Hornsea Project Three
Offshore Wind Farm

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Environmental Statement:
Volume 5, Annex 11.1 - Radar Early Warning Technical Report

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Hornsea 3
Offshore Wind Farm

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Environmental Impact Assessment

Environmental Statement

Volume 5

Annex 11.1 – Radar Early Warning Technical Report

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5 Howick Place,

London, SW1P 1WG

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Prepared by: University of Manchester

Checked by: Sergio Zappulo

Accepted by: Sophie Banham

Approved by: Sophie Banham

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Glossary

Term	Definition
Radar returns	The electromagnetic signal that has been reflected back to the radar antenna. Such reflections contain information about the location and distance of the reflecting object.
Clutter	Clutter is the term used for unwanted echoes in electronic systems, particularly in reference to radars. Such echoes are typically returned from ground, sea, rain, animals/insects, chaff and atmospheric turbulences, and can cause serious performance issues with radar systems.
Doppler signature	Doppler signature is the parameter used by Doppler enabled radars to produce velocity data about objects at a distance. It does this by bouncing a microwave signal off a desired target and analysing how the object's motion has altered the frequency of the returned signal. This variation gives direct and highly accurate measurements of the radial component of a target's velocity relative to the radar.
Radar Shadow	Radar shadow is the region whereby the radar beam is unable to fully illuminate a region due to blockage from terrain or structures within the area of coverage. Radar shadowing causes objects within the shadow region to produce reduced radar returns which can affect the radar's ability to detect such objects.
Target detection	A radar's ability to distinguish between radar returns from wanted targets and returns from clutter and/or the system's noise level.
Target tracking	This refers to the radar's ability to continually detect the target. Target tracking is a component of a radar system, or an associated command and control system, that associates consecutive radar observations of the same target into tracks. Radar tracking uses software algorithms to track objects and compensate for momentary loss of detection without losing the track.

Acronyms

Acronym	Description
AD	Air Defence
AIS	Automatic Identification System
ATC	Air Traffic Control
CAD	Computer Aided Design
CFAR	Constant False-Alarm Rate
CPA	Closest Point of Approach
ERRV	Emergency Response and Rescue Vessels
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
LOS	Line of Sight
MSL	Mean Sea Level
MTI	Moving target indicator
UHF	Ultra high frequency
RCS	Radar cross section
REWS	Radar Early Warning System
Spirit Energy	Spirit Energy Ltd, a new company arising from a Centrica E&P and Bayerngas Norge AS joint venture; part of the Centrica Group.
TCPA	Time to the Closest Point of Approach
VTS	Vessel Traffic Services

Units

Unit	Description
dB	Decibel
dBsm	Decibel Square Metres
GHz	Giga Hertz
GT	Gross tons
MHz	Mega Hertz

1. Introduction

1.1 Overview

1.1.1.1 This annex of the Hornsea Three Environmental Statement considers the potential impact of the Hornsea Project Three offshore wind farm (hereafter referred to as Hornsea Three) during the operation and maintenance phase on Radar Early Warning Systems (REWS) located on offshore oil and gas platforms. Specifically, this annex considers the effects of Hornsea Three on the REWS's ability to detect vessels within the vicinity of the wind farm and the effect of rerouted traffic on the REWS alarm rates. There may be effects associated with the construction and decommissioning phase of Hornsea Three in regard to increased movement within the Hornsea Three array however this has not been included in the assessment which considers the maximum design scenario for the operation and maintenance phase of Hornsea Three.

1.1.1.2 The modelling work presented within this report considers a typical REWS configuration, based on technical information provided by the REWS suppliers. It concentrates mainly on the effects of Hornsea Three on target (i.e. vessel) detection due to raised thresholds and clutter returns generated from the turbines. The effect of radar shadowing was also considered within this study and has been used within the Closest Point of Approach (CPA) assessment.

1.1.1.3 The report considers two platforms within close proximity to the proposed projects where REWS are installed. The two identified platforms are Spirit Energy's J6A platform and ConocoPhillips's Saturn Platform. The J6A platform REWS installation also provides radar coverage for nearby offshore platforms (i.e. the Chiswick, Markham ST-1, Windermere and Grove platforms), whilst the Saturn platform REWS installation provides coverage for the Tethys, Mimas, Viking KD, and Vampire OD platforms.

1.1.1.4 This report also provides the technical information and modelling results considering the cumulative impact of Hornsea Three and other projects and plans, specifically other projects within the former Hornsea Zone, namely Hornsea Project One and Hornsea Project Two offshore wind farms. No other developments (other than the above mentioned) have been identified as being within close enough proximity to Hornsea Three to result in a cumulative impact on REWS and the CPA assessments.

1.2 Background

1.2.1.1 Wind farm turbines and associated offshore structures (such as accommodation platforms and offshore substations) located within the line-of-sight (LOS) of radars, may interfere with the radar performance and degrade its ability to distinguish between turbines and associated offshore structures, and returns from targets of interest.

1.2.1.2 REWS are primarily used to detect and track vessels navigating within the vicinity of offshore oil and gas assets and provide collision warning when vessels are in breach of defined CPA and Time to Closest Point of Approach (TCPA) parameters. The impact of offshore wind farms on REWS may arise from a number of factors such as; high radar returns from the turbines and associated offshore structures, increased number of detections and false alarm/track generation.

1.2.1.3 Offshore wind turbines are large structures with geometries and materials that may cause them to have a high radar cross-section (RCS). Furthermore, the rotation of the turbine blades produces a time-variable RCS fluctuation and a Doppler frequency shift that can confuse radars that rely on moving target indicator (MTI) filters to distinguish between static objects and moving targets of interest. The interference to Doppler based ATC and AD radars due to the rotating blades and the large reflection of the radar signal has been well reported and explained (Jago and Taylor, 2002; Poupart, 2003 and Wind Energy, Defence & Civil Aviation Interests Working Group, 2002). However, this technical report discusses and models the potential impact of Hornsea Three on the REWS used on oil and gas platforms which have been selected as potentially being affected by Hornsea Three due to their location (i.e., ConocoPhillips's Saturn Platform and Centrica's J6A platform). Typically, REWS does not employ Doppler processing and MTI filters as it operates in naval environments whereby the returns from the sea surface (and the movement of the waves) may generate radar returns with Doppler signatures similar to that of surface vessels. REWS can be integrated with newer radar transceivers that are capable of Doppler processing if deemed necessary (see paragraph 1.1.1.1).

1.2.1.4 For non-Doppler based radars such as the REWS, the potential impact from offshore wind farms may arise due to the large radar returns. The large RCS of turbines may cause target spreading at extended ranges and potential detections through the sidelobes at close ranges. This will cause smearing and cluttering of the radar screen and potentially mask other targets in the area. In addition, depending on the thresholding techniques used within a radar system, the presence of turbines and associated offshore structures may increase the threshold over parts of the array area, which potentially may cause smaller targets to be lost.

1.2.1.5 Degradation of the radar performance may also be caused by the radar shadow due to the presence of wind turbines within the LOS of the radar, as shown in Figure 2.1. Shadowing may cause smaller targets to temporarily disappear from the radar display as it moves in and out of the shadow regions. The extent of the impact caused by shadowing depends on the size and height of the turbine and the target of interest (i.e. different effects may be observed if looking at surface targets or air targets). However, previous studies and trials showed that the effect of shadowing can be considered to be an effect of secondary importance that may have little impact on the REWS performance due to the size of vessels that the REWS is typically interested in detecting (Butler and Johnson, 2003) (Greenwell, 2016).

1.2.1.6 This report uses a number of modelling techniques developed at the University of Manchester to model and predict the impact of turbines and associated offshore structures on radar systems. These allow the radar returns coming both from the wanted target and Hornsea Three to be simulated so that the effects on radar detection can be evaluated. The results from the models can then be used to indicate the regions within which vessels can be detected and tracked. Section 2 below describes the different modelling techniques utilised in the Hornsea Three assessment.

1.3 Document structure

1.3.1.1 The document utilises the following structure:

- Section 1 (this section) gives an introduction to the report;
- Section 2 outlines the scope of the assessment;
- Section 3 presents a summary of the modelling techniques and parameters used;
- Section 4 presents the modelling results for the Spirit Energy REWS on the J6A platform;
- Section 5 presents the modelling results for the ConocoPhillips REWS on the Saturn platform;
- Section 6 presents the assessment on effect of the rerouting of traffic on the TCPA alarms; and
- Section 7 presents the conclusions and summary of the results along with further considerations for future studies if required.

2. Scope of Assessment

2.1 Target masking

2.1.1.1 The size, geometry and construction materials of turbines cause them to have a radar return. This may cause target spreading (smearing) at extended ranges and potential detections through the sidelobes at close ranges. Such effects will add clutter to the radar screen and potentially mask other targets in the area. This effect may also affect the tracking software performance when vessels are travelling within Hornsea Three causing the tracks from the vessels to be seduced and merged into the larger returns generated from the turbines. This report addresses the impact of target masking and compares the levels of the turbine radar returns against that of a vessel as it travels along a defined path through Hornsea Three. This report does not consider the effects of varying turbine returns on the tracker as this requires a detailed knowledge of the employed tracking software which is proprietary information, discussed further in paragraph 2.5.1.1. Despite this, it remains possible to draw robust conclusions.

2.2 Shadowing effects

2.2.1.1 The extent and length of the shadow region cast by a turbine depends on the size of the turbine, the distance to the radar antenna, the height of the radar and the height of the target of interest. The severity of the shadow will also depend on the distance of the target from the turbine. This is illustrated in Figure 2.1.

2.2.1.2 Due to the diffraction of the radar waves around the turbine, increasing the range between the target and the turbine will reduce the severity of the attenuation to the target's returns. It has been reported that a target 1 km behind the turbine will experience 6 dB reduction in the returned power while targets that are significantly further suffer only 2 dB reduction in the received radar echo (Butler and Johnson, 2003). This is an important characteristic of the radar shadow and is illustrated in Figure 2.1. This is in good agreement with the recent measurement campaign carried out by Ultra Electronics to assess the effects of wind farms on the REWS performance located in the east Irish Sea (Greenwell, 2016). The measurement campaign and the work presented in Danoon and Brown (2014) indicate that shadowing may not have a significant effect on the performance of the REWS due to the diffraction effects and the size of the vessel, which might be larger than the shadow region generated from individual turbines.

2.2.1.3 For completeness, a shadowing assessment has been undertaken within this assessment and is used in conjunction with the study of the rerouting of traffic around the wind farm (see section 6). Within this assessment the radar shadows were modelled based on optical shadowing. Optical shadows conservatively assume no diffraction effects and therefore ignore the improvement in the shadow region at extended ranges. Depending on the turbine size and radar height, the optical shadows may extend all the way to the radar horizon. The use of optical shadows is used to assess scenarios which might have an impact on the radar's performance.

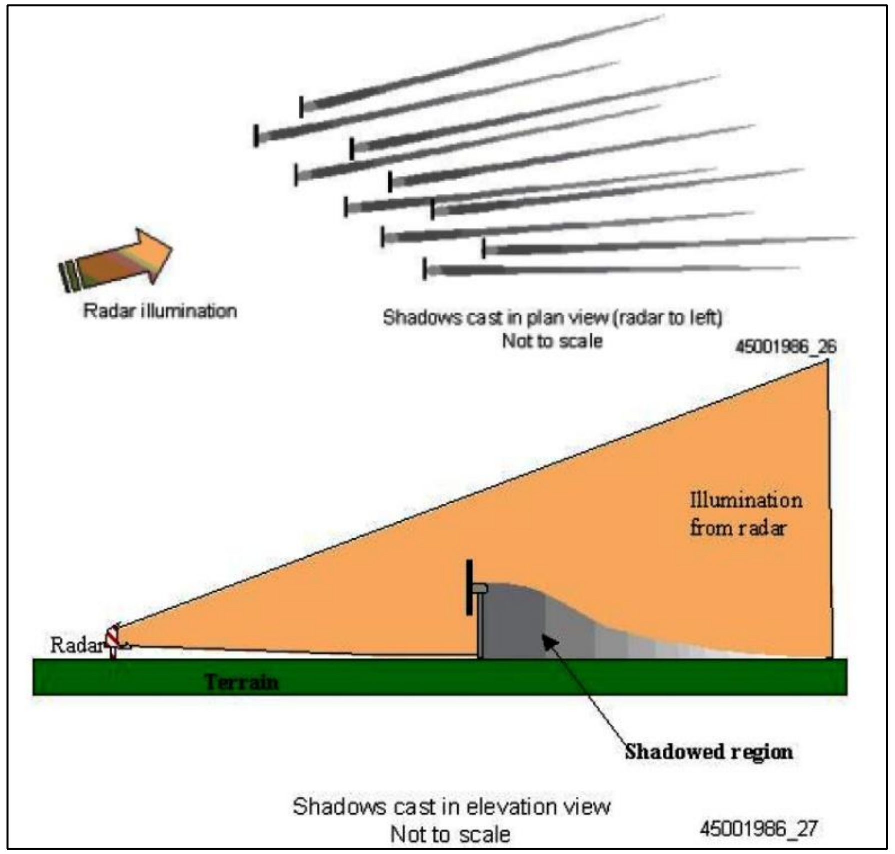

Figure 2.1: **Illustration of radar shadowing with diffraction effects (Butler and Johnson, 2003).**

2.3 Rerouted traffic

2.3.1.1 Existing shipping lanes may be altered by the physical presence of Hornsea Three and vessels may be rerouted nearer to the platforms covered by the REWS as they deviate around the wind farm. This may cause an increase in the CPA/TCPA alarm rates. The shipping routes are often defined by their mean/central line and the associated standard deviation that represents the width of the route. The detailed modelling procedure and the effects of the rerouting of traffic on the alarm rates are discussed in section 6 below.

2.4 Adaptive detection threshold modelling

2.4.1.1 A REWS deploys a number of techniques for clutter thresholding, target extraction and tracking. The use of adaptive thresholding algorithms such as Constant False Alarm Rate (CFAR) is very common within offshore REWS installations. A variety of CFAR algorithms can be used to adjust the threshold around noisy/cluttered areas to avoid unwanted and false detections depending on the clutter within the local environment. REWS uses CFAR techniques to dynamically adjust the detection threshold over sea clutter. Digital signal processing is applied to calculate a constant false alarm rate for plot-extraction by generating a video threshold below which all video samples are ignored as they are considered to be noise or clutter. The threshold is calculated individually for each radar cell using a two dimensional sliding window area technique whereby surrounding cells in both range and azimuth are considered. Typically, the mean and standard deviation of samples is calculated and the threshold is set to the mean value plus a factor derived from the standard deviation of the sample.

2.4.1.2 Finally, it is worth noting that as CFAR uses multiple adjacent range and azimuth cells (see Figure 2.2) to derive the detection threshold. The presence of a single turbine will affect the threshold of multiple cells around it as shown in Figure 2.2.

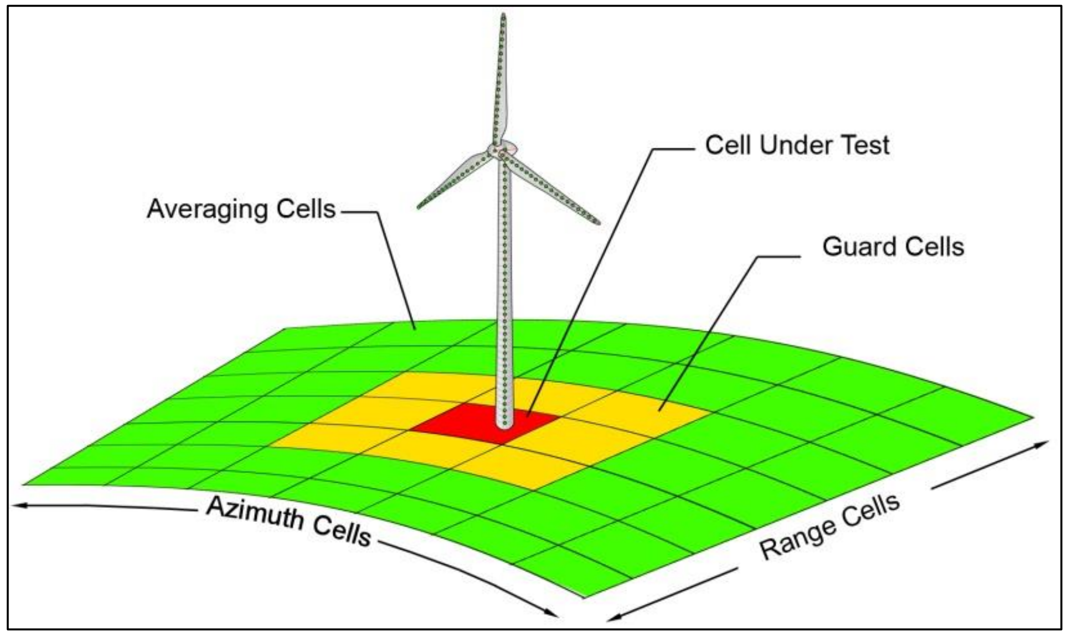

Figure 2.2: **2D CFAR cells around a given cell with wind turbine present.**

2.5 Tracker modelling

2.5.1.1 Radar trackers provide the radar operator with a processed and clear image of the location and bearing of moving targets in the area of interest. It is also very common for currently used radar trackers to compensate for momentary loss of detection of a target over one or more radar rotations and maintain an active track. The presence of advanced tracking within REWS can greatly benefit and enhance the operator's ability to maintain radar visibility of moving targets near or within a wind farm. REWS deploy proprietary tracker algorithms, which may vary depending on the system supplier. The impact of the wind farm on the tracker performance cannot be accurately modelled without detailed knowledge of the tracker and the proprietary tracking algorithms -which are not available to Hornsea Three and so were not included in this assessment.

2.6 UHF communication links

2.6.1.1 Depending on the REWS system and the tracker software, it is possible that returns from the turbines will add new target detections to the track-table. The track-tables are shared with Emergency Response and Rescue Vessels (ERRVs) via ultra high frequency (UHF) radio links. UHF links use a low-bandwidth telemetry system and have a limit on the total number of tracks that can be transmitted. The maximum size of the track-table is a system limitation that depends largely on the hardware used and hence cannot be modelled. A typical number for the maximum track-table size is assumed to be between 400 and 600 tracked targets. Depending on the tracking software, the number of tracks within the track-table can be reduced by applying non-acquire zones over the wind farm area or by applying filters to track moving targets only.

2.7 Other effects

2.7.1.1 The variation of the radar returns over multiple range-cells may initiate false tracks. However, the radar tracker requires consecutive detections over a number of radar rotations, which will reduce the likelihood of false track initiation. Furthermore, to raise a TCPA alarm, the track vector must continue to breach the TCPA condition for multiple radar rotations. Thus, raising false alarms due to range-cell spreading is considered unlikely and was not included in this assessment.

2.7.1.2 It is also possible to model the effects of multiple reflections of the radar signal within the Hornsea Three array area, and between the turbines and nearby large targets, using the radar and WinR (Wind Turbine RCS) models developed at the University of Manchester. However, as the closest modelled turbine in the Hornsea Three array area is approximately 13 km away from any REWS, the effects of the multiple reflections were considered to be of second order (not a primary cause or concern) and were not included in the models (QinetiQ, 2005) (Baker, 2007).

2.7.1.3 Depending on the detailed structure of the REWS host platform, the presence of external fittings near the radar antenna such as masts, wires and other structural elements may cause distortion of the antenna pattern and possibly the appearance of false reflection if a flat surface is near the antenna. These effects were not modelled. This was confirmed to be acceptable during Hornsea Project Two consultation for the REWS on the Saturn Platform operated by ConocoPhillips (ConocoPhillips, 23 November 2012, *pers.comm.,* 2012).

3. Modelling Parameters

3.1 Hornsea Three

3.1.1 Wind turbine parameters

3.1.1.1 The maximum dimensions of the turbines proposed for Hornsea Three have been defined in order to produce a generic turbine model that considers the overall size and rotor diameter. However, due to the electrical size of the turbines (i.e. the physical size in comparison to the radar wavelength), which extends over many hundreds of radar wavelengths, better representation of the geometry is needed to give more accurate Radar Cross Section (RCS)modelling results.

3.1.1.2 The precise detail of the RCS will depend on the actual wind turbine in use. However, a good representation can be obtained from a generic model of a 5 MW turbine geometry, which includes the blades airfoil profile and nacelle geometry. The generic 5 MW turbine has a rotor diameter of 120 m and a hub height of 86 m. The generic turbine geometry was then scaled to achieve the approximate dimensions of the proposed Hornsea Three turbines, with the maximum design scenario being the maximum number of turbines in the Hornsea Three array area, 342 turbines with a maximum rotor diameter of 185 m and an associated hub height of 127 m. Subsequent to the completion of the REWS modelling, the maximum number of turbines in the Hornsea Three array area was reduced from 342 turbines to 300 turbines. These 300 turbines will have a maximum rotor diameter of 195 m and an associated hub height of 153 m. A validation assessment for the J6A platform has been completed to understand the implications of this change to the maximum design scenario and is presented in section 4.3 below. The J6A platform was selected for the validation assessment due to its proximity to the Hornsea Three array area. The REWS on the Saturn platform was considered too far from the Hornsea Three array area to be affected by the change in the size and number of turbines.

3.1.1.3 The scaled CAD geometries for the modelled turbines (i.e. 342 turbines with a rotor diameter of 185 m and a hub height of 127 m) used to compute the RCS of the turbines are shown in Figure 3.1 below. Details such as ladders, warning lights, wind measurement/lightning protection equipment etc., were removed from the turbine CAD for RCS modelling as these will not have a significant effect on the scattering profile which is dominated by the larger components (i.e. tower, blades and nacelle), and will greatly increase the computational complexity.

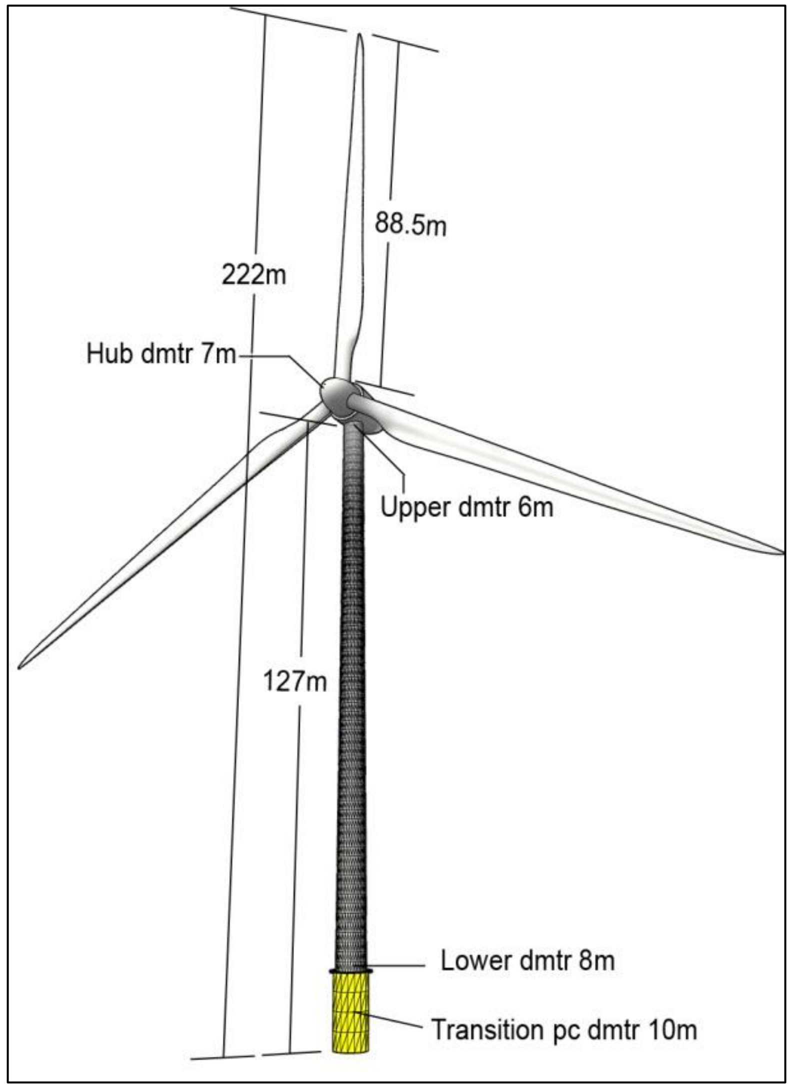

Figure 3.1: Modelled turbine geometry.

3.1.1.4 Within this assessment, the maximum design scenario has assumed the turbines are mounted on a monopile foundation with a transition piece leading to the tower. Traditionally, the monopile with the transition piece design gives a very large radar return, which in some cases might dominate the turbine RCS. This is due to the shape and construction materials of the transition piece which makes it highly reflective to the radar. The upright cylindrical and parallel, metallic sides of the transition piece will reflect the radar energy directly to the radar which may make up to 80% of the total radar signature generated from the turbine. Other supporting structures, such as jacket foundations are expected to have tapered sides and smaller reflective areas which will not be as prominent as the monopile foundation. Monopile foundations therefore represent the maximum design scenario for RCS.

3.1.1.5 When assessing the potential impact of Hornsea Three (alone) and Hornsea Project One, Hornsea Project Two and Hornsea Three (cumulatively) on a given REWS, the wind is conservatively assumed to be coming from the radar site in the direction of the centre of the wind farms. This results in the majority of the turbines facing the radar, which will then give the maximum RCS value (maximum design scenario). As the RCS of each turbine is individually computed, the blades rotation angle on each turbine is generated randomly as a value between 0° and 119°. This results in a different RCS for each turbine rather than an unrealistic unified rotation angle across all turbines.

3.1.2 Hornsea Three indicative turbine layouts

3.1.2.1 The REWS performance is expected to be more greatly affected by the presence of a large number of smaller turbines compared with fewer larger turbines. The presence of a greater number of turbines increases the shadowing effects and also increases the detection threshold levels over a larger region within the Hornsea Three array area. Based on these observations, the indicative layout A from the Preliminary Environmental Information Report (PEIR) was chosen as the maximum design scenario (see layout A, volume 1, chapter 3: Project Description of the PEIR). Subsequent to the completion of the REWS modelling, the maximum number of turbines in the Hornsea Three array area was reduced from 342 turbines to 300 turbines. As such, indicative layout A was revised to reflect a maximum number of 300 turbines. A validation assessment for the J6A platform has been completed to understand the implications of this change to the maximum design scenario and is presented in section 4.3 below. The J6A platform was selected for the validation assessment due to its proximity to the Hornsea Three array area. The REWS on the Saturn platform was considered too far from the Hornsea Three array area to be affected by the change in the size, number and layout of turbines.

3.1.2.2 The indicative Hornsea Three layout was imported into the models using assumed coordinates for each turbine and offshore substation/platform. The assumed locations of the offshore substations/platforms and the imported turbine locations are shown in Figure 3.2 below.

3.1.2.3 Within all the modelling results that are shown within this report, the offshore substations/platforms were modelled as large offshore structures and their scattering was estimated by modelling a number of scattering points distributed within a rectangular box of 80 m by 80 m by 80 m (providing a general dimension for all structures). The total RCS of each substation was set to be 3,000 m^2. This is an approximate value used to assess the impact of the substation on the shadowing and the radar detection threshold. The exact scattering characteristic will depend on the substation's geometry and construction material as well as its range from the radar antenna.

3.1.2.4 Once the locations of the turbines and the offshore substations/platforms were defined, a process was followed to identify the location of nearby offshore platforms and any REWS installations that might be affected by the presence of the turbines and other large structures such as the offshore substations. The location of offshore platforms and the identified REWS host platforms are also shown in Figure 3.2 below.

3.1.2.5 Typically, a 30 km (16 nm) detection range is assumed to be the minimum requirement for REWS to detect and track smaller vessels (100 m^2 RCS). This indicates that the Spirit Energy operated J6A platform REWS (located 7.0 nm from Hornsea Three) will have a direct LoS with the Hornsea Three array area. Additionally, the ConocoPhillips operated Saturn platform REWS (located 17.6 nm from Hornsea Three) and Murdoch platform REWS will have coverage that might illuminate the turbines at the edges of Hornsea Three. However, since the Murdoch platform REWS (located 16.8 nm from Hornsea Three) has an overlapping coverage with the ConocoPhillips operated Katy platform REWS (located 24.2 nm from Hornsea Three), the Murdoch platform REWS was not considered within this assessment.

3.1.2.6 In addition, the Saturn platform REWS is located within close proximity of Hornsea Project One and Hornsea Project Two. The cumulative effects from Hornsea Project One, Hornsea Project Two and Hornsea Three were therefore considered.

3.2 REWS modelling

3.2.1.1 REWS provides coverage over offshore oil and gas installations and provides early warning to the operators' when vessels breach the alarm settings. REWS use pre-set collision alarm rules. Typically, an Amber alarm is raised if a vessel is within CPA of 0.5 nm and a Red alarm is raised if the CPA is 0.27 nm. TCPA alarms are raised for vessels that are 25 minutes away. Should a vessel breach these rules an automatic alarm is raised to alert the operator. It is worth noting that TCPA alarms are only triggered if the vessel's vector remains in breach of the TCPA condition for a set number of radar rotations (typically10 radar rotations). This setting is included to avoid alarms due to temporary vector breach of the TCPA while vessels are turning.

3.2.1.2 In addition to radar data, REWS are often integrated with Automatic Identification Systems (AIS) fitted onboard ships. If a vessel is fitted with an AIS transponder and is detected by the radar, the REWS will include the AIS data into the track data.

3.2.1.3 Within this annex, the performance of the REWS is based on the specification of Raytheon's Pathfinder/ST MK2 X-band transceiver with Mariners Pathfinder X-band 12 ft antenna system supplied by Ultra Electronics Security & Surveillance (ESS). The details of the modelling parameters used are shown in Table 3.1 and the antenna pattern used in the modelling is shown in Figure 3.3.

3.2.1.4 The modelling is conducted at a rainfall rate of 0 mm/hr and sea-state 4 (wind speeds 9.6 ms^{-1} and average wave height of 1.3 m). When computing returns from the sea surface and the rain clutter the models provide the mean levels of returns.

3.2.1.5 REWS processing deploys scan-to-scan correlation, which improves the noise and clutter suppression. However, this is not considered in depth as part of this study as it requires detailed knowledge of the proprietary software used within the system's signal processing.

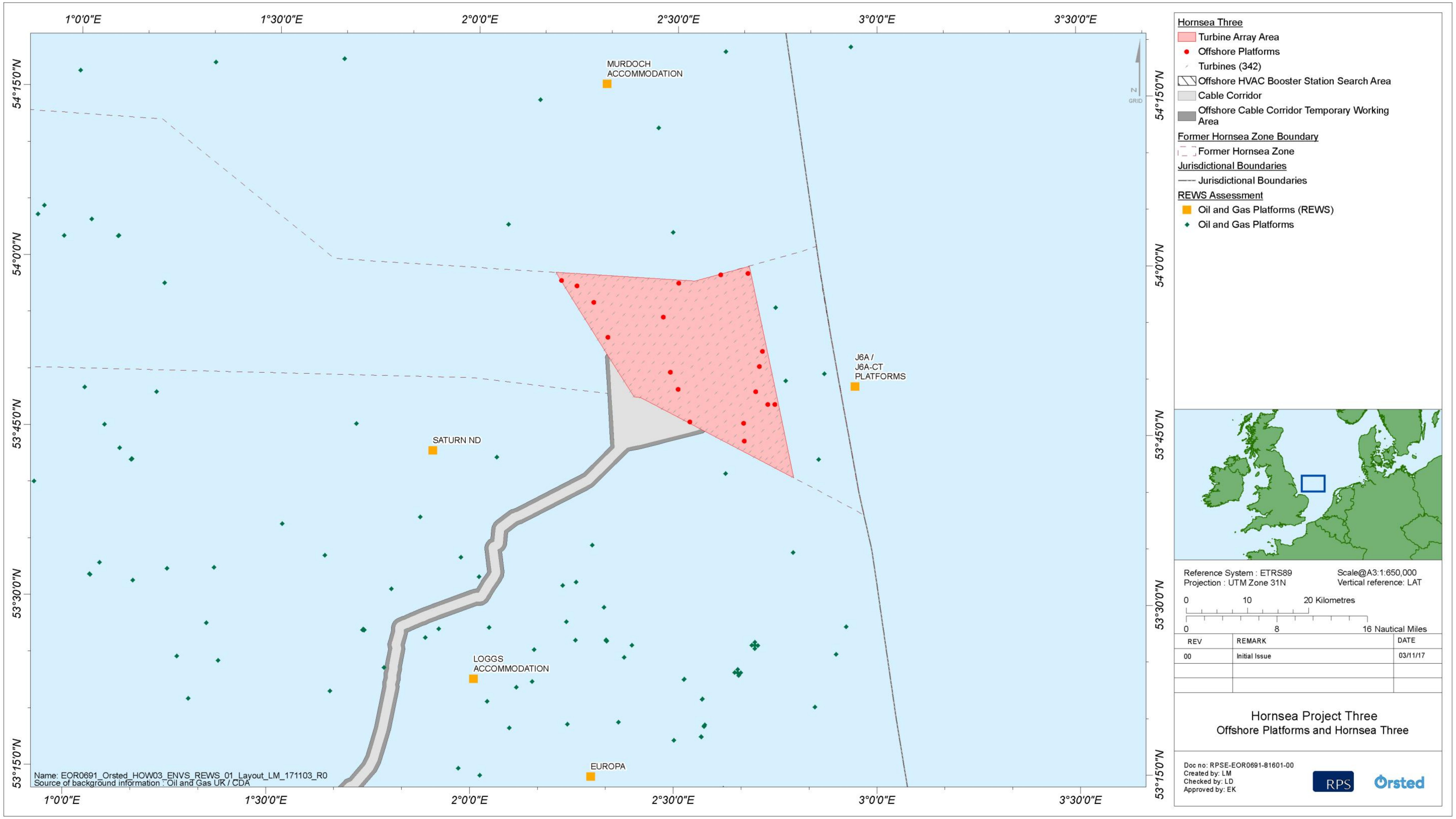

Figure 3.2: **Indicative Hornsea Three maximum design scenario layout (342 turbines) with nearby offshore platforms with REWS.**

Table 3.1: Radar modelling parameters.

Modelling parameter	Value
Gain	30 dB
Transmitter Power	25 kW
Frequency	9.411 GHz
Pulse Width	250 ns
Rotation Rate	25 RPM
Pulse Repletion Frequency	2.0 KHz
Noise Figure	5.5 dB
Dissipative Losses	1.0 dB
Beam-shape Losses	0.6 dB
Azimuth beam width	0.7°
Elevation beam width	23.0°
Antenna Height	50 m (AMSL)

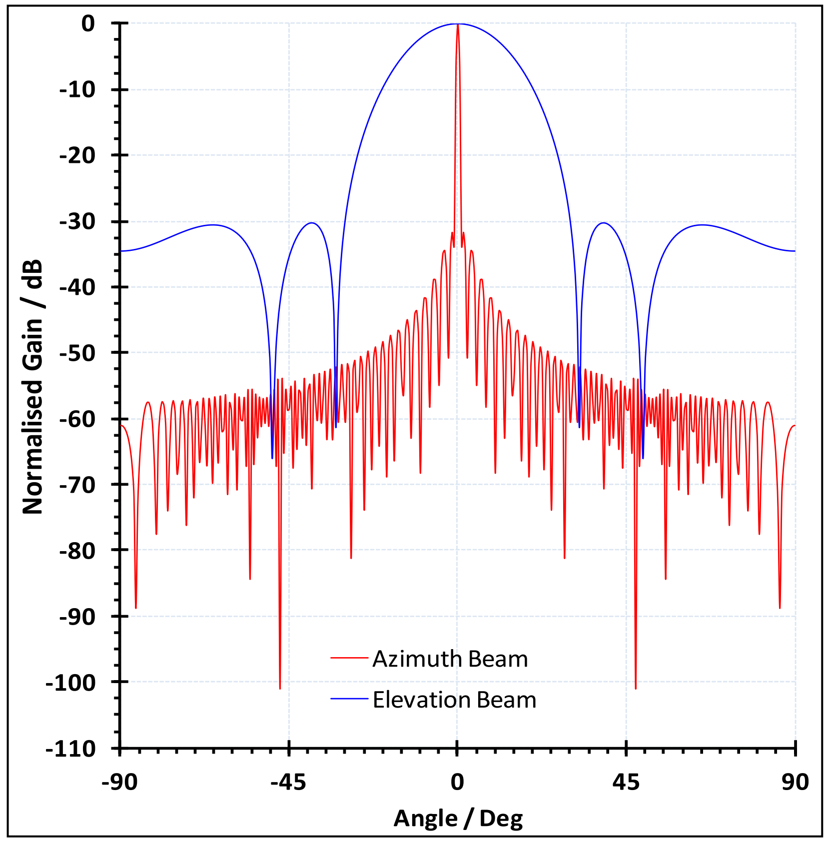

Figure 3.3: The radar antenna elevation and azimuth patterns.

3.2.1.6 It is worth noting that only the medium pulse width of 250 ns was used throughout the Hornsea Three assessment. This gives an approximated range resolution of 37.5 m which is then equated to the range-cell length. As the turbine rotor diameter is much larger than the range cell length (depending on the yaw angle with respect to the radar), parts of the blades will fall into adjacent range-cells as the turbine blades rotate. This phenomenon will be referred to as “range-cell spreading” within this annex.

3.3 Detection threshold (CFAR)

3.3.1.1 There are multiple variations of CFAR that can be used where different weights can be applied to each cell prior to the final averaging. However, within this annex and to examine the effect of Hornsea Three on the threshold levels, a Constant Averaging (CA) CFAR is applied over the clutter map. The CA-CFAR modelled within this assessment uses two range cells on both sides of the cell under test as the guard region while the averaging considers six range cells on both sides of the guard region. In Azimuth the modelled CA-CFAR uses one guard cell and two averaging cells on both sides in azimuth. The overall resultant threshold was set to provide a constant 10^{-5} probability of false alarm.

3.4 Target modelling

3.4.1.1 REWS are mainly interested in detecting and tracking surface targets such as large fishing boats, maintenance vessels and larger ships and tankers. The role of the REWS is to alert the operator when a vessel is on a collision course with the platform. Although air targets may also appear on the radar display, the management and trafficking of air targets is controlled by other radar systems such as Air Traffic Control (ATC) primary and secondary radars or Air Defence (AD) radar systems. Thus, the analysis of the potential impact of Hornsea Three on REWS is limited to surface targets only.

3.4.1.2 Within this report the test target was set to represent a medium sized maintenance vessel with a steel/metallic hull. The test vessel is assumed to have an RCS of 100 m^2 and a height of 6 m. These parameters were provided by the REWS supplier (Ultra Electronics) and they comply with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) Vessel Traffic Services (VTS) guidelines for radar modelling of different vessel types. The test vessel was set to have an average speed of 12 knots (22.2 km/hr).

3.4.1.3 Large vessels in excess of 1,000 gross tons (GT) are the primary concern when it comes to managing the safety of offshore platforms (Love, 2014). Therefore, in some cases, in addition to the smaller 100m^2 RCS vessel, the detection of larger vessels (1,000m^2 RCS) was also considered within this assessment to assess the impact of Hornsea Three on the detection of vessels travelling through the corridors between adjacent wind farms.

3.5 Turbine shadow modelling

3.5.1.1 As discussed in section 2.2, when turbines are placed within the LOS of radar systems, radar shadowing will occur behind the structure. The extent and length of the shadow region depends on the size of the turbine, the distance to the radar antenna, the height of the radar and the height of the target of interest. Shadowing produced by turbines may cause targets to be lost as they move in and out of the shadow region. Depending on the size of the shadow region, this may cause existing tracks to be lost or discontinued.

3.5.1.2 As REWS are mainly used to detect and track surface moving targets (ships, boats etc.), only surface or near-surface shadowing is considered. This can be approximated by using the optical shadowing/blockage cast by the turbine over the sea surface. The use of optical blockage to estimate the radar shadowing will give pessimistic results but is deemed acceptable for objects that are much larger than the radar wavelength at relatively short ranges (such as offshore wind turbines). Optical blockage does not account for diffraction effects around the structure which would normally reduce the shadow length. Diffraction and partial shadowing of an object has been shown to significantly improve the radar detection. Practical measurements and other studies show that the shadowing effects from the turbines may reduce the overall detection range of the radar but may not severely affect the detection of objects within the shadow regions.

3.5.1.3 1,000 GT plus vessels (which are the main safety concern to offshore platforms) vary in size and typical vessel lengths are between 15 and 60 m. However, the shadows from the turbines are relatively narrow and are typically between 4 and 20 m in width. This indicates that a large 1,000 GT vessel will be partially shadowed by the turbine as it moves through the shadow regions (as shown in Figure 3.4). Partial shadowing will allow some of the radar energy to be reflected back to the radar and it might be possible for this energy to be detected by the REWS. Hence, smaller vessels can be assumed as point scatterers while larger vessels can be assessed for partial shadowing.

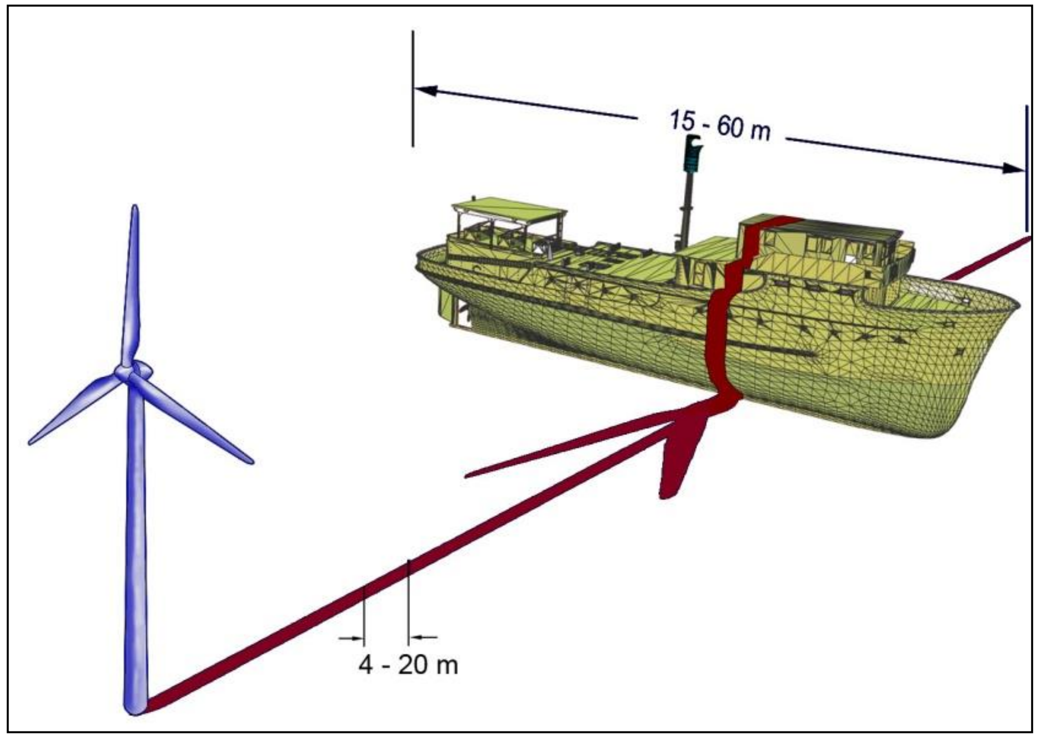

Figure 3.4: Optical blockage and partial shadowing.

4. Spirit Energy J6A Platform REWS Assessment

4.1.1.1 The REWS on the Spirit Energy operated J6A platform provides coverage and protection to the J6A platform and four other nearby platforms namely: the Chiswick platform, the Markham ST-1 platform, the Windermere platform, and the Grove platform. Consultation with Centrica (now Spirit Energy) indicates that the Markham ST-1 platform is expected to be decommissioned prior to the offshore construction of Hornsea Three in 2022. Consultations with INEOS indicate that the Windermere platform is expected to be decommissioned prior to 2023.

4.1.1.2 Designed-in mitigation measures shall be put in place to reduce the effect of Hornsea Three on the REWS on the J6A platform (see volume 2, chapter 11: Infrastructure and Other Users). The mitigation measures will be based on the mitigation measures identified for Hornsea Project Two for the Saturn platform (see paragraph 5.1.1.2) and developed in consultation with Spirit Energy. The modelling results presented in section 4.2 and 4.3 below do not include this mitigation.

4.2 REWS returns and detection modelling for Hornsea Three with 342 turbines

4.2.1.1 This section presents the REWS returns and detection modelling associated with 342 turbines with a rotor diameter of 185 m and a hub height of 127 m scenario on the J6A platform. As noted above in paragraph 3.1.1.2, the maximum number of turbines in the Hornsea Three array area has subsequently been reduced to 300 turbines with a maximum rotor diameter of 195 m and an associated hub height of 153 m. A validation assessment has been completed of the REWS returns and detection modelling associated with the J6A platform for Hornsea Three with 300 turbines. This is presented in section 4.3 below.

4.2.1.2 The modelled indicative layout of turbines (342) and substations (19) within the Hornsea Three array area and the nearby platforms are shown in Figure 4.1. The red circle around each platform denotes the 0.27 nm Red CPA alarm while the yellow circle denotes the 0.5 nm Amber CPA alarm. Figure 4.2 shows the power received (radar returns) from the turbines along with the assumed clutter generated from the sea surface.

4.2.1.3 As shown in Figure 4.1 and Figure 4.2, Hornsea Three falls within very close proximity of the Windermere platform and within close proximity to Chiswick platform (1.45 nm), Grove platform (2.43 nm), Markham ST-1 platform (4.48 nm) and the J6A platform (6.9 nm).

4.2.1.4 This close proximity is likely to increase the potential effects on the REWS's ability to detect and track vessels travelling through the Hornsea Three array area. If the REWS is unable to detect and track the vessel within the Hornsea Three array area it may cause the REWS to issue delayed TCPA alarms, resulting in insufficient response times to deal with potential collision threats.

4.2.1.5 To further assess the REWS's ability to detect vessels within the Hornsea Three array area, a CFAR threshold over the detection region was modelled using a 2D CA CFAR. as highlighted in section 3.3. The modelling results are shown in Figure 4.3. The figure shows the regions with higher detection threshold as brighter shades of green. The strong returns from the turbines will significantly alter the threshold levels. It can be noted that the threshold is raised over multiple cells around each turbine since the CFAR threshold averages the returns over a 2D sliding window of multiple cells in azimuth and range.

4.2.1.6 In order to establish the detection regions for a given vessel, the returns from the vessel are modelled with respect to range and plotted around the REWS as shown in Figure 4.4 for the smaller 100 m^2 RCS test vessel. Figure 4.4 shows that the vessel has high returns at close ranges which then reduces as range increases up to approximately 16 nm (30 km). Higher returns are illustrated by brighter shades of green.

4.2.1.7 The returns from the vessel are then compared against the CFAR detection threshold shown in Figure 4.3 to establish the detection regions. If the vessel returns are above the CFAR threshold, then the vessel is detected, however, if the returns are below the threshold, the target is assumed to be undetected within that region. Figure 4.5 shows the detection plot for the 100 m^2 test vessel over the Hornsea Three array area. Dark areas within the plot denote regions where the vessels will not be detected.

4.2.1.8 The results show that the raised threshold levels caused by the presence of turbines will cause detection loss of vessels travelling through the Hornsea Three array area. This effect, in combination with the shadowing effects, may cause the REWS to lose tracks of the vessels and fail in raising TCPA alarms in a timely manner. To further illustrate the effect of turbines on the detection threshold, two radial cuts are taken from the radar to points that are 33 nm away located at bearing angles of 270° and 283°. The results are shown in Figure 4.6 and Figure 4.7 respectively.

4.2.1.9 The results show that at close ranges the REWS easily detects the test vessel as the returns are above the detection threshold. Once the vessel is travelling within the Hornsea Three array area, the raised threshold over the cells around each turbine can cause loss of detection.

4.2.1.10 Given that Hornsea Project One and Hornsea Project Two are considered to be outside the detection range of the REWS on J6A (located 7.0 nm from Hornsea Three), no further effects are expected to impact the performance of the J6A REWS. Therefore, no further assessments were undertaken to establish the effects of the combined wind farms on the J6A REWS.

4.2.1.11 No assessment of the larger 1,000 m^2 target was presented in relation to the J6A REWS as it would not add to the observed effects shown for the smaller 100 m^2 target. Additionally, the detection range for the larger target would not extend beyond the boundaries of Hornsea Three, and hence, no cumulative assessment was undertaken.

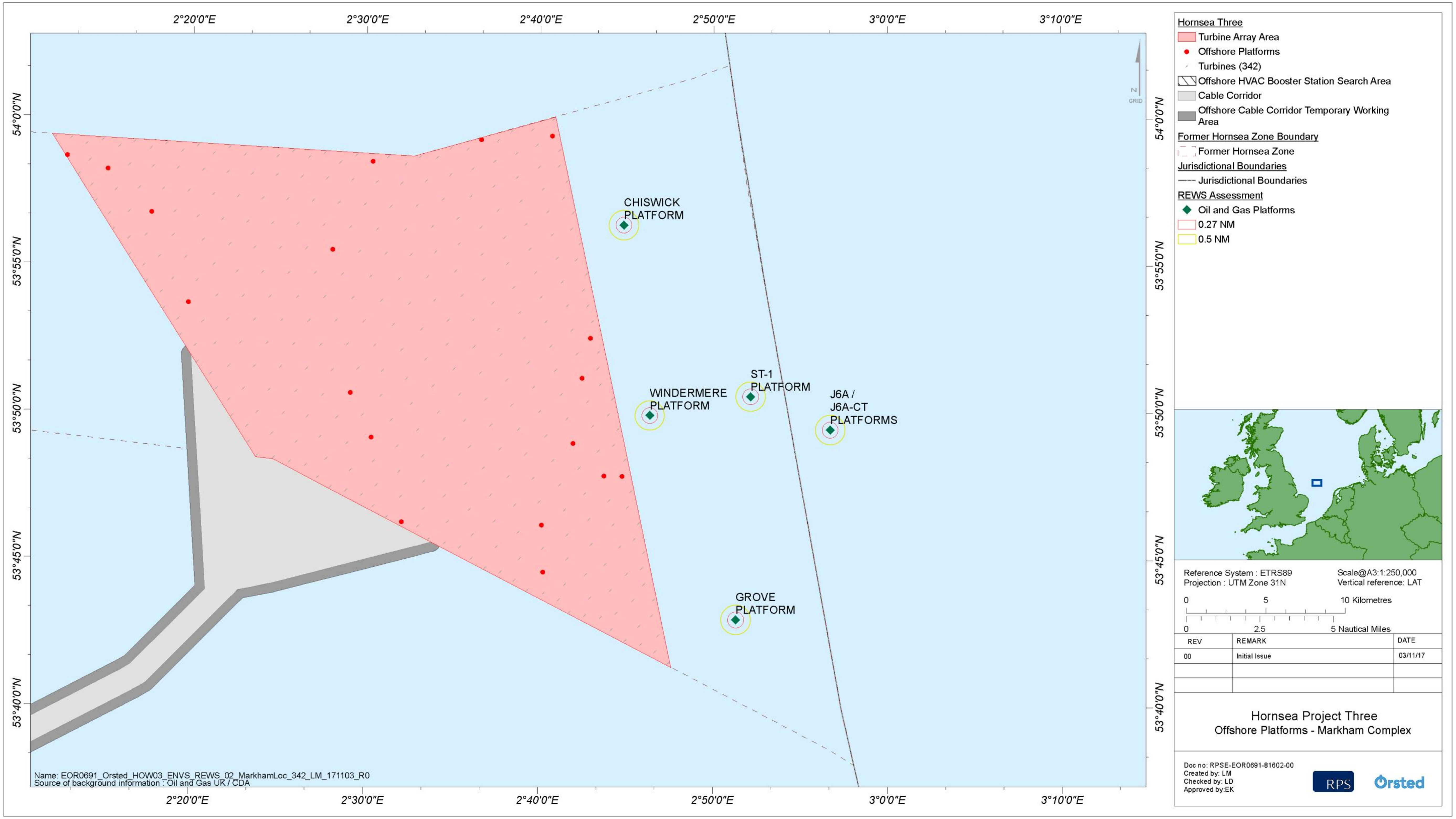

Figure 4.1: **Modelled layout for Hornsea Thee (342 turbines) and the Spirit Energy operated Markham complex of platforms.**

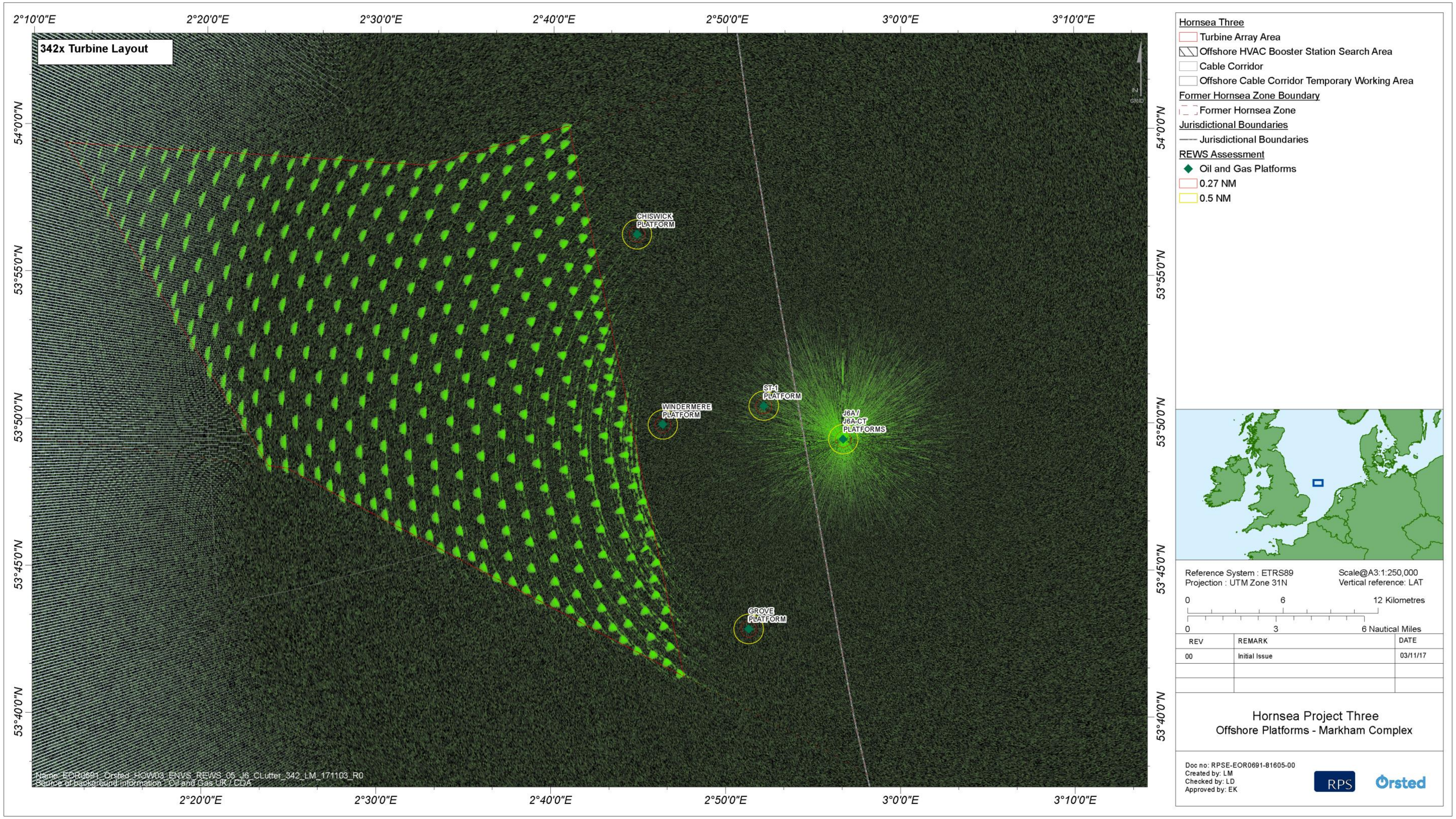

Figure 4.2: **J6A platform REWS clutter map showing returns from the turbines (342 turbines) and sea clutter.**

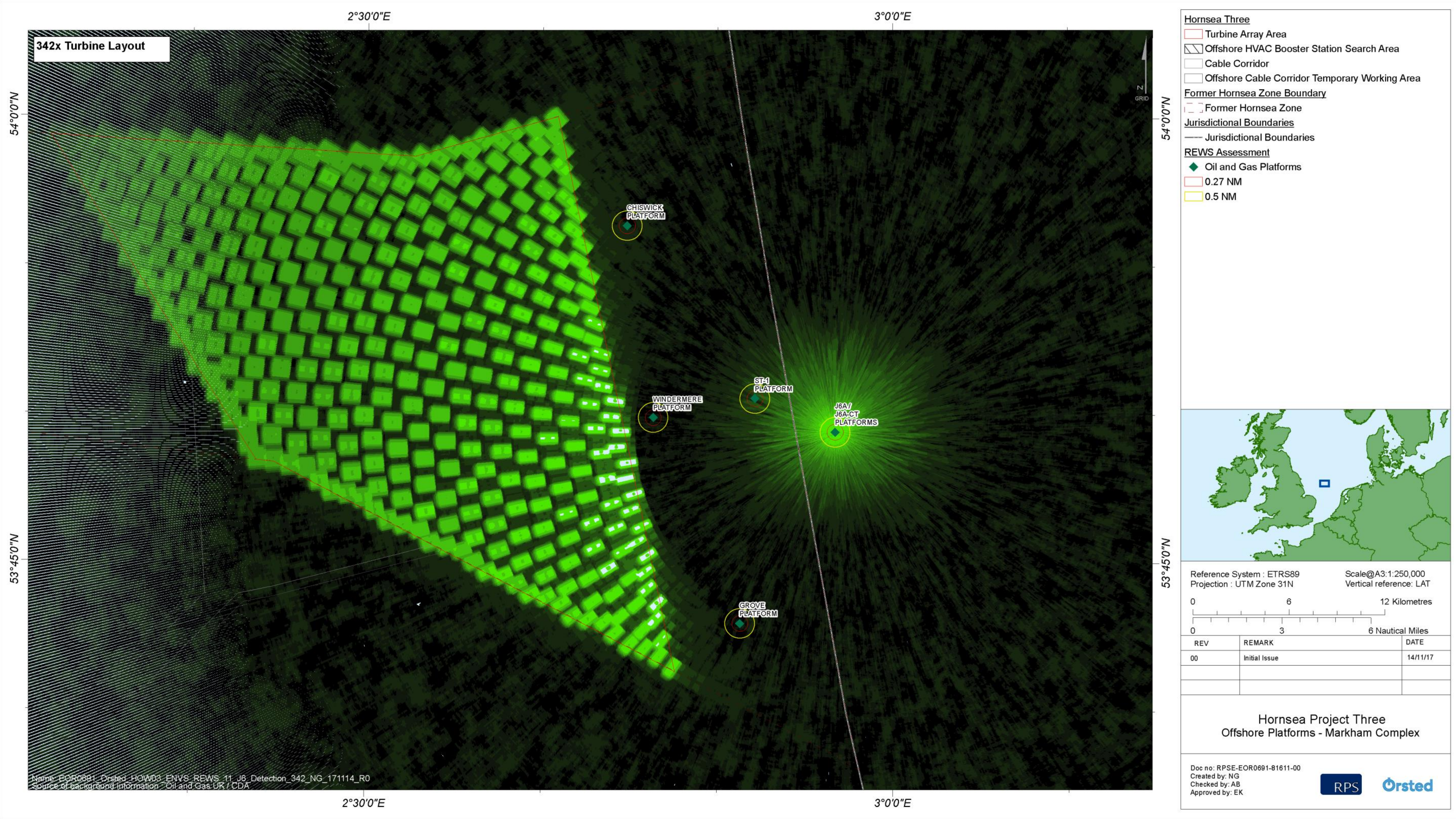

Figure 4.3: J6A platform REWS detection threshold over the Hornsea Three array area (342 turbines).

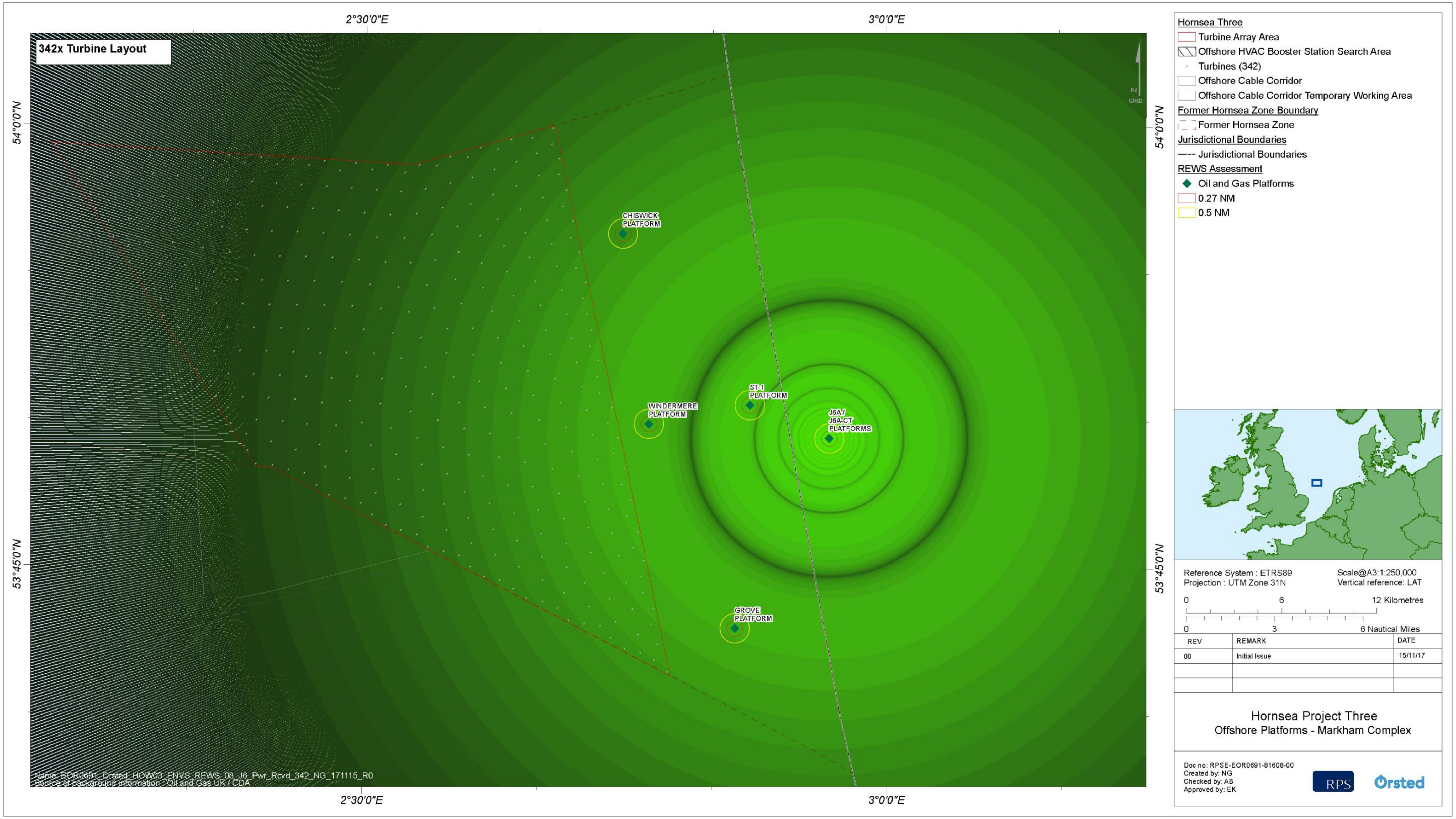

Figure 4.4: **Modelled power received from 100 m² target (coverage).**

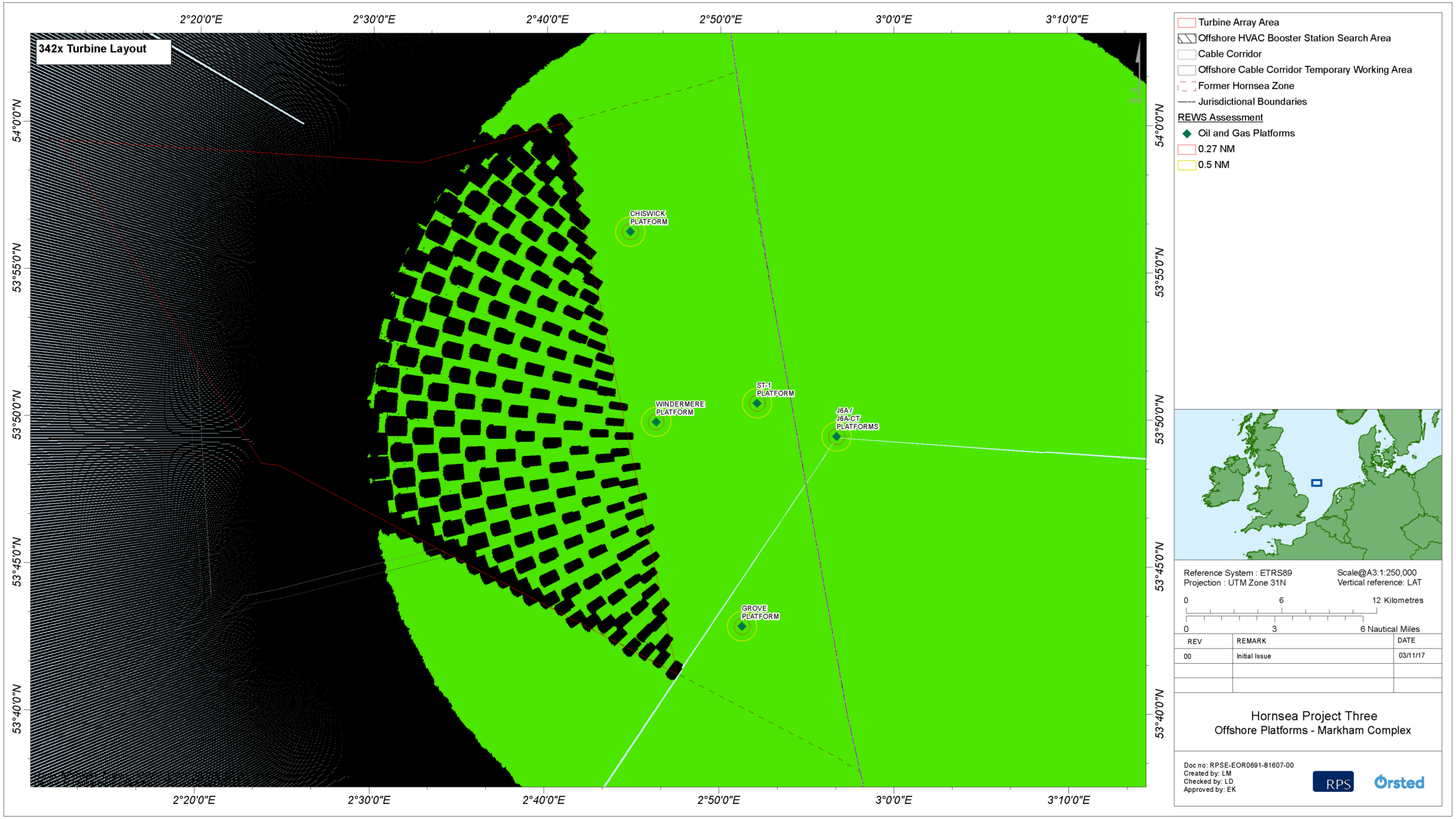

Figure 4.5: **J6A platform REWS detection plot showing loss regions for a 100 m² target.**

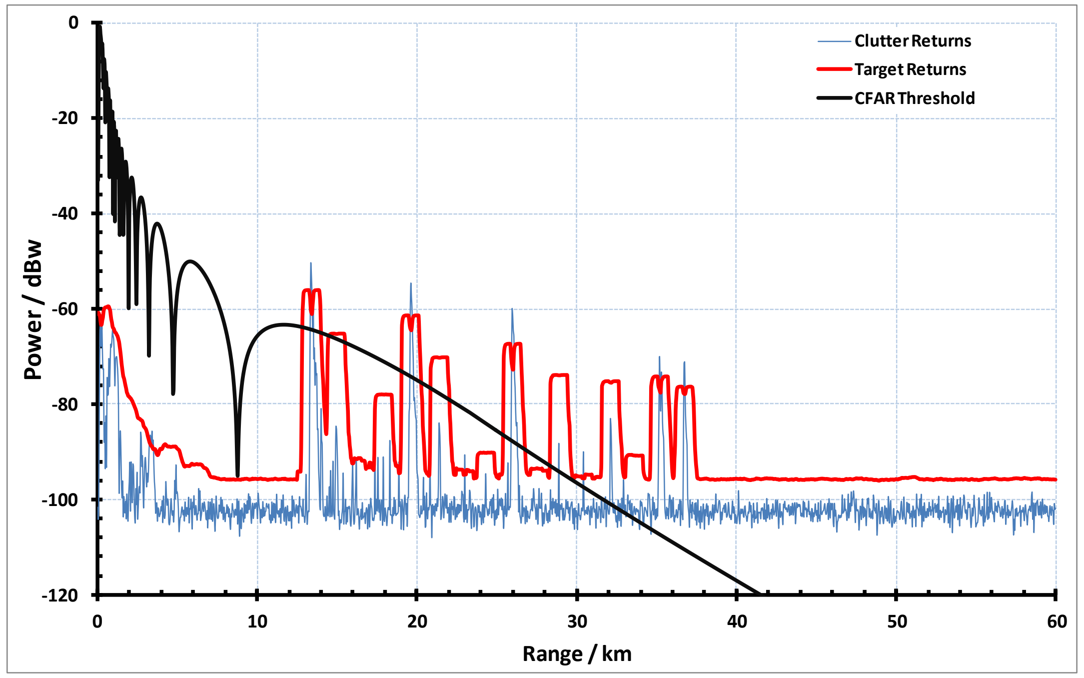

Figure 4.6: Power received from small target at 270° bearing angle.

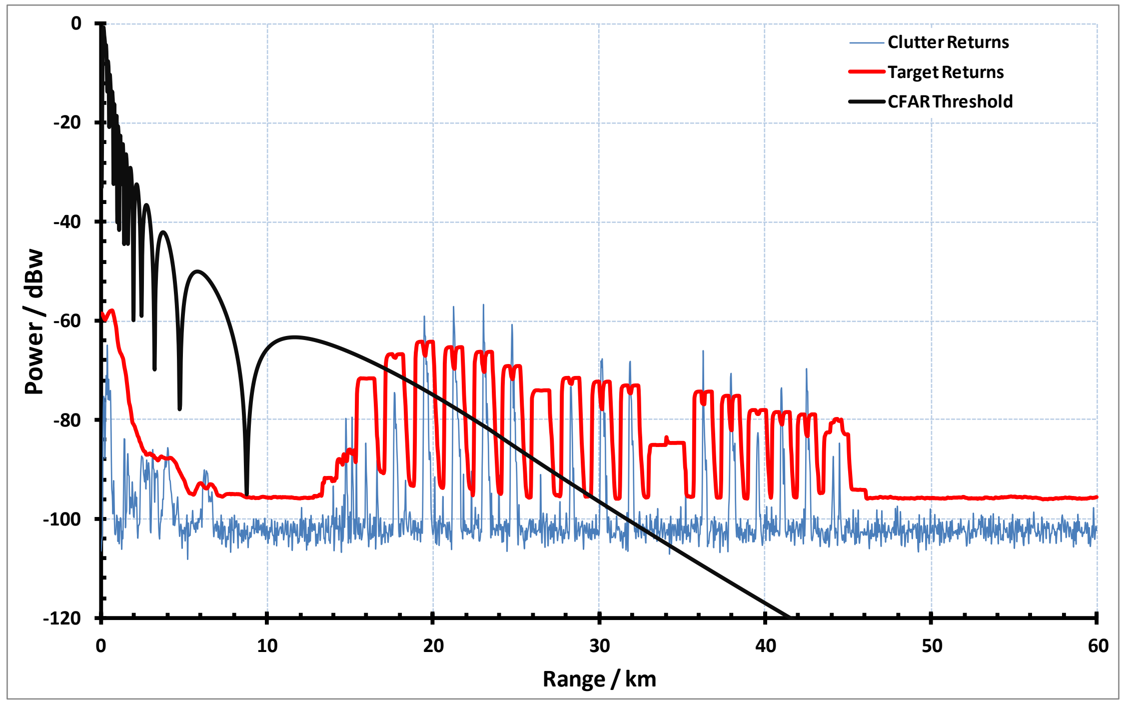

Figure 4.7: Power received from small target at 283° bearing angle.

4.3 REWS returns and detection modelling for Hornsea Three with 300 turbines

4.3.1.1 Section 4.2 of this report considers the REWS performance based on 342 turbines with a rotor diameter of 185 m and a hub height of 127 m which was considered for the PEIR. The design has subsequently been modified to a maximum of 300 turbines with a maximum rotor diameter of 195 m and an associated hub height of 153 m. A validation assessment has therefore been undertaken to understand the REWS returns and detections from 300 turbines with a rotor diameter of 195 m and a hub height of 153 m. The modelled layout for the validation assessment is shown in Figure 4.8, while the turbine parameters are shown in Table 4.1.

4.3.1.2 The results of modelling radar returns from the Hornsea Three 300 turbine scenario are shown in Figure 4.9. Figure 4.10 shows the modelling results of the 2D CFAR threshold while Figure 4.11 shows the detection plot for the 100 m^2 test vessel.

4.3.1.3 The validation assessment has shown that 342 MW turbine scenario has a greater effect on the REWS than the 300 MW turbine scenario and therefore presents a maximum design scenario. This is due to the fact that, in general, using a lower number of larger turbines will generate less shadowing than a larger number of smaller turbines. This is due to the fact the shadowing is predominantly due to the size and height of each turbine tower, with more towers casting more shadows. Additionally, although the radar returns from the 300 larger turbine scenario are expected to be of higher amplitude than that of the 342 turbine scenario, the effect of the turbines on the detection region immediately surrounding the turbine is not expected to change significantly. Hence, the results of the target detection over the Hornsea Three region using the 300 turbine scenario is improved in comparison to the 342 turbine scenario considered in section 4.2 above, whereby there are more radar detection within the Hornsea Three array area and in between the turbines.

4.3.1.4 It is noted that the rotating blades of the larger turbines associated with the 300 turbine scenario may occupy more than one range/azimuth cells (due to increased size of blade for the 300 turbine scenario). The variation of the radar returns over multiple adjacent cells may cause the tracking algorithms to initiate new tracks. If this occurs, it is expected to last over a limited number of radar rotations and is it very unlikely to produce any false TCPA alarms to the REWS.

Table 4.1: Turbine numbers and specifications used within the cumulative impact modelling.

Turbine parameter	Maximum dimensions for 300 turbines (m)
Tip height	250
Hub height	153
Blade length	94
Rotor Diameter	195
Lower blade tip height	35 (minimum)

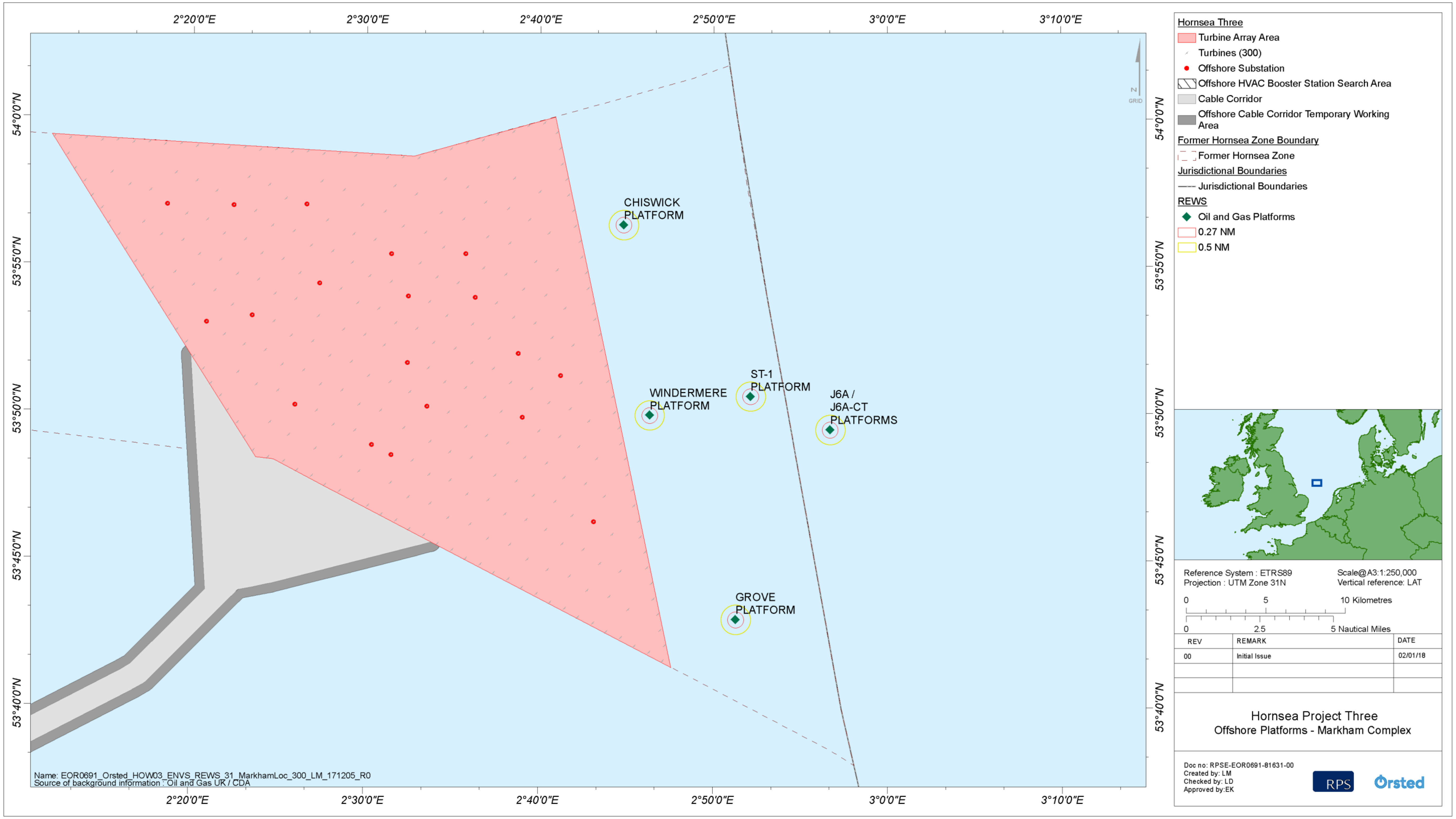

Figure 4.8: **Modelled maximum design scenario layout (300 turbines) of Hornsea Three and the Spirit Energy operated Markham complex of platforms.**

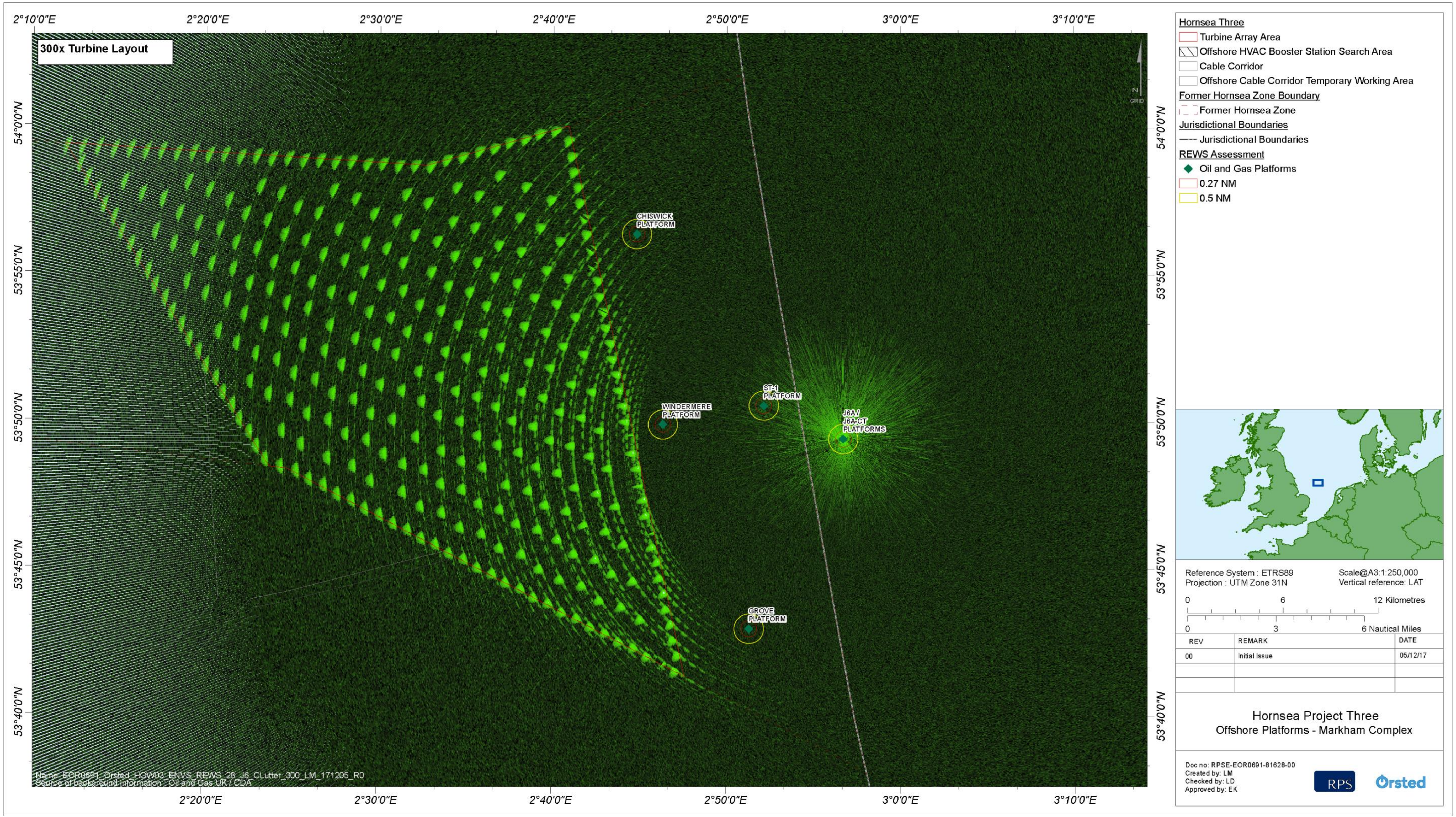

Figure 4.9: **J6A platform REWS clutter map showing returns from 300 turbines and sea clutter.**

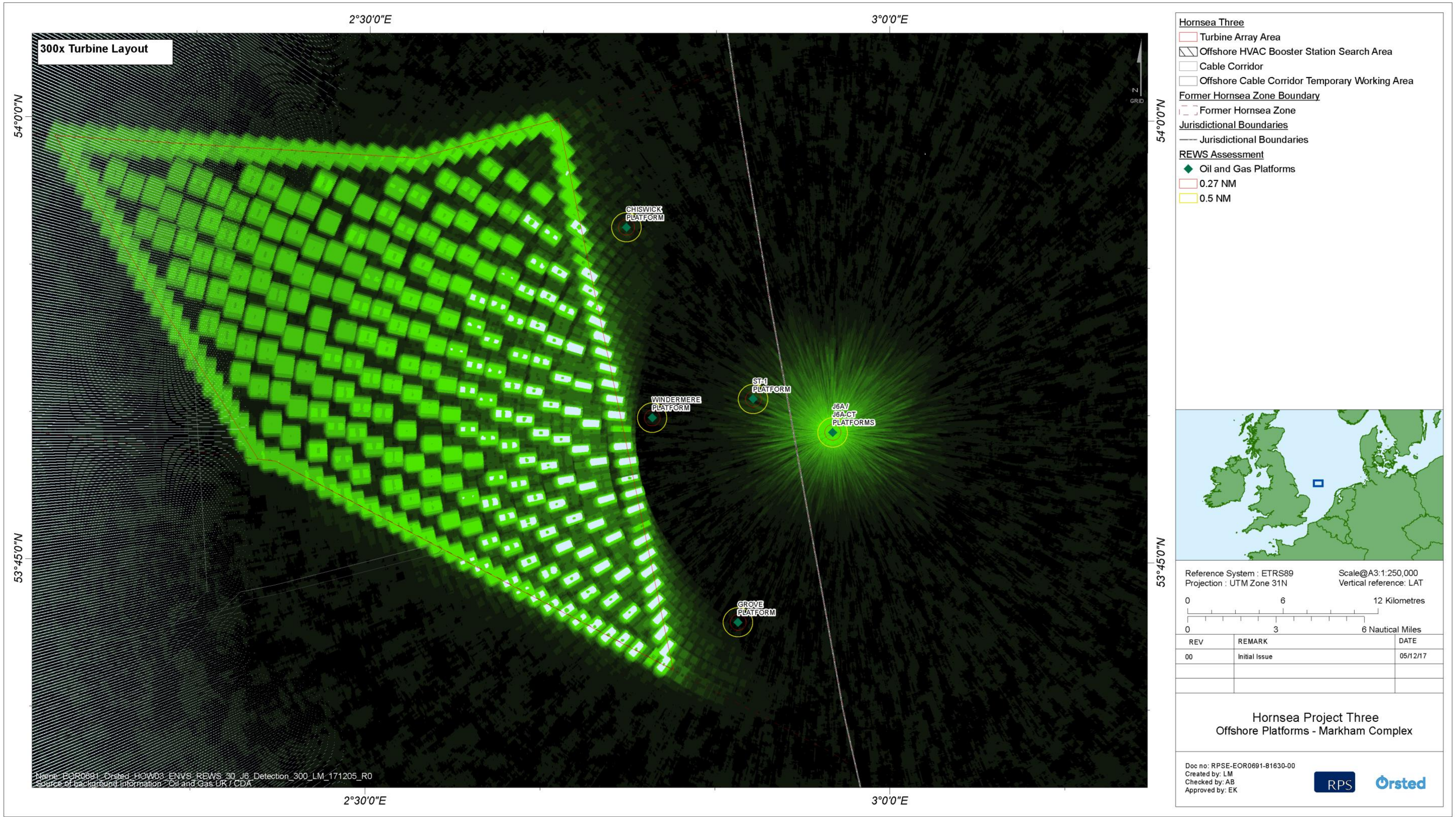

Figure 4.10: J6A platform REWS detection threshold over the Hornsea Three (300 turbines).

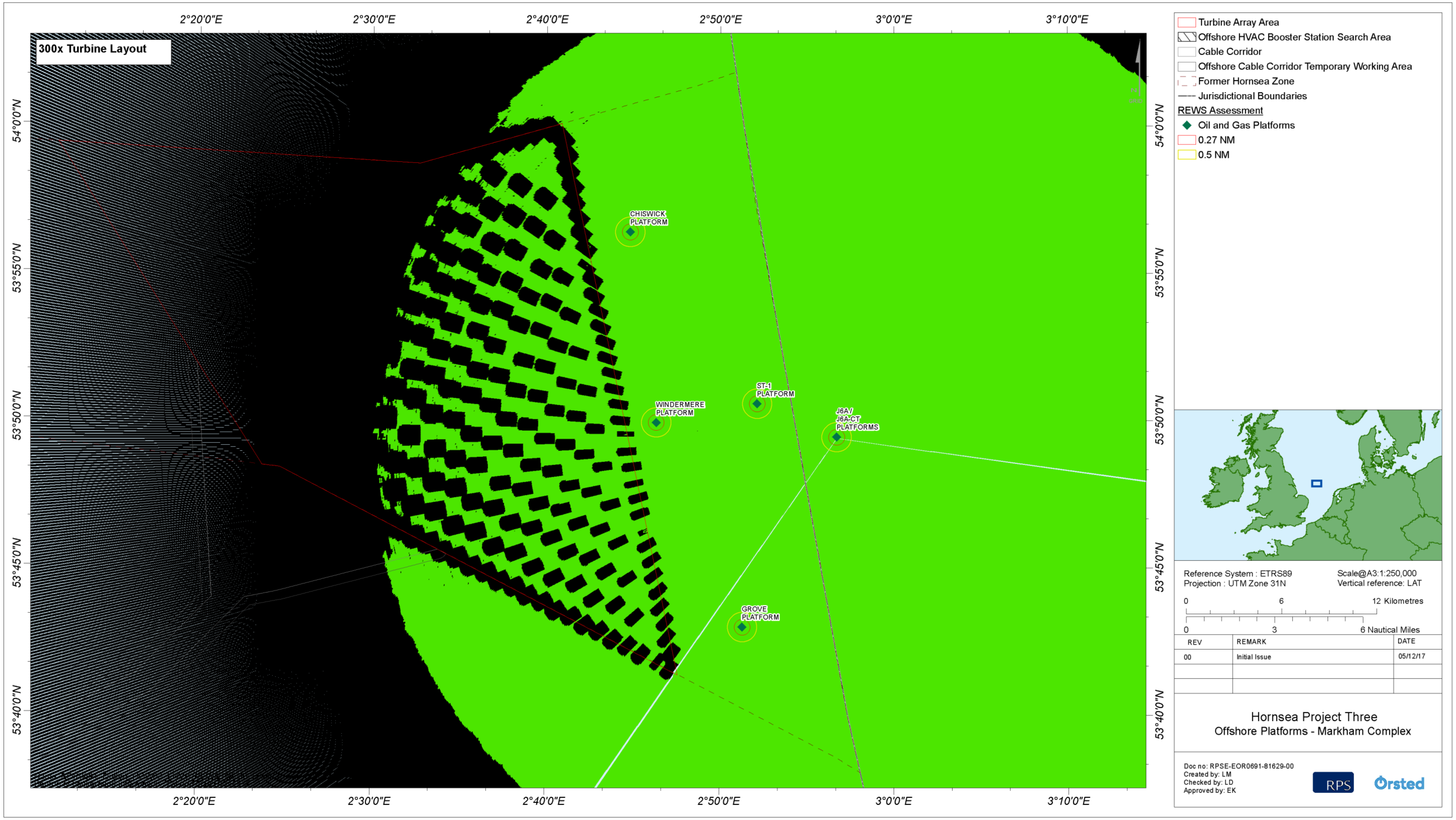

Figure 4.11: **J6A platform REWS detection plot showing loss regions for a 100 m² target (300 turbines).**

5. ConocoPhillips Saturn Platform REWS Assessment

5.1.1.1 ConocoPhillips operates a number of offshore platforms in the North Sea. Some of these platforms are located within close proximity of the Hornsea Three array area, as well as Hornsea Project One and Hornsea Project Two. This assessment report considers the effects of Hornsea Three on the ConocoPhillips REWS located on the Saturn platform due to its proximity to Hornsea Three array area (17.6 nm) as well as Hornsea Project One and Hornsea Project Two (11.0 nm). Other ConocoPhillips REWS installations were considered to be too far from Hornsea Three and no potential impact is expected – and hence these were not assessed. The physical presence of the Hornsea three HVAC booster stations located within the HVAC booster station search area along the offshore cable route corridor have not been assessed based on the assumption that singular structures are not expected to have a notable effect on REWS.

5.1.1.2 It is a condition of the Hornsea Project Two Development Consent Order (DCO) to mitigate any adverse impacts from Hornsea Project Two on the Saturn REWS to ensure the safety of the Saturn, Mimas and Tethys platforms. Schedule 1, Part 3, requirement 25 of the Hornsea Project Two DCO requires that construction of any Hornsea Project Two wind turbine may not commence until the Secretary of State, having consulted with ConocoPhillips, is satisfied that appropriate mitigation will be implemented and maintained for the life of Hornsea Project Two. There is very little effect on the REWS located on the Saturn platform from the Hornsea Three turbines due to their distance from the platform. As such, the mitigation measures described for Hornsea Project Two shall reduce the potential for any cumulative effect to arise with Hornsea Three on the ConocoPhillips operated REWS located on the Saturn platform. The modelling results presented in sections 5.2, 5.3 and 5.4 below do not include this mitigation.

5.2 Hornsea Three REWS returns and detection modelling

5.2.1.1 The REWS on the Saturn platform provides coverage to the Tethys platform, Mimas platform, Viking KD platform, and the Vampire OD platform. The REWS on the Loggs platform also provides overlapping radar coverage to protect assets south of the Saturn platform.

5.2.1.2 As outlined in section 3.1.2 above, the indicative Hornsea Three layout (Layout A) was imported to the model as shown in Figure 5.1. The models were then used to compute the radar returns and the resultant CFAR threshold shown in Figure 5.2 and Figure 5.3 respectively.

5.2.1.3 To assess the impact of Hornsea Three on the Saturn platform, two vessel sizes were considered; a small 100 m^2 RCS vessel and a larger 1,000 m^2 RCS vessel that represents a 1,000 GT vessel.

5.2.1.4 This section presents the REWS returns and detection modelling associated with 342 turbines with a rotor diameter of 185 m and a hub height of 127 m scenario on the Saturn platform. As noted above in paragraph 3.1.1.2, the maximum number of turbines in the Hornsea Three array area has subsequently been reduced to 300 turbines with a maximum rotor diameter of 195 m and an associated hub height of 153 m. A validation assessment has been completed of the REWS returns and detection modelling associated with the J6A platform for Hornsea Three with 300 turbines. This is presented in section 4.3 above. No validation assessment has been completed for the Saturn platform because results of the initial assessment with the 342 turbines indicates that the Hornsea Three array is located at the edge of the radar detection region and will not have a considerable effect on the REWS detection regardless of the number and size of the turbines.

5.2.2 Smaller 100 m^2 RCS vessel

5.2.2.1 The typical radar coverage for a 100 m^2 target is reported to be approximately 16 nm (30 km). This is in agreement with the modelling results shown in Figure 5.4 which shows the power received from a 100 m^2 target at varying ranges.

5.2.2.2 The results show that for the 100 m^2 test target, the Hornsea Three array area will not have an impact on the REWS since the closest turbine is approximately 31 km away from the REWS. However, the operators of the REWS might be interested in detecting and tracking vessels travelling within the corridor which will be formed between Hornsea Three and the adjacent Hornsea Project One and Hornsea Project Two. This is discussed in section 5.3, which considers the cumulative impact associated with Hornsea Project One, Hornsea Project Two and Hornsea Three. This is also of importance for the assessments on the effect associated with rerouted traffic (see section 6).

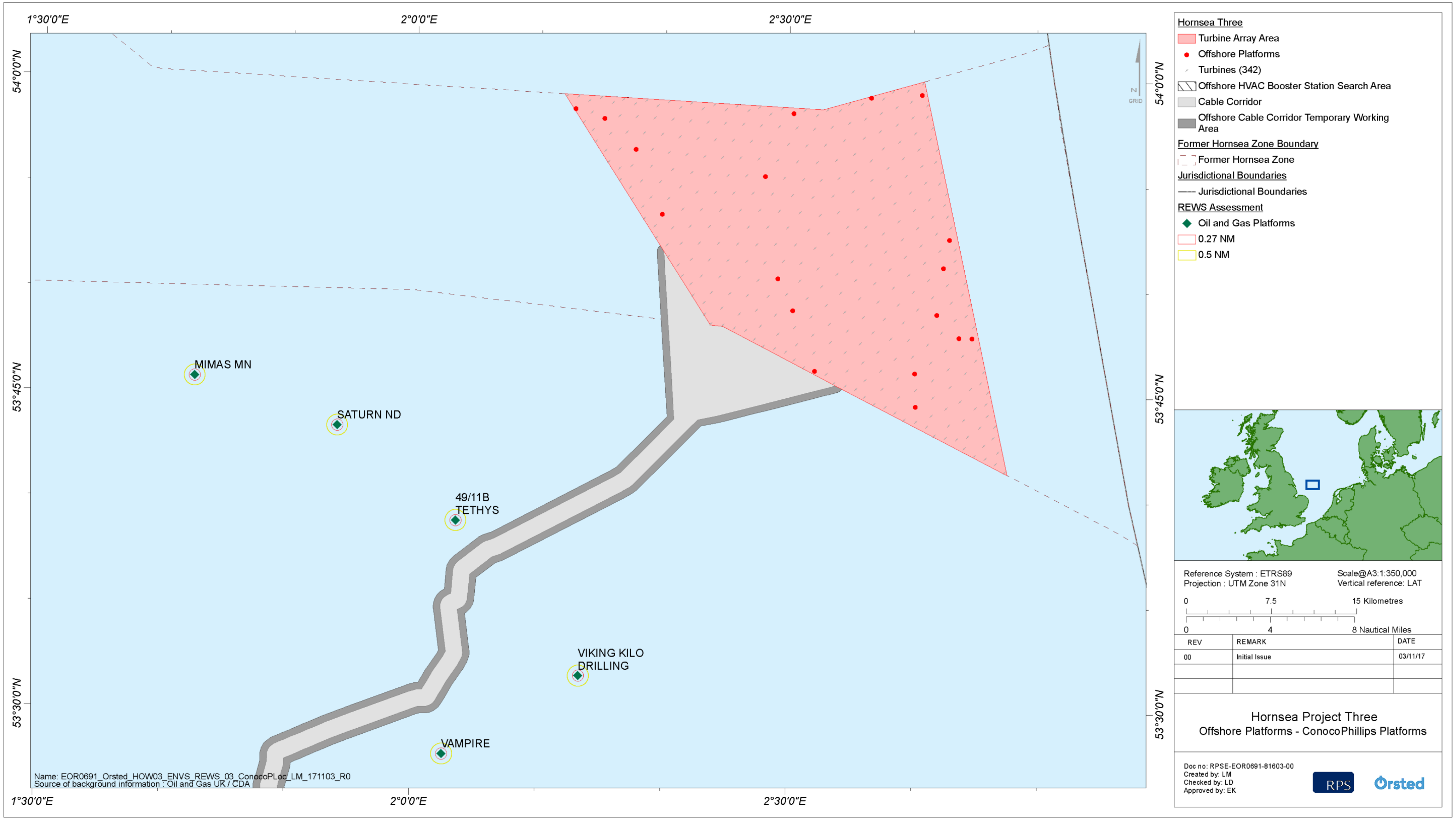

Figure 5.1: **Modelled layout for Hornsea Three (342 turbines) and the ConocoPhillips's platforms.**

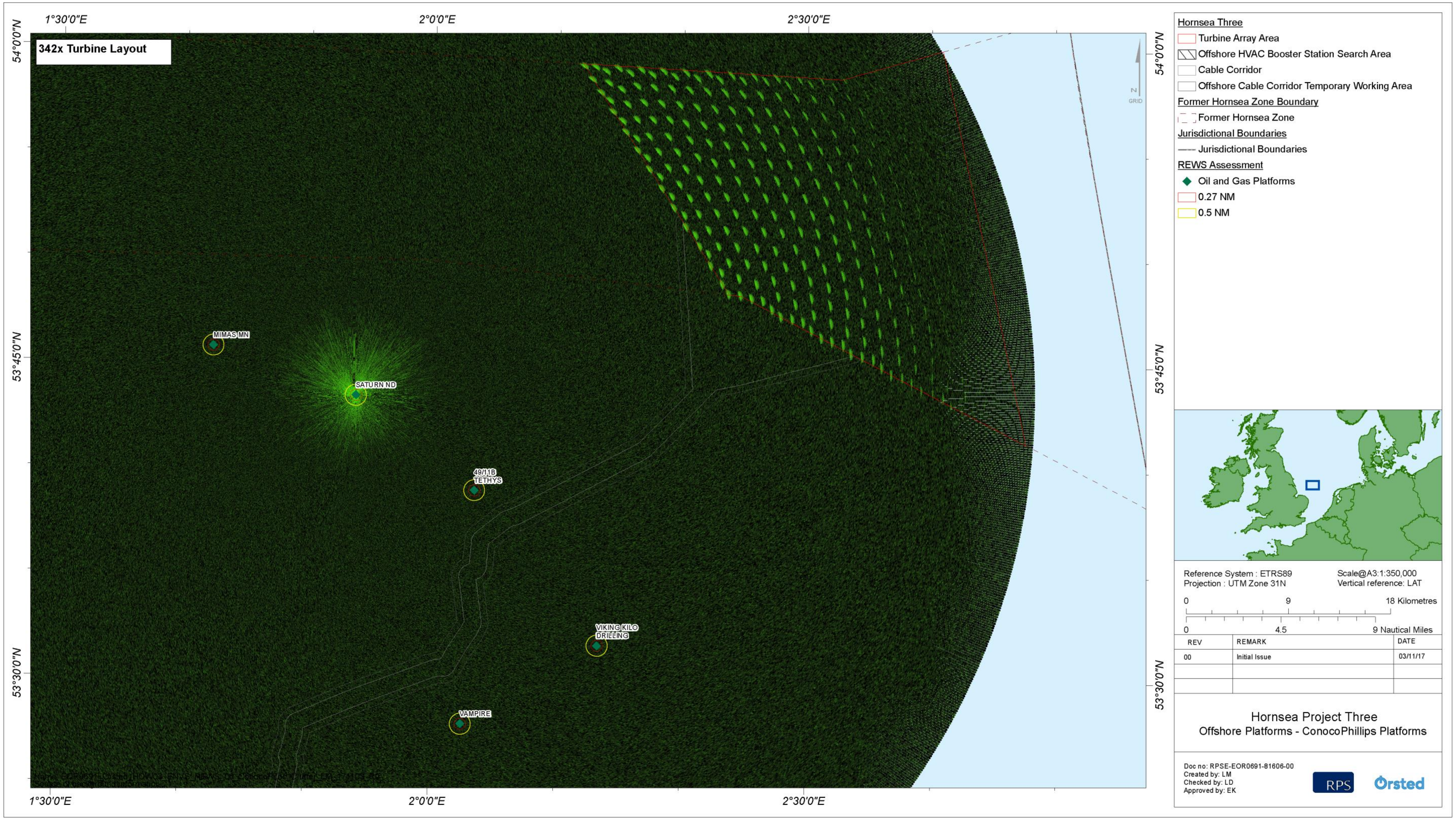

Figure 5.2: **Saturn platform REWS clutter map showing returns from Hornsea Three (342 turbines) and sea clutter.**

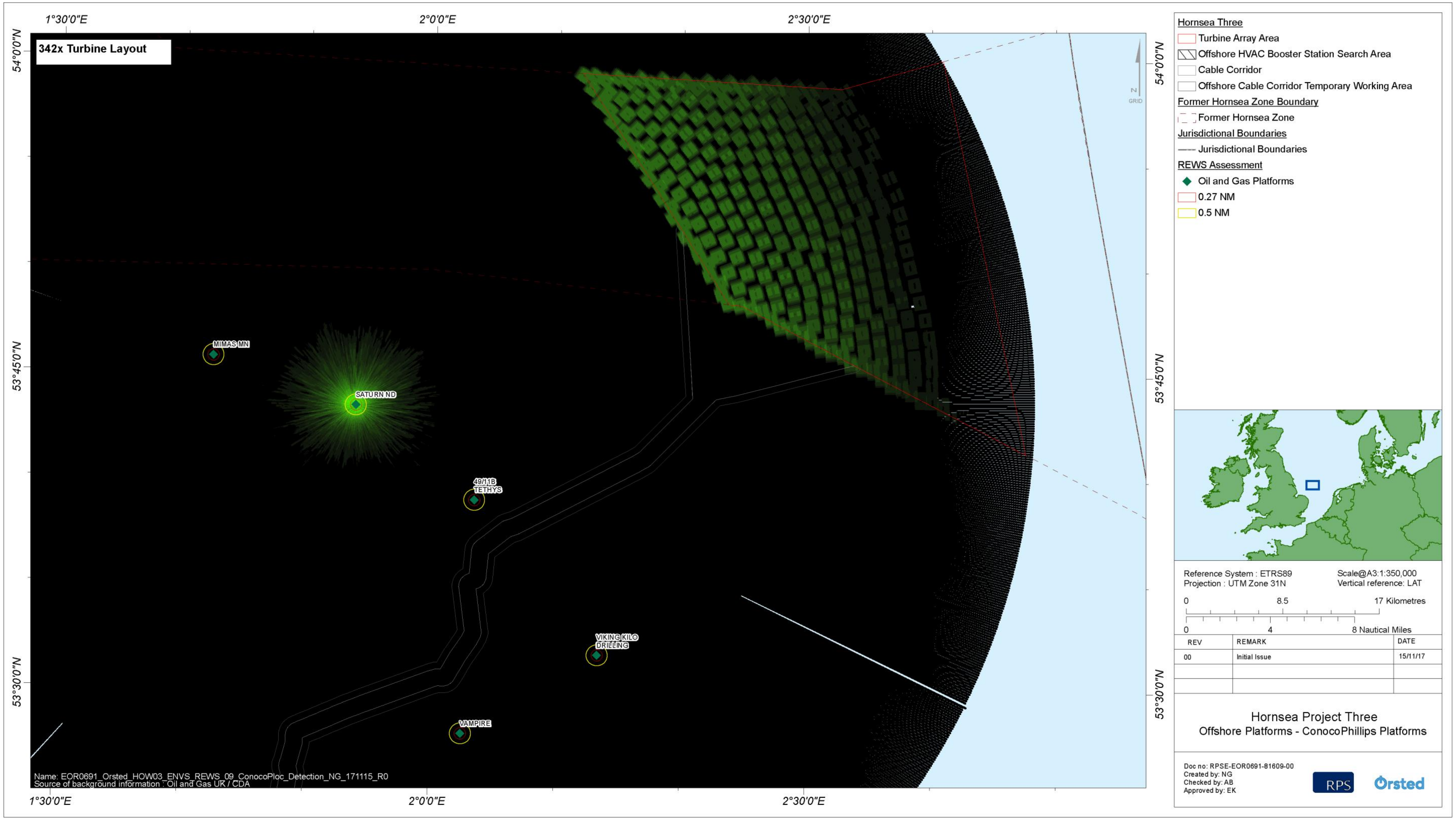

Figure 5.3: **Saturn platform REWS detection threshold over the Hornsea Three array area (342 turbines).**

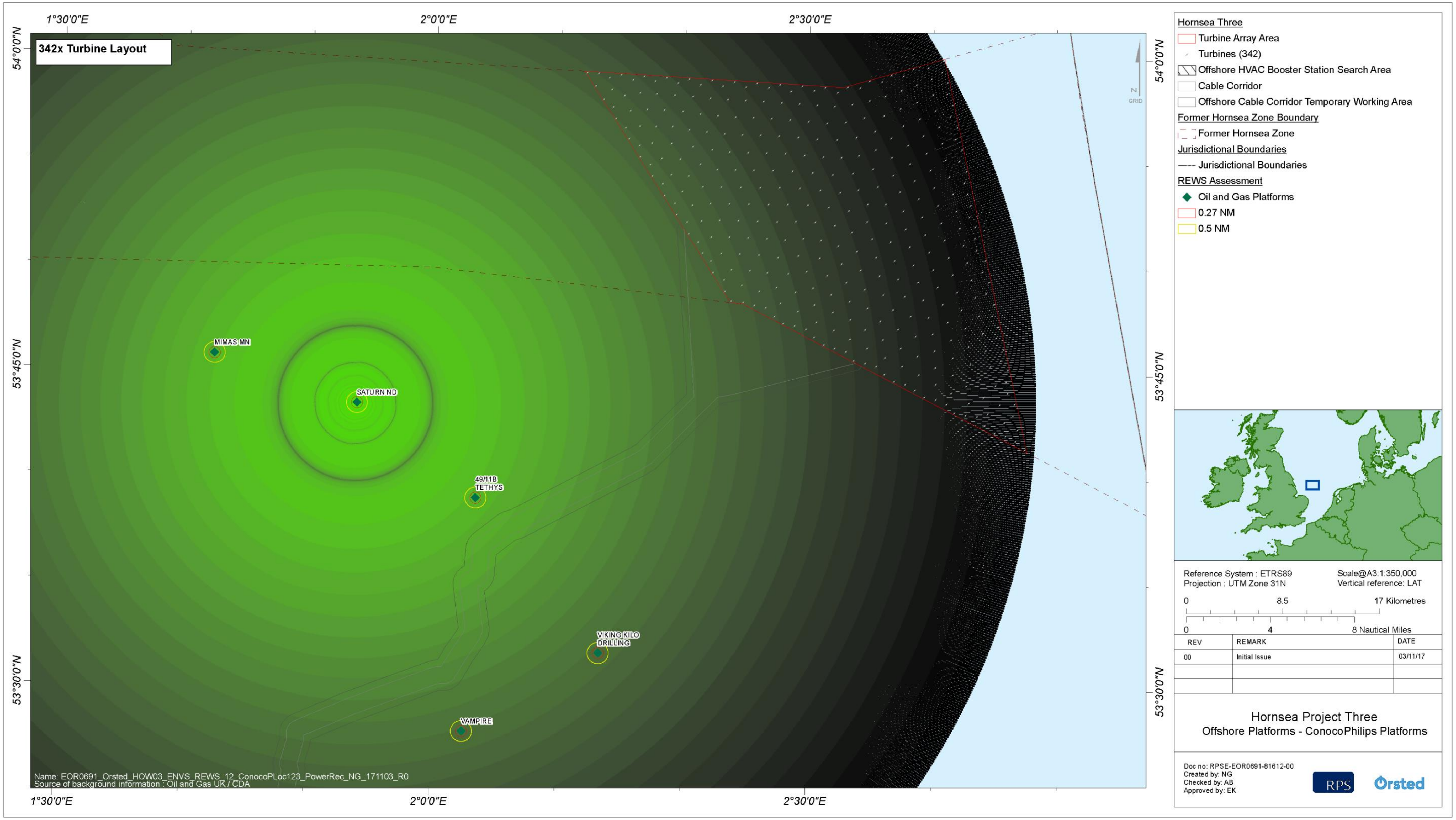

Figure 5.4: **Modelled power received from 100 m² target (coverage) (342 turbines).**

5.2.3 Large 1,000 m² RCS vessel

5.2.3.1 The modelling indicates that the typical radar detection range for a 1,000 m² RCS target is approximately 26.6 nm (48 km). When considering the CFAR threshold over the Hornsea Three array area, the detection of the 1,000 m² RCS target is shown in Figure 5.5. Figure 5.6 shows a cut taken at a 39° bearing angle to show the returns from the target against the turbine returns and the detection threshold.

5.2.3.2 The results show that Hornsea Three is unlikely to affect the performance of the REWS on the Saturn platform. There will be some detection loss at the edges of the Hornsea Three array area; however, this is sufficiently far to uphold the integrity of the TCPA alarms. The loss of detection along with the shadow analysis might be needed when assessing the rerouting of traffic (see section 2.3).

5.3 Cumulative REWS returns and detection assessment of Hornsea Project One, Hornsea Project Two and Hornsea Three

5.3.1.1 Previous modelling results in section 5.2 indicated that Hornsea Three is sufficiently far away from the Saturn REWS and will not affect the detection of vessels or the integrity of the TCPA alarms. However, for completeness, this assessment considers Hornsea Three along with Hornsea Project One and Hornsea Project Two. The combined impact modelling of Hornsea Three along with Hornsea Project One and Hornsea Project Two on the Saturn platform REWS was conducted in the same manner as that shown previously for Hornsea Three alone. Turbine numbers and specifications used within the cumulative impact modelling are presented in Table 5.1 below.

5.3.1.2 It is noted that offshore wind farms seek consent for a maximum design scenario and the 'as built' offshore wind farm will be selected from the range of consented scenarios. In addition, the maximum design scenario quoted in the application (and the associated Environmental Statement) are often refined during the determination period of the application. For example, it is noted that the Applicant for Hornsea Project One considered a maximum of turbines 332 turbines within the Environmental Statement, but has gained consent for 240 turbines. In addition, it is now known that Hornsea Project One 'as built' will consist of 174 turbines. Similarly, Hornsea Project Two has gained consent for an overall maximum number of turbines of 300, as opposed to 360 considered in the Environmental Statement and the as built number of turbines is likely to be less than this. This process of refinement can result in a reduction to associated project parameters, for example the number of offshore substations. The cumulative assessment presented in this report has been undertaken on the basis of information presented in the Environmental Statements, for Hornsea Project One and Hornsea Project Two. Given that this broadly represents a maximum design scenario, the level of cumulative impact on REWS would highly likely be reduced from those presented here.

5.3.1.3 The total layout of the combined wind farms shown in Figure 5.7 was imported into the models and the power received was calculated based on the location, orientation and the turbine specifications for each project. The power received from the turbines and the sea clutter are shown in Figure 5.8 while the detection threshold levels are illustrated in Figure 5.9.

5.3.1.4 From the results shown in Figure 5.8 it can be noted that the Hornsea Three turbines will also be detected adding to the total number of targets on the track-table. Also, the threshold is raised over a very large area which can cause detection loss over the affected area. This effect is investigated in more detail depending on the target size in sections 5.3.2 and 5.3.3 below.

Table 5.1: Turbine numbers and specifications used within the cumulative impact modelling.

Project	Number of turbines	Turbine rotor diameter (m)	Hub height relative to LAT (m)
Hornsea Project One	332	180	107
Hornsea Project Two	360	135	90
Hornsea Three	342 [a]	185	127

a Note the turbine numbers and specifications have been refined as discussed in section 4.3.

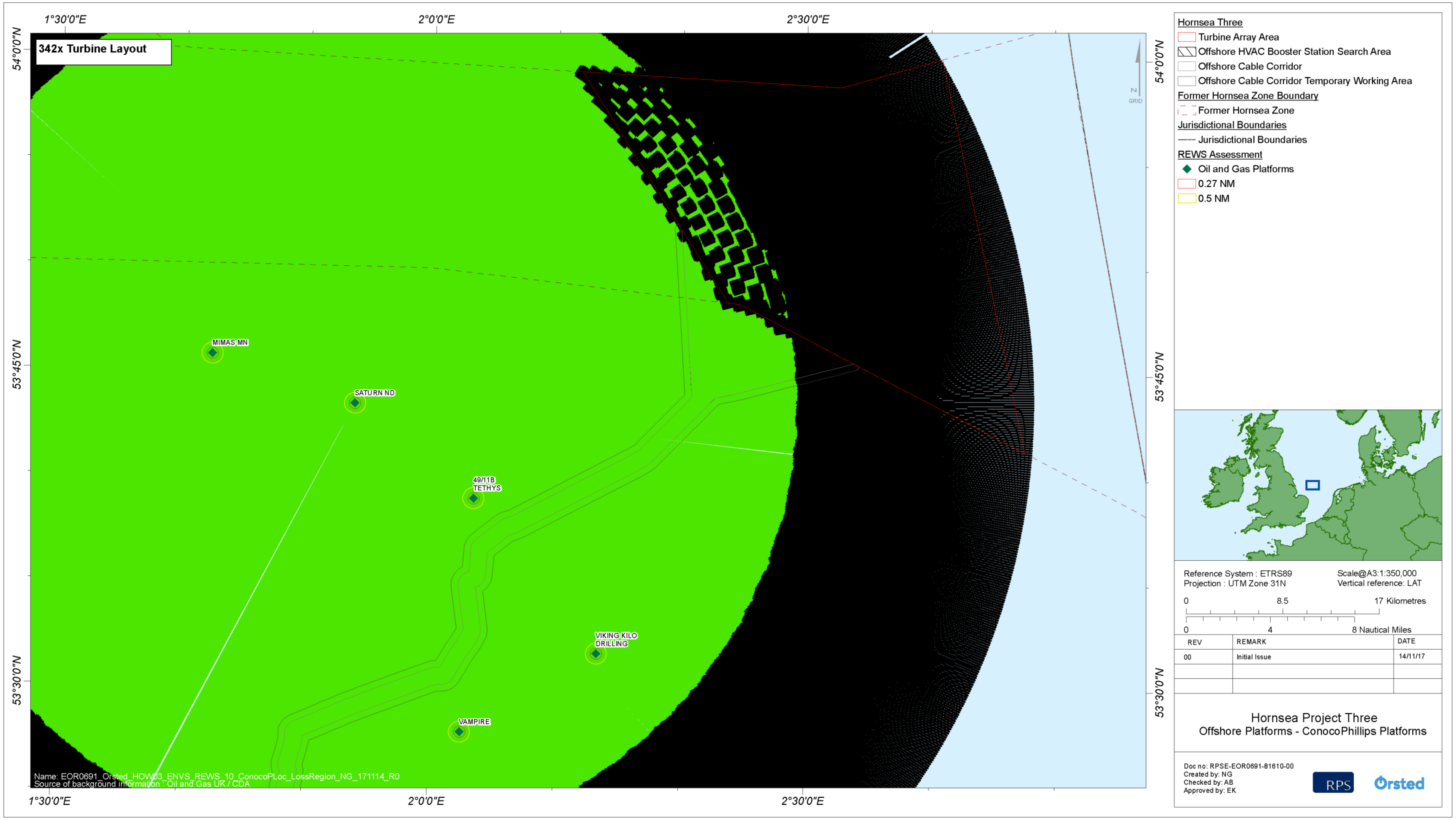

Figure 5.5: **Saturn platform REWS detection plot showing loss regions for a large 1000 m² RCS target over the Hornsea Three array area (342 turbines).**

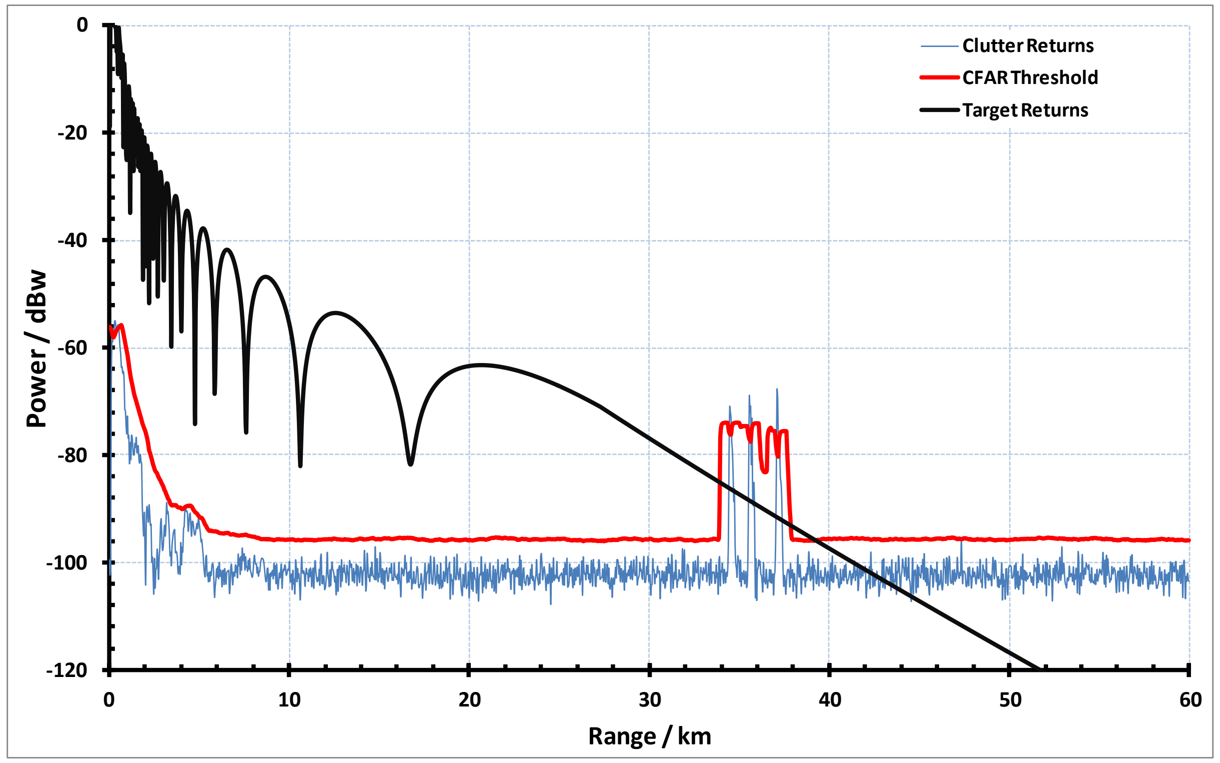

Figure 5.6: Power received from large target at 39° bearing angle.

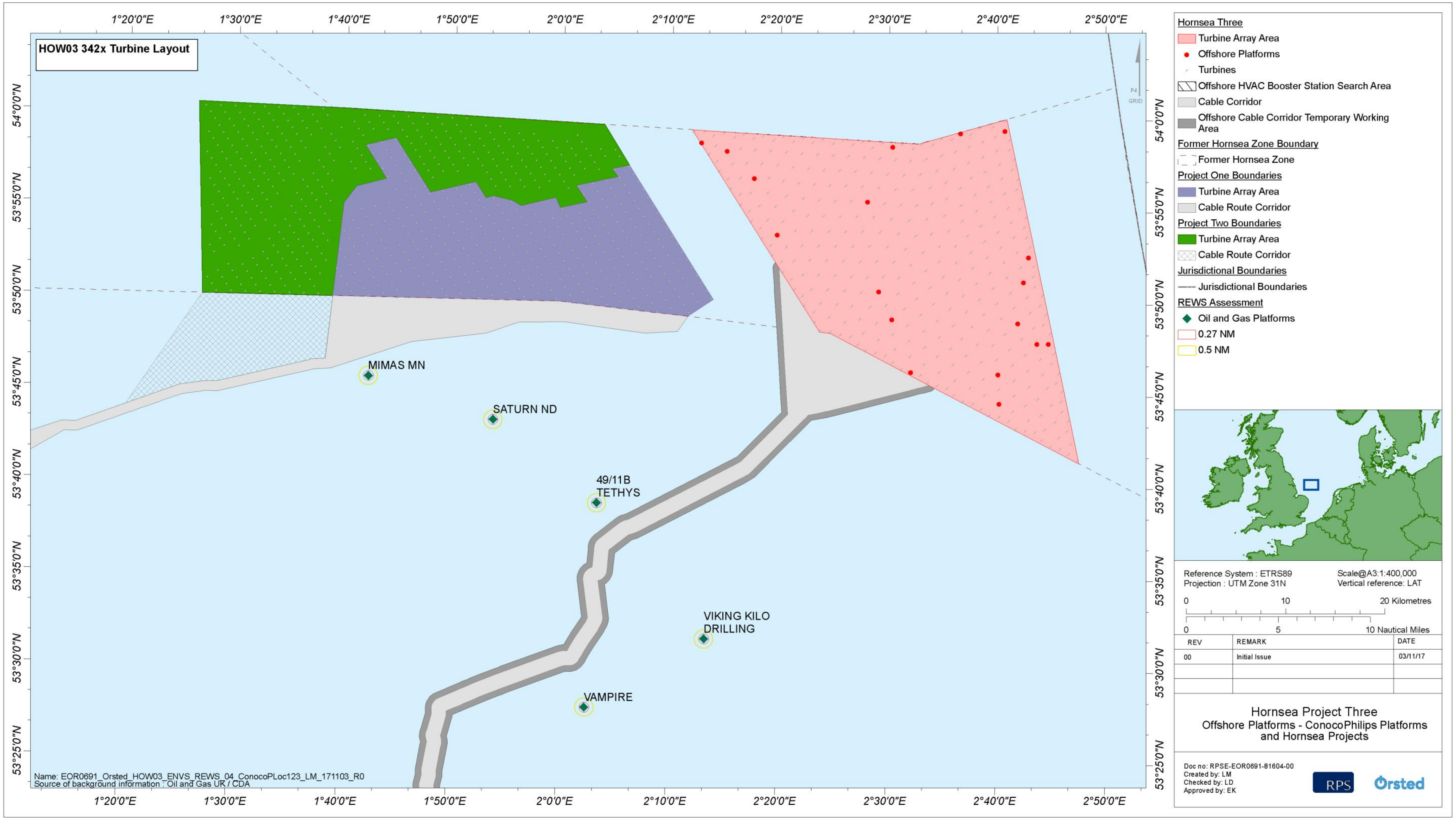

Figure 5.7: **Modelled combined layout of Hornsea Project One, Hornsea Project Two and Hornsea Three (342 turbines) with respect to ConocoPhillips's platforms.**

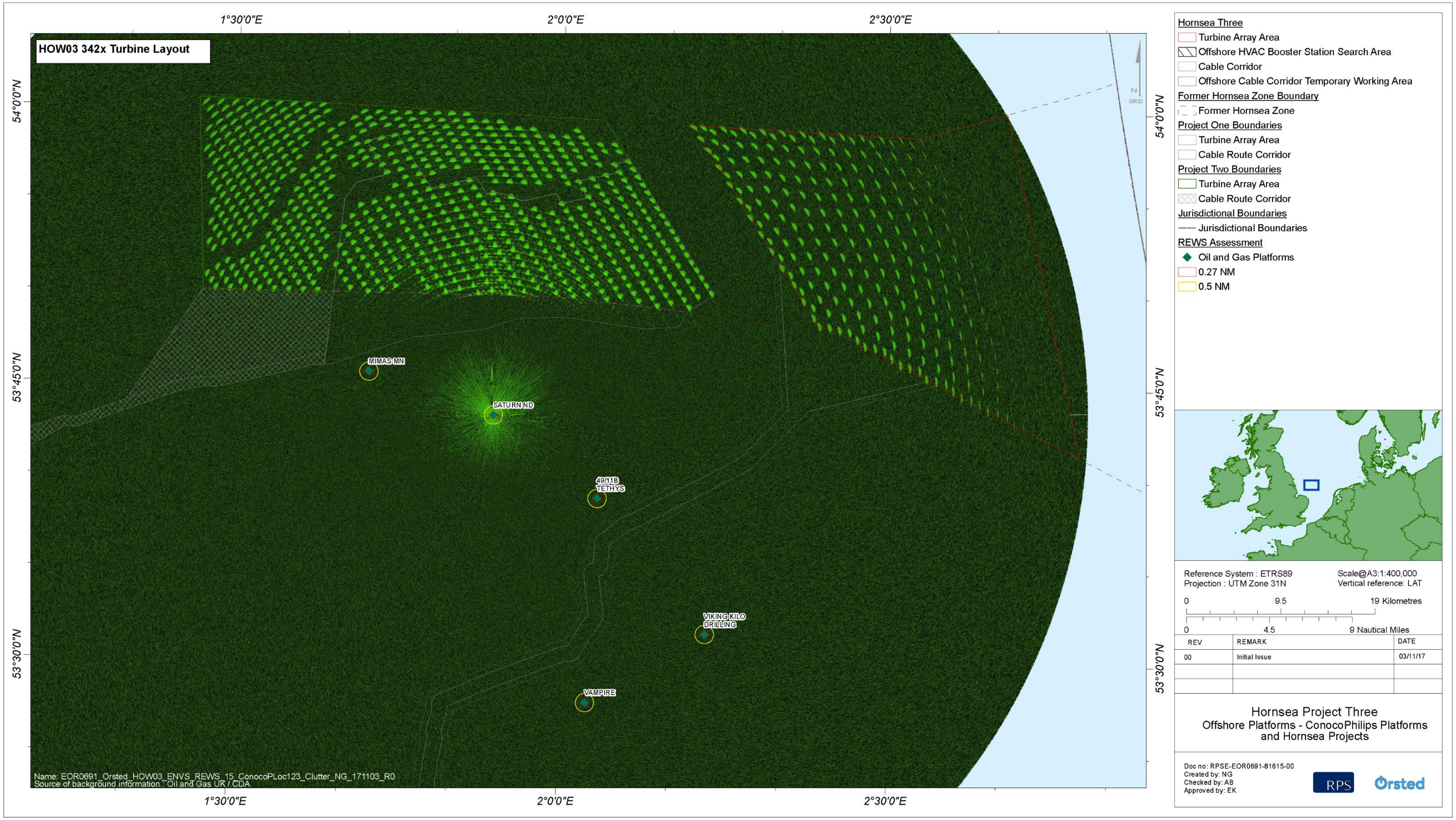

Figure 5.8: **Saturn platform REWS clutter map showing returns from the combined Hornsea Project One, Hornsea Project Two and Hornsea Three (342 turbines) and sea clutter. (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).**

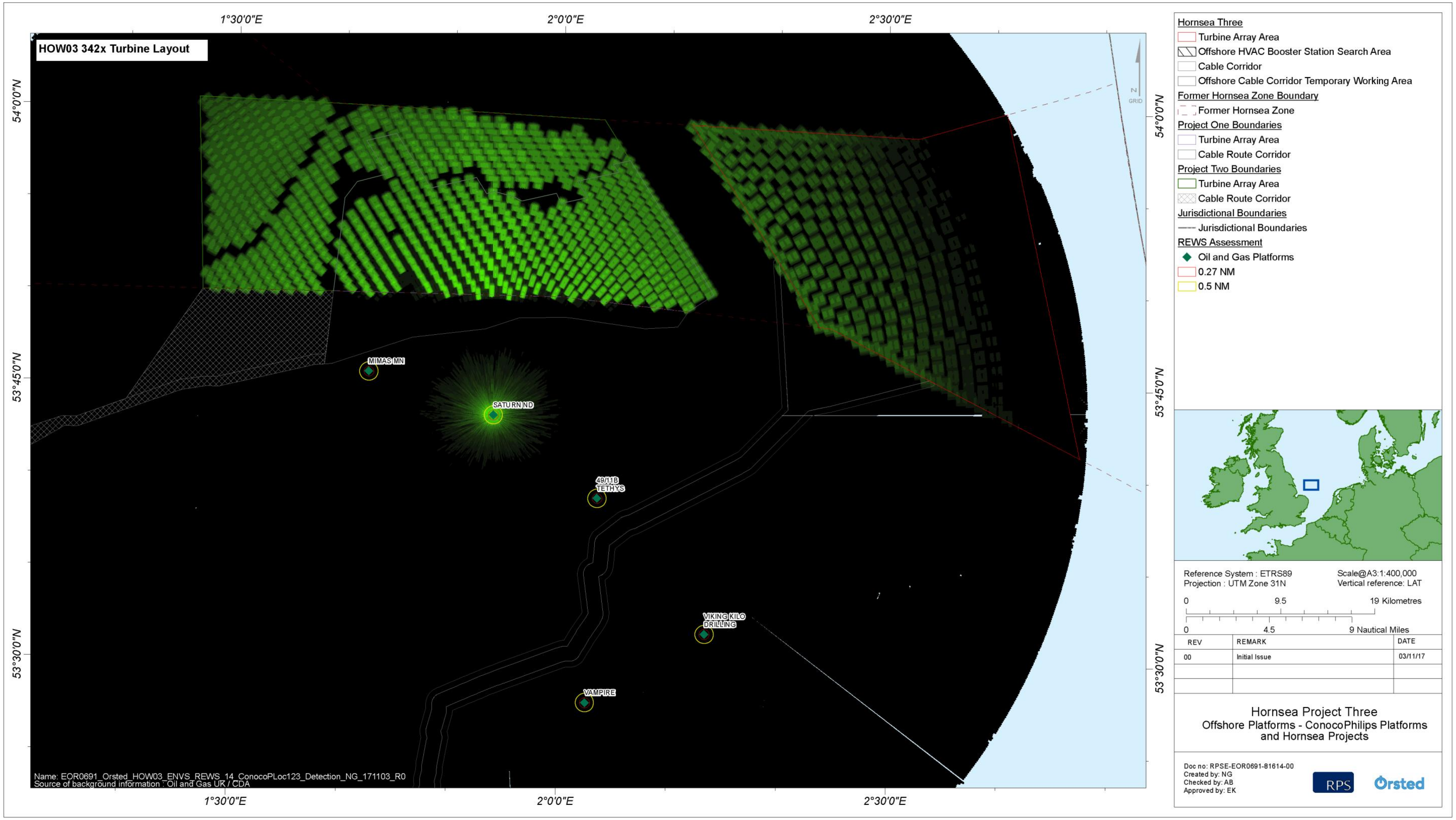

Figure 5.9: Saturn platform REWS detection threshold over the combined Hornsea Project One, Hornsea Project Two and Hornsea Three (342 turbines). (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).

5.3.2 Smaller 100 m² RCS vessel

5.3.2.1 As shown previously in section 5.2.2, for a smaller vessel the radar coverage extends only up to the near edge of the Hornsea Three array area. However the radar coverage does extend over Hornsea Project Two and Hornsea Project One as well as part of the corridor which is formed between Hornsea Three, and Hornsea Project One and Hornsea Project Two (as shown in Figure 5.9). Vessels travelling through this corridor are important to detect and track as they may change direction and travel through the wind farm and towards the platforms. Therefore, the presence of the turbines may affect the detection of traffic passing between the wind farms. The detection performance based on the comparison between the target returns and the detection threshold is shown in Figure 5.10.

5.3.2.2 The results of the detection analysis demonstrate that the introduction of the Hornsea Three turbines will not affect the detection of smaller vessels travelling through the corridor as the turbines are located beyond the radar detection range (Figure 5.11). However, using this particular thresholding algorithm, the REWS may struggle to detect smaller targets travelling within the wind farms region (mainly within Hornsea Project One and Hornsea Project Two). This agrees with the observations following the practical measurements conducted by Ultra ESS near the east Irish Sea wind farms (Greenwell, 2016). However, the threshold levels are highly dependent upon the CFAR algorithms deployed within the REWS which is proprietary to the system in use.

5.3.2.3 To further illustrate the comparison between vessel returns, clutter returns and the resultant threshold, Figure 5.12 and Figure 5.13 show a cut through the radar returns at bearing angles of 39° and 0° respectively. The cut taken at 39° shows the radar performance in the direction of the Hornsea Three array area, while illuminating a portion of the corridor between Hornsea Three, and Hornsea Project One and Hornsea Project Two.

5.3.3 Large 1000 m² RCS vessel

5.3.3.1 To assess the REWS's performance in detecting larger vessels of 1,000 GT or above, the study was extended to include modelling the returns and detections of a 1,000 m² RCS target as stated previously in paragraph 3.5.1.3. The coverage for the large target is shown in Figure 5.14 while the detection performance is shown in Figure 5.15.

5.3.3.2 Although the larger vessel will generate stronger radar returns, the results show that REWS will still have large areas where it would not be able to detect the vessel as it travels through the combined Hornsea Project One, Hornsea Project Two and Hornsea Three wind farms. This is mainly due to the strong turbine returns which will increase the detection threshold around the turbines in Hornsea Project One and Hornsea Project Two. The presence of Hornsea Three does not add to the negative effects generated from the turbines within Hornsea Project one and Hornsea Project Two and is not expected to further impact the overall detection performance of the REWS.

5.3.3.3 Larger vessels are likely to be detected as they travel through the corridor between Hornsea Three, and Hornsea Project One and Hornsea Project Two. This can be seen by examining Figure 5.16, which shows a cut at a bearing angle of 39°. The power from the target is clearly above the detection threshold between the 28 km and the 34 km marks on the figure (which corresponds to the corridor region at that bearing angle). The details of the detection over particular paths are assessed separately in section 6.

5.4 REWS returns and detection modelling for Hornsea Three with 300 turbines

5.4.1.1 As shown in section 5.3 above, the turbines deployed within Hornsea Three can be considered sufficiently far from the Saturn REWS that they will not contribute significantly to the loss of detection of vessels in the region of interest. Additionally, section 4.3 indicates that using larger turbines in fewer numbers may improve the detection region over the wind farm. Therefore, given the above, no modelling of the 300 turbine scenario was undertaken for the Saturn REWS.

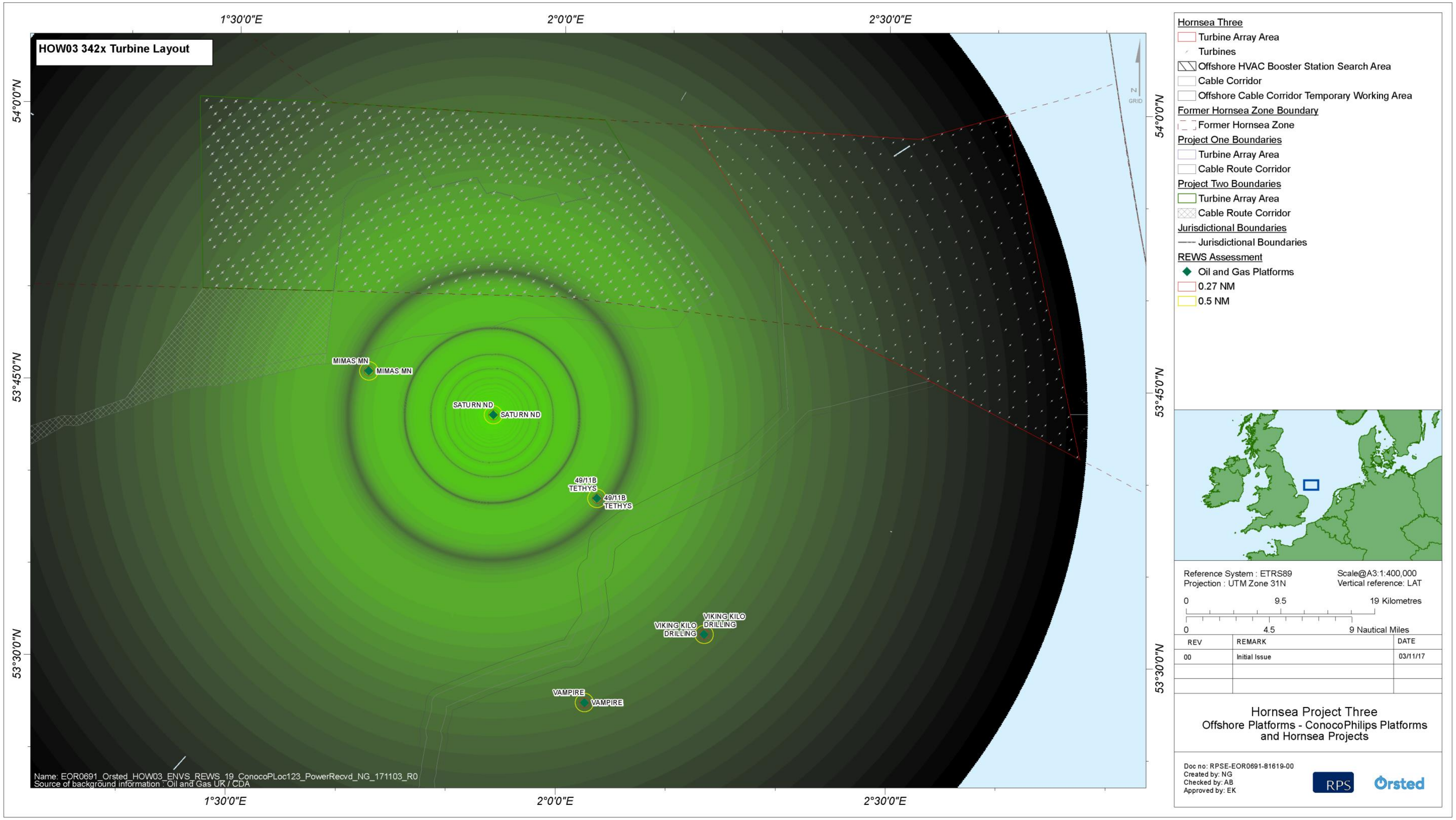

Figure 5.10: Modelled power received from 100 m² target (coverage) (342 turbines). (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).

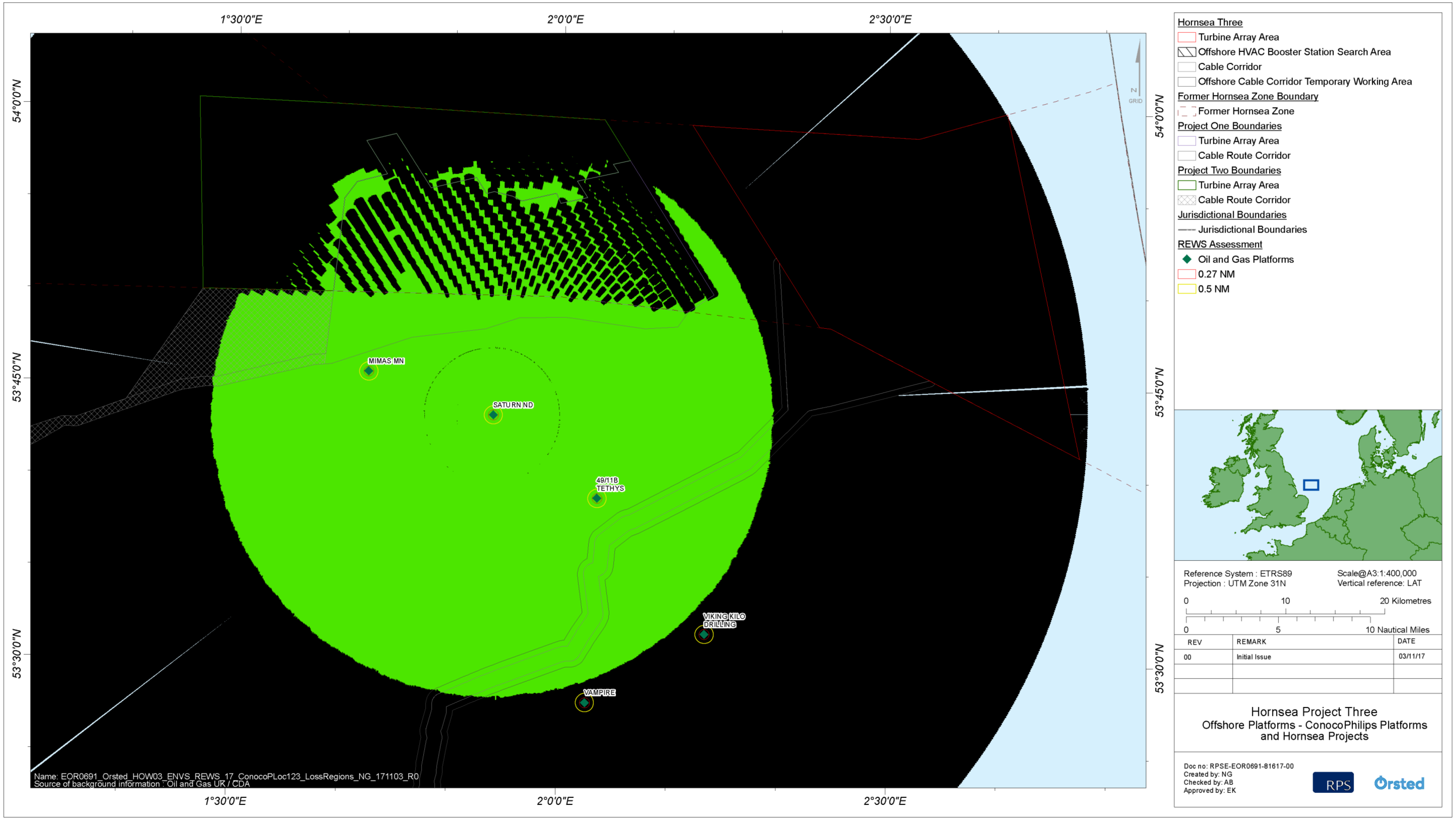

Figure 5.11: Saturn platform REWS detection plot showing loss regions for a 100 m^2 target over the combined Hornsea Project One, Hornsea Project Two and Hornsea Three (342 turbines). (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).

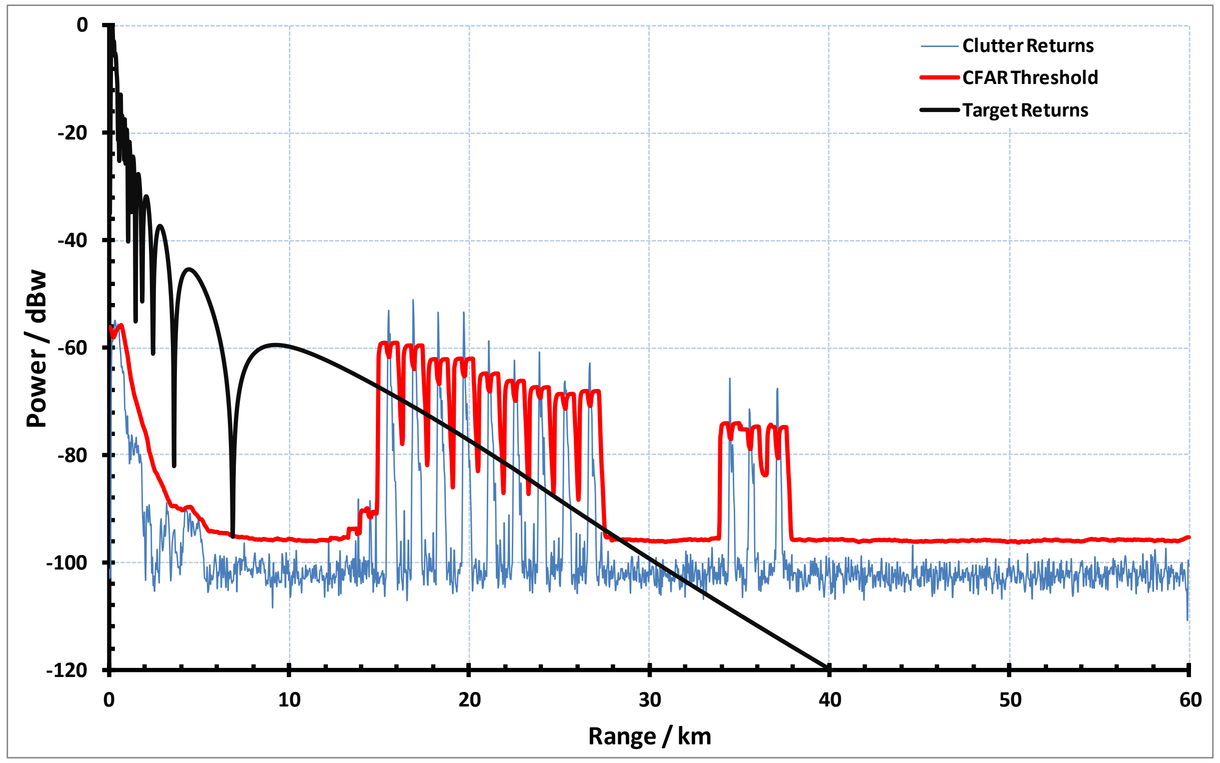

Figure 5.12: Power received from small target at 39° bearing angle.

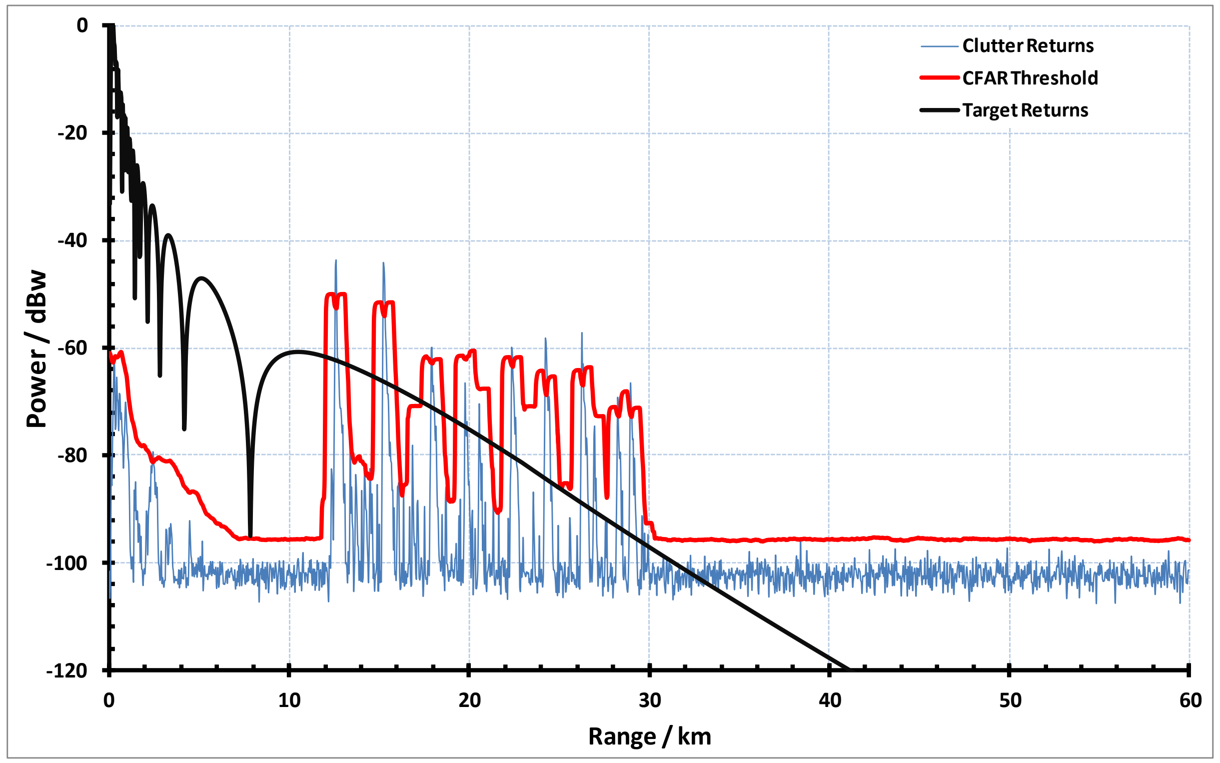

Figure 5.13: Power received from small target at 0° bearing angle.

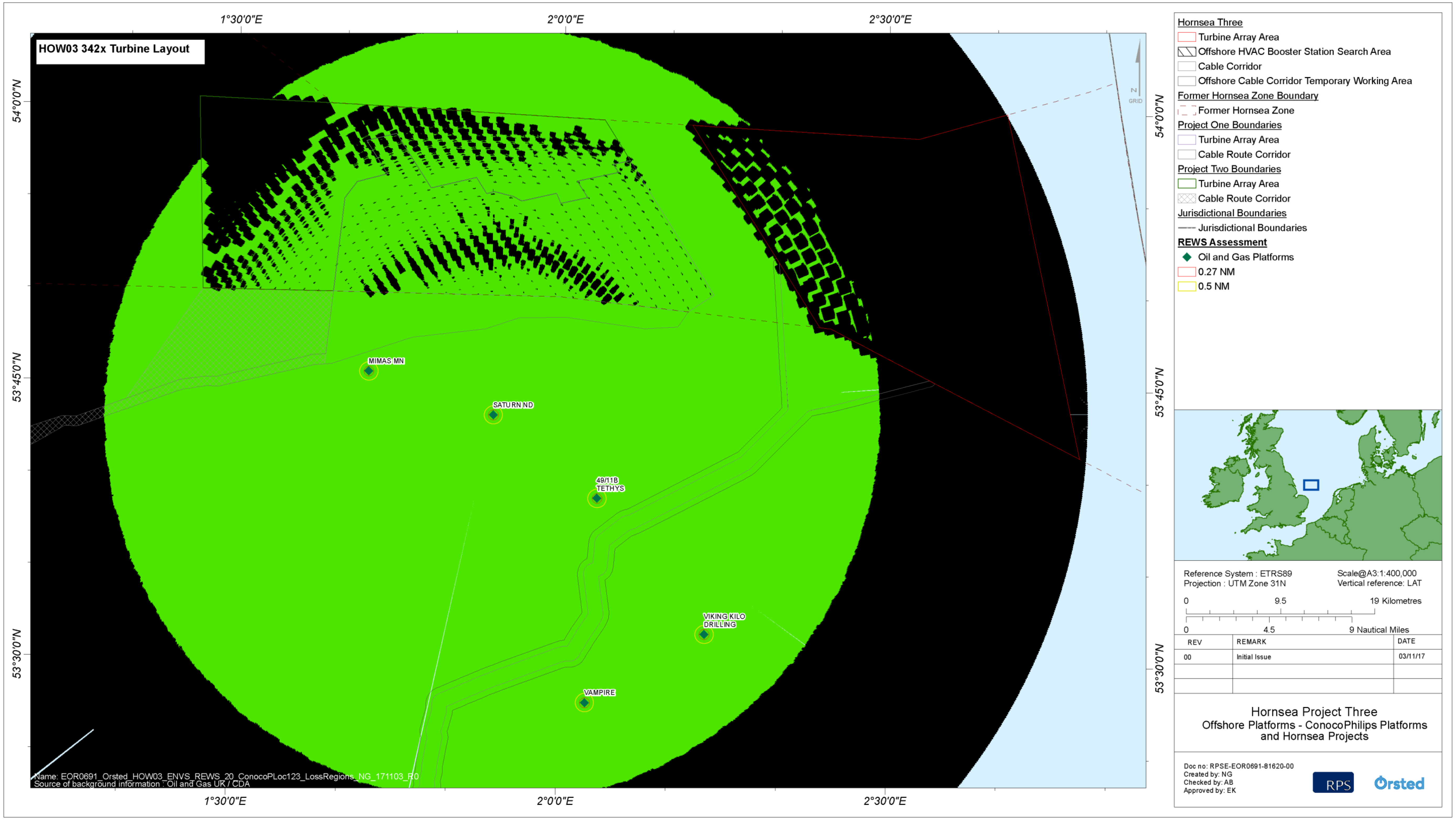

Figure 5.14: **Modelled power received from the large 1,000 m² target (coverage) (342 turbines). (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).**

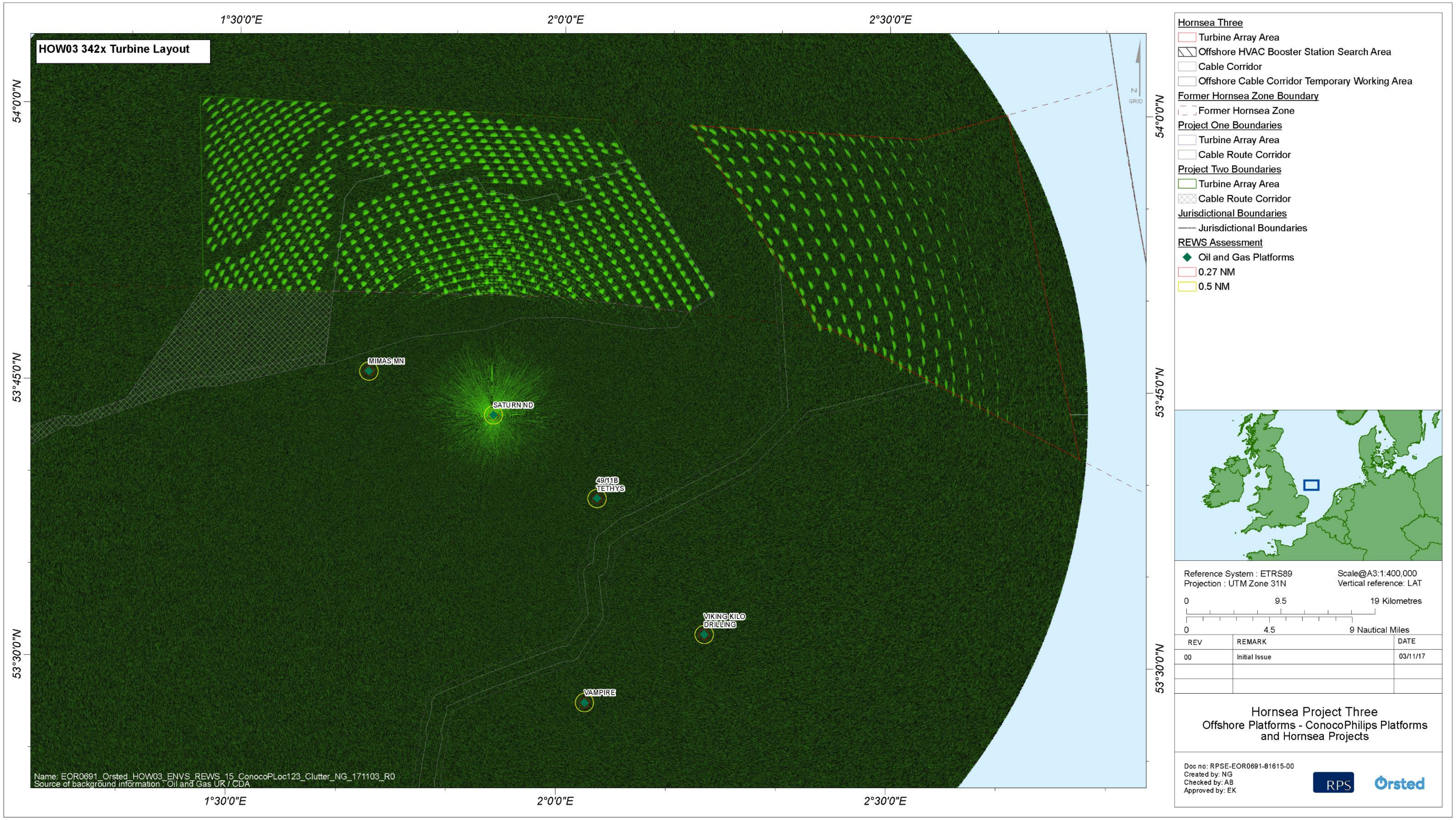

Figure 5.15: Saturn platform REWS detection plot showing loss regions for a large 1,000 m² target over the combined Hornsea Project One, Hornsea Project Two and Hornsea Three (342 turbines). (Note that the Hornsea Project One and Hornsea Project Two consented layouts have less turbines than those shown in this figure).

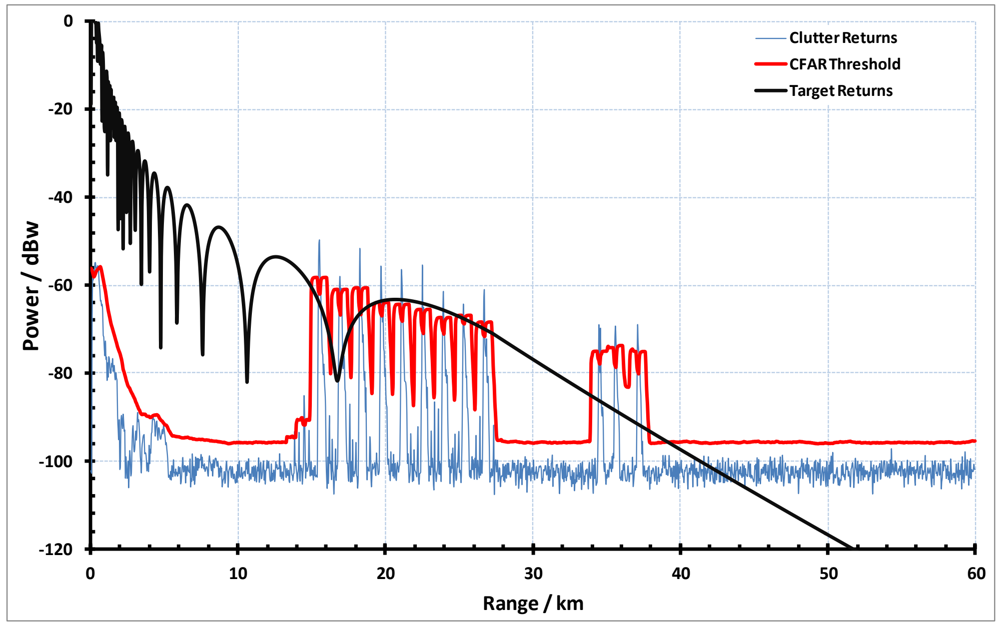

Figure 5.16: Power received from large target at 39° bearing angle.

6. Assessment of Rerouted Traffic on the REWS Alarms

6.1.1.1 The REWS uses the radar returns to monitor and track vessels within the detection region and alert the operator when a proximity violation or a collision threat is detected. The REWS uses a defined set of rules to identify a breach of the CPA and TCPA parameters. Typically, an Amber alarm is raised if a vessel is within CPA of 0.5 nm and a Red alarm is triggered if the CPA of a vessel is 0.27 nm or less. The red TCPA alarms are raised for vessels that are on a collision vector 25 minutes away and an Amber alarm is raised for vessels that are 35 minutes away. To avoid alarms due to temporary vector breach of the TCPA while vessels are turning, TCPA alarms are only triggered if the vessel's vector remains in breach of the TCPA condition for a set number of radar rotations (typically 10 radar rotations).

6.1.1.2 Within this assessment report, the effect of the rerouting of traffic on the REWS alarm rates have been modelled based on the existing traffic in the region and the predicted alterations to the traffic around Hornsea Three and cumulatively with Hornsea Project One and Hornsea Project Two.

6.1.1.3 This assessment was based on the Hornsea Three array area and location, and is not dependent on the number of turbines within the Hornsea Three array area. Due to the location of Hornsea Three and the predicted changes to the existing routes, this assessment considers the effect of rerouted shipping routes on the ConocoPhillip's operated Mimas, Saturn and Tethys platforms (which is protected by the REWS located on the Saturn Platform). Other platforms with REWS in the vicinity of Hornsea Three (and Hornsea Project One and Hornsea Project Two) will not be affected as the predicted shipping routes are expected to either move further away from these platforms or remain unchanged.

6.2 Routes and alarms modelling

6.2.1.1 Anatec, following a review of vessel movements in the region, provided predicted shipping re-routes to account for Hornsea Three in isolation, and cumulatively with Hornsea Project One and Hornsea Project Two. The routes and their statistical data (including each routes mean and standard deviation) were imported into the REWS models. The statistical data enables the REWS models to estimate the width of the shipping route and the likelihood of vessels to deviate from the central (mean) route. Accounting for possible deviations from the central line of the route in a manner which is representative to the real movements of traffic in the region provides a good indication of the the overall existing and future alarm rates.

6.2.1.2 Once the discrete route statistical data are imported, the models then used linear interpolation between data points to extract the standard deviation at intermediate points. Then, to achieve enough statistical data for each route, the models were used to generate 1,000 vessel paths along each route in both the forward and reverse directions (a total of 2,000 runs per route). This large number of runs was then used to estimate the probability of raising TCPA or CPA alarms for each route.

6.2.1.3 For each of the platforms considered in the assessment (Saturn, Mimas and Tethys), the assessment utilised the CPA/TCPA parameters described in paragraph 6.1.1.1 above (specifically a Red CPA alarm at 0.27 nm, a Red TCPA alarm at 25 minutes, an Amber CPA alarm at 0.5 nm and an Amber TCPA alarm at 35 minutes). The vessel speed was assumed to be a constant 18 knots (20.7 mph). A TCPA/CPA alarm was assumed to be raised whenever a vessel breached the alarm rules. To reduce the modelling complexity, the models were set to give the total number of alarms triggered due to the breach of the TCPA and/or the CPA for all the protected platforms (i.e. Saturn, Mimas and Tethys).

6.2.1.4 A number of the assessed routes branch into two portions (e.g. Immingham to Cuxhaven route (see Figure 6.1)). In such cases, the models were set to assess the main branch as a whole and the sub-branch separately. The data given in tables highlights the alarm probabilities for each of the main branch and the sub-branch separately, in order to identify the sources of alarms.

6.2.1.5 Finally, to avoid false alarms due to temporary vector breach of the TCPA while vessels are turning, the models were set to only issue a TCPA alarm if the vessel continues to breach the TCPA rules for more than 10 radar rotations (as noted in paragraph 6.1.1.1 above).

6.3 Modelling results for existing traffic (pre-development of Hornsea Three)

6.3.1.1 In order to be able to estimate a change in alarm rates due to the rerouting of traffic around the Hornsea Three boundaries, a base case scenario was considered. The base case scenario utilises the existing traffic data within the region, as provided by radar and AIS data, along with extrapolated data in the regions where no data was available.

6.3.1.2 This study assessed a region of 12 nm around each of the Saturn, Mimas and Tethys platforms in order to provide a sufficient range to assess the TCPA alarms. The assessed routes and their 90th percentile width are shown in Figure 6.1.

6.3.1.3 Figure 6.2 illustrates the modelled output using Route 7 (Tees to Amsterdam – forward direction) as an example, for 1,000 runs, showing the variation of route traffic around the mean line.

6.3.1.4 The modelled results are shown in Table 6.1 below. Table 6.1 provides the percentage of alarms raised for each route shown on Figure 6.1 for both forward and reverse direction. As noted in paragraph 6.2.1.3, in order to reduce the modelling complexity, the models were set to give the total number of alarms triggered due to the breach of the TCPA and/or the CPA for all the protected platforms (i.e. Saturn, Mimas and Tethys). The results in Table 6.1 give the total number of alarms raised from both TCPA and CPA breaches. For example, for Route 7 (Tees to Amsterdam) in the forward direction, the models estimated that a total of 80 Red alarms and 306 Amber alarms were raised during the 1,000 runs of the route (i.e. 8% and 30.6% probability of alarms).

6.3.1.5 It is noted that in some instances within the base-case scenario, such as Routes 3, 7, and 17, the models indicate that there is more than 30% probability that an alarm will be raised due to a breach in either/or the CPA and TCPA rules. Although the results presented are an estimate of the existing effect of traffic on the REWS alarms, it provides a good platform from which to compare predicted future cases.

6.4 Modelling results for predicted shipping re-routes around Hornsea Three in isolation

6.4.1.1 In a similar manner to the base-case scenario, the vessel traffic around Hornsea Three (in isolation) was modelled based on the predicted re-routes. Both the mean line for each route, along with its standard deviation, were considered in the model. The predicted rerouted traffic (specifically the route 90th percentile width) is shown in Figure 6.3. This data was then used to create 1,000 runs for each route in either direction (total of 2,000 runs). Figure 6.4 shows the model output as an example, of Route 7.

6.4.1.2 Once each route was modelled and the probabilities of alarms were obtained, the modelling results for the predicted traffic were compared against the base-case. The results in Table 6.2 show the change in the probability of alarm against the base case. For example, Route 7 has seen an improvement in (reduced) alarm rates (i.e. the base case forward direction produced 8% probability of Red alarms while the predicted routes for Hornsea Three in isolation produced 0% probability of Red alarms). There is, therefore, an improvement (or decrease) in alarm rates of -8%. This is due to the displacement of the rerouted traffic further away from the platforms which can be seen when comparing Figure 6.2 and Figure 6.4.

6.4.1.3 The modelling results indicate that many of the routes will see a reduction in the probability of alarms due to the displacement of traffic away from the platforms. Some routes will see a small increase in the probability of alarms, while Route 1 and Route 9 will see a greater increase in alarms. For Route 1, the traffic vector is directed towards Mimas causing an increase in TCPA alarms. Route 9 was not assessed in the base case due to its location, which is sufficiently far away from the platforms. However, with the presence of the Hornsea Three array area, Route 9 traffic will be passing closer to both the Saturn and Tethys platforms causing an increase in probability for both TCPA and CPA alarms.

6.4.1.4 It should be noted that the modelling results have predicted shipping re-routes as a result of Hornsea Three in isolation. This situation is not considered likely to arise as the Hornsea Project One and Hornsea Project Two wind farms have been consented and construction will start on both projects prior to Hornsea Three. For this reason the cumulative assessment considered in section 6.5 is considered the likely scenario.

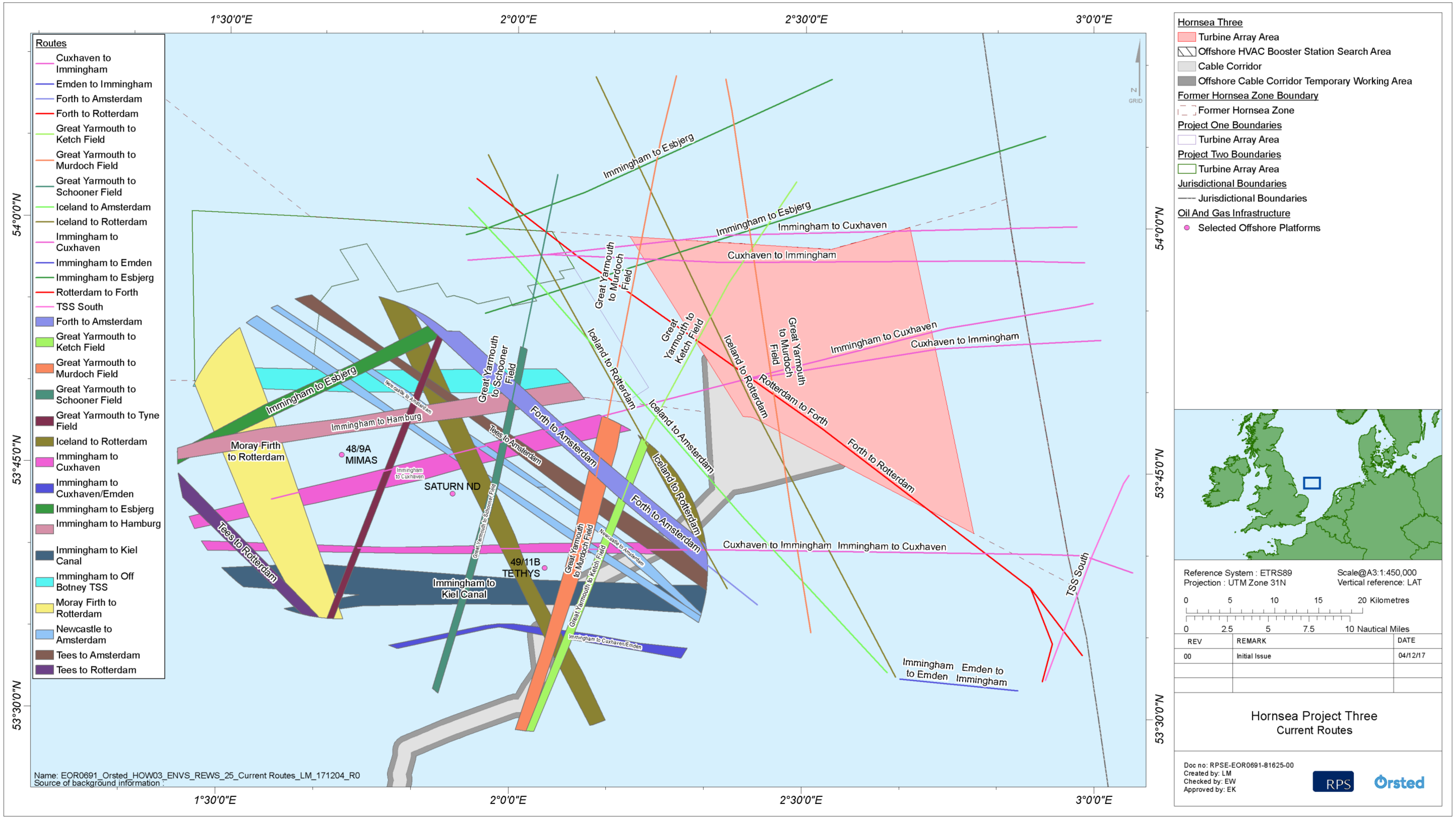

Figure 6.1: **Existing routes around the Mimas, Tethys and Saturn platforms.**

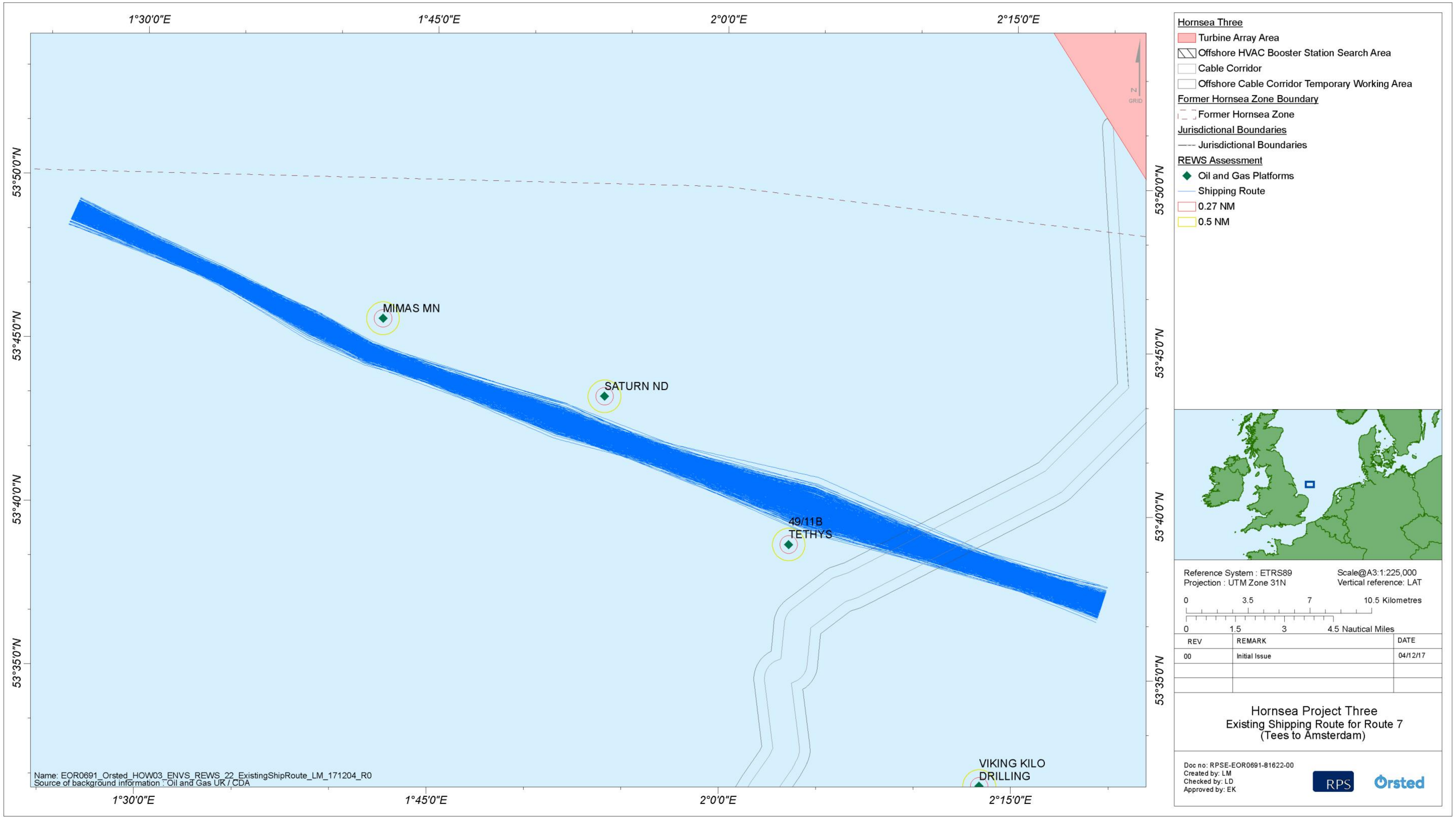

Figure 6.2: **Existing shipping route for Route 7 (Tees to Amsterdam).**

Table 6.1: Existing routes and alarm rates based on 1,000 runs in both the forwards and backwards direction.

Route number	Route name	Forward direction		Reverse direction		Frequency (vessels per day)
		Percentage of red alarms	Percentage of amber alarms	Percentage of red alarms	Percentage of amber alarms	
1	Immingham to Cuxhaven	0.4	15.6	2.4	12.8	2.5
2	Immingham to Cuxhaven	0.4	25.2	0.8	2.8	1.5
3	Newcastle to Amsterdam	12.2	37.8	82.8	99	1
4	Newcastle to Amsterdam	1.8	13	1.2	29	1
5	Moray Firth to Rotterdam	0	0	0	0	0.5
6	Immingham to Cuxhaven/Emden	0	0	0	0	0.5
7	Tees to Amsterdam	8	30.6	16.8	44.6	0.33
10	Immingham to Hamburg	7	23.4	0.6	6.6	0.5
11	Immingham to Off Botney TSS	0.2	0.6	0	2.4	0.5
12	Immingham to Kiel Canal	6.2	10.2	3.4	6.8	0.75
12	Immingham to Kiel Canal South	12.2	26	0	0	0.25
13	Great Yarmouth to Schooner Field	0.2	1.2	0	0	0.67
15	Great Yarmouth to Ketch Field	0	0	0	0	0.2
16	Great Yarmouth to Tyne Field	0	10.8	0	0	0.2
17	Forth to Amsterdam	21.8	58.8	39	79.2	1
19	Tees to Rotterdam	0	0	0	0	1

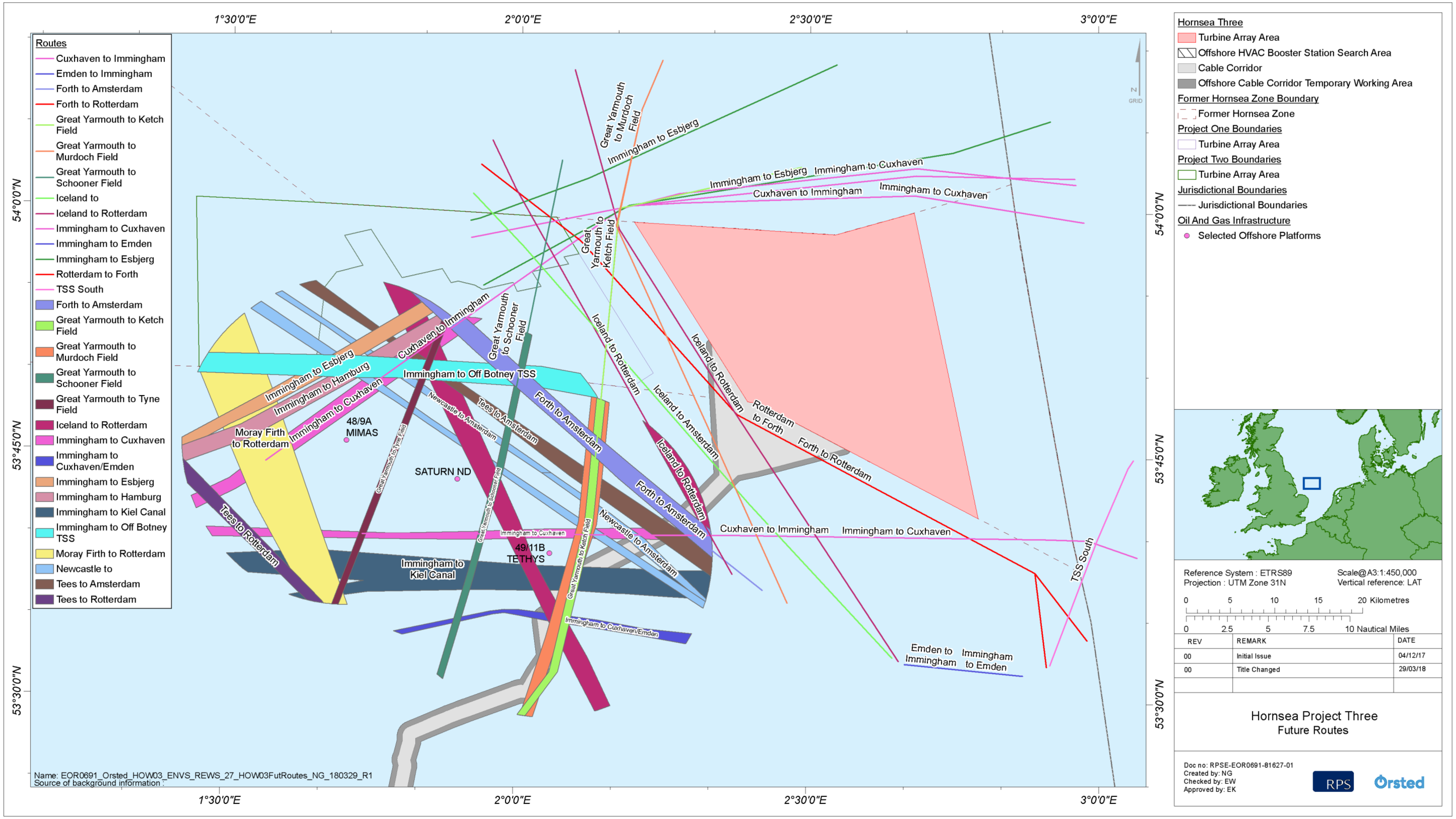

Figure 6.3 Predicted rerouted traffic around Hornsea Three in isolation.

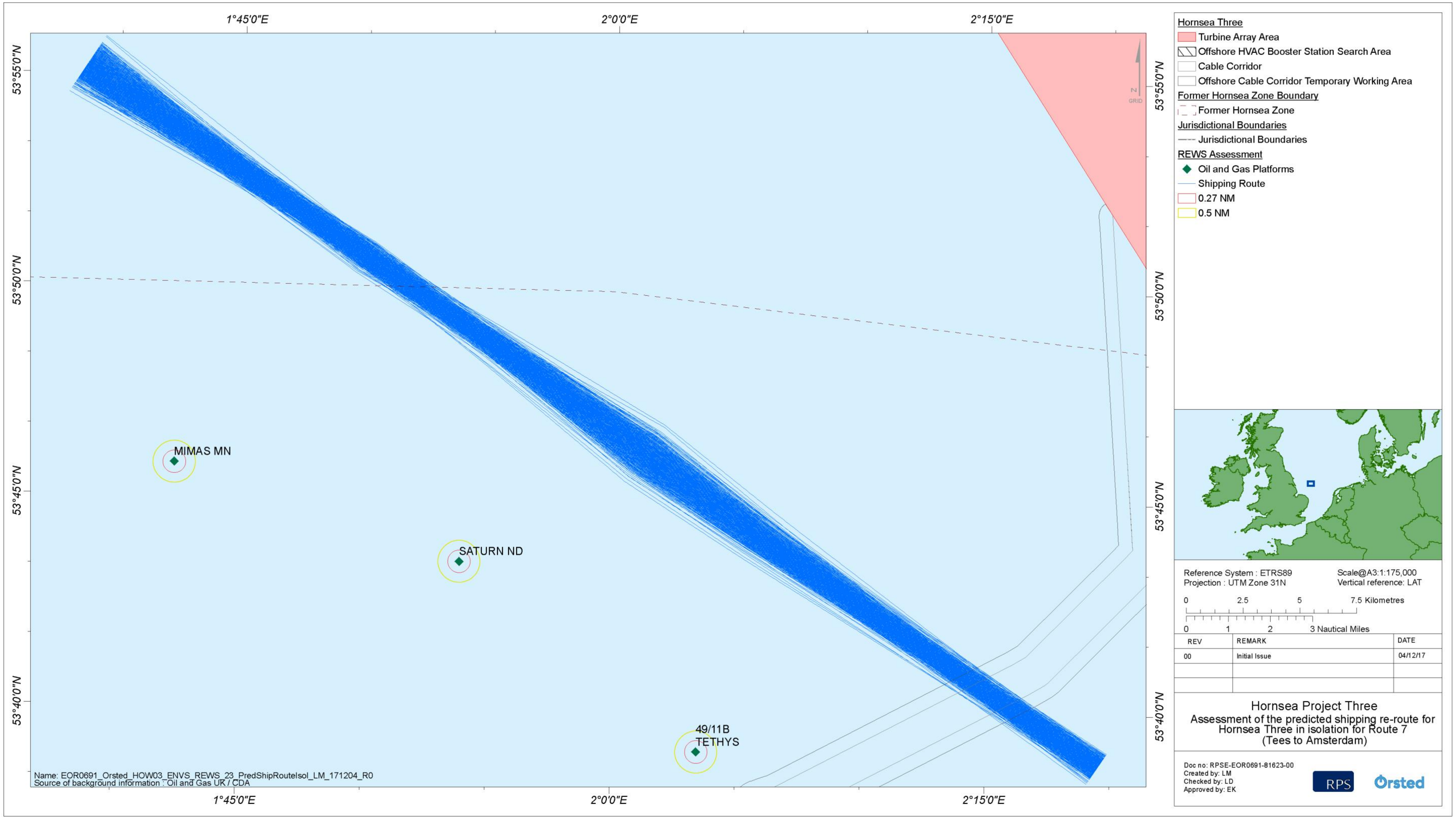

Figure 6.4: **Assessment of the predicted shipping re-route for Hornsea Three in isolation for Route 7 (Tees to Amsterdam).**

Table 6.2: Change in alarm rates for shipping re-routes around Hornsea Three in isolation. Red indicates an increase in the alarm rate while green indicates a reduction in the alarm rates.

Route number	Route name	Forward direction		Reverse direction		Forward direction		Reverse direction	
		Percentage change in red alarms	Percentage change in amber alarms	Percentage change in red alarms	Percentage change in amber alarms	Percentage of red alarms	Percentage of amber alarms	Percentage of red alarms	Percentage of amber alarms
1	Immingham to Cuxhaven	3.6	26.2	-2.4	-12.6	4	41.8	0	0.2
2	Immingham to Cuxhaven	0.2	-5.2	-0.2	0.4	0.6	20	0.6	3.2
3	Newcastle to Amsterdam	-12.2	-37.8	-82.8	-99	0	0	0	0
4	Newcastle to Amsterdam	-1.8	-13	-1.2	-29	0	0	0	0
5	Moray Firth to Rotterdam	1	2.6	0	0	1	2.6	0	0
6	Immingham to Cuxhaven/Emden	0	0	0	0	0	0	0	0
7	Tees to Amsterdam	-8	-29.6	-16.8	-44.6	0	0	0	0
8	Immingham to Esbjerg	0	0	0	0	0	0	0	0
9	Iceland to Rotterdam	19	47	7.4	27.2	19	47	7.4	27.2
10	Immingham to Hamburg	-6.8	-22.8	-0.6	-6.6	0.2	0.6	0	0
11	Immingham to Off Botney TSS	0	0	0	-2.4	0.2	0.6	0	0
12	Immingham to Kiel Canal	1.6	5.4	-0.8	0	7.8	15.6	2.6	6.8
12	Immingham to Kiel Canal North	3.4	7.2	0	0	3.4	7.2	0	0
12	Immingham to Kiel Canal South	2.6	3	0	0	14.8	29	0	0
13	Great Yarmouth to Schooner Field	0	0	0	0	0	0	0	0
14	Great Yarmouth to Murdoch Field	1.2	2.8	0	0	1.2	2.8	0	0
15	Great Yarmouth to Ketch Field	0	0	0	0	0	0	0	0
16	Great Yarmouth to Tyne Field	0	-10.8	0	0	0	0	0	0
17	Forth to Amsterdam	-21.8	-58.8	-39	-79.2	0	0	0	0
19	Tees to Rotterdam	0	0	0	0	0	0	0	0

6.5 Modelling results for predicted shipping re-routes around Hornsea Three alongside Hornsea Project One and Hornsea Project Two.

6.5.1.1 In a similar manner to the Hornsea Three scenario, the vessel traffic around Hornsea Three considered cumulatively with Hornsea Project One and Hornsea Project Two was modelled based on the predicted re-routes. The predicted re-routed traffic (specifically the route 90th percentile width) is shown in Figure 6.5. This data was then used to create 1,000 runs for each route for each direction (2,000 runs in total). Figure 6.6 shows the output of Route 7, as an example.

6.5.1.2 Table 6.3 presents the change in the probability of alarms against the base case. It can be noted that the changes in the alarm rates are all small. The overall total change in:

(a) Red alarms in the forward direction = 4.2%

(b) Amber alarms in the forward direction = 13.4%

(c) Red alarms in the reverse direction = -4.4%

(d) Amber alarms in the reverse direction = -5%

6.5.1.3 It is worth noting that since the routes are generated in a random manner (based on the mean and standard deviation of each route), the results of the statistical analysis may vary slightly depending on the normal distribution around the mean line of each route. Therefore, some of the small changes in the alarm rates observed in Table 6.3 (less than 5%) can be assumed to fall within the error margins of the predicted data and the statistical approach used within the models. Hence, in general, it can be assumed that the actual rerouting of traffic around the combined projects may result in a small (0% - 10%) overall change in the total alarm rates.

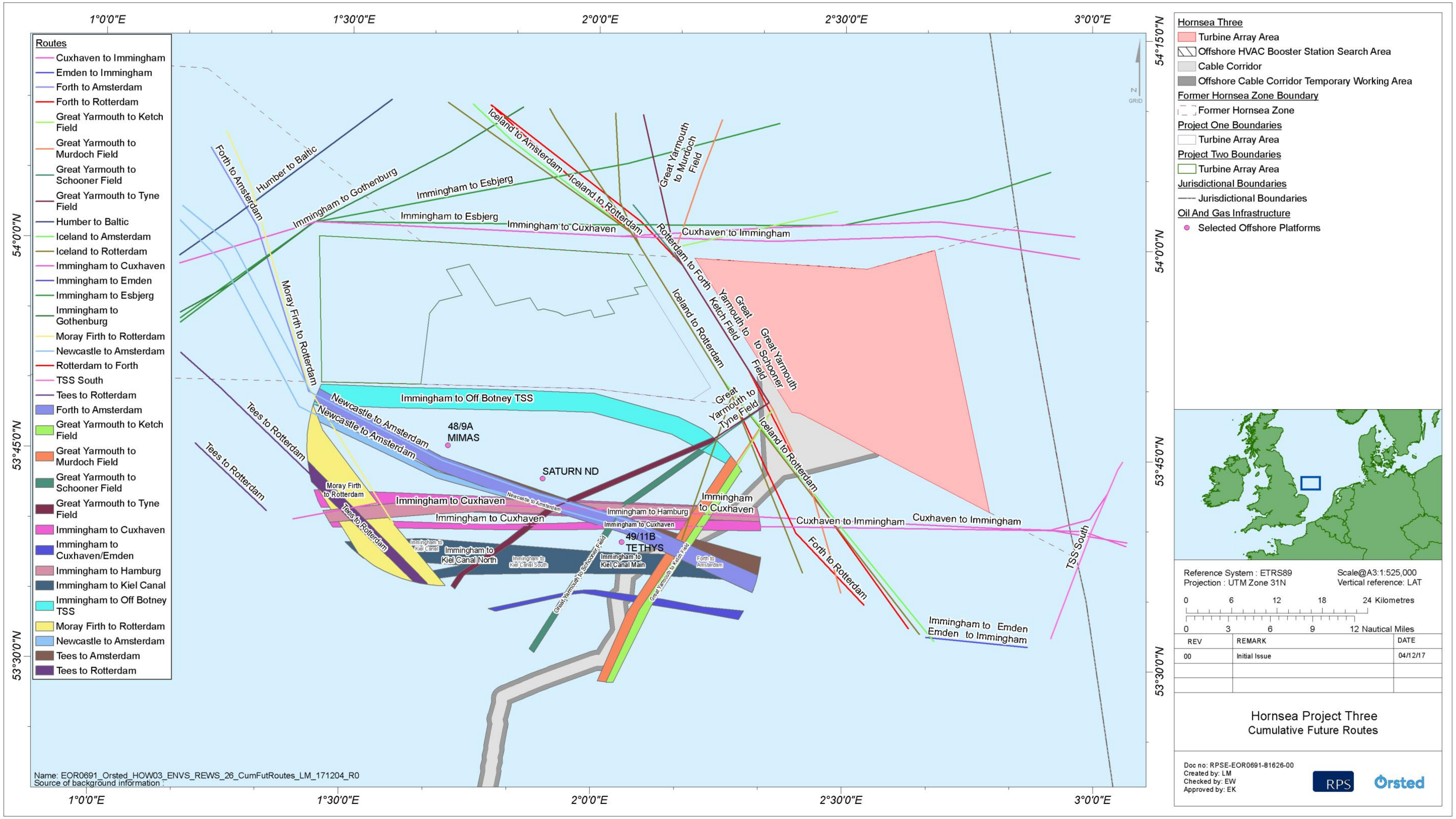

Figure 6.5: **Predicted shipping re-routes around Hornsea Three considered cumulatively with Hornsea Projects One and Hornsea Project Two.**

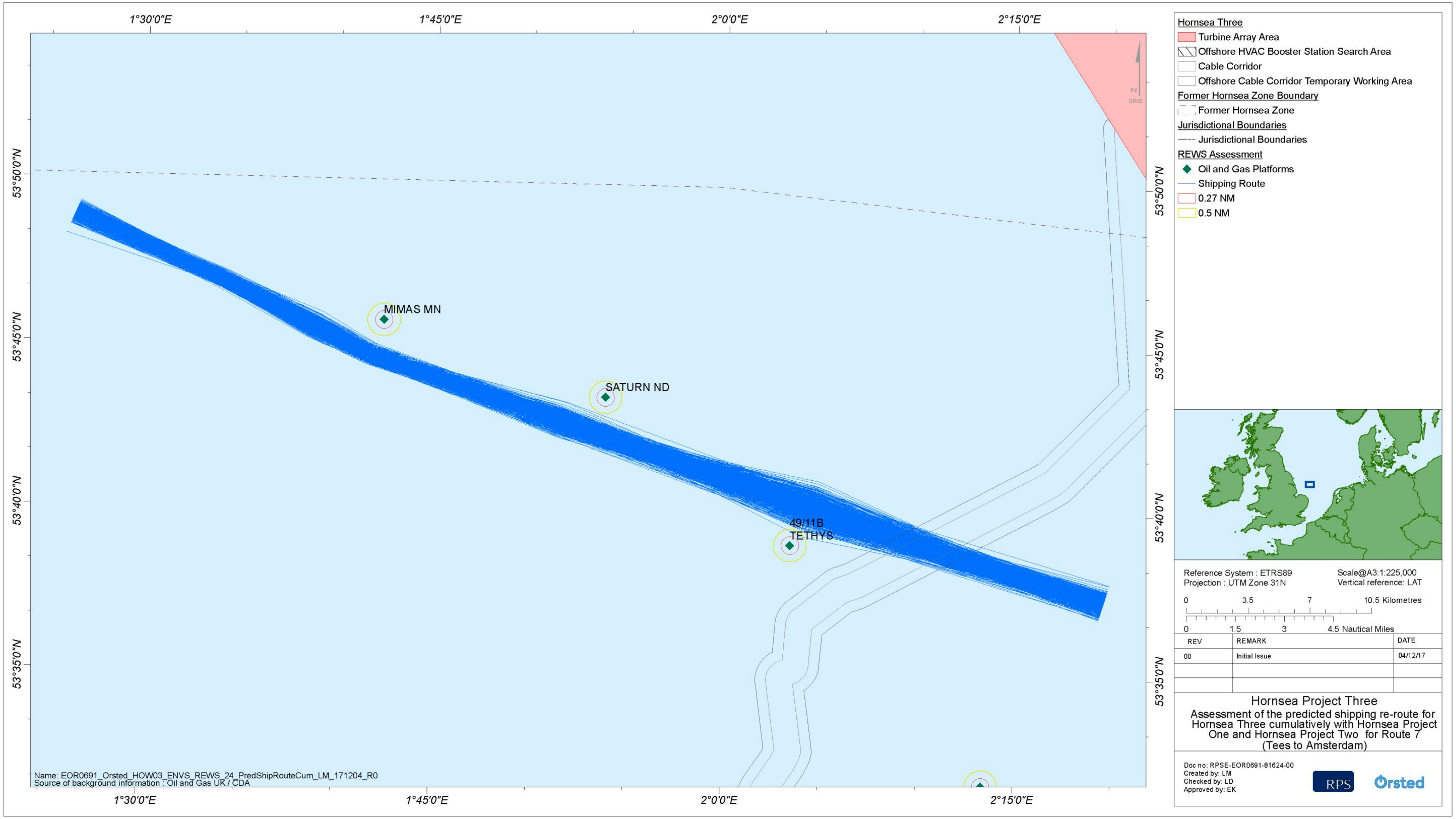

Figure 6.6: **Assessment of the predicted shipping re-route for Hornsea Three considered cumulatively with Hornsea Project One and Hornsea Project Two for Route 7 (Tees to Amsterdam).**

Table 6.3: Change in alarm rates for Hornsea Three cumulatively with Hornsea Project One and Hornsea Project Two. Red indicates an increase in the alarm rate while green indicates a reduction in the alarm rates.

Route number	Route name	Forward direction		Reverse direction		Forward direction		Reverse direction	
		Percentage change in red alarms	Percentage change in amber alarms	Percentage change in red alarms	Percentage change in amber alarms	Percentage of red alarms	Percentage of amber alarms	Percentage of red alarms	Percentage of amber alarms
1	Immingham to Cuxhaven	0.8	3.6	-0.6	-3.2	1.2	19.2	1.8	9.6
2	Immingham to Cuxhaven	-0.2	-3	0.2	1.2	0.2	22.2	1	4
3	Newcastle to Amsterdam	-1.8	3.2	-2.8	0.4	10.4	41	80	99.4
4	Newcastle to Amsterdam	0	-0.8	0.6	4.8	1.8	12.2	1.8	33.8
5	Moray Firth to Rotterdam	0	0	0	0	0	0	0	0
6	Immingham to Cuxhaven/Emden	0	0	0	0	0	0	0	0
7	Tees to Amsterdam	1.8	-1	-1.7	-1.5	9.8	28.6	14	42.6
10	Immingham to Hamburg	-1	-0.8	-0.4	-6	6	22.6	0.2	0.6
11	Immingham to Off Botney TSS	0.4	1	0	-0.8	0.6	1.6	0	1.6
12	Immingham to Kiel Canal	0.2	1.2	-1	-1	6.4	11.4	2.4	5.8
12	Immingham to Kiel Canal South	2.6	3.4	0	0	14.8	29.4	0	0
13	Great Yarmouth to Schooner Field	0.4	1.8	0	0	0.6	3	0	0
15	Great Yarmouth to Ketch Field	0	0	0	0	0	0	0	0
16	Great Yarmouth to Tyne Field	0	2.2	0	0	0	13	0	0
17	Forth to Amsterdam	1	2.6	2.4	1.6	22.8	61.4	41.4	80.8
19	Tees to Rotterdam	0	0	0	0	0	0	0	0

7. Summary and Conclusions

7.1 General REWS modelling remarks

7.1.1.1 This assessment was undertaken for the maximum design scenario based on the available project parameters. It considered a larger number of smaller turbines rather than a smaller number of large turbines. The presence of more turbines is expected to increase the effects on the REWS by adding more shadow regions and increasing the detection threshold around more turbines which will reduce the REWS's ability to detect and track targets within the affected area.

7.1.1.2 The RCS profile will depend on the size and the geometry of the turbines ultimately built within the Hornsea Three array area, along with other external factors such as blade bending and tower vibration.

7.1.1.3 Generic turbine geometries were modelled to provide the maximum design parameters for the largest number of turbines. Towers with monopile transition pieces were modelled which give high RCS. A larger transition piece will increase the static RCS of the turbine.

7.1.1.4 Optical shadowing was used to approximate the shadowing effects produced by the turbine towers. This assumes no diffraction around the tower and hence extended shadow lengths.

7.1.1.5 The shadows from the towers are assumed to generate detection nulls for point targets. The modelling results show that the width of the nulls varies between 4 and 15 m. For larger vessels over 1,000 GT, the dimensions of the vessel may exceed the width of the shadowing null. This can cause a portion of the radar signal to be reflected back to the radar. Depending on the levels of the reflected energy, it may be possible to detect the vessel while moving behind the turbines.

7.1.1.6 REWS often use proprietary thresholding algorithms which are dependent on the system configuration and the operating environment. Constant Averaging (CA) CFAR is applied over the clutter map to provide a constant 10^{-5} probability of false alarm. The CA-CFAR within this study uses two range cells on both sides of the cell under test as the guard region while the averaging considers six range cells on both sides of the guard region. In Azimuth the modelled CA-CFAR uses one guard cell and two averaging cells on both sides in azimuth.

7.1.1.7 The test vessel parameters were chosen based on the information provided by the REWS operators and comply with the IALA VTS modelling standards.

7.2 Spirit Energy J6A platform REWS assessment

7.2.1.1 Target spreading due to large turbine RCS occurs and may cause occasional masking of targets depending on the vessel size and path. The modelling indicates that sidelobe detection may not impact the overall performance of the REWS.

7.2.1.2 The radar is considered to be sufficiently far that the possibility of significant multiple reflections between turbines (only) is small, and therefore have not been modelled.

7.2.1.3 When a target is very close to the turbines (less than 1.5 km) it is possible that multiple reflections between the target and the turbine can occur which could generate false detections. However as this is normally considered a second order effect it has not at this stage been computed. Such effects can be included in the simulations as a standard feature, but add significantly to the modelling run time.

7.2.1.4 When considering the maximum design scenario with 342 turbines, Hornsea Three may introduce up to 361 new target detections on the REWS which might be added to the track table.

7.2.1.5 The high returns from the turbines and the offshore wind farm platforms will raise the detection threshold over multiple cells around each turbine/platform. This will cause returns from smaller targets to fall under the detection threshold and therefore lose detection while travelling within some parts of the Hornsea Three array area.

7.2.1.6 Shadowing generated from the turbines and substations may add to the loss of detection caused by the elevated threshold within the Hornsea Three array area.

7.2.1.7 Given the close proximity of Hornsea Three to Spirit Energy's Markham complex platforms, the performance of the REWS on the J6A platform is likely to be impacted negatively by the presence of the Hornsea Three turbines. The raised detection threshold and the shadowing from the turbines will impact the REWS's ability to detect and track targets within the Hornsea Three wind farm. This may reduce the REWS's efficiency in issuing TCPA alarms in a timely manner as vessels exit the Hornsea Wind farm from the eastern edge towards the Spirit Energy platforms.

7.2.1.8 It is expected that there will be no further adverse effects on target detection when considering the effects from Hornsea Project One and Hornsea Project Two in combination with Hornsea Three.

7.2.1.9 As noted in section 4 above, mitigation measures shall be put in place to reduce the effect of Hornsea Three on the REWS on the J6A platform. The mitigation measures will be based on the mitigation measures identified for Hornsea Project Two for the Saturn platform and developed in consultation with Spirit Energy.

7.3 ConocoPhillips Saturn platform REWS assessment

7.3.1.1 In general, the boundary of the Hornsea Three array area falls beyond the critical range of the REWS on the Saturn platform (approximately 32 km to the closest Hornsea Three turbine). However, when considering the case whereby 342 turbines are deployed (which it should be noted has now been reduced to 300 turbines), Hornsea Three could introduce 361 new target detections to be added to the track table depending on the setting of the REWS. The operator may choose to limit the maximum range of the REWS to reduce the number of added detections.

7.3.1.2 Overall, aside from the increase of the size of the track table due to the detection of the Hornsea Three turbines, the outcome of the REWS assessment on the ConocoPhillips platforms has shown that Hornsea Three is located at the edge of the radar detection range and will introduce no additional effects that require mitigation measures.

7.3.1.3 The REWS will still be able to detect vessels travelling along the corridor formed between Hornsea Three, and Hornsea Project One and Hornsea Project Two. However, this is subject to detailed analysis of the vessel sizes and routes along with the analysis of the shadows generated from Hornsea Project One and Hornsea Project Two. The detection within the corridor is mainly affected by Hornsea Project One and Hornsea Project Two while Hornsea Three is considered too far to negatively affect the vessel detection.

7.3.1.4 When assessing the cumulative impact of Hornsea Three along with Hornsea Project One and Hornsea Project Two, it becomes clear that (with the utilised thresholding algorithm) the detection of vessels within the combined wind farm is likely to be impacted negatively causing target loss mainly within the Hornsea Project One and Hornsea Project Two wind farms. This is mainly caused by Hornsea Project One and Hornsea Project Two turbines and is not affected by the presence of Hornsea Three turbines.

7.3.1.5 Importantly, and as noted in section 5, it is a condition of the Hornsea Project Two DCO to mitigate any adverse impacts from Hornsea Project Two on the Saturn REWS to ensure the safety of the Saturn, Mimas and Tethys platforms. Schedule 1, Part 3, requirement 25 of the Hornsea Project Two DCO requires that construction of any Hornsea Project Two wind turbine may not commence until the Secretary of State, having consulted with ConocoPhillips, is satisfied that appropriate mitigation will be implemented and maintained for the life of Hornsea Project Two. There is very little effect on the REWS located on the Saturn platform from the Hornsea Three turbines due to their distance from the platform. As such, the mitigation measures described for Hornsea Project Two shall reduce the potential for any cumulative effect to arise with Hornsea Three on the ConocoPhillips operated REWS located on the Saturn platform.

7.4 General CPA/TCPA modelling remarks

7.4.1.1 The shipping routes and re-routes were modelled based on the available data provided by Anatec, which included measured radar and AIS data for the base case and predicted data for future re-routes around Hornsea Three in isolation and around Hornsea Three considered cumulatively with Hornsea Project One and Hornsea Project Two. The data included route widths based on their 90^{th} percentiles. This was then used to derive the mean central line and the standard deviation values along each assessed route and re-route.

7.4.1.2 The modelled routes and re-routes were chosen based on their close proximity to the Mimas, Saturn and Tethys platforms (for CPA alarms assessment) and their general heading vectors (for TCPA alarms assessment). No other platforms in the area were assessed as the re-routed traffic is expected to move further away from such platforms and are expected to see no change to their alarm rates.

7.4.1.3 Once Hornsea Three is constructed, some routes might be pushed further away from the assessed platforms while others might result in closer proximity to the platforms. Therefore, when assessing Hornsea Three in isolation, additional routes were modelled (Routes: 8, 9, 12 north and 14) as they were expected to contribute to the alarm rates.

7.4.1.4 One thousand vessel paths were generated along each route in both the forward and reverse directions (a total of 2,000 runs per route). This was used to estimate the probability of raising a TCPA and/or CPA alarm for each route. The number of actual alarms per day was dependant upon the frequency of vessels travelling along each route.

7.4.1.5 The models were set to only issue a TCPA alarm if the vessel continues to breach the TCPA rules for more than 10 radar rotations. This was implemented to avoid false alarms due to temporary vector breach of the TCPA while vessels are turning. This is considered a typical figure for REWS; however, different REWS configurations may have different settings which may alter the alarm probabilities slightly.

7.5 REWS TCPA/CPA Alarm modelling (Saturn, Mimas and Tethys platforms)

7.5.1.1 The modelling indicates that the overall (total) number of TCPA/CPA alarms will experience a decrease when Hornsea Three is introduced in isolation. When Hornsea Three was assessed cumulatively with Hornsea Project One and Hornsea Project Two, a slight increase in alarms is predicted (0% to 10%).

7.6 Further considerations

7.6.1.1 The variation of returns in range cells due to rotation of the blades may cause the tracker to initiate false tracks. In order for the false track to raise a TCPA alarm the generated track needs to maintain its vector for a set number of radar rotations (typically10). This is deemed to be unlikely; however, the effect of this cannot be quantified due to not having access to the supplier's proprietary algorithms used within the system.

7.6.1.2 The introduction of turbines to the radar coverage area will increase the number of target detections. Depending on the tracker configuration, turbine detections may be included in the track-table. The track-table is transmitted to ERRV's via a low bandwidth UHF telemetry link. When using non-acquire zones, configuration of the tracker to include only moving targets in the track-table should be considered to reduce the load on the UHF links.

7.6.1.3 The REWS uses a tracking algorithm to predict the vessels movement and compensate for momentary loss of detection. Such tracking algorithms are proprietary to the manufacturer. In general such tracking may allow improved performance in the Hornsea Three array area vicinity to compensate for temporary losses due to raised threshold levels or shadowing effects. However, typically a track will be established within 10 rotations of the radar antenna (for antenna with 24 RPM, this is equivalent to 12.5 seconds).

7.6.1.4 Large (time varying) returns from turbines might cause the processed tracks from vessels to be seduced into the large turbine returns causing errors in tracking. This will be corrected after a number of radar rotations and the correct track will be resolved eventually. However, this is dependent on the tracking algorithm and post signal processing, which may be mitigated through the use of narrow non-acquire zones around each turbine.

7.6.1.5 Improvements to the CFAR performance might be achieved by using more sophisticated CFAR algorithms with different weighting on the averaging cells in order to improve the radar performance within the wind farm. Also, modification to the way that the CFAR calculations compute the threshold average over the wind farm might be modified to minimise the blind regions as mentioned within the Ultra ESS measurements report (Greenwell, 2016).

7.6.1.6 In the event mitigation is required on the REWS there are various options available, including those outlined in paragraphs 7.6.1.4 to 7.6.1.5 above. The implementation of any mitigation measures through software modifications is highly dependent on the REWS supplier's/operator's setup and a separate study might be needed to establish if such mitigation measures are possible and to meet the platform operator's requirements and safety standards.

7.6.1.7 When considering the re-routing of traffic around the proposed Hornsea Three boundaries, the three affected ConocoPhillips platforms are at the extremity of (North) quad 49 (approx. 20 miles from LOGGS and Viking) where the ERRV is positioned. Therefore a reduction in the passing distance of rerouted vessels reduces the response time for the ERRV, which may already be considered to be operating at its limit given its proximity to the affected platforms. However, the re-routing data and the modelling results indicate that there are no notable reductions in the passing distance and no significant increase in the alarm rates. Further consideration of the impact of Hornsea Three on ERRVs is considered within volume 5, annex 9.1: Navigational Risk Assessment.

8. References

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