MEMO

MARSHALL DAY Acoustics

Project:	St Patricks Plains Wind Farm	Document No.:	Mm 003 R01
To:	Ark Energy	Date:	17 January 2024
Attention:	Donna Bolton	Cross Reference:	Rp 001 R06 20190433
Email/Delivery:	By email	Project No.:	20190433
From:	Christophe Delaire / Justin Adcock	No. Pages:	20
Subject:	EPA Request for additional information		

The following reports, prepared by Marshall Day Acoustics Pty Ltd (MDA), were appended to the Environmental Impact Statement for the St Patricks Plains Wind Farm (the Project)[1]:

- MDA report Rp 001 R06 *St Patricks Plains Wind Farm – Environmental noise assessment*, dated 10 July 2023 (referred to herein as the environmental noise assessment)
- MDA report Rp 002 R01 *St Patricks Plains Wind Farm – Background noise assessment*, dated 10 July 2023 (referred to herein as the background noise assessment)

Responses to the additional information required by EPA Tasmania[2] relating to the above reports (referred to herein as the EPA RFI), detailed in query references 60, 62, 63, 64 and 65 of Table 1, are presented in the following sections.

[1] ERA Planning and Environment report *St Patricks Plains Wind Farm Environmental Impact Statement*, dated 29 June 2023

[2] *EPA - St Patricks Plains Wind Farm Pty Ltd – St Patricks Plains Wind Farm - Additional information requirements part 2 – Representations*, dated 20 November 2023

Certified System ISO 9001

QUERY REF. 60 PARAGRAPHS 1 TO 2 – GROUND EFFECTS

> ***"In relation to the following requests for information, it is noted that the site surroundings are dominated by hard surfaces including large water bodies. The EPA South Australia Wind Farms Environmental Noise Guidelines (2021) (Wind farms environmental noise guidelines (epa.sa.gov.au)) suggests using hard ground (zero ground factor) as a conservative ground conditions modelling input.***
>
> ***Therefore, it is considered appropriate that noise modelling for the proposal should use ground factor of G=0 as a modelling input. "***

We acknowledge that parts of the surrounding area include hard surfaces and bodies of water. However, these characterisations are not applicable to the majority of the ground between noise sensitive locations (receivers) and the proposed turbine locations. Further, while a ground factor of G = 0 represents a conservative input selection, the noise modelling is already based on conservative modelling choices, and the additional level of conservatism associated with a G = 0 ground factor is not warranted. We therefore maintain that the appropriate ground characterisation is G = 0.5, corresponding to mixed ground conditions. Further noise modelling based on alternative ground factor selections has therefore not been conducted. However, we provide the following additional information in response to the EPA's query.

An aerial image of the site, as presented in Figure 1 in Section 6.4 of the environmental noise assessment, is reproduced in Figure 1 below for reference. The image indicates three large bodies of water located in the vicinity of the Project beyond the predicted 30 dB L_{A90} noise contour, comprising Arthurs Lake to the northeast, Lagoon of Islands to the southeast, and Penstock Lagoon to the west. There are also half a dozen small bodies of water within the northern section of the Project, within the 40 dB L_{A90} noise contour.

Importantly, the large bodies of water are not located between the proposed wind turbines and the assessed receivers and will therefore have no bearing on the ground effect associated with noise propagation from the wind farm to the receivers. The small bodies of water located within the Project site represent a very small component of the intervening ground between receivers and the more distant turbine locations of the proposed wind farm. The small bodies of water are therefore inconsequential to noise propagation from the wind farm to the receivers.

In terms of the mixed ground composition around the site, the following key definitions are noted from the ISO 9613-2 calculation standard used for the noise modelling:

The acoustical properties of each ground region [between the source and receiver] are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

a) Hard ground, which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground G = 0.

...

b) Porous ground, which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground G=l.

c) Mixed ground: if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

The ground factor is therefore a characterisation of the extent of soft and hard ground that is present between the source and receiver, rather than a characterisation of the porosity of a particular surface type. A strict characterisation of the site would therefore correspond to porous ground (i.e. ground covered by grass, trees or other vegetation) with a G value of 1, or values approaching 1 where there are small areas of water or hard ground between specific pairings of receivers and proposed turbine locations. The ground factor of G = 0.5 used for the noise modelling of the Project is therefore conservative based on the definitions of ISO 9613-2.

Further guidance on the subject of mixed ground conditions is provided in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (UK IOA good practice guide). The guidance acknowledges the use of G = 0 as a conservative choice, but ultimately recommends the use of G = 0.5. The use of G = 0 is reserved for situations where the majority of the ground between a turbine and receiver is hard, which is not applicable to the ground between the receivers and the proposed turbine locations of the Project. The relevant text of the UK IOA good practice guide states:

> *A soft ground factor (G=1.0) should not be used. Although a ground factor of G=0.0 is commonly used, as it will tend to provide robust predictions in most situations, this can over predict noise levels. For consistency it is recommended to use a ground factor of G=0.5. If the majority of the propagation between source and receiver occurs over paved ground (such as may occur in urban environments) or over large bodies of water such as wide rivers or lakes, the use of G=0.0 is advised.*

We note that the UK IOA good practice guide is based on a number of studies which compared wind farm noise predictions and measurements in a range of environments. These included a study[3] of wind farm sites in the UK which demonstrated that the use of G = 0 consistently overpredicted noise levels. Importantly, these overpredictions were evident even at the sites where ground conditions were characterised as hard between the turbines and receivers (persistent ground water, waterlogged peatbogs and rocky ground). The study also notes that the inclusion of other conservative adjustments for turbine sound power levels (as included in the noise modelling for the Project) would lead to significant margins of overprediction.

We acknowledge that the SA EPA Guidelines recommend the use of G = 0 for the purposes of a conservative assessment, as indicated in the above extract from the UK IOA good practice guide. However, a relevant point of context is that the same section of the SA Guideline refers to the use of the CONCAWE prediction method which, despite its development in the UK, is not used in the UK for wind farm assessment, and is not recommended in the UK IOA good practice guide. An extensive noise propagation study referenced in the UK IOA good practice guide also demonstrated that the CONCAWE prediction method significantly overpredicted noise levels and was overly sensitive to input parameters. This context indicates the very conservative nature of the default prediction guidance in the SA Guideline. In this respect, it is also important to note that the SA EPA Guidelines subsequently acknowledges the use of alternative prediction methods and inputs, subject to full details of the model being provided (see Section 4.3 and Appendix G of the environmental noise assessment). Further, the prediction method and inputs detailed in the environmental noise assessment have been consistently accepted by the SA EPA for projects in South Australia.

The above discussions and context support the use of G = 0.5 for the noise modelling of the Project. This is consistent with our own noise prediction validations and measurement studies at multiple wind farm sites in Tasmania and across Australia. However, notwithstanding the suitability of the noise modelling, compliance with the noise limits in practice would need to be demonstrated by noise measurements. In the unlikely event that noise levels were found to be higher than predicted, the project operators would be required to implement remedial measures to ensure that compliance with the noise limits is achieved at all non-involved receivers around the wind farm.

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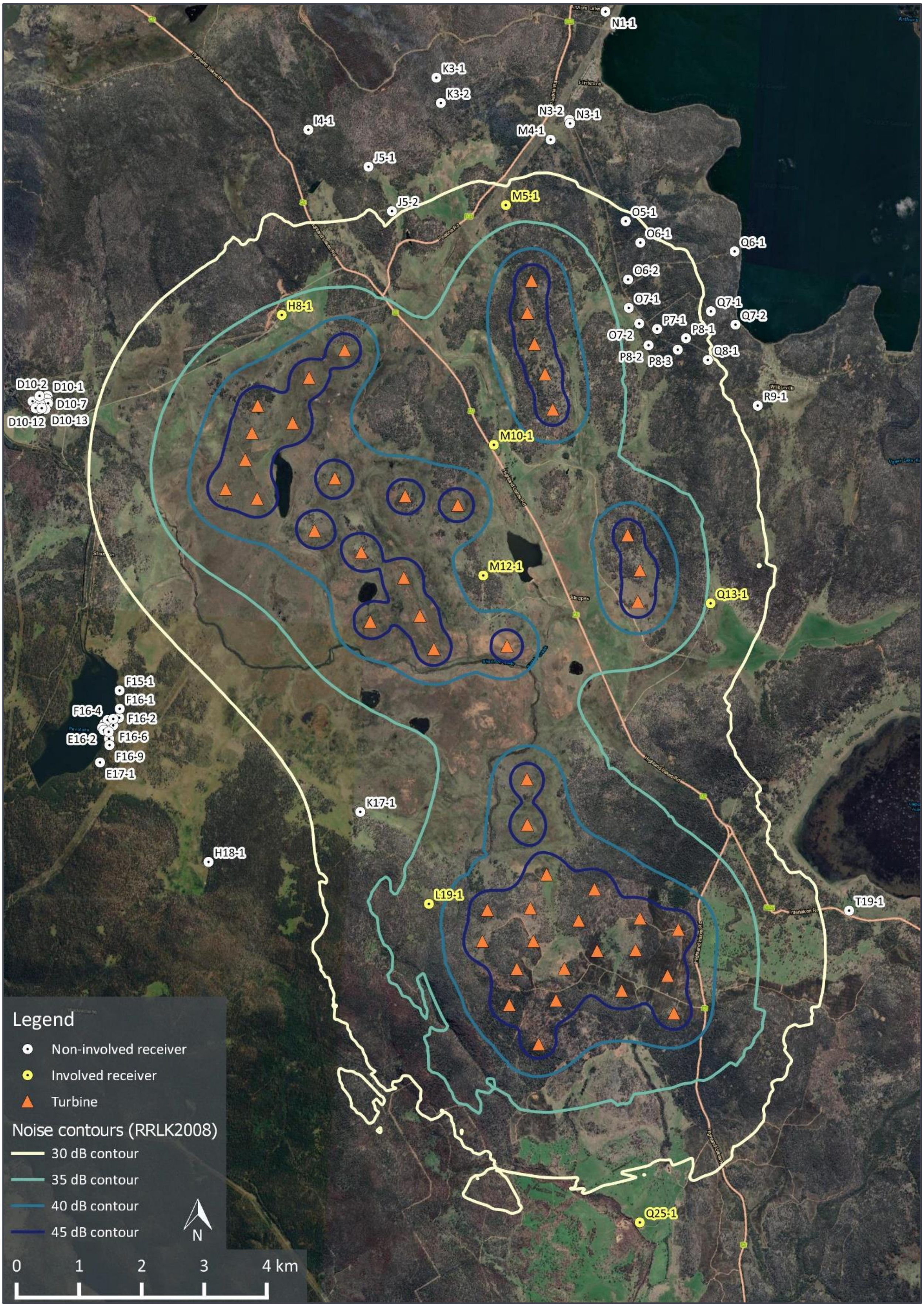
[3] A. Bullmore, J. Adcock, M. Jiggins, M. Cand, *Wind Farm Noise Predictions and Comparison with Measurements*. Proc. Wind Turbine Noise 2009 Conference, Aalborg Denmark, June 2009.

Figure 1: Noise contour map
(reproduction of Figure 1 of the environmental noise assessment)



QUERY REF. 60 PARAGRAPH 3 – CANDIDATE TURBINE MODEL

> ***"Further, as the actual wind turbine model for the proposal is not finalised and the actual sound power level is not yet known, it is expected that the inputs into the noise modelling in relation to sound power level (20 Hz to 8000 Hz) and the size of turbines (hub height and rotor diameter) are defined and specify the maximum scope of the proposal."***

Section 6.2 of the environmental noise assessment presents a discussion of the wind turbine noise model used to assess the Project. At the planning stage, the exact make and model of wind turbine that would be used is not usually known. In particular, a final turbine selection for a wind farm project is not normally made until well after a project has been approved. At that point, the final selection is based on a range of design requirements including achieving compliance with the planning permit noise limits at surrounding receivers.

A representative candidate wind turbine model therefore needs to be considered for noise assessment purposes. A candidate turbine is chosen to reflect the envelope of turbine dimensions that an approval is being sought for, and which is representative of the range of noise emissions for a variety of potential turbine options. For this purpose, turbines with atypically low noise emissions are not usually nominated as a candidate turbine, as the project's viability could be impractically restricted to a limited number of turbine suppliers. Conversely, turbines with atypically high noise emissions are not usually nominated, as the noise emissions of a turbine are among the most important procurement criteria, meaning that turbines with atypically high noise emissions are not usually a viable option for Australian sites. With these considerations in mind, the main purpose of the candidate turbine is to assess the viability of achieving compliance with the applicable noise limits, based on noise emission levels that are typical of the size of turbines being considered for the site.

Based on the above, the proponent for the project has nominated the Vestas V162-6.2MW as the candidate turbine. Our review of the data for this turbine confirms it provides a suitable representation of the noise emissions that are expected to be achievable by realistic commercial turbine options for the Project.

The sound power level data of the candidate turbine is documented in Section 6.3.1 of the environmental noise assessment, and includes octave band frequencies from 31.5 Hz to 8,000 Hz inclusive. Note that the 31.5 Hz octave band includes frequencies extending down to 22 Hz (31.5 Hz is the centre frequency of the range of frequencies included in the octave band). Also, while this data has been provided, we note that the lowest frequencies do not significantly contribute to the total predicted noise levels at the receivers. In particular, the contribution of the 31.5 Hz octave band has a negligible influence on the total predicted noise levels.

The sound power data provided in Section 6.3.1 of the environmental noise assessment characterises a range of different turbine operating modes, including unrestricted and noise-restricted modes of operation. We confirm that the noise modelling of the Project has been based on the highest noise emissions of the candidate turbine for all proposed turbine locations. That is, the modelling is based on all turbines operating without the use of noise-restriction modes. In addition, the data for the noise modelling has been adjusted by the addition of +1 dB to include a margin for typical values of test uncertainty.

To provide further context to the suitability of the selected candidate turbine, Section 6.3.1 of the environmental noise assessment also provides a discussion of the relationship between turbine size, power, and noise level. Specifically, a review of sound power data for a range of turbine models showed no clear relationship between turbine size or power output and the noise emission characteristics of a given turbine model. In practice, the overall noise emissions are dependent on a range of factors, including the turbine size and power, and other important factors such as the blade design and rotational speed. Therefore, while turbine sizes and power ratings of contemporary turbines have increased, the noise emissions of the turbines are comparable to, or lower than, previous generations of turbines as a result of design improvements (notably, measures to reduce the speed of rotation of the turbines, and enhanced blade design features such as serrations for noise control). Further information is presented in Appendix A.

QUERY REF. 60 PARAGRAPH 3 – WIND TURBINE NOISE EMISSION CHARACTERISTICS

> ***"Noise emissions from the proposed wind farm can potentially incur +5 dB correction factor for low frequency noise and further corrections for other special audio characteristics (i.e., tonal, impulsiveness, modulation) when assessed in accordance with the Tasmanian Noise Measurement Manual. The potential for this to affect predicted noise levels should also be considered and discussed when presenting modelling results."***

The potential for wind farm noise to attract adjustments for noise characteristics is acknowledged.

The Tasmanian Department of Environment publication *Noise Measurement Procedures Manual Second Edition July 2008* (the Tasmanian Noise Measurement Manual) provides guidance on aspects of the measurement and assessment of wind farm noise. The guidance is based on the now superseded standard NZS 6808:1998[4].

However, our experience of contemporary assessments for wind farm developments in Tasmania is that the current version of the standard, NZS 6808:2010[5], is the relevant technical reference for the assessment of proposed wind farms. Further, NZS 6808:2010 has been previously referenced in Tasmanian wind farm development approvals as a complete methodology for defining noise limits and conducting post-construction compliance measurements. The Tasmanian Noise Measurement Manual has therefore not been referenced for wind turbine noise in the environmental noise assessment. The environmental noise assessment has referenced NZS 6808:2010 in anticipation that, if an approval for the Project is issued, the conditions of approval would reference NZS 6808:2010 (subject to the application of a reduced base limit of 35 dB, in accordance with a communiqué[6] by the EPA Board from Regular Meeting 140).

In relation to low frequency noise, Section 5.5.2 of NZS 6808:2010 states the following:

> *Claims have been made that low frequency sound and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. the paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended in 5.2 and 5.3.*

Section C5.5.2 of NZS 6808:2010 then goes on to state:

> *The World Health Organization recognises that adverse noise effects can be increased by sound with a large proportion of low frequency components. Measurements show that wind turbine sound does not contain a large proportion of low frequency components. As sound propagates from a wind farm (or any other source) the higher frequency components are attenuated quicker than lower frequency components. At a distance from any sound source it is often lower frequency components that are audible, albeit at a low sound level. Wind farm low frequency sound at a noise sensitive location which is tonal or has amplitude modulation would be penalised for special audible characteristics (see 5.4).*
>
> *Research claiming to show a causal link between wind turbine sound and vibro-acoustic disease has been reviewed during the preparation of this Standard. The research published at the time of this review does not show a causal link.*

This is consistent with experience of wind farm sites across Australia which indicates that low frequency noise is not a significant feature of a correctly functioning wind farm. Further discussion of infrasound and low frequency noise is provided subsequently in response to EPA query reference 64.

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4 NZS 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators*

5 NZS 6808:2010 *Acoustics – Wind farm noise*

6 EPA Tasmania weblink

In relation to other characteristics of wind farm noise which can attract an adjustment, Section 5.4.2 of NZS 6808:2010 states:

> *Wind turbine sound levels with special audible characteristics (such as tonality, impulsiveness and amplitude modulation) shall be adjusted by arithmetically adding up to +6dB to the measured level at the noise sensitive location.*

A discussion of this topic is provided in section 6.3.2 of the environmental noise assessment. The discussion noted that, while special audible characteristics (SACs) comprising tonality, impulsiveness and amplitude modulation are potential features of the noise from wind turbines, their occurrence in the noise of contemporary multi-megawatt turbine designs is unusual. This is supported by evidence of operational wind farms in Australia which indicates that the occurrence of these characteristics is infrequent.

Given that SACs are uncommon, and their occurrence cannot be reliably predicted, it is not normal practice for penalty adjustments to be assumed in the planning stage noise modelling of a wind farm. Accordingly, penalty adjustments have not been applied to the noise modelling of the Project.

This point is recognised in Section 5.4.1 of NZS 6808:2010 which notes that data about special characteristics cannot always be predicted and refers to measurement-based assessment:

> *Wind farms shall be designed so that wind farm sound does not have special audible characteristics at noise sensitive locations. However, as special audible characteristics cannot always be predicted, consideration shall be given to whether there are any special audible characteristics of the wind farm sound when comparing measured levels with noise limits.*

The UK IOA good practice guide similarly notes:

> *It is highly unlikely that any specific information on tonality at representative receptor separation distances in accordance with the ETSU-R-97 methodology will be available at the planning application stage. When such information is available, it should be appropriately applied. It is standard to control the potential presence of tones in practice through the use of suitable planning conditions.*

While SACs are uncommon, and cannot be reliably predicted at the planning stage of a project, post-construction noise compliance monitoring for the Project would need to include an assessment of SACs. In the unlikely event that SACs are a feature of the noise, adjustments in accordance with NZS 6808:2010 may be applicable, and remedial actions may be required in order to achieve compliance with the noise limits (e.g. rectification of an identified turbine fault or adoption of noise mitigation modes of operation).

QUERY REF. 60 PARAGRAPHS 5, 6, AND 7 – CATTLE HILL WIND FARM NOISE

> ***"1. Cattle Hill Wind Farm noise***
>
> ***Noting the above and that Cattle Hill Wind Farm is currently operational, provide the following:***
>
> ***a) Confirmation whether the consultant(s) for the proposal undertook any noise measurement to understand the impact of Cattle Hill Wind Farm at the surrounding sensitive premise (e.g., Penstock Lagoon) and to understand whether any adjustment is required for special audio characteristics. If so, discuss the nature of the special audio characteristics detected in the monitoring.***
>
> ***b) Use the actual Cattle Hill Wind Farm turbine model source data, and update modelling accordingly to predict noise emissions from the existing Cattle Hill Wind Farm."***

An assessment of cumulative noise levels associated with operation of the existing Cattle Hill Wind Farm and the proposed Project is presented in Section 6.5 of the environmental noise assessment.

Given that the Cattle Hill Wind Farm is located over 10 km from the proposed turbine locations of the Project, cumulative noise considerations represent a very low risk. Notwithstanding the low risk, a quantitative assessment based on noise modelling is presented in the environmental noise assessment for completeness. The noise modelling results are consistent with expectations for the separation distances involved, and demonstrated that cumulative noise levels are not a material consideration for the two projects. In this context, measurement based investigations of the Cattle Hill Wind Farm were not considered to be warranted and were therefore not conducted as part of the study.

In terms of the basis of the noise modelling, we are not aware of any site-specific sound power level data being available for the turbines installed at the Cattle Hill Wind Farm. We can however confirm that the cumulative noise modelling presented in the environmental noise assessment is based on sound power level data for the same make and model of turbine installed at the Cattle hill Wind Farm, albeit a slightly higher power variant (sound power data for the 3.4 MW variant rather than the 3.0 to 3.2 MW variants installed at the Cattle Hill Wind Farm).

In terms of the potential for special audible characteristics associated with the Cattle Hill Wind Farm, we are not aware of any information to suggest that these characteristics are evident in the noise of the wind farm. However, a review of the noise monitoring compliance report[7] prepared in 2021 by Vipac Engineers and Scientists Ltd (Vipac) notes that tonality was not identified at receivers near the Cattle Hill Wind Farm.

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[7] Vipac document 30T-20-0060-TRP-6824867-5 revision 05 *Operational Noise Survey Report* dated 3 March 2021

QUERY REF. 60 PARAGRAPHS 8 AND 9 – NOISE MODELLING AND INVERSIONS

> ***"2. Modelling of noise impacts of proposal Using the results from (1) above, and incorporating appropriate parameters as noted above, update the modelling undertaken in the EIS to predict noise emissions for the proposal and cumulative noise impact on sensitive receivers in conjunction with Cattle Hill Wind Farm.***
>
> ***Include discussion of the potential for the presence of an inversion layer, and what impact if any this would have on the predicted noise levels."***

In relation to the suitability of the noise modelling of the Project and the Cattle Hill Wind Farm, please refer to our responses to the preceding elements of query reference 60.

The predicted noise levels are based on the ISO 9613-2 calculation standard for atmospheric conditions which increase noise levels at distant receivers. These atmospheric conditions include downwind conditions (i.e. when the wind is directed from the source to the receiver, or the wind is at an angle but there is a vector component wind speed in the direction from the source to the receiver) or a moderate ground-based temperature inversion (a condition when temperatures increase with increasing height above ground level) . In both cases, the speed of sound changes with increasing height above ground level, subsequently causing sound to be refracted towards the ground. The noise level at distant locations is then moderately increased as a result of the cumulative effect of sound travelling via multiple paths.

Atmospheric conditions which enhance the propagation of sound from a wind farm are primarily related to wind direction and wind speed. More specifically, it relates to wind shear which describes changes in wind speed with height and, in turn, relative changes in the speed of sound with increasing height.

In contrast, temperature inversions are not considered to be a material factor influencing the propagation of noise from wind turbines. Firstly, temperature inversions are normally associated with still conditions and, as a result, a broad temperature inversion across an area is only likely to occur during still or low wind speed conditions when the turbines are either not operating or are rotating slowly and producing low or negligible noise emissions. Secondly, while a temperature inversion could occur in sheltered locations where air movement is reduced (i.e. at lower heights than the turbines, such as a site where cool air collects in valleys), this type of localised temperature inversion condition would not be representative of the overall noise propagation path from the turbine rotors.

QUERY REF. 62 – NOISE MODELLING AND CONTINGENCY STRATEGIES

> ***"After re-modelling as per request, provide updated results showing all receivers with predicted levels greater than 30 dB(A).***
>
> ***Clarify whether sensitive receivers for which predicted levels are modelled to be greater than 35 dB(A) are involved with the project in respect to agreements in perpetuity (e.g. deeds placed on the title), and the extent to which noise levels articulated in such agreements correlate with modelled noise levels.***
>
> ***Discuss a contingency management plan to address nuisances, potential exceedances and noise complaints."***

The preceding sections provide additional explanation of the modelling and the suitability of the results presented in the environmental noise assessment for planning purposes.

For ease of reference, Table 10 of Section 6.4 of the environmental noise assessment is reproduced below and identifies the predicted noise levels for all receivers within the predicted 30 dB L_{A90} contour of the Project. To confirm, the predicted noise levels are based on the highest noise emission data of the candidate turbine model, adjusted by the addition of 1 dB to account for typical test uncertainties and provide a margin of conservatism to the assessment.

In terms of noise agreements with involved land owners, the proponent for the project has advised that the agreements will be registered as caveats on the title of the property and remain in place for the life of the wind farm, including any potential repowering.

Table 1: Highest predicted noise level at receivers with predicted levels greater than 30 dB L_{A90} (PO6200) (reproduction of Table 10 in the environmental noise assessment report)

Receiver	Predicted level, dB L_{A90}
H8-1 (I)	36.3
K17-1	31.8
L19-1 (I)	38.0
M5-1 (I)	32.7
M10-1 (I)	37.3
M12-1 (I)	38.2
O5-1	30.3
O6-1	31.0
O6-2	32.8
O7-1	33.6
O7-2	33.1
P7-1	31.9
P8-1	31.0
P8-2	32.8
P8-3	30.9
Q8-1	31.5
Q13-1 (I)	34.4

(I) Involved receiver

The results presented in Table 1 demonstrate that the predicted noise levels at all non-involved receivers are below the base (minimum) noise limit of 35 dB L_{A90} by a margin of at least 1.4 dB. This finding, in conjunction with the conservative modelling used for the study, supports that compliance with the applicable noise limits is readily achievable.

However, while the predicted noise levels are below the base (minimum) noise limit, if the project is approved and developed, noise measurements would need to be conducted at a representative selection of non-involved receivers to assess whether compliance is achieved in practice. The compliance assessment would need to be based on measurements that are representative of, or can be related to, full power operation of the project (e.g. not based on conditions when the wind farm's noise levels may be lower as a result of factors such as power output restriction imposed by the Australian Energy Market Operator – this would need to be verified by an independent assessment of the wind farm's operating state). The compliance measurements would need to account for the level of wind farm noise, and any relevant adjustments (penalties) that could apply in the unlikely event that SACs such as tonality are a feature of the noise of the wind farm.

In the event that the measurements and assessment indicate a non-compliance at any of the non-involved receivers, remedial measures would need to be implemented to achieve compliance.

The following summarises two key measures available to reduce the noise:

- **Procurement contract:** the procurement contract for the supply of turbines to the site would include specifications concerning the allowable noise levels and characteristics of the turbines. If the turbines exceed the contracted values, the supplier will be required to implement measures to reduce the noise to the contracted value. This can include measures to rectify manufacturing defects or appropriate control settings.
- **Noise reduction management strategy:** modern wind farms include control systems which enable the operation of the turbines to be varied according to environmental constraints. Specifically, variable pitch turbines as proposed for this site include control functions which enable the noise emissions of the turbines to be selectively controlled; by adjusting the pitch of the turbine's blades, the noise emissions of the turbine can be reduced. In addition, where required, the turbines can be selectively shut down for relevant wind speeds and directions. These types of control measures can be used separately, or in combination, to achieve noise reductions for predetermined wind speed ranges and directions.

The appropriate type of remedial measure would depend on the cause and nature of the compliance outcome. For example, if a non-compliance was detected as a result of an adjustment for identified tonality, the priority remedial measure would be to reduce or eliminate the source of the tone. If a non-compliance was detected as a result of the total level of the noise, the remedial measures could involve rectification of defects, implementation of noise control modes, or a combination of the two.

If remedial measures are required, a noise remediation plan should be prepared, including details of the proposed controls, the timing for implementation, and how the effectiveness of the controls would be verified (for example, if noise measurements and/or routine checks and observations by maintenance personnel are required).

QUERY REF. 63 – MITIGATION MEASURES

> ***"It appears that, with adjusted input parameters and consideration of special audio characteristics, the proposal has the potential to exceed applicable noise limits at some sensitive receivers, particularly where current modelling indicates receivers are close to the 35 db(A) contour.***
>
> ***It is suggested that the supplement include a modelling scenario without wind turbines located closer to these receivers operating and discuss whether shutting down any of these turbines can be considered as a mitigation measure to achieve compliance."***

The preceding sections provide additional explanation of the modelling and the suitability of the results presented in the environmental noise assessment for planning purposes. Information has also been provided to explain that adjustments for special audible characteristics are not applicable at planning stage.

Based on the results of conservative modelling, assuming the highest sound power levels for the candidate turbine, the predicted noise levels are below the base noise limit. As a result, there are no indications that layout changes or noise mitigation strategies are warranted.

However, as discussed in the preceding section, in the unlikely event that noise levels need to be reduced in practice, this can be readily achieved with the use of noise control modes or, in extreme cases, selective turbine shutdowns when required. If noise reductions are required, we recommend a noise remediation plan is prepared which is tailored to the specifics of the situation. Options for noise remediation, and our recommendations concerning noise remediation plans, are provided in the preceding section.

As an indication of the level of noise reduction that can be achieved with operational noise modes, Table 8 of Section 6.3.1 of the environment noise assessment presents a sample of reduced power and noise modes that are available for the candidate turbine. These types of reduced noise modes are a common feature of pitch-regulated variable speed turbines that are now standard for all commercial scale wind farm development. The data from Table 8 is reproduced in Table 2 below.

The Project has been modelled without application of any noise control modes (referred to as operating mode PO6200, which designates a power optimised mode and a turbine rating of 6,200kW/6.2MW). The data in Table 2 below shows that the sound power of the candidate turbine is able to be reduced by up to 4.8 dB from the reference sound power level used in the noise modelling. The corresponding reduction in noise level at the receiver would differ from this value (as the frequency spectrum of the turbine usually changes slightly when noise reduction modes are used and the frequency spectrum of any sound source changes with distance). However, the difference is indicative of the significant reduction in noise level that is able to be achieved if required.

In light of the above findings, additional modelling scenarios are not warranted at this stage of the Project.

Table 2: Sound power levels versus hub height wind speed, dB L_{WA} (reproduction of Table 8 in the environmental noise assessment)

Operating mode	Power output, MW	Hub height wind speed, m/s								
		4	5	6	7	8	9	10	11	≥12
PO6200	6.2	95.1	95.3	97.2	100.2	103.0	105.3	105.8	105.8	105.8
Mode 0	5.6	94.7	95.3	98.3	101.2	103.9	105.0	105.0	105.0	105.0
SO2	5.0	94.7	95.3	98.3	101.2	103.0	103.0	103.0	103.0	103.0
SO3	4.8	94.7	95.3	98.3	101.2	102.0	102.0	102.0	102.0	102.0
SO4	4.6	94.7	95.3	98.3	100.7	101.0	101.0	101.0	101.0	101.0

QUERY REF. 64 – INFRASOUND

"Include a statement or a brief discussion, based on relevant literature, on the potential impact/risk of infrasound sound associated with the proposed development."

The limits adopted for the assessment of operational noise from wind farms represent relatively low levels which have been specified in recognition of the quieter rural environments in which wind farms are normally located.

However, consistent with noise policies applied to other forms of development, the criteria are not intended to restrict wind farm noise to inaudible levels. A wind farm which complies with the criteria may therefore still be audible at the receivers on some occasions; this will depend on a range of factors such as the time of day, the speed and direction of the wind, proximity to turbines, the extent of vegetation around the dwelling, and the degree to which the dwelling is sheltered from prevailing wind conditions. Irrespective of the relatively low noise levels which operational wind farm noise is restricted to, an individual's judgement of the audible noise from a wind farm is highly subjective and will be influenced by a range of contextual factors.

The subject of wind farm noise and its characteristics has attracted considerable attention. Specific attention has been directed to alleged matters relating to low frequency sound as well as infrasound and vibration. Low frequency sounds are generally regarded as sounds above 20 Hz and extending upwards into the range of 100-200 Hz. The definition of infrasound often varies in different jurisdictions, but is generally accepted to refer to frequencies of sound which lie below 20 Hz. While 20 Hz is commonly cited as the lower bound of audibility, frequencies below 20 Hz can still be audible, provided that the level of the sound is sufficiently high to exceed the threshold of audibility at those frequencies.

In common with many other sources of noise, wind turbines emit infrasound, low frequency sound and ground vibrations. However, what is often overlooked is that these types of sound and vibration are a feature of the everyday environment within which wind farms are located. Sources of low frequency and infrasound include natural sources such as the wind and the ocean, and man-made sources such as domestic appliances, transportation and agricultural equipment. The important point in relation to wind turbines is that the levels of these types of emissions are low and therefore, in many cases, cannot generally be perceived or reliably measured amid normal background noise levels at receivers.

NZS 6808:2010 provides specific advice concerning infrasound at Section 5.5 noting:

> *Although wind turbines may produce some sound at (ultrasound and infrasound) frequencies outside the normal range of human hearing these components will be well below the threshold of human perception.*
>
> *Claims have been made that low frequency sound and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. The paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended* [in the Standard].

These types of emissions have been the subject of considerable misrepresentation in media commentary. Notably, the work of Dr Geoff Leventhall, a prominent UK consultant in the field of acoustics and vibration, and researcher in the field of low frequency noise is often cited in some documents which continue to claim concerns about infrasound and low frequency noise from wind turbines. However, Dr Leventhall has regularly made clear statements to assert that there is no significant infrasound from current designs of wind turbines and very little low frequency sound, neither of which are anywhere near the sorts of levels which would represent a direct health risk for neighbouring residents of modern wind farms. An example such publication, co-authored by Dr Leventhall, was published in the UK Institute of Acoustics Bulletin in March 2009[8]. This publication was prepared as an agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed by local councils and community groups campaigning against wind farm developments. The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern.

On the subject of infrasound and low frequency noise, the article notes:

> *Infrasound is the term generally used to describe sound at frequencies below 20Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20Hz to 200Hz are conventionally referred to as low frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.*
>
> *A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.*

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8 Institute of Acoustics Bulletin – Bowdler, Bullmore, Davis, Hayes, Jiggins, Leventhall, McKenzie - *Prediction and Assessment of Wind Turbine Noise* –March 2009

Another example of the misrepresentations made in relation to the environmental effects of wind turbines centred around work conducted by Keele University in the UK on ground vibration. Professor Peter Styles and his team at Keele University undertook a study of the effects of wind turbines on the seismic detection array at Eskdalemuir, Scotland. The results of this work were widely misinterpreted and resulted in a statement[9] from Professor Styles:

> *We are writing to clarify some misconceptions [...] about wind farm noise. Whilst it is technically correct that 'vibrations can be picked up as far away as 10km', to give the impression that they can be felt at this distance is highly misleading. The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect. The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health. It is, however, an issue for the Eskdalemuir seismic array, as it can detect this level of vibration. It is designed to detect explosions and earthquakes of a low magnitude from all over the world. The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health.*

More recent measurements[10, 11] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines, noting that:

> *Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70dB(G) were common at both wind farm and non-wind farm sites.*
>
> *Organised shutdowns of the wind farms adjacent to* [measurement locations] *indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites.*

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9 Low Frequency Noise and Wind Turbines Keele University Rejects Renewable Energy Foundation's Low Frequency Noise Research Claims – August 2005. See https://archive.md/d3WB

10 Sonus report for Pacific Hydro - *Infrasound measurements from wind farms and other sources* – November 2010. See https://www.aph.gov.au/DocumentStore.ashx?id=9fd15e9f-cb10-416b-9ba1-87175a773a0f

11 Evans, T., Cooper, J. & Lenchine, V., *Infrasound levels near wind farms and in other environments*, South Australian Environment Protection Authority, Adelaide, 2013. See https://www.epa.sa.gov.au/files/477912_infrasound.pdf

In 2010, the UK Health Protection Agency published a report[12] on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

> *Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.* [...]
>
> *For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.*

A Victorian Department of Health document[13] also concludes the following in relation to infrasound from wind farms:

> *Infrasound is audible when the sound levels are high enough. The hearing threshold for infrasound is much higher than other frequencies. Infrasound from wind farms is at levels well below the hearing threshold and is therefore inaudible to neighbouring residents.*

These studies all indicate that infrasound levels from the proposed wind farm are anticipated to be comparable with existing ambient levels.

In 2014, the National Health and Medical Research Council (NHMRC) released a draft report[14] for public comment addressing human health effects of wind farms which includes consideration of noise.

From well over 2,500 articles which were identified during the NHMRC review, eleven (11) studies across Europe, North America and Australia satisfied a set of pre-specified eligibility criteria for detailed review and therefore form the basis of the report, which concludes:

> *There is no consistent evidence that noise from wind turbines—whether estimated in models or using distance as a proxy—is associated with self-reported human health effects. Isolated associations may be due to confounding, bias or chance.*
>
> *There is consistent evidence that noise from wind turbines—whether estimated in models or using distance as a proxy—is associated with annoyance, and reasonable consistency that it is associated with sleep disturbance and poorer sleep quality and quality of life. However, it is unclear whether the observed associations are due to wind turbine noise or plausible confounders.*

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[12] Health Protection Agency UK – *Health Effects of Exposure to Ultrasound and Infrasound – Report of the independent Advisory Group on Non-ionising Radiation* - February 2010 https://assets.publishing.service.gov.uk/media/5a7dfba8ed915d74e33ef48e/RCE-14_for_web_with_security.pdf

[13] Public Statement: Wind Turbines and Health - July 2010

[14] *Systematic review of the human health effects of wind farms - 2014*

The NHMRC subsequently issued further advice in 2015 based on this research. The NSW government publication *Noise Assessment Bulletin* issued in December 2016 refers to this advice and states the following in its section on Noise and Health:

> *High levels of noise are associated with adverse health outcomes. To examine this potential relationship the National Health and Medical Research Council (NHMRC) undertook a comprehensive assessment of the scientific evidence on wind farms and human health. In 2015, the NHMRC concluded that "there is no direct evidence that exposure to wind farm noise affects physical or mental health", and there is currently no consistent evidence supporting a link between wind energy projects and adverse health outcomes in humans relating to infrasound. More specifically, they stated that, "while exposure to environmental noise is associated with health effects, these effects occur at much higher levels of noise than are likely to be perceived by people living in close proximity to wind farms in Australia".*

These studies all indicate that infrasound levels are anticipated to be comparable with existing ambient levels and, as such, are not expected to represent an impact from the proposed wind farm. Similarly, vibration levels from wind turbines are well below perception thresholds, and low frequency levels are typically low.

Considerations relating to environmental noise primarily relate to sound in the audible frequency range which is addressed by the requirements of NZS 6808:2010, as adopted in the environmental noise assessment.

QUERY REF. 65 – CONSTRUCTION NOISE

> ***"It is noted that there is a commitment for a blast management plan for construction, but it is not clear whether there will be a construction management plan for all construction noise.***
>
> ***Clarify whether such a plan is proposed, and whether there is any risk of blasting within 1km of any sensitive receiver, noting that the EIS indicates that it is 'unlikely'."***

The protocols and management measures which would apply for the control of construction noise are proposed to be documented in the overall construction management plan.

The measures to be addressed in the construction management plan include:

- normal construction hours and details of any exceptional works which may need to occur outside of normal working hours (e.g. oversized component deliveries that need to occur out of hours for traffic and safety reasons);
- selection of as-new low-noise plant and equipment, where possible;
- use of 'broadband alarms' to minimise annoyance related to traditional tonal reversing alarms;
- regular maintenance of equipment to manufacturer standards; and
- communication with residents nearest to construction activities.

The proponent has advised that blasting within 1 km of dwellings is unlikely, however the locations where blasting may occur are subject to further geotechnical investigations and detailed design. As a result, the need for blasting within 1 km of involved receivers cannot be ruled out entirely. This would need to be addressed in the blasting management plan.

APPENDIX A COMPARISON OF WIND TURBINE SOUND POWER LEVELS

Subject:	Comparison of wind turbine sound power levels		
Date:	21 September 2023	**No. Pages:**	2

To assess a proposed wind farm during the planning stage, it is necessary to consider a candidate wind turbine model that is representative of the size and type of wind turbines being considered. The purpose of the candidate wind turbine is to assess the viability of achieving compliance with the applicable noise limits, based on noise emission levels (sound power levels) that are typical of the size of wind turbines being considered for the site.

A review of sound power data has been undertaken for a range of turbine models from the same manufacturer, with and without blade serrations, based on publicly available information.

The review compares the noise emissions of turbine models with different rotor diameters and power ratings, based the following acoustic data:

- Highest overall A-weighted sound power level, typically corresponding to the wind turbine reaching rated power output; and
- Low frequency noise content, based on the combined A-weighted sound power level of frequencies up to 500 Hz only.

  This calculated value represents the frequencies that are most relevant to the propagation of noise levels at distant locations (higher frequencies of sound are more effectively attenuated by atmospheric absorption and therefore tend to contribute less to the total noise level at distant locations).

Results of the comparison are presented in Appendix A.

It can be seen from this review that there isn't a clear relationship between turbine size or power output and the noise emission characteristics of a given turbine model from the same manufacturer.

In practice, the overall noise emissions of a turbine are dependent on a range of factors, including the turbine size and power output, and other important factors such as the blade design and rotational speed of the turbine. Therefore, while turbine sizes and power ratings of contemporary turbines have increased, the noise emissions of the turbines are comparable to, or lower than, previous generations of turbines as a result of design improvements (notably, measures to reduce the speed of rotation of the turbines, and enhanced blade design features such as serrations for noise control).

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APPENDIX A COMPARISON RESULTS

Figure 1: Highest overall A-weighted sound power level vs. wind turbine rotor diameter

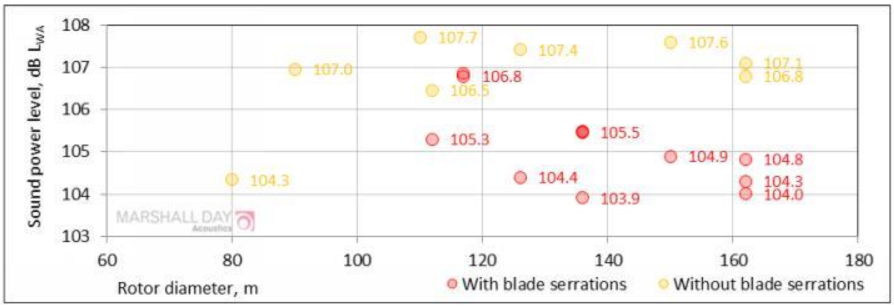


Figure 2: Highest overall A-weighted sound power level vs. wind turbine rated power output

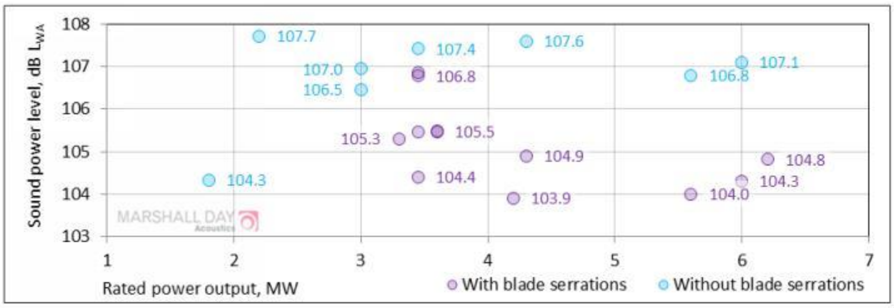


Figure 3: Combined A-weighted sound power level (frequencies up 500 Hz only) vs. wind turbine rotor diameter

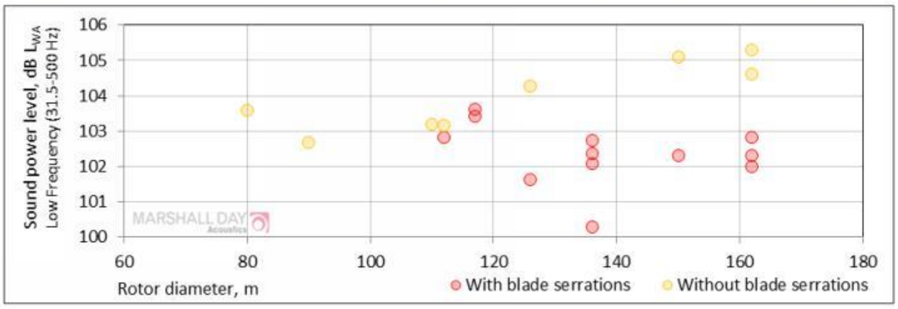
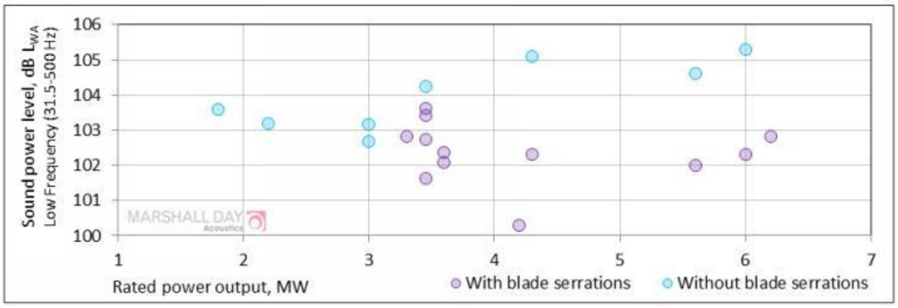


Figure 4: Combined A-weighted sound power level (frequencies up 500 Hz only) vs. wind turbine rated power output



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