MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Environmental Statement

Volume 4, Annex 14.1: Airborne construction sound technical report

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Glossary

Term	Meaning
A-weighting	A frequency weighting devised to attempt to account for the fact that human response to sound is not equally sensitive to all frequencies. It consists of an electronic filter in a sound level meter which attempts to build this variability into the indicative sound level reading so that it will correlate, approximately, with the human response.
Airborne Sound	Sound waves which propagate through the air.
Ambient Sound Level, $L_{Aeq,T}$	The steady sound level which, over a period of time T, contains the same amount of A-weighted sound energy as the time varying sound over the same period. Also known as the equivalent continuous sound pressure level.
Attenuation	The reduction in magnitude of sound energy.
Decibel (dB)	A unit used to measure or compare the intensity of a sound by comparing it with a given reference level on a logarithmic scale.
Extrapolation	The extension of a graph, curve, or range of values by inferring unknown values from trends in the known data.
Fast Fourier Transform	A computational algorithm which allows for the conversion of a time signal to a representation in the frequency domain.
Finite Difference Method	A method for converting partial differential equations into a system of linear equations that can be solved using linear algebra techniques.
Geometric Divergence	The loss of energy from a wavefront as a consequence of geometrical spreading, observable as a decrease in wave amplitude. Spherical divergence decreases energy with the square of the distance. Cylindrical divergence decreases energy with the distance.
Ground Factor, *G*	A dimensionless parameter which allows for the consideration of the acoustic properties of the ground surface between a sound source and the receptor.
Helmholtz Wave Equation	A time-independent version of the wave equation which allows for the means of mathematically describing the propagation of waves (including travelling and standing waves).
Noise	An unwanted or unexpected sound.
Numerical Modelling	A modelling technique that uses iterative time-stepping techniques to provide approximate solutions to complex physical problems.
Parabolic Equation Method	A method which efficiently describes diffraction and forward-scattering processes in inhomogeneous terrains.
Partial Differential Equation	An equation containing an unknown function of two or more variables and its partial derivatives with respect to these variables.
Propagation	The transmission of acoustic energy through a medium via a sound wave.
Radial Velocity	The velocity of an object along the line of sight from the observer to the object.
Reflection	The phenomena of sound waves bouncing back off a surface or barrier.
Refraction (Atmospheric)	The deviation of a sound wave from a straight line as it passes through the atmosphere due to the variation in air density as a function of height.
Sound	Fluctuations of pressure within a medium (gas, solid or fluid) within the audible range of loudness and frequencies which excite the sensation of hearing.

Term	Meaning
Sound Power Level, L_w	The total sound energy emitted by a source per unit time.
Sound Pressure Level, L_p	The amount of force a sound wave exerts on a surface area perpendicular to the direction of travel. A measure of the variation of sound level over a distance.
Spectrum	The presentation of sound in terms of the amount of energy at different frequencies.
Surface Impedance	The opposition of a medium to wave propagation.
Transmission Loss	A measure of the reduction in sound level of a sound source as it propagates through a medium.
Wavenumber	The number of sound waves in a unit distance.

Acronyms

Acronym	Description
BPM	Best Practicable Means
BS	British Standard
CEA	Cumulative Effect Assessment
CNPE	Crank-Nicholson Parabolic Equation
EIA	Environmental Impact Assessment
FFT	Fast Fourier Transform
IoA	Institute of Acoustics
LOAEL	Lowest Observed Adverse Effect Level
MDS	Maximum Design Scenario
NOEL	No Observed Effect Level
NPSE	Noise Policy Statement for England
NPPF	National Planning Policy Framework
PPG	Planning Practice Guidance
SOAEL	Significant Observed Adverse Effect Level

Units

Unit	Description
°	Degrees (Angular)
°C	Degrees Centigrade
dB	Decibel
Hz	Hertz
kHz	Kilohertz

Unit	Description
kJ	Kilojoules
km	Kilometres
m	Metres
mins	Minutes
%	Percentage

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1 Airborne construction sound technical report

1.1 Introduction

1.1.1.1 This airborne construction sound technical report provides the methodology and results of numerical modelling undertaken to assess the noise impacts at onshore receptors due to the construction of the Morgan Offshore Wind Project: Generation Assets (hereafter referred to as the 'Morgan Generation Assets').

1.1.1.2 The airborne construction sound study area has been reduced from that presented in the Morgan Offshore Wind Project Environmental Impact Assessment Scoping Report, (2022) from noise-sensitive receptors located within 50 km of the Morgan Array Area to 20 km where construction piling is required.

1.1.1.3 The above study area is presented graphically in Figure 1.1 below. The Morgan Generation Assets are situated approximately:

- 22.22 km from the east coast of the Isle of Man;
- 37.13 km from the north-west coast of England; and
- 58.5 km from the north coast of Wales.

1.1.1.4 This reduction in the airborne construction sound study area is based on noise impact assessment works for other offshore projects following the submission of the Environmental Impact Assessment (EIA) Scoping Report. Additional details are provided in section 1.2.

1.1.1.5 A bespoke long-range propagation model has been developed which incorporates the meteorological conditions, surface impedance and roughness, sound speed profile and atmospheric turbulence into the calculations.

1.1.1.6 Details of this refinement are provided in this technical report along with the modelling works undertaken to show the sound levels predicted within the airborne construction sound study area due to offshore piling activities.

1.2 Study Area Refinement

1.2.1.1 The study area for airborne construction sound proposed in the EIA Scoping Report included noise sensitive receptors within 50 km of the Morgan Array Area. The justification for such a large study area primarily relates to the nature of sound propagation over water.

1.2.1.2 The speed of sound is dependent upon the temperature of the medium through which it travels. In air at a temperature of 20°C, the speed of sound is 343 m/s. However, this value varies by approximately 3 m/s for every degree centigrade. The air above a body of water is slightly lower in temperature than the air higher above the water surface. As such, the temperature gradient dictates the speed at which sound travels. Sound waves further above the water surface will travel faster than those below them due to the increase in temperature. This temperature gradient results in the bending of sound waves downwards towards the receptor and can result in a slower rate of decay in the energy of the sound wave. Downward refraction can result sound propagating further over water than on land since less energy is lost as the sound wave propagate towards a receptor.

1.2.1.3 Since the submission of the EIA Scoping Report, the assessment of noise impacts due to offshore piling activities has been undertaken for similar projects such as:

- Mona Offshore Wind Project; and
- Morgan and Morecambe Offshore Wind Farms: Transmission Assets

1.2.1.4 A similar study area was proposed for both assessments at Preliminary Environmental Assessment Report (PEIR) stage. The noise and vibration assessment work for these projects was undertaken based upon the maximum design scenario at PEIR which was represented by monopiling of the foundations for the wind turbines and Offshore Substation Platforms (OSPs) using an impact hammer with a hammer energy of 5,500 kJ/cycle. A hammer energy of this magnitude demanded careful consideration of the potential airborne noise impacts to onshore receptors due to the abnormally high sound emission levels.

1.2.1.5 It should be noted that monopiling of the foundations for the Morgan Generation Assets (and Mona Offshore Wind Project Application) has been removed from the project design envelope following consultation. The maximum hammer energies proposed for the piling activities required for the Morgan Generation Assets are 4,400 kJ/cycle which are well below those assessed historically.

1.2.1.6 Typically, the sound power level associated with a given hammer energy may be scaled upwards or downwards to estimate the sound power level of the impact hammer to be used for piling activities. However, given the large hammer energies and pile diameters proposed, this method would result in a high degree of uncertainty in the estimated sound power levels. As such, numerical modelling was commissioned by Seiche Ltd. as part of Volume 4, Annex 3.1: Underwater sound technical report of the Environmental Statement for the above projects and the results were used to produce a more accurate estimation of the sound power level (see section 1.7.4 of this technical report for full details of the methodology).

1.2.1.7 The same numerical model outlined in section 1.7 was used to predict the potential noise impacts from offshore piling activities at onshore receptors. The results showed that even with a hammer energy of 5,550 kJ/cycle, no high or medium noise impacts were predicted at distances beyond 10 km.

1.2.1.8 The numerical model has since been refined to increase computational efficiency and improve the accuracy of the results produced. The primary modification involves the modelling of the sea surface via the surface impedance parameters.

1.2.1.9 The validity of the numerical model has been tested against measured data obtained as part of a sound survey undertaken for the Rampion Offshore Wind Farm in September 2016 (Anderson Acoustics, 2021). The results of the survey predict a sound level of 85 dB(A) at 65 m from the piling activities assuming a sound power level for the impact hammer of 129 dB(A).

1.2.1.10 The numerical model developed predicts a level of between 84-86 dB(A) depending upon the duration of the piling activities. This range is within ±1 dB of the measured levels and suggests good agreement with the measured data. Exact agreement cannot be expected since it is not known what the meteorological conditions were during the survey period.

1.2.1.11 Based on the above, the study area of 50 km has been shown to be excessive for the purpose of predicting onshore noise impacts due to offshore construction activities. Such a study area results in unnecessarily computationally expensive calculations and the sound levels at this distance are highly unlikely to result in any significant environmental effects.

1.2.1.12 As such, a conservative yet robust study area of 20 km has been proposed for the assessment or airborne construction noise impacts due to offshore piling activities.

This study area is shown in Figure 1.1 below and does not include any onshore receptors. However, an assessment of the proposed piling activities has been undertaken to demonstrate via prediction and calculation that no significant airborne sound effects are likely due to the construction of the Morgan Generation Assets.

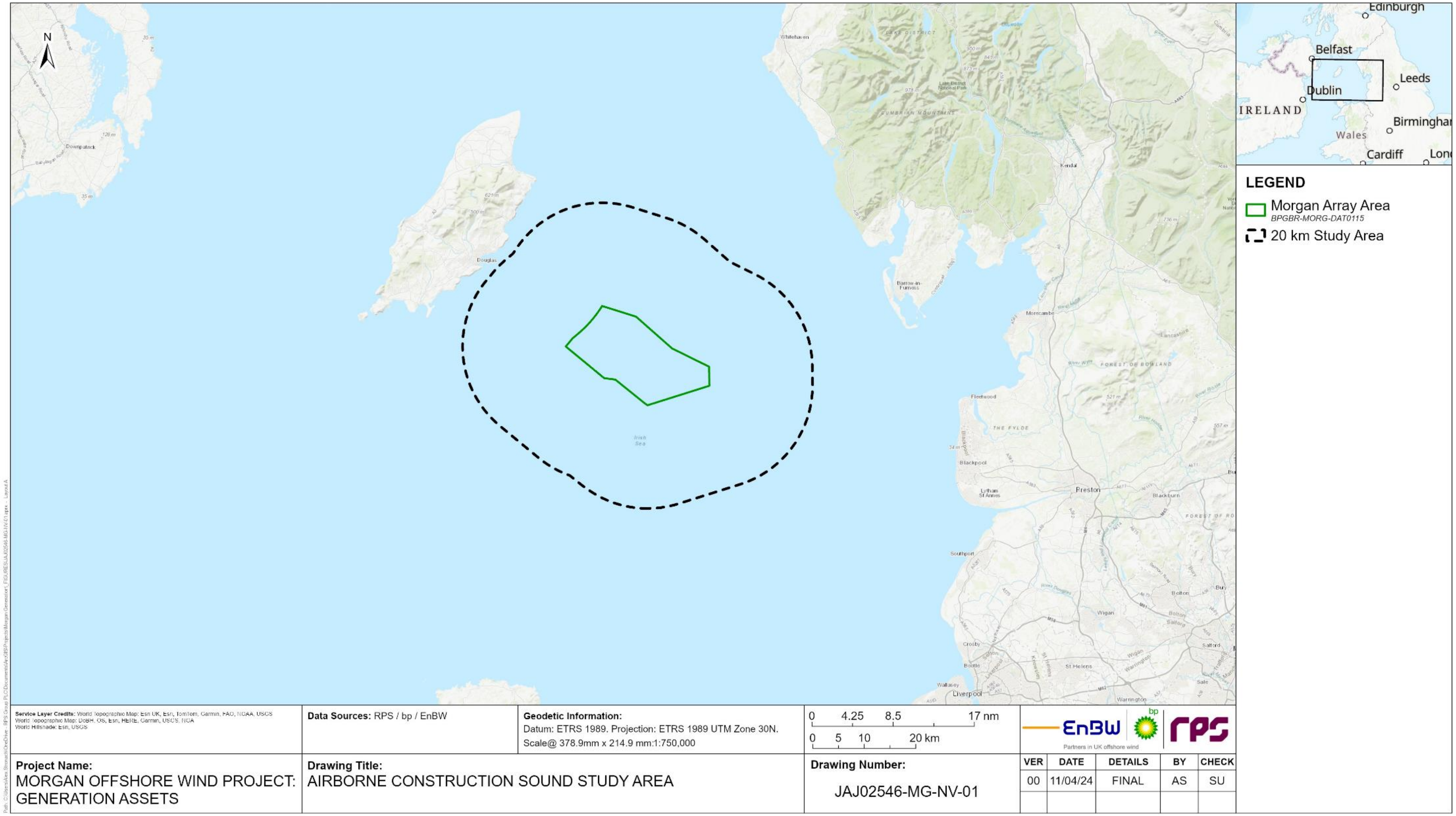

Figure 1.1: Airborne construction sound study area.

1.3 Consultation

1.3.1.1 A summary of the key issues raised during consultation activities undertaken to date specific to airborne sound is presented in Table 1.1.

Table 1.1: Summary of key consultation topics raised during consultation activities undertaken for the Morgan Generation Assets relevant to airborne sound and vibration.

Date	Consultee and type of response	Topics raised	Response to topic raised and/or where considered in this technical report
July 2022	The Planning Inspectorate – Scoping Opinion	Table 6.16 of the EIA Scoping Report contained proposals to scope out noise and vibration impacts during the operation phase of the Morgan Offshore Wind Project. The Planning Inspectorate agreed that significant effects are unlikely due to the large propagation distance and the character of the noise and vibration emissions emitted. As such, the Inspectorate agreed this matter may be scoped out of the Environmental Statement.	Impacts due to operational noise and vibration has been scoped out of the assessment.
July 2022	The Planning Inspectorate – Scoping Opinion	Paragraph 6.5.10.1 and Annex A of the EIA Scoping Report outlined that no transboundary impacts due to the Morgan Offshore Wind Project generation assets have been identified during the screening exercise and thus are proposed to be scoped out of the Environmental Statement. The Inspectorate agreed that significant onshore transboundary effects from noise and vibration are unlikely and can be scoped out of the Environmental Statement.	Transboundary impacts have been scoped out of the assessment.
July 2022	The Planning Inspectorate – Scoping Opinion	Table 6.15 of the EIA Scoping Report contained proposals to scope in the assessment of noise impacts during the construction and decommissioning phases of the Morgan Offshore Wind Project. This is due to the potential for the long-range propagation of the low frequency noise emitted during the construction of the Morgan Generation Assets involving piling methods. The Planning Inspectorate noted that section 6.5.5 of the Scoping Report stated the potential for a range of potential impacts, including during the operation phase of the Morgan Offshore Wind Project. The Inspectorate request that the Environmental Statement should capture all potential sources of noise and vibration considered within the assessment of significant effects, as well as a detailed characterisation of all operational noise impacts.	The only potential sources of noise which have the potential to give rise to significant effects are those associates with the piling methods required for the installation of the foundations for the Morgan Generation Assets. As stated above, the Planning Inspectorate agreed that significant effects during the operational phase of the Morgan Generation Assets are unlikely and thus can be scoped out of the Environmental Statement. All potential sources of noise are captured within the assessment of construction noise impacts and are detailed in section 1.7.4 of this technical report.

Date	Consultee and type of response	Topics raised	Response to topic raised and/or where considered in this technical report
July 2022	The Planning Inspectorate – Scoping Opinion	The Planning Inspectorate noted that whilst the contribution of operational effects to the cumulative effects is not likely to be significant, the EIA Scoping Report does explicitly propose to scope them out of the cumulative assessment. As such, the Inspectorate requests that the Environmental Statement set out the activities included within the cumulative assessment or excluded, providing clear reasoning for the decisions made.	Cumulative effects due to airborne construction noise are unlikely due to the large propagation distances to onshore receptors. An assessment of the cumulative effects is presented in Volume 2, Chapter 14: Human health of the Environmental Statement.

1.4 National Planning Policy

1.4.1.1 A summary of the relevant national planning guidance for noise is provided below.

1.4.1 The National Planning Policy Framework

1.4.1.1 The National Planning Policy Framework (NPPF) was published in 2012 and updated in 2023 (Department for Levelling Up, Housing and Communities, 2023). The NPPF sets out the Government's planning policies for England.

1.4.1.2 The NPPF does not contain any specific policy or criteria relating to noise and vibration. Instead, it provides a framework for local authorities to produce local and neighbourhood plans to reflect the needs and priorities of communities within their jurisdiction.

1.4.1.3 Paragraph 180(e) of the NPPF states the following:

'Planning policies and decisions should contribute to and enhance the natural and local environment by:

[…]

e) preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability.'

1.4.1.4 Paragraph 191 of Section 15 of the NPPF states the following:

'Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In doing so they should:

a) mitigate and reduce to a minimum potential adverse impacts resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and the quality of life[65];

b) identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason; and

c) limit the impact of light pollution from artificial light on local amenity, intrinsically dark landscapes and nature conservation.

[65] See Explanatory Note to the Noise Policy Statement for England (Department for Environment, Food & Rural Affairs, 2010).'

1.4.2 Planning Practice Guidance – Noise

1.4.2.1 The Planning Practice Guidance (PPG) (Department for Levelling Up, Housing and Communities and Ministry of Housing, Communities and Local Government, 2019) supports the NPPF and provides guidance across a range of topic areas.

1.4.2.2 The noise section of the PPG provides outline guidance and refers to general guidance on noise policy and assessment methodology detailed in the NPPF, the Noise Policy Statement for England (NPSE) and British Standards. The NPSE sets out noise management policy in the form of the Government's long-term vision to manage noise and improve health and quality of life.

1.4.2.3 The following guidance is presented within the PPG on how noise impacts may be determined:

"Plan-making and decision making need to take account of the acoustic environment and in doing so consider:

whether or not a significant adverse effect is occurring or likely to occur;

whether or not an adverse effect is occurring or likely to occur; and

whether or not a standard of amenity can be achieved."

1.4.2.4 A noise exposure hierarchy is provided as supplementary guidance in tabular form and is recreated in Table 1.2 below. The guidance outlines the need to avoid and prevent the occurrence of significant adverse effects due to noise.

Table 1.2: Summary of noise exposure hierarchy from NPSE and PPG.

Response	Examples of outcomes	Increasing effect level	Action
No Observed Effect Level (NOEL)			
Not present	No effect.	No Observed Effect.	No specific measures required.
No Observed Adverse Effect Level (NOAEL)			
Present and not intrusive	Noise can be heard but does not cause any change in behaviour, attitude, or other physiological response. Can slightly affect the acoustic character of the area but not such that there is a change in the quality of life.	No Observed Adverse Effect.	No specific measures required.
Lowest Observed Adverse Effect Level (LOAEL)			
Present and intrusive	Noise can be heard and causes small changes in behaviour, attitude or other physiological response (e.g. turning up volume of television, speaking more loudly, where there is no alternative ventilation and having to close windows for some of the time because of the noise). Potential for some reported sleep disturbance. Affects the acoustic character of the area such that there is a small actual or perceived change in the quality of life.	Observed Adverse Effect.	Mitigate and reduce to a minimum.
Significant Observed Adverse Effect Level (SOAEL)			

Response	Examples of outcomes	Increasing effect level	Action
Present and disruptive	The noise causes a material change in behaviour, attitude or other physiological response (e.g. avoiding certain activities during periods of intrusion, where there is no alternative ventilation and having to keep windows closed most of the time because of the noise). Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in acoustic character of the area.	Significant Observed Adverse Effect.	Avoid.
Present and very disruptive	Extensive and regular changes in behaviour, attitude or other physiological response and/or an inability to mitigate effect of noise leading to psychological stress (e.g. regular sleep deprivation/awakening, loss of appetite, significant, medically definable harm e.g. auditory and non-auditory).	Unacceptable Adverse Effect.	Prevent.

1.5 Guidance

1.5.1.1 This section contains a summary of the relevant guidance for construction noise and vibration control.

1.5.2 British Standard 5228

1.5.2.1 British Standard (BS) comprises two parts:

- BS 5228-1:2009+A1:2014 – '*Code of practice for noise and vibration control on construction and open sites*' – Part 1: Noise
- BS 5228-2:2009+A1:2014 – '*Code of practice for noise and vibration control on construction and open sites*' – Part 2: Vibration.

1.5.2.2 The Standard provides guidance, information, and procedures for the control of noise and vibration from demolition and construction sites. BS 5228-1:2009+A1:2014 and BS 5228-2:2009+A1:2014 gained approval as guidance on appropriate methods for minimising noise from construction and open sites under the relevant sections of the CoPA 1974.

1.5.2.3 There are no set standards for the definition of the significance of construction noise effects. However, noise example criteria are provided in BS 5228-1:2009+A1:2014 Annex E.

1.5.2.4 BS 5228-1:2009+A1:2014 provides basic information and recommendations for methods of noise control relating to construction and open sites where work activities/operations generate significant noise levels. It includes sections on:

- Community relations
- Noise and persons on site
- Neighbourhood nuisance
- Project supervision
- The control of noise.

1.5.2.5 It is noted that the noise control methods outlined in BS 5228-1:2009+A1:2014 are not all applicable to offshore construction works. As such, reference to this guidance is included only for the derivation of appropriate noise impact magnitude criteria against which the offshore construction works may be assessed. The noise impact magnitude criteria are defined in section 1.6 below.

1.5.3 Institute of Acoustics (IoA) – A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise – Supplementary Guidance Note 6: Noise Propagation Over Water for On-Shore Wind Turbines

1.5.3.1 ETSU-R-97 (Department of Trade and Industry, 1996) is the UK government's preferred method of assessing the impacts of noise from wind farms for planning purposes. The IoA produced a Good Practice Guide (Institute of Acoustics, 2013) to supplement the ETSU-R-97 guidance.

1.5.3.2 The assessment procedure in the IoA guidance relates primarily to operational noise from wind turbines and thus isn't directly applicable to this assessment.

1.5.3.3 However, Supplementary Guidance Note 6 (Institute of Acoustics, 2014) highlights the lack of published research or guidance on wind turbine noise propagation over water.

1.5.3.4 Guidance is presented in the form of a summary of the available published research to aid practitioners in the assessment of noise propagation over water, particularly long distances. The important variables to consider include:

- The distance between source and receiver
- The losses due to geometric divergence of the sound waves including a correction for the tendency of the sound waves to deviate from spherical spreading (a decay in the amplitude with the inverse of the square of the source-receiver separation) to cylindrical spreading (a decay in the amplitude with the inverse of the source-receiver separation) at distances greater than 700 m
- The ground reflections from the water surface
- Atmospheric absorption.

1.6 Criteria

1.6.1.1 Impact criteria for airborne construction sound have been derived in accordance with Annex E of BS 5228-1:2009+A1:2014 which states the following:

'Noise levels generated by site activities are deemed to be potentially significant if the total noise (pre-construction ambient plus site noise) exceeds the pre-construction ambient noise by 5 dB or more, subject to lower cut-off values of 65 dB, 55 dB and 45 dB $L_{Aeq,T}$ *from site noise alone, for the daytime, evening and night-time periods, respectively; and a duration of one month or more, unless works of a shorter duration are likely to result in significant effect.'*

1.6.1.2 The assessment has been undertaken based upon the lower cut-off threshold values associated with areas in which the existing ambient noise levels are low. The LOAEL and SOAEL are thus defined as presented in Table 1.3 below.

Table 1.3: LOAEL and SOAEL for construction noise impacts.

Adverse Effect Level	Construction Noise Level, $L_{Aeq,T}$ dB(A)		
	Weekdays (7am-7pm) and Saturdays (7am-1pm)	Weekdays (7-11pm) Saturdays (1-11pm) and Sundays (7am-11pm)	Night-time (11pm-7am)
LOAEL	70	60	50
SOAEL	65	55	45

1.6.1.3 Based on the above, the construction noise impact magnitude criteria in Table 1.4 have been adopted for this assessment.

Table 1.4: Construction noise impact magnitude criteria

Magnitude of Impact	Construction Noise Level
High	$L_{Aeq,T} \geq$ SOAEL + 5 dB
Medium	SOAEL +4 dB $\leq L_{Aeq,T} <$ SOAEL + 5 dB
Low	SOAEL +2 dB $\leq L_{Aeq,T} <$ SOAEL + 4 dB
Negligible	$L_{Aeq,T} \leq$ SOAEL

1.7 Methodology

1.7.1 Overview

1.7.1.1 Offshore construction activities include impact driven or drilled piled jacket foundations for the wind turbines and OSPs. The equipment required has high sound emission levels and the low frequency elements of the construction sound have the potential to travel long distances due to the acoustically reflective sea surface.

1.7.1.2 There are other sound-generating activities required during the construction phase of the Morgan Generation Assets such as the construction of the OSPs and the gravity-based foundations for strengthening the piles. However, both activities are unlikely to generate sound levels of the same magnitude and for the same duration as those associated with piling activities. As such, the assessment has been undertaken for piling only which are the worst-case construction activities proposed.

1.7.1.3 There are many outdoor sound propagation models available for the prediction of sound levels at receptors. Typically, these models account for losses due to physical effects such as geometrical divergence, atmospheric absorption, ground attenuation, reflections from surfaces and barrier attenuation where each is appropriate.

1.7.1.4 However, long-range sound propagation from a sound source out at sea is likely to be influenced more greatly by meteorological effects such as the vertical temperature and velocity profiles which result in the downward refraction of sound waves. Prediction methods such as the Nord2000 and Harmonoise P2P model include meteorological corrections, however they can be limited in the approximation methods required to characterise these propagation effects. These standards are also primarily intended for use in sound propagation over land.

1.7.2 Propagation model

1.7.2.1 The parabolic wave equation is frequently adopted for long-range sound propagation since the surface impedance and roughness, sound speed profile and atmospheric turbulence can all be accounted for in the calculations. This method allows for the calculation of the sound pressure level in the propagation direction by solving the Helmholtz wave equation.

1.7.2.2 The Helmholtz wave equation is a partial differential equation which allows for the prediction of the behaviour of sound as it propagates in 3-dimensions. This partial differential equation can be discretised using the Crank-Nicholson method which is a finite difference method for solving partial differential equations numerically. As such, any PE solved using this method may typically be referred to as a Crank-Nicholson Parabolic Equation (CNPE).

1.7.2.3 The 3D Helmholtz wave equation may be reduced to a 2D form giving the following CNPE to be solved:

$$\frac{\partial^2 q}{\partial x} + \frac{\partial^2 q}{\partial z^2} + k^2 q = 0 \qquad (1)$$

1.7.2.4 The terms in this equation are defined as follows:

- x and z are the 2D coordinates considered within the calculations. This assessment is concerned with sound propagation in the direction of the receiver (x) due to a source with a height of z above the sea surface.
- k is the effective wave number defined as the number of wave cycles within a given distance and is dependent upon the frequency of the sound and the effective sound speed.
- q is equal to $p_c\sqrt{x}$ where the term p_c represents the complex sound pressure amplitude and x the distance between the source and the receiver.

1.7.2.5 The numerical model developed has the benefit of increased computational efficiency by not requiring the discretisation of the sea surface and instead, defining the surface as a flat, totally reflective layer. Other key parameters accounted for include:

- A vertical sound speed profile which allows for the inclusion of downward sound refraction which bends the sound waves toward the receiver thereby presenting the maximum design scenario
- An effective sound speed which varies with temperature which is influential out at sea
- Atmospheric turbulence due to random fluctuations in wind speed which can result in higher sound pressure levels than expected.

1.7.2.6 However, the wide-angle version of the CNPE (equation 1) is limited to an elevation angle between source and receiver of approximately ±30°. Assuming a receiver height of 4.5 m, approximately equal to the height of a first-floor window above ground level, and a source height of around 30 m, the CNPE can estimate sound levels accurately above a distance of approximately 50 m.

1.7.2.7 Equation 1 has been solved numerically using finite difference methods to derive the transmission loss as sound propagates away the offshore piling activities in the direction of onshore receptors.

1.7.3 Sea Surface Characteristics

1.7.3.1 The sea surface is continuously in motion due to the influence of the wind and currents. An undulating sea surface can scatter sound waves in different directions as they propagate close to the surface. A convenient way to characterise the acoustical properties of the sea surface is by deriving an effective surface impedance to define simply how resistant the surface is to acoustic waves being transmitted through it. A high surface impedance means more sound is reflected and a lower impedance means more sound is transmitted into the medium.

1.7.3.2 Attenborough *et al.* (2005) derived an effective impedance model for a rough sea surface in varying states of undulation. However, Attenborough also states that given the specific impedance of seawater is greater than that of air by four orders of magnitude, the sea surface may be considered to be totally reflective.

1.7.3.3 As such, an effective impedance model has been incorporated to the numerical modelling which defines the surface as totally reflective and static. This represents the ‘worst-case’ scenario in terms of propagation since no energy will be lost due to scattering from the undulating sea surface.

1.7.4 Source levels

1.7.4.1 Appendix A of Volume 5, Annex 3.1: Underwater sound technical report of the Environmental Statement contains details of numerical modelling undertaken to estimate the excitation force of the hammer, the pile, and sound propagation in the water column. This detailed modelling was necessary since at the time the study was undertaken, the Maximum Design Scenario (MDS) was represented by an impact hammer with an energy of around 5,500 kJ. The MDS is now represented by the following hammer energies:

- Up to 4 OSP foundation and up to 16 wind turbine foundation locations: 4,400 kJ
- Up to 48 wind turbine locations: 3,000 kJ.

1.7.4.2 Both scenarios have been assessed for completeness since the exact locations where each hammer will be used are not yet known.

1.7.4.3 Due to the differences in the ways in which sound propagates in water compared to air, there is no direct relationship between the sound emission levels determined for underwater sound propagation and the airborne sound emission levels due to the impact hammer.

1.7.4.4 An estimation of the sound source levels has been undertaken using the radial velocity impulse response output by the numerical modelling undertaken by Seiche Ltd.

1.7.4.5 A Fast Fourier Transform (FFT) has been computed of the radial velocity response to obtain a frequency spectrum for the airborne sound power levels of the impact hammer. Extrapolation of the results provided by Seiche Ltd. show each strike to have an impulse response length of around 180 milliseconds (ms). Assuming up to 80 strikes per minute, the results of the analysis yield an airborne sound power level for each impact hammer energy as presented in Table 1.5 below.

Table 1.5: Estimated sound power spectrum for the offshore piling activities.

Source	Sound power level (dB) at 1/1-octave band centre frequency (Hz)									dB(A)
	31.5	63	125	250	500	1k	2k	4k	8k	
Impact Piling Hammer (4,400 kJ)	122	133	146	138	127	124	120	114	111	**134**
Impact Piling Hammer (3,000 kJ)	121	131	144	136	125	122	118	112	109	**132**

1.7.5 Methodology

1.7.5.1 The MDS is represented by impact piling for the foundations of the Morgan Generation Assets Wind Turbines and OSPs. The following scenarios have been considered:

- Piled Jacket foundations for the wind turbines and OSP foundations using an impact hammer with a maximum energy of 4,400 kJ for up to 6 hrs and 21 minutes
- Pile Jacket foundations for the wind turbine foundations using an impact hammer with a maximum hammer energy of 3,000 kJ for up to 6 hrs and 21 minutes at two concurrent locations up to 15 km apart.

1.7.5.2 The parameters forming the basis of the maximum design scenario are presented in Table 1.6 below.

Table 1.6: Maximum design scenario for impact piling.

Parameter	Maximum design scenario	
	Wind Turbines	OSPs
Pile diameter (m)	5.5	5.5
Penetration depth (m)	75	75
Hammer energy (kJ) (up to 16x wind turbine locations)/(up to 48x wind turbine locations)	4,400/3,000	4,400
Number of strikes	26,690	
Total duration (mins)/(hours)	381/6.35	345/5.75
Number of concurrent events	2	1
Minimum spacing between concurrent piling events (m)	15,000	N/A

1.7.5.3 The piling process involves the following:

- **Initiation:** The initial strikes of the pile starting at as low a strike-rate as possible
- **Soft start:** Increasing the strike rate to approximately 10% of the maximum hammer energy

- **Standard operation:** The strike rate is increased to the standard operational value.

1.7.5.4 The maximum design scenarios for the impact piling schedule are presented in Table 1.7 to Table 1.8 below.

Table 1.7: Maximum design scenario for impact piling schedule (up to 4 OSPs foundations and up to 16 wind turbine foundation locations).

Stage	Duration (mins)	Hammer energy (kJ)	Strike rate (per minute)	Number of strikes	Description
Initiation	10	320	1	10	Preparing the piles (alignment etc.) with 1 strike every 90 seconds.
Soft start	20	440	10	200	Soft start at low hammer energy
Ramp up	20	440-4,400	15	300	Increase in hammer energy after soft start
Maximum power	331	4,400	80	26,480	Driving piles at maximum hammer energy

Table 1.8: Maximum design scenario for impact piling schedule (up to 48 wind turbine locations).

Stage	Duration (mins)	Hammer energy (kJ)	Strike rate (per minute)	Number of strikes	Description
Initiation	10	320	1	10	Preparing the piles (alignment etc.) with 1 strike every 90 seconds.
Soft start	20	320	10	200	Soft start at low hammer energy
Ramp up	20	320-3,000	15	300	Increase in hammer energy after soft start
Maximum power	331	3,000	80	26,480	Driving piles at maximum hammer energy

1.7.5.5 Numerical modelling has been used to predict noise impacts in the frequency range of 31.5 Hz and 250 Hz. Beyond 250 Hz, the number of points per element required to undertake the calculations, and thereby the computational time, increases significantly. In the frequency range defined, the attenuation effects due to air absorption are less. Moreover, the CNPE method shows that the attenuation rate is slower under downward refraction and the sound propagates cylindrically and reduces at a rate proportional to inverse of the distance. This is slower than the rate of attenuation for a point source which reduces at a rate proportional to the inverse of the square of the distance.

1.7.5.6 Indicative calculations of the noise impacts in the frequency range between 500 Hz and 8 kHz have been undertaken in line with the guidance in the IoA's Supplementary Guidance Note 6, as discussed in section 1.5.3 above. This equation does not fully account for the effects of cylindrical propagation due to downward refraction but does account for air absorption which is the more prevalent propagation loss associated with this frequency range.

1.7.5.7 The guidance provides the following equation to calculate the variation in sound level L_s from wind turbines with distance r from the source, also accounting for the frequency dependent absorption coefficient ΔL_a as defined in ISO 9613-2:1996.

$$L = L_s - 20\log_{10}(r) - 11 + 3 - \Delta L_a + 10\log_{10}\left(\frac{r}{700}\right) \quad (2)$$

1.7.5.8 Calculations of the noise impacts have been undertaken in line with the guidance in ISO 9613-2:1996 (International Organisation for Standards, 1996) in downwind conditions at various distances to assess where the impacts change. A temperature of 15°C and relative humidity of 15% have been assumed to calculate the atmospheric attenuation coefficients. The -11 dB term in equation 2 above relates to the losses associated with a wave spreading spherically away from the source with no influence from any reflecting surfaces. The +3 dB term in equation 2 accounts for the increase in sound level due to constructive interference between the direct and reflected waves off a totally reflecting surface.

1.7.6 Desktop study

1.7.6.1 Information on modelling techniques and the extent of the airborne construction sound study area was collected through a detailed desktop review of existing studies and datasets. These are summarised at Table 1.9 below.

Table 1.9: Summary of key desktop sources.

Title	Source	Year	Author
A parabolic equation for sound propagation in two dimensions over any smooth terrain profile: the generalised terrain parabolic equation (GT-PE)	Applied Acoustics	1995	A.R. Sack, M. West
Computational atmospheric acoustics	Kluwer Academic Publishers	2001	E.M. Salomons
Predicting outdoor sound	CRC Press	2022	K. Attenborough, T. Van Renterghem
Prediction of the underwater sound emissions during construction of the Morgan and Mona Offshore Wind Projects	Novicos GmBH	2022	Novicos GmBH
Google Earth Imagery	Data SIO, NOAA, U.S Navy, NGA, GEBCO	2022	Google

1.7.7 Results

1.7.7.1 The distances at which the impact magnitude changes are presented in Table 1.10 below. These results are presented graphically in Figure 1.2 and Figure 1.3 below for night-time periods only since this is the period where impacts occur over the greatest distance. The noise impact magnitude bands have been presented graphically from the boundary of the Morgan Array Area to demonstrate the noise impacts from the closest point where works may be undertaken to the nearest onshore receptors on the Isle of Man.

1.7.7.2 It should be noted that the assessment period for the OSP foundations is assumed to be equivalent to that for the wind turbine locations to simplify the modelling and assessment process. The noise impacts are likely to be less than those predicted since the piling activities are proposed to be undertaken for a shorter period as outlined in Table 1.6 above.

Table 1.10: Construction noise impact magnitudes (up to 4 OSP foundation and up to 16 wind turbine foundation locations).

Magnitude of Impact	Upper Impact Magnitude Band Distance (m)		
	Weekdays (7am-7pm) and Saturdays (7am-1pm)	Weekdays (7-11pm) Saturdays (1-11pm) and Sundays (7am-11pm)	Night-time (11pm-7am)
High	1,200	6,100	10,700
Medium	1,300	6,600	11,200
Low	1,700	7,800	13,700

Table 1.11: Construction noise impact magnitudes (up to 48 wind turbine foundation locations).

Magnitude of Impact	Upper Impact Magnitude Band Distance (m)		
	Weekdays (7am-7pm) and Saturdays (7am-1pm)	Weekdays (7-11pm) Saturdays (1-11pm) and Sundays (7am-11pm)	Night-time (11pm-7am)
High	1,000	4,000	8,900
Medium	1,200	4,200	10,200
Low	1,500	5,100	11,200

1.7.7.3 The results presented in Table 1.10 and Table 1.11 show no high impacts beyond a distance of 10.7 km and 8.9 km from the piling activities and no medium impacts beyond a distance of 11.2 km and 10.2 km for the 4,400 kJ and 3000 kJ hammer energies, respectively.

1.7.7.4 Impacts become negligible at distances greater than 13.7 km and 11.2 km from the source for the 4,400 kJ and 3,000 kJ hammer energies, respectively. The nearest onshore receptors are situated along the coast of the Isle of Man approximately 22 km from the Morgan Array Area.

1.7.7.5 The results show that even for the maximum design scenario associated with each construction activity and by adopting highly conservative consumptions regarding the sound emission levels, sound propagation, and sea surface, there is no pathway of potential impact to onshore receptors and, as such, the magnitude of the noise impacts due to airborne construction sound are predicted to be negligible overall.

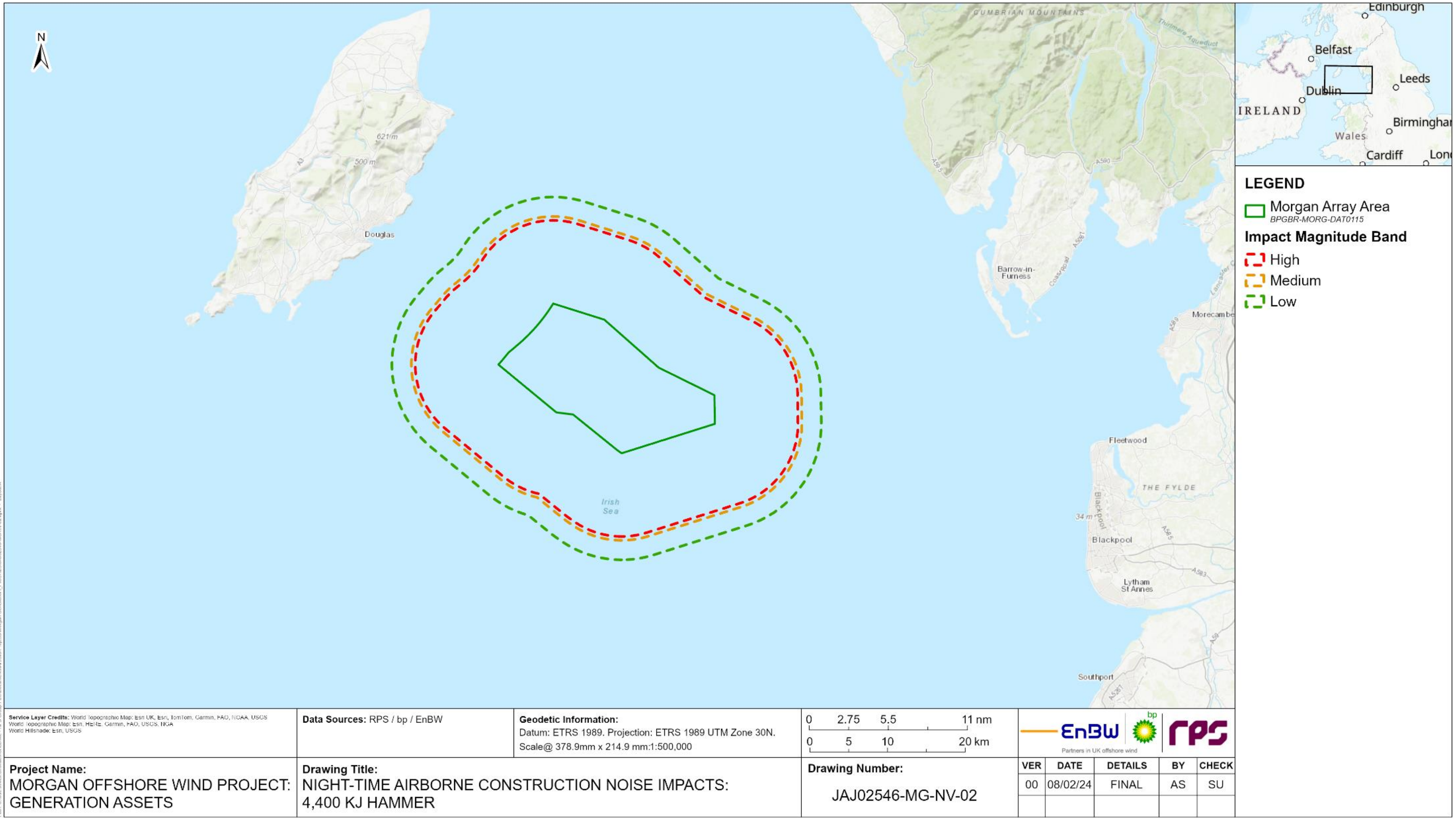

Figure 1.2: Night-time airborne construction noise impacts: 4,400 kJ hammer.

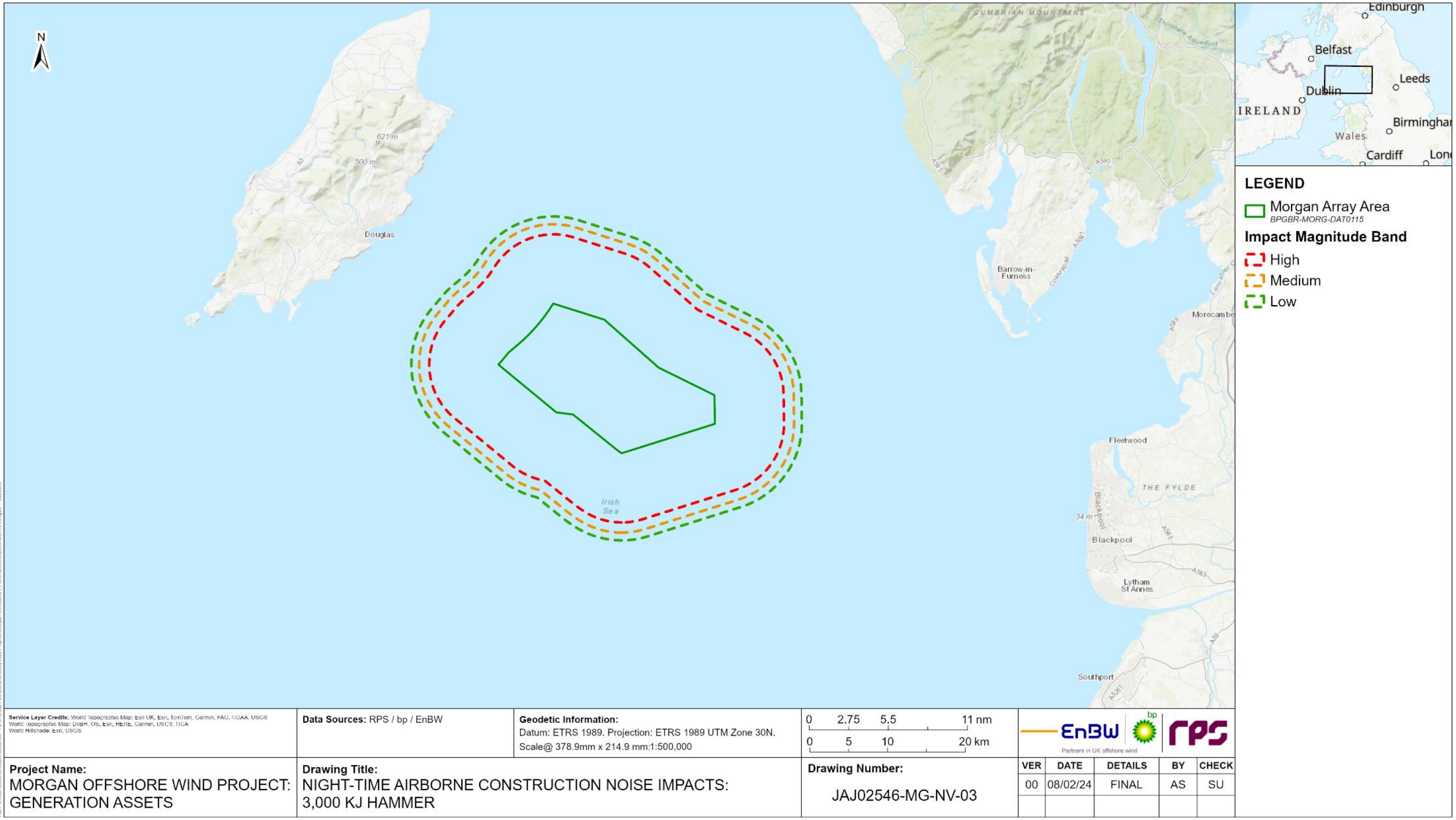

Figure 1.3: Night-time airborne construction noise impacts: 3,000 kJ hammer.

1.8 Summary

1.8.1.1 The airborne construction sound study area has been reduced from that presented in the Morgan Offshore Wind Project Environmental Impact Assessment Scoping Report, (Morgan Offshore Wind Limited, 2022) from 50 km to 20 km. This refinement is based upon noise impact assessment works for other offshore construction works and validation of the numerical model with measured data.

1.8.1.2 A bespoke numerical model has been developed to calculate the variation in the airborne construction sound levels due to offshore piling activities. This model has been developed to better account for the influence of meteorological parameters such as the vertical wind velocity and temperature profile, the speed of sound and atmospheric turbulence.

1.8.1.3 The model includes the assumption that the sea is static and acoustically reflective, and that sound is propagating under downwind conditions towards the nearest receptors resulting in a slower rate of attenuation with distance, due to the downward refraction of sound waves.

1.8.1.4 The results of the modelling show that the impacts become negligible at a distance greater than 13.7 km when a hammer energy of 4,400 kJ is required for the offshore piling works, and beyond 11.2 km when a hammer of energy of 3,000 kJ is required.

1.8.1.5 The nearest receptors are situated along the coast of the Isle of Man approximately 22 km from the Morgan Array Area. As such, there is no pathway for potential impact to onshore receptors due to airborne construction sound from offshore piling activities.

1.9 References

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