed to the distance offshore and the moderate water depth.

5.13 This finding adds further weight to the information provided in the previous section that vessel activity within the Hornsea Three array area is relatively low.

Traffic Behaviour Internally within Existing Arrays

5.14 London Array Offshore Wind Farm has been fully operational since 2013 and was consented within a busy and seasonal area for small craft. A specific buoyed navigation channel (Fouglars Gat) was designed in the position of an existing preferred route, although does not form part of either of the primary lines of orientation in the array layout. The minimum turbine spacing at London Array is approximately 650 m.

5.15 As part of the Hornsea Three NRA, a year of AIS data, collected between March 2016 and February 2017, was analysed within the London Array site boundary in order to gain an understanding of the behaviour of vessel traffic transiting internally within an array.

5.16 Figure 5.4 presents the recreational vessel tracks recorded within the London Array site boundary. During the one-year period 140 unique recreational transits were recorded, all but eight tracks transited through Foulgers Gat for the majority of their transit; these vessels generally made passage in straight lines using the buoyed navigation channel. Of those eight tracks which did not fully stay within Foulgers Gat, passage was not necessarily in straight lines, and was not dictated by the available lines of orientation.

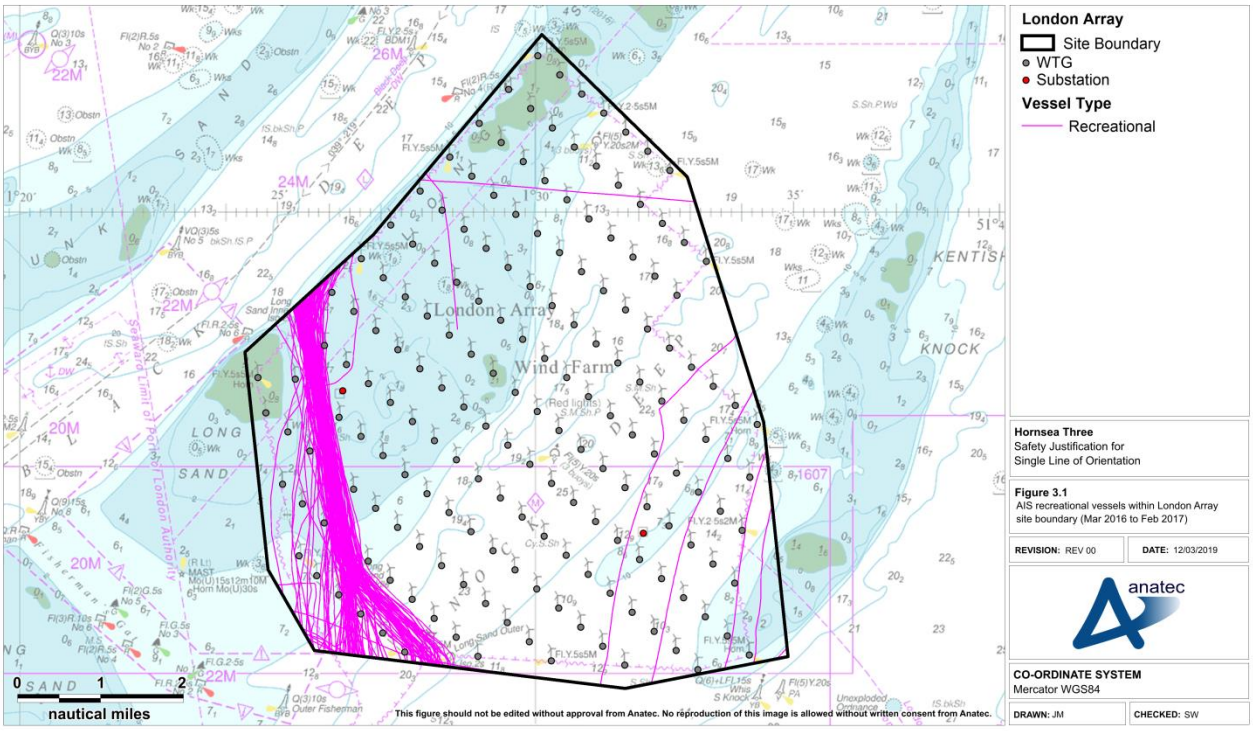

Figure 5.4: AIS recreational vessels within London Array site boundary (Mar 2016 to Feb 2017)

5.17 Figure 5.5 presents the fishing vessel tracks recorded within the London Array site boundary. Only 32 unique fishing vessel transits were recorded. Of the 49 tracks recorded, 23 broadcast a navigational status of “engaged in fishing”, with these near the southern boundary; the remaining 26 tracks consisted of passages through the array, with vessels not, in the majority, following the main lines of orientation. This is reflective of comments from fishing representatives during consultation, as noted in section 4.

5.18 This technical evidence provides useful context re the MCA's assertion that the safest way to navigate through an offshore wind farm is when multiple lines of orientation are in place (see MCA consultation in section 2), with vessels at London Array opting to take alternative routes which are not necessarily confined to the available lines of orientation. Moreover, evidence suggests that larger commercial vessels are not likely to navigate through an offshore wind farm; this is evidenced by extensive traffic surveys and has been reiterated by commercial operators over many years during consultation for many developments. As noted in section 4 (Regular Operators), this is also the case for Hornsea Three, with large commercial operators in the area such as DFDS Seaways making clear during consultation that they would not make passage through the array.

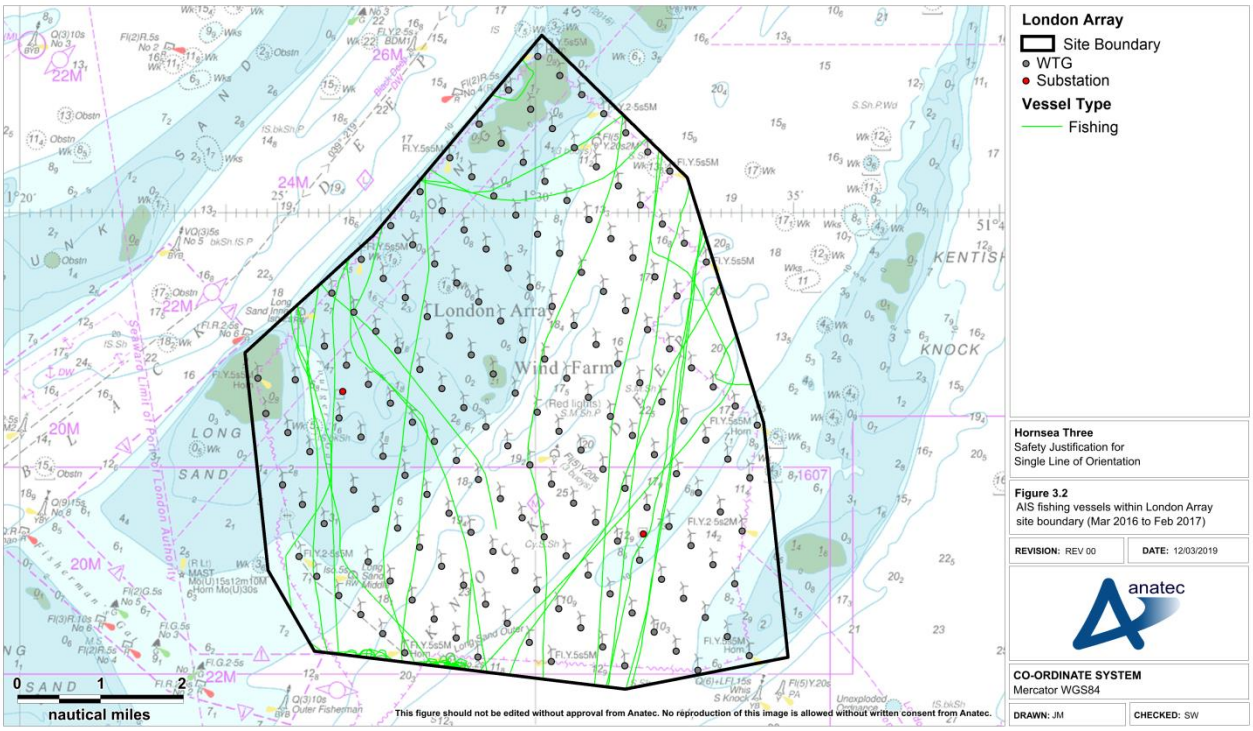

Figure 5.5: AIS fishing vessels within London Array site boundary (Mar 2016 to Feb 2017)

6. Search and Rescue

6.1 Extensive technical assessment has been undertaken on the impact of Hornsea Three on the ability of SAR helicopters to undertake operations within the array area, led by Mark Prior, SAR Helicopter Specialist. Appendix 14 to the Applicant's Deadline 2 submission provides an in-depth analysis of the impact the development may have on SAR accessibility; some of the key points raised are outlined in the following subsections.

Mark Prior Bio

6.2 Mark Prior is a highly experienced aviation professional with a wide range of expertise in certification, safety analysis, investigation, operations, technical issues and regulations. Over 38 years' experience as a pilot, initially in the Royal Air Force (RAF), then as a licensed civil pilot with concurrently 25 years of experience as an Experimental Test Pilot. Since 2003 mark has been an industry representative on a number of rule-making, operational and research groups.

Search and Rescue Access Lanes

6.3 From Annex 5 to MGN 543, a SAR access lane is an area within which "there shall be no OREIs, or other structures, in the wind farm or on the boundary that present an obstacle or risk to SAR helicopters flying along". The purpose of a SAR access lane is to ensure that "a SAR helicopter can fly from one side of a wind farm to the other". Furthermore, "the lanes also provide safer and more predictable paths through a wind farm for surface rescue vessels".

Lack of Precedent

6.4 No current experience exists with SAR aviation operations in UK offshore wind farm, with only trials undertaken to date which have not incorporated Round 3 offshore wind farms, with the exception of at Rampion Offshore Wind Farm (3.6 MW turbines in a grid layout). In particular, there is no experience of conducting a search in an array where the turbines are spaced at least one kilometre (km) apart and current Standard Operating Procedures (SOP) are based on more tightly packed arrays, which will be of limited validity for Hornsea Three. However, the MCA have conducted flights with spacing around 800 to 900 m to explore SAR issues.

6.5 In some ways a parallel can be drawn to searching in hilly terrain where the helicopter can be constrained to valleys when the hill tops are covered in cloud. Unlike hilly terrain, all obstacles in a turbine array will be controlled, accurately mapped and information provided to the crew by paper and electronic means. The MCA, and their helicopter contractor, are able to modify their search profiles and procedures to take account of the obstacle environment presented in Round 3 offshore wind farm arrays.

Turning Within the Array

6.6 The MCA provided data to the Applicant from a trial conducted by their SAR helicopter contractor over Loch Ness in Scotland during the summer of 2018. Conducting such trials is problematic and can require the use of specialist tracking equipment in order to produce accurate and repeatable results. The Applicant raised a concern that the single image provided by the MCA appeared to show turns at an inconsistent angle of bank as the orbits were not round, despite it being stated that the turns were flown in zero wind. Furthermore, it did not appear to show the diameter being measured accurately.

6.7 The MCA later provided two diagrams showing turning performance. The first showed a turn into a 40 kt wind with the wind 30 degrees (°) to the right of track. The radius of turn for a 180° turn of 0.12 nm coincides with the Applicant's calculations. A second diagram with the 40 kt wind at 90° to the right showed a reduced turning radius for a 180° turn of 0.1 nm. These diagrams support the Applicant's calculations of turning circle. The Applicant used weather data from the J6A platform and seven years' worth of met data from the Hornsea Project One array area to confirm that simultaneous occurrences of poor visibility and strong winds were extremely uncommon. The J6A met data for one year had no occurrences of visibility below 1000 m and wind speed above 30 kt, whilst the Hornsea Project One data, recorded at 10 minute intervals for seven years, had a probability of 0.0166% of strong winds and poor visibility occurring concurrently.

6.8 The European Aviation Safety Agency (EASA) Part Standardised European Rules of the Air (SERA) is used for guidance as to the speeds flown against visibility. Although an advisory airspeed is provided, this is really the ground speed, as that determines the closure rate with obstacles. Table 6.1 gives the recommended speeds for differing levels of visibility.

Table 6.1: EASA Part SERA recommended speeds

Visibility (m)	Advisory speed (kt)	Time to cover "visible distance" at "advisory speed" (seconds)
800	50	31
1,500	100	29
2,000	120	32

6.9 With visibility in excess of 1,000 m, the turbine ahead, and laterally, will be visible and so a turn can be made without risk of colliding with the turbine. With visibility below 1,000 m, the airspeed will be reduced towards 50 kt, requiring a smaller distance to turn.

6.10 The MCA have suggested that a turn would likely be undertaken with an angle of bank of 20 to 30°, with the greatest speed applied 80 kt (where visibility is good). The MCA have also suggested that 1 nm is required to allow sufficient space to turn an aircraft, particularly in poor weather. Classic aerodynamic theory shows that:

$$r = \frac{v^2}{g \tan \emptyset}$$

6.11 Where:

$r = radius\ of\ turn\ (m)$
$g = 9.81 m/s^2$
$v = true\ airspeed\ (kt)$
$\emptyset = angle\ of\ bank\ (°)$

6.12 Applying this to a turn at 80 kt with angle of bank 20°, the radius of turn would be approximately 0.25 nm (diameter 0.50 nm). In poor visibility the airspeed would be reduced, and thus the radius of turn would also be reduced. The MCA and Applicant have different positions on whether a Helicopter Refuge Area is essential. However, agreement reached on Principle 5 does provide for a Helicopter Refuge Area whose exact dimensions will be determined post consent.

Minimum Spacing

6.13 Table 6.2 presents the minimum spacing at a number of operational or under construction offshore wind farms in the UK. Values are based on distances obtained from United Kingdom Hydrographic Office (UKHO) Admiralty charts.

Table 6.2 Minimum spacing at UK offshore wind farm developments

Development	Minimum Turbine Spacing within NRA (m)	Increase in Minimum Turbine Spacing at Hornsea Three
Hornsea Project One	878	13.9%
Hornsea Project Two	924	8.23%
East Anglia One	675	48.2%
East Anglia Three	675	48.2%
Rampion	600	66.7%
London Array (Round 2 development)	650	53.9%

6.14 The minimum spacing between turbines for Hornsea Three of 1,000 m is greater and in some cases significantly greater than other offshore wind farms in the UK. The two other Hornsea developments are the only cases where the minimum spacing is somewhat similar and layouts for these developments have a SLoO.

6.15 The greater minimum spacing gives vessels more sea room to navigate and manoeuvre within the Hornsea Three array area (including turning circles and rates of turn).

6.16 Given the distance offshore and the presence of project vessels for Hornsea Three the likelihood of a SAR operation in which a widespread search is required is very low. Helicopter Refuge Areas are intended to support access to, and within, the array area, including in the instance that a medical evacuation is required.

7. Historical Incidents

7.1 The NRA considers SAR operations data within the Hornsea Three array area study area and found that in the five-year period between 2011 and 2015 a total of nine SAR operations were recorded, as shown in Figure 7.1.

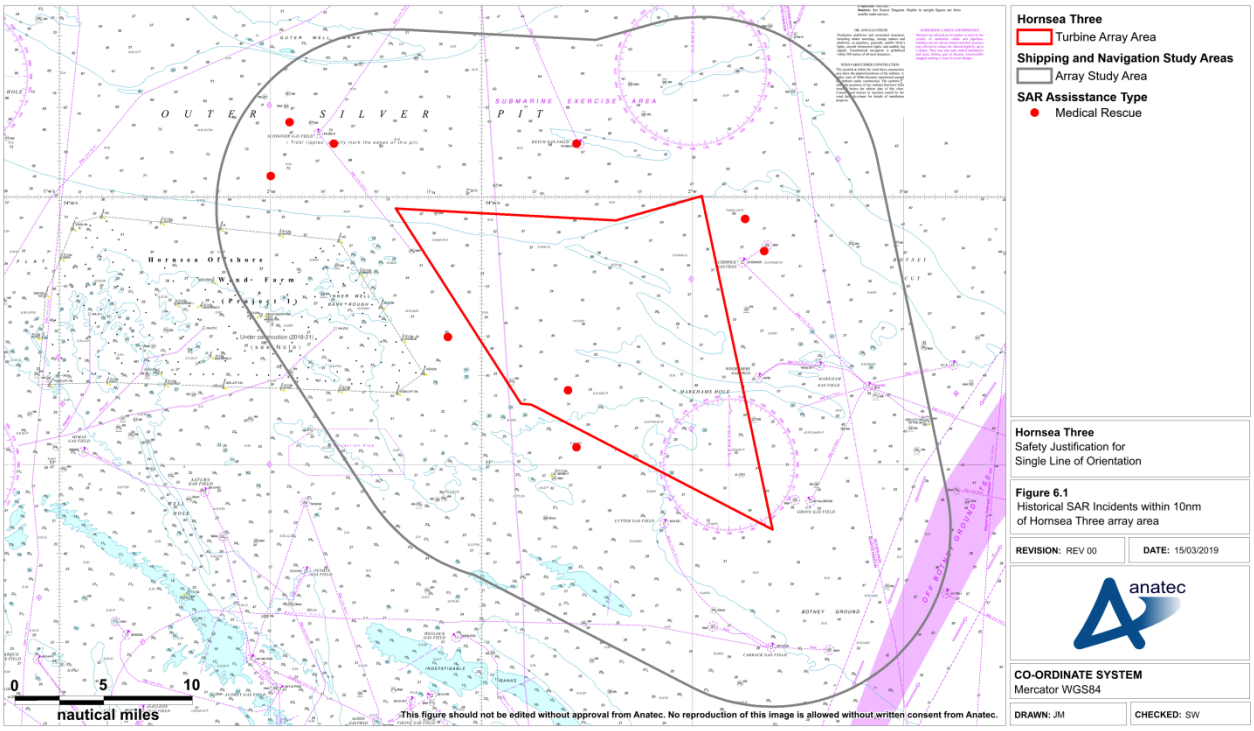

Figure 7.1 Historical SAR incidents within 10 nm of Hornsea Three array area

7.2 Only one of these SAR operations was recorded within the Hornsea Three array area and all the incidents involved a medical rescue conducted in the daytime without the need for a search. From this data it is evident that the region within the southern North Sea where Hornsea Three is to be located does not endure a high level of marine incidents which require SAR operations. This will be furthered by the presence of Hornsea Three since project vessels will be fully certified and very likely able to render assistance under SOLAS obligations in addition to a SAR Asset (see section 8 – SOLAS Obligations), and in the case of less protracted incidents may be able to provide a sufficient response without the need for a SAR Asset. Further discussions will take place with the MCA post consent as part of the ERCoP on emergency response requirements.

7.3 In addition to incidents involving SAR operations, the NRA also analysed incident data provided by the Maritime Accident Investigation Branch (MAIB) and Royal National Lifeboat Institution (RNLI) during the 10-year period between 2005 and 2014.

7.4 Figure 7.2 presents the locations of accidents, injuries and hazardous incidents reported to the MAIB within the various study areas considered in the NRA relating to shipping and navigation.

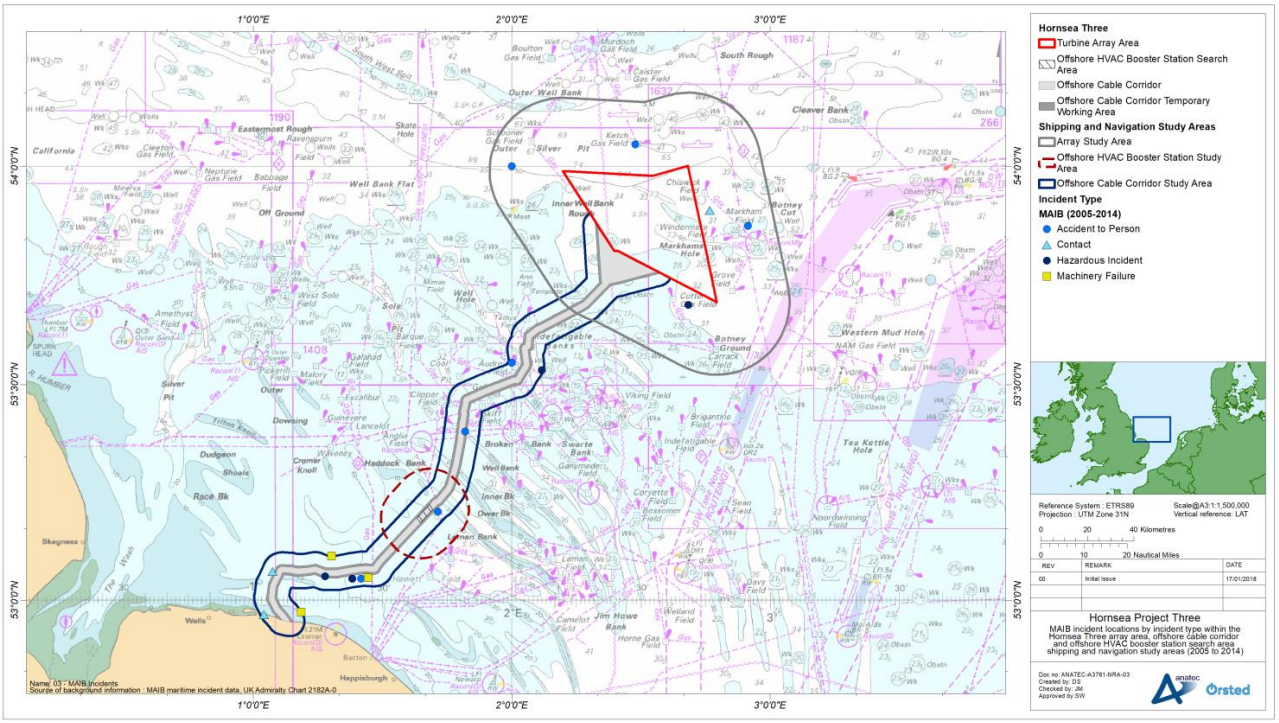

Figure 7.2 MAIB incident locations by incident type within 10 nm of Hornsea Three array area

7.5 A total of five unique incidents, with one incident involving two vessels, were reported within the Hornsea Three array area study area, corresponding to an average of one incident every two years. None of these incidents occurred within the Hornsea Three array area. "Accident to Person" was the most frequent incident type and Oil & Gas affiliated vessels were the most frequent casualty type.[3]

7.6 Figure 7.3 presents the locations of incidents responded to by the RNLI within the various study areas considered in the NRA relating to shipping and navigation.

7.7 It was found that no launches to incidents were reported by the RNLI within the Hornsea Three array area study area with the closest incident approximately 215 m outside of the study area. This reflects the strategic performance standard of the RNLI of reaching casualties up to a maximum of 100 nm from shore – the RNLI may respond to a drifting vessel but are unlikely to respond to a life-saving incident in proximity to the Hornsea Three array area owing to the time it would take to get to the incident from shore.

[3] It is noted that construction and operations of Hornsea Three may lead to potential industry incidents requiring SAR response; however this is related to the wind farm rather than the internal layout. All wind farm personnel will be issued with Personal Locator Beacons (PLBs) and will be required to wear these when engaged in activities that present an elevated risk, which should assist the SAR helicopter with pinpointing the casualty.

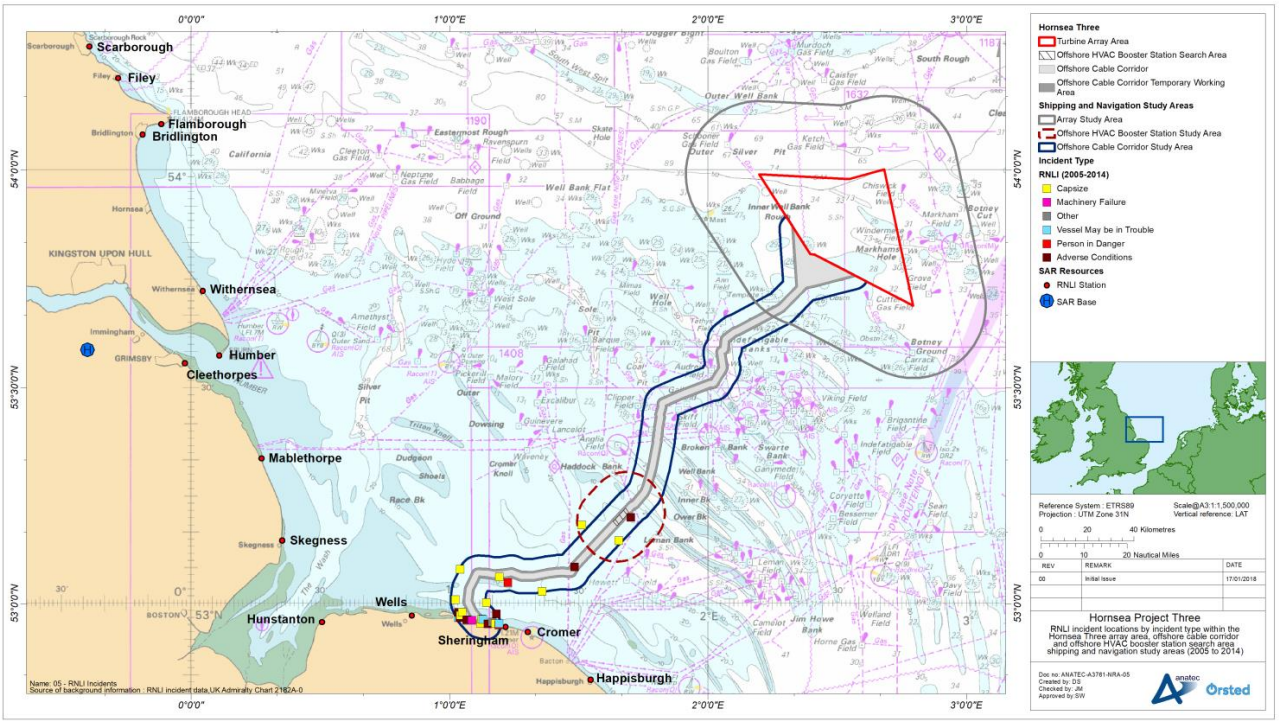

Figure 7.3 RNLI incident locations by incident type within 10 nm of Hornsea Three array area

7.8 The NRA also considers historical collision and allision incidents involving offshore wind farms. Research found that there were 13 incidents between 2005 and 2016, as detailed in Table 7.1. The majority of incidents resulted in minor or moderate damage to the casualty vessel and no serious injuries were reported. The MCA has indicated that there have been additional incidents since 2016.

7.9 It is noted that the cause of each of the incidents detailed in Table 7.1 was not related to the layout of the wind farm structures. Causes typically involved negligence by persons, such as misuse of the auto-pilot. Therefore for these incidents the presence of multiple of lines of orientation would not have prevented the incident and thus it is anticipated that a SLoO would be sufficient for minimising the risk of a collision or allision incident.

Table 7.1: Summary of historical collision and allision incidents involving wind farm sites

Project or third party	Incident type	Date	Damage to vessel (as per the incident reports)	Injury to person	Source
Project	Allision – service vessel with turbine	7 August 2005	Minor damage to gangway on the vessel	No injury	Maritime Accident Investigation Branch (MAIB)

Project or third party	Incident type	Date	Damage to vessel (as per the incident reports)	Injury to person	Source
Project	Allision – service vessel with turbine	29 September 2006	No damage to vessel	No injury	MAIB
Project	Allision – service vessel with disused pile	8 February 2010	Minor damage to vessel	Injury	MAIB
Third party and project in harbour	Collision – service vessel with vessel	23 April 2011	Moderate damage to vessel	No injury	MAIB
Project	Allision – service vessel with turbine	18 November 2011	Major damage to vessel	No injury	MAIB
Project	Collision – service vessel with service vessel	2 June 2012	Moderate damage to vessel	No injury	UK Confidential Reporting Programme for Aviation and Maritime (CHIRP)
Project	Allison – service vessel collision with OWF structure	20 October 2012	Minor damage to vessel	No injury	MAIB
Project	Allision – service vessel with buoy[4]	21 November 2012	Major damage to vessel	No injury	MAIB
Project	Allision – service vessel with turbine	21 November 2012	Moderate damage to vessel	Injury	MAIB
Project	Allision – service vessel with turbine	16 February 2013	Minor damage to vessel	No injury	UK CHIRP

[4] Previously this incident was listed as being with a turbine but the MCA have provided clarification.

Project or third party	Incident type	Date	Damage to vessel (as per the incident reports)	Injury to person	Source
Project	Allision – service vessel with turbine	July 2013	Minor damage to vessel	No injury	International Marine Contractors Association (IMCA) Safety Flash
Project	Allision – service vessel with turbine	14 August 2014	Minor damage to vessel and pollution	No injury	UK CHIRP
Third party	Allision – fishing vessel with turbine	26 May 2016	Moderate damage to vessel	Injury	Web search (BBC, 2016)

8. Other Evidence

Mitigation Measures – Pre Submission

8.1 The NRA includes an extensive list of mitigation measures adopted as part of Hornsea Three, including both embedded mitigation measures and additional mitigation measures required to bring specific risks to ALARP. The following list outlines mitigation measures which are relevant to the case that a SLoO is sufficient for Hornsea Three, noting the NRA assessed a SLoO:

- Charting of Hornsea Three array area – the Hornsea Three array area will be marked on relevant UKHO Admiralty charts.
- Compliance with UK and Flag State regulations and IMO 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. SOLAS is discussed in further detail in the next section.
- ERCoP – an ERCoP will be developed and implemented for all phases of the project. The array layout and SAR Access Lanes (compliant with the Layout Development Principles) will be included as standard.
- IALA guidance and Aids to Navigation – structures within the wind farm will be marked and lit in accordance with *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, and will be placed and characterised in agreement with TH (and MCA) prior to the start of construction.
- 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.
- Other means of communication to assist third parties – use of offshore Very High Frequency (VHF) aerials, AIS transceivers and the on-site vessels.

- Shut down procedures – the individual turbines structures will have functions and procedures in place for generator shut down in emergency situations.
- 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. This may include additional consultation above and beyond the minimum standard required.
- Self-help capability – provision of self-help capabilities to deal with wind farm associated emergencies. Consideration shall be given to towage, pollution response and man overboard.

Mitigation Measures – Post Submission

8.2 Agreement (as confirmed at the ISH1 on 14th December 2018) has been reached with TH that AIS transmitters may be fitted to turbines in order to assist with SAR operations. The use of AIS will provide additional situational awareness to the SAR crew, above and beyond that provided by the multiple onboard navigation systems and sensors.

8.3 The version of the Layout Development Principles published in Volume 4, Annex 3.7: Layout Development Principles of the Environmental Statement has since been updated following discussions with the MCA and TH. The Applicant has made concessions from the version included in the Environmental Statement including:

- Commitment to a Helicopter Refuge Area (HRA) with a width of between 0.5399nm and 1nm (rather than 1km);
- Tolerance of 100 m either side of the centre line of internal development lanes (rather than 150 m); and
- Tolerance of 50 m either side of the centre line of perimeter development lanes (rather than 150 m).

8.4 It is noted that the final SAR Access Lanes will be agreed as part of the Emergency Response Cooperation Plan (ERCoP). However, as per the Layout Development Principles, Hornsea Three have committed to SAR Access Lanes which shall:

- Be parallel to turbine development corridors; and
- Satisfy the minimum width of 500 m required by MGN 543 to facilitate SAR Asset access, where this width is measured tip to tip.

8.5 Allow a SAR Asset (at altitudes below 500 feet (ft) to enter the Hornsea Three array area from a position outside of the Hornsea Three array area (or outside of a phase) and exit the other side of the Hornsea Three array area (or the other side of a phase) without altering its heading or coming into close proximity (less than 250 m radius) to any surface infrastructure. With these mitigation measures in place the navigational risk posed to a vessel navigating within the array is anticipated to be minimal which further negates the need for multiple lines of orientation.

8.6 The Applicant acknowledges that further discussions will be required post consent with the MCA to finalise the details of mitigation measures such as the ERCoP.

SOLAS Obligations

8.7 Annex 5 of MGN 543 includes the following:

8.8 *"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."*

8.9 In the case of an incident internally within the array a passing vessel may be obliged to navigate through the array to render assistance as per SOLAS obligations. In such a case two lines of orientation may be helpful for larger vessels navigating the array; however there is anticipated to be a large number of accommodation platforms and vessels on site during operation. As per the Design Envelope used to inform the NRA, these are as follows:

- Up to three accommodation platforms or up to four Offshore Support Vessels (OSV) which are likely to carry daughter craft;
- Up to 20 Crew Transfer Vessels (CTV);
- Supply vessels which are likely to carry daughter craft; and
- Marine traffic coordination 24/7.

8.10 Given the anticipated vessel support on site throughout the majority of the operation and maintenance phase, emergency response impacts can be effectively managed. Accounting for the level of resource on site and the relatively low number of third party vessels in the area (see the vessel density analysis in section 5), the NRA concluded that it is highly probable that a Hornsea Three project vessel would be the first responder to render assistance in the event of an emergency internally within the array. Hence it is considered extremely unlikely that a third-party vessel would need to enter the Hornsea Three array area under any SOLAS obligation.

8.11 Further consultation will take place with the MCA post consent regarding the emergency response capability of project vessels.

Hornsea Three as a Standalone Development

8.12 Annex 5 of MGN 543 includes the following:

8.13 *"Wind farms which are extended, or adjacent developments which are constructed close to each other […] All developers involved must undertake to ensure that layouts are harmonised and of the same general orientation."*

8.14 Hornsea Three is not an extension of any existing offshore wind farms. Hornsea Project One and Hornsea Project Two are located adjacently to Hornsea Three, but these other developments are separated from Hornsea Three by a navigational corridor of 3.9 nm width and therefore Hornsea Three should be perceived as a stand-alone array. There are no future developments planned which would alter this.

8.15 Since Hornsea Three is considered a standalone development, there are no existing lines of orientation which the array is obligated to follow.

Internal Allision Risk Impact from Navigational Risk Assessment

8.16 As well as providing the evidence supporting a SLoO, the NRA also assessed the allision risk for vessels navigating internally within the Hornsea Three array area. The following subsections replicate the commentary provided in the NRA and the assessment undertaken in the ES for each phase of the project. It should be noted that much of the evidence outlined in the preceding sections is used here. The MCA agreed with the impact assessment presented in the NRA. The evidence procured since the NRA (in particular the SAR operations work undertaken by Mark Prior) shows agreement with the NRA's findings.

Construction and Decommissioning Phases

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

8.18 Mitigation measures adopted as part of Hornsea Three include:

- Buoyed construction (or decommissioning) area clearly identifying the location of construction (or 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. Additionally, 50 m pre-commission safety zones will be used to ensure users are aware of the risk associated with approaching pre-commissioned turbines;
- A Marine Coordination 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.

8.19 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 with shore (see Figure 8.1).

8.20 However 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 on-site 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. This will be discussed further with the MCA post consent.

8.21 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** (**minor adverse significance** in the Environmental Statement).

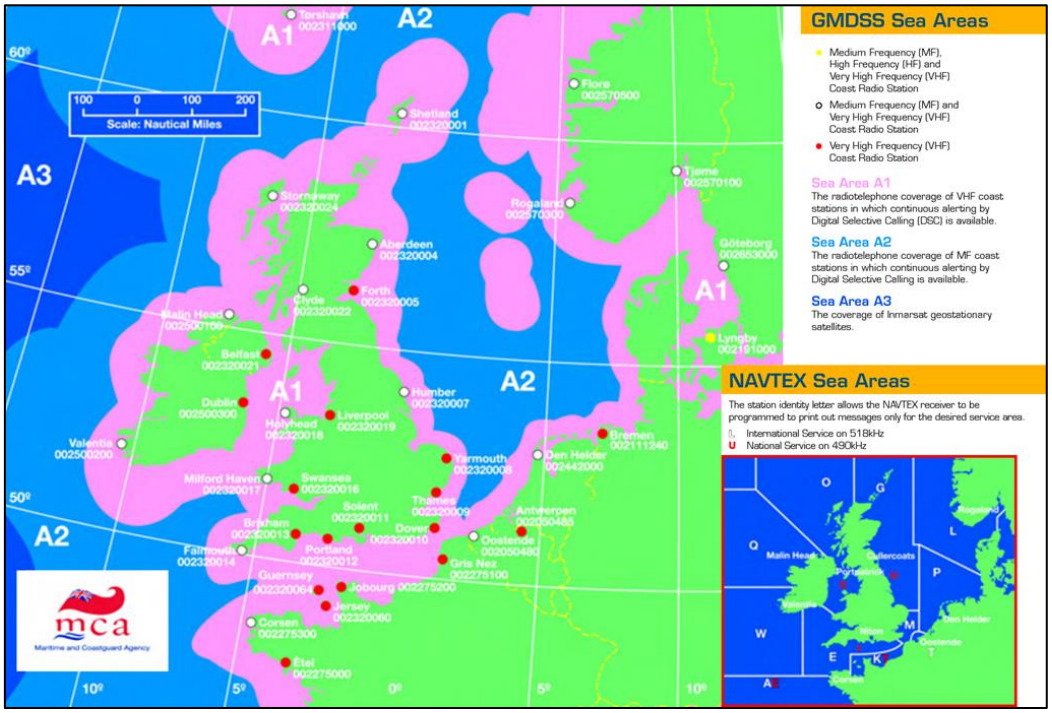

Figure 8.1: GMDSS sea areas

Operation and Maintenance Phase

Project Vessels

8.22 Any vessel and crew present within the Hornsea Three array area during the operation 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), vessels will typically be larger than previously seen at offshore wind farm developments closer to the coast, and will be fully certified as per flag state 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 one or zero vessels (scale is six to zero, with six 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

8.23 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 (intentionally) 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 in other countries (such as the Netherlands) commercial vessels are excluded from entering offshore wind farms by the regulatory authority.

8.24 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).

8.25 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.

8.26 Although not specified within the Design Envelope, based on experience of other offshore wind farms it is assumed that there will be vessel support on site throughout the majority of the operation and maintenance 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.

8.27 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.

8.28 Given the 1,000 m 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. Table 22.1 *[omitted – see Table 6.2 above]* presents the 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).

Experience at an Existing Offshore Wind Farm

8.29 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. It 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).

8.30 Fishing and recreational vessels were identified from AIS data collected between 1 March 2016 and 28 February 2017 (365 days) within the London Array offshore wind farm site boundary. During this period 140 unique recreational transits were recorded, with only eight vessels not using Fouglars Gat for the majority of their transit. Of those eight tracks and those that did not fully stay within Fouglars Gat it was seen that they also do not opt to remain fully within the available straight lines of orientation.

8.31 During the 12 month period only 32 unique fishing vessel transits were recorded within the site boundary. Of the 49 tracks recorded, 23 broadcast a navigational status of “engaged in fishing”, with these near the southern boundary; the remaining 26 consisted of passages through the array, with vessels not, in the majority, following the main lines of orientation.

8.32 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, TH and key recreational users dependant on the final layout selected.

8.33 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.

8.34 Given mitigation measures adopted as part of Hornsea Three and the potential for additional Aids to Navigation, the impact on internal navigation is considered **tolerable with mitigation** (Development Principles) and ALARP (**moderate adverse significance** in the Environmental Statement).

Increased Internal Allision for Commercial Fishing Vessels and Recreational Craft

8.35 Presence of infrastructure within the Hornsea Three array area may increase vessel to structure allision risk for commercial fishing vessels navigating internally within the turbine array. The estimated allision frequencies of one every 5.74 years could be considered high when compared to other allision assessments carried out on developments within UK waters. However the model and the results reflect the significant maximum surface area assumed for all the structures that could be developed within the Hornsea Three array area against the medium density of fishing activity. The fishing allision model assumes that the fishing vessel density following development will remain the same as current levels; however in reality it is likely both that fishing activity will decrease and/or fishing vessels will adapt to the layout and continue to fish between the turbines (as seen at existing operational developments). The model does not assume what type of allision incident will occur and in reality the most likely would be a minor or low energy impact resulting in little or no damage to the vessels.

8.36 During consultation, the Dutch Fishing Association VISNED also noted that in good weather fishing vessels are likely to transit through the wind farm. All foundation types including the jacket foundations considered in the maximum design scenario are assumed to be ALARP based on the minimum 1,000 m spacing and designed in measures in place to ensure that fishing vessels are able to safely passage plan transits and activity within the Hornsea Three array area. Further information is contained within volume 2, chapter 6: Commercial Fisheries.

8.37 As with fishing vessels it is considered likely that recreational craft will adapt to navigating within Layout A given the minimum spacing of 1,000 m; recreational traffic levels are also very low within the Hornsea Three array area and negligible levels of recreational transits are likely to be seen.

8.38 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).

8.39 Following consultation feedback as part of Section 42, the final layout will meet the Development Principles, including maintaining a single line of orientation, as referenced in section 9.5 *[of the NRA]*.

8.40 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 will be **tolerable with mitigation** (Development Principles) (**moderate adverse significance** in the Environmental Statement):

- 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 (minimal snagging risks)

and minimum spacing rather than the alignment. Overall, the majority of risk associated with internal navigation is related to vessels engaged in fishing rather than transiting;

- 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, noting that fishing in the array area has been determined to be low (see section 5);
- Consultation indicates that commercial vessels (in transit), other than commercial fishing vessels, 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 the PEIR layouts and did not raise any further concerns during section 42 consultation;
- With regards to the PEIR layouts the CA confirmed their general policy that wind farms 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" therefore is assumed that the single line of orientation is a further improvement on random layouts.
- 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 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 this however would be decided by TH post consent;
- Visibility is generally good or very good at the Hornsea Three array area. Appendix C includes further detail on visibility. The total percentage of time that the visibility is below 2 km is around 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; and
- 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.

8.41 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 8.1 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 Table 8.1 can be used to inform post-consent layout designs.

Table 8.1: 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 1,000 m minimum spacing for all structures on internal navigation	Recreational craft – low frequency user	No negative responses were received by recreational consultees. One thousand metre spacing would allow recreational craft to manoeuvre between structures given the maximum size of 24 m for recreational vessels (as per the Recreational Craft Regulations 2017 No. 737). 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 1,000 m between all structures.
Impact of 1,000 m minimum spacing for all structures on internal navigation	Commercial fishing vessels – medium frequency over the Hornsea Three array area	Commercial fishing consultees favoured fewer and larger turbines and noted that the separation between turbines is more important than the regularity of the layout.	No further mitigation associated with minimum spacing required, draft DCO shall state minimum of 1,000 m between all structures.
Impact of no maximum spacing for structures on internal navigation	Recreational craft – low frequency user	At greater than 1,000 m 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 turbines will be more visible with fewer echoes on marine Radar systems. Consultation raised no concerns about maximum spacing.	No further mitigation associated with maximum spacing required, draft DCO shall state no maximum spacing.
Impact of no maximum spacing for structures on 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, they will have access to greater knowledge about the site and 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.

Issue	Receptor and Frequency of Receptor	Sources Considered	Risk and Proposed Mitigation
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" 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 greater than1,000 m 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.
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 the PEIR Layouts given the low frequency. CA noted that they preferred alignment but agreed with the low frequency. The CA section 42 consultation response 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 allision risk. 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 fishing, including trawling and fly-shooting, would be possible in amongst the indicative layouts shown in the PEIR if the weather was suitable and the fish are present. 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.	As with recreational craft, increased spacing inversely decreases the impact of misalignment.

8.42 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.

9. Other Constraints

9.1 Array or wake losses can account for as much as 10% of loss in energy yield within a wind farm, depending on the proposed layout and wind conditions. The material benefits of optimising layout are increased efficiency of turbine use and wind capture, maximising the availability of the turbine array to winds and thus increasing renewable energy production.

9.2 While wake losses constitute one of the primary sources of production loss in offshore wind farms, it is possible to partially mitigate these losses through optimised layout and wind farm design. The primary mitigation is to increase the distances between turbines in the prevailing wind direction, thus allowing wake recovery. This mitigation method is not possible to implement to a great degree in a fixed grid layout. However, a SLoO layout would allow for this mitigation to be implemented. While the distance between the development lanes would be fixed, as described in the Layout Development Principles, it is possible to offset the turbines in alternating roles, thus increasing the distance between two turbines in the prevailing wind direction. This offers the project a way to optimize electricity production within the parameters set out by the Layout Development Principles.

9.3 Detailed geophysical and geotechnical investigations are typically undertaken post financial decision due to the large costs involved. Ground investigations undertaken for previous projects have shown that glacial features historically present in this area of the southern North Sea have led to higher than expected spread and density of boulders (clearing boulders complicates site preparation and costs). Having the ability to site turbines away from such glacial geological features mitigates the need to clear wider areas of boulders and thus reduces the extent of interaction with the seabed.

10. Summary and Conclusion

10.1 This report has considered the content of Volume 5, Annex 7.1: Navigational Risk Assessment of the Environmental Statement and materials produced in the examination process since the NRA was submitted in order to provide a justification for the safe implementation of a SLoO for the Hornsea Three array.

10.2 In particular, key points of the safety justification which were discussed in consultation meetings with the MCA and TH in December 2017 have been considered in detail:

- Vessel traffic levels within the array area are low;
- Minimum spacing and foundation types are a greater concern to fishermen than the lines of orientation since activity will be dictated by targeted fishing grounds;
- Hornsea Three resources on site are capable of providing an incident response; and
- No other project borders the Hornsea Three array area.

10.3 A number of other points supporting the case for a SLoO have been discussed and include the following:

- Agreement between regular commercial operators in the area that commercial vessels would not generally use the array area for transiting;
- Large minimum spacing between array structures eases CA concern over irregular layout patterns[5];
- RYA are unconcerned by the number of lines of orientation applied within the array layout (given the distance from shore and the low level of traffic);
- Vessel traffic density is lower at Hornsea Three compared to the other Hornsea developments which were both consented with a SLoO;
- Historical AIS data for a large existing array suggests that small craft do not consider the lines of orientation within the array layout, taking alternative routes instead;
- The Applicant has provided evidence and shared expert helicopter pilot experience during examination and is of the view that SAR helicopters will be able to turn without risk of a collision with a turbine in the array area, including in poor visibility;
- The minimum spacing for Hornsea Three is significantly greater than many existing UK offshore wind farms and gives vessels greater sea room to navigate and manoeuvre within the array area;
- Historical incident data suggests a collision or allision incident involving Hornsea Three would not result in major damage to the vessel(s) or serious injury to persons, and any historical incidents would not be prevented by the inclusion of more than a SLoO;
- Given the distance offshore and the presence of project vessels for Hornsea Three the likelihood of a SAR helicopter search operation being required are very low;

[5] Noting this comment was based on an irregular layout assessed at PEIR and not the SLoO assessed within the application.

- A suite of mitigation measures will be in place which minimise the risk to a vessel navigating within the array; and

10.4 The number of Hornsea Three vessels anticipated to be on site during operation will be determined post consent but will be available to respond to safety incidents. Considering this, the likelihood of a third party vessel being required to enter the array area under SOLAS obligations is low. Based upon the Layout Development Principles, which the Applicant proposes should be secured by condition in the DMLs included in the DCO, Hornsea Three commits to:

- Adhering to the guidance contained within MGN 543 (MCA, 2016) with the Layout Development Principles considered a refinement of the guidance specifically to meet the requirements of Hornsea Three;
- Locating all structures within the Hornsea Three array area;
- A minimum spacing of 1,000 m between structures;
- SAR Access Lanes parallel to turbine development corridors based on a SLoO (with this safety justification);
- A minimum width of 500 m for SAR Access Lanes (tip to tip);
- Capability for a SAR Asset to enter and exit opposite sides of the Hornsea Three array area without altering its heading or coming into close proximity with a structure;
- An HRA with minimum width of between 0.5399nm and 1nm should SAR Access Lanes exceed 10 nm length or between phases (if a phased development is used and each phase has different SAR Access Lane alignments);
- Dense boundaries based on consented minimum spacing;
- Internal structures positioned up to 100 m from the centre line of the internal development lanes (including micro-siting);
- More than one adjacent SAR Access Lane depending upon the spacing between structures;
- Arrangement of perimeter structures in a straight line to a tolerance of ±50 m, with the proviso that a curved line may be required to manage the interrelationship with existing or proposed offshore infrastructure (such curvature would be agreed with the MMO in consultation with the MCA and TH);
- Broadly parallel alignment of the western boundary of the Hornsea Three array area with the eastern boundaries of Hornsea Project One and Hornsea Project Two; and
- A width no less than 3.91 nm for the Navigation Corridor between the Hornsea developments.

10.5 As a prudent developer, the Applicant has gone to great lengths to meet the guidance laid out in MGN 543 (in consultation with the MCA). In particular, MGN 543 states that “developers should plan for at least two lines of orientation unless they can clearly demonstrate that fewer is acceptable”. This document has demonstrated a compelling safety justification for the layout of Hornsea Three to be based on a SLoO that should be deemed "acceptable" for the purposes of MGN 543. Therefore, the ExA and Secretary of State (and MCA and TH) can have confidence in approving the Layout Development Principles, including Principle 3, which provides for a SLoO.

11. References

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