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Development of Noise Setbacks for Wind Farms

Requirements for Compliance with MOE Noise Limits

Protecting our environment. Ontario

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Requirements for Compliance with MOE Noise Limits

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1.0 INTRODUCTION

Prompted by the introduction of the *Green Energy Act*, the Noise Unit of the Ministry of the Environment's (MOE) – Environmental Assessment and Approvals Branch was requested to develop a conservative method for addressing noise impact on receptors due to wind power projects. Specifically, the requirement was to establish a "setback" for noise (ie. minimum distance between a receptor and the closest wind turbine) with the intention of facilitating the planning and review process of such projects while protecting human health and the environment.

The existing MOE approval process requires proposed wind farm projects to comply with the guidance document titled "Noise Guidelines for Wind Farms – October 2008" (the Guide). This document provides substantial background information for this study. The overall objective for this study was to produce a practical guide for enabling proponents of wind farms to produce effective project plans, while maintaining the noise performance limits compatible with the Ministry policy to protect human health and the environment.

This report presents some background, identifies variables affecting setbacks, defines the scope of a practical scenario, proposes a technical approach for establishing setbacks, and presents results of setback values applicable for wind farms typical to a rural setting in Ontario.

2.0 BACKGROUND

In order to understand how to approach this problem, it is necessary to identify the variables that affect noise levels and setbacks in a wind farm project. These variables must balance the complexities of wind farm design with the need to achieve target noise limits at receptors. Following are the main variables for consideration:

- Wind turbine acoustic emission levels at different wind speeds.

- Site specific wind-shear effects on wind turbine acoustic emission levels.

- Frequency spectra of wind turbine acoustic emissions.

- Number of wind turbine units within an area of influence from a receptor.

- Wind turbine layout relative to the closest wind turbine unit to a receptor.

- Selection of sound propagation parameters for predicting noise levels at receptors.

- Location of Point of Reception relative to the type of building (i.e., height and siting on the property).

- Classification of ambient noise area at receptors according to MOE publications NPC-205 and NPC-232.

- Applicable noise limit at receptors.

- Background noise levels at receptors.

- Range of wind turbine generator electrical power rating and size.

- Topography (i.e., land-based, near-shore, or off-shore).

- Noise contributions from Transformer Substation(s).

- Noise contributions from adjacent wind farms.

Due to the number of variables involved in a typical wind farm, there are many permutations affecting the noise impact at any given receptor. Consequently, there is no single setback that can accommodate all the variable aspects of a wind turbine project design as well as the compliance with the applicable noise limits. A matrix of setbacks would be more appropriate.

3.0 SCOPE

Given the different scenarios found in typical wind farms and based on projects reviewed to date, the scope was set to address land-based wind turbine generating projects with unobstructed and relatively flat landscape. This would include wind turbine generators in the range of about 50 kW to 3 MW. Furthermore, it was selected to address projects set predominately in low ambient noise areas, such rural, wilderness, or quiet suburban areas (ie. classified as Class 3 Areas in the Guide).

4.0 METHOD

The general approach taken for this study was to derive a setback using a conservative approach. This included utilizing the procedure for predicting the noise impact at Points of Reception described in the MOE "Noise Guidelines for Wind Farms – October 2008". Using one receptor relative to a selected array of wind turbines, the noise impact at the receptor was calculated by the standard method recommended in the International Standard ISO 9613-2. The separation distance required between a receptor and the closest turbine in the array that would satisfy the MOE noise limit was then determined. The result would be the minimum setback for the given set of variables. Based on this premise, the following steps were taken:

4.1 For the purpose of this study, the term "setback" was defined as the plan distance separating the centre of a dwelling (or a specific location on a vacant lot) and the base of the closest wind turbine. Note that the resulting distance could be about 30 m longer if the location of the receptor was taken to be at the Point of Reception as defined in the Guide. The reason for this approach was to simplify the method of accounting for the locations and distance between a wind turbine and a receptor using only two sets of coordinates. Also, this approach can be shown to satisfy the noise limit required at the locations defined by Point of Reception.

4.2 As mentioned earlier no single setback would be appropriate for most wind power projects, therefore it was chosen for this study to develop a matrix with setbacks corresponding to a practical set of defined variables. Two of these variables are the number of units and the type of wind turbines in a project.

4.3 Based on MOE experience, typical wind farms in Ontario consist of a number of wind turbine units ranging from about three up to about one hundred-forty units, with many wind farms consisting of five units. These wind turbine units may be spread over an area ranging from about 1 to 100 km^2. For the purpose of this study and based on typical projects reviewed by MOE to date, three types of projects were considered, namely: - Projects consisting of either **five (5), ten (10), or twenty-five (25)** wind turbine units.

4.4 A simple layout was formulated for each group of wind turbines based on an array in a grid pattern with 400 m separation between the units. Based on experience with wind farms in Ontario, this separation between wind turbines is normal for ensuring proper wind distribution amongst the turbines. The separation distance between wind turbines is often greater due to other project and site constraints. The assumed array of wind turbines relative to a receptor and the setback distance are illustrated for two scenarios in Figure 1. The array was positioned at a setback distance "**d**" between the closest wind turbine unit and the receptor. This provided a reasonable simulation of wind turbine distance ranging from about 1 km to 3 km for the groups of 5 and 25 wind turbines, respectively.

4.5 In order to address the various acoustic emissions data that correspond to different wind turbine makes, sizes, power capacity and operating conditions, the approach was to identify a suitable quantity for analysis and reference. This data, which is normally supplied by the manufacturer, relies on a testing procedure performed in accordance with the International Standard IEC 61400-11 (also adopted by Canadian Standards Association in Canada). Since the noise from a wind turbine generally varies with wind speed, there can be several values for the acoustic emissions data. Also, the data may be subject to adjustments due to wind shear effects prevailing in the local area. In order to account for such variances, the quantity adopted for this study was the **guaranteed values of the Sound Power Level corresponding to 95% rated power output**.

4.6 Based on current information, for most wind turbines the electrical power capacity and the acoustic emissions are variable and thus not well correlated. Consequently, it was decided to rely on the acoustic emissions alone for categorizing wind turbines regardless of its other specifications. Based on the acoustic emissions from some of the currently available wind turbine generating equipment, four groups of acoustic emissions were identified for analysis. These groups were classified in terms of the overall Sound Power Levels corresponding to 95% rated power output as follows: **102, 104, 105, and 107 dBA**.

4.7 The coordinates for the receptor were selected to correspond with the centre of the dwelling, as defined in 4.1 above, and the height above grade was **4.5 m** (the height of an upper room in a two-storey dwelling).

4.8 The current Guide sets the noise limits at a receptor in rural areas ranging from 40 dBA up to 51 dBA depending on wind speeds in the range of 6 to 10 m/s (at 10 m height). In most cases, due to the profile of the acoustic emission with respect to wind speed, the critical condition for compliance with the noise limits occurs at the 6 m/s wind speed or 40 dBA limit. Therefore, consistent with the proposed approach, the noise limit at the receptor was taken to be the same for all wind speeds and wind turbine operating conditions at **40 dBA**.

Based on the method outlined, the resulting setbacks may be considered to be conservative with respect to noise impact at receptors as compared to the detailed procedure indicated in the Guide.

5.0 ANALYSIS

The computations were done using a spreadsheet set to calculate the sound level at a receptor using the Sound Power Level from the noise sources, in terms of full octave frequency bands, based on the International Standard ISO 9613-2.

The receptor height was set at 4.5 m and all other parameters affecting sound propagation were set, as required in the Guide. Contribution from transformer substation noise was not included.

Sample results from the computations corresponding to each of the four groups of wind turbine acoustic emissions are shown in the Appendix.

6.0 RESULTS AND CONCLUSIONS

Based on the foregoing conditions set in the analysis, the results are summarized in Table 1.

Table 1 – Proposed Setbacks for Land-based Wind Power Projects

Number of Wind Turbines (1)	**Minimum Setback to Closest Wind Turbine per Group**			
	107 dBA (2)	**105 dBA** (2)	**104 dBA** (2)	**102 dBA** (2)
25	1500 m	1250 m	850 m	750 m
10	1200 m	1000 m	700 m	650 m
5	950 m	850 m	600 m	550 m

(1) Refers to the number of wind turbines (25, 10 and 5) within a radius from a receptor of 3, 2, and 1 km, respectively.
(2) Value is the Sound Power Level in dBA re 1 pW, corresponding to the wind turbine operating at 95 % of rated electrical power capacity.

Based on the results shown in Table 1, the minimum setback distances required between a receptor location (centre of dwelling) and the base of the closest wind turbine range

from 550 m up to 1500 m. This depends on the number of units within a radius from the receptor of up to 3 km and on the specified Sound Power Level of the wind turbine.

Table 1 may be applied to any wind power project, including any other wind turbines from adjacent wind farms located within the above noted range of 3 km from the receptor.

In conclusion, a matrix of setbacks suitable for most land-based wind power projects was developed for possible use as simple screening criteria for planning and approval of wind power projects.

REFERENCES

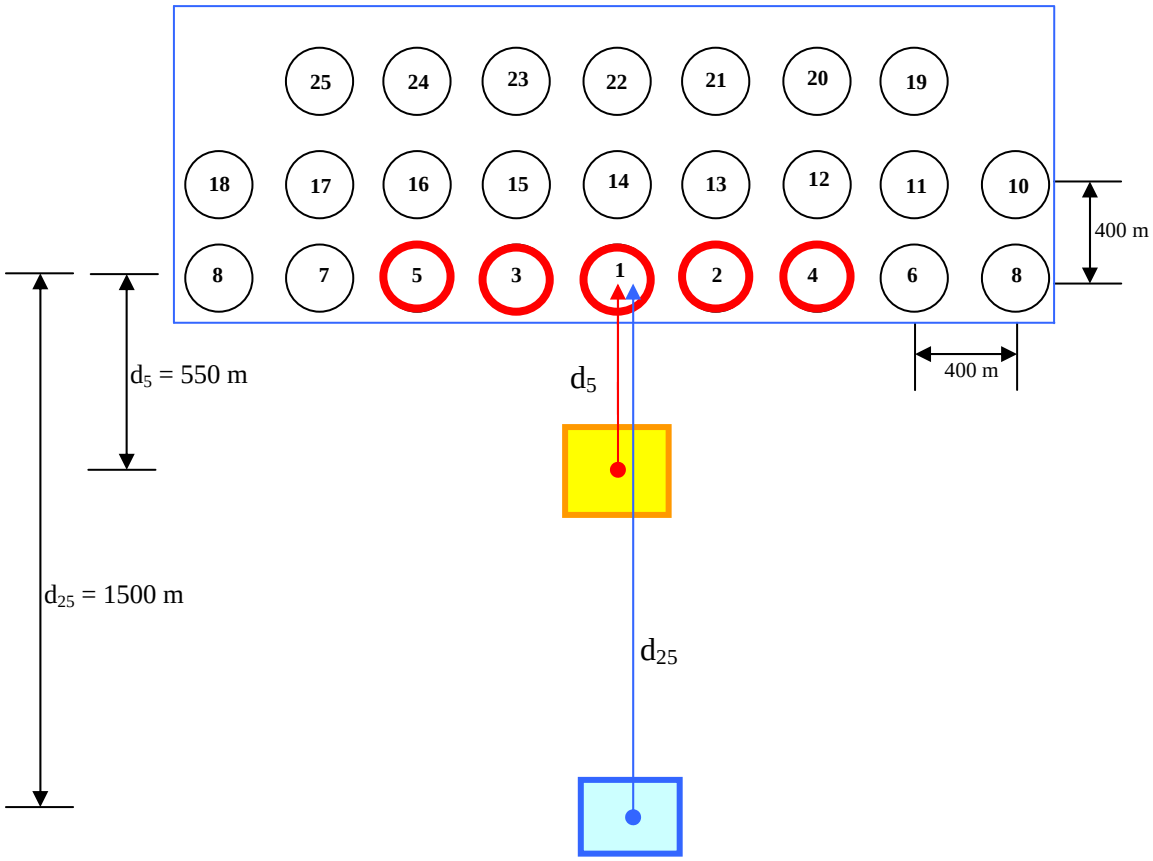
Noise Guidelines for Wind Farms – Interpretation for Applying MOE NPC Publications to Wind Power Generating Facilities - October 2008

ISO 9613-2 Acoustics – Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation.

CAN/CSA-C61400-11-07, "Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement techniques"

Figure 1

Assumed Array of Wind Turbines



Legend

- # – Wind Turbine Locations, ID
- $d_{\#}$ – Setback Distance for Listed Groupings of Wind Turbines, where # represents the number of wind turbines in the grouping
- – Residence d_5
- – Residence d_{25}

APPENDIX

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

107 dBA 25 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 1502 m	16.8	18.6	24.0	24.3	21.9	9.9	-26.7	-162.6	29.1
2 Dist to POR = 1554 m	16.5	18.3	23.7	23.9	21.4	9.1	-28.7	-169.1	28.7
3 Dist to POR = 1554 m	16.5	18.3	23.7	23.9	21.4	9.1	-28.7	-169.1	28.7
4 Dist to POR = 1702 m	15.7	17.4	22.7	22.9	20.1	6.9	-34.3	-187.1	27.6
5 Dist to POR = 1702 m	15.7	17.4	22.7	22.9	20.1	6.9	-34.3	-187.1	27.6
14 Dist to POR = 1901 m	14.7	16.4	21.6	21.5	18.4	4.0	-41.8	-211.4	26.3
6 Dist to POR = 1922 m	14.6	16.3	21.4	21.4	18.2	3.7	-42.6	-214.0	26.2
7 Dist to POR = 1922 m	14.6	16.3	21.4	21.4	18.2	3.7	-42.6	-214.0	26.2
13 Dist to POR = 1943 m	14.5	16.2	21.3	21.2	18.0	3.4	-43.4	-216.5	26.1
15 Dist to POR = 1943 m	14.5	16.2	21.3	21.2	18.0	3.4	-43.4	-216.5	26.1
12 Dist to POR = 2063 m	14.0	15.6	20.7	20.5	17.1	1.7	-47.8	-231.0	25.4
16 Dist to POR = 2063 m	14.0	15.6	20.7	20.5	17.1	1.7	-47.8	-231.0	25.4
8 Dist to POR = 2194 m	13.5	15.0	20.0	19.7	16.1	-0.1	-52.7	-247.0	24.6
9 Dist to POR = 2194 m	13.5	15.0	20.0	19.7	16.1	-0.1	-52.7	-247.0	24.6
11 Dist to POR = 2248 m	13.2	14.8	19.7	19.4	15.7	-0.8	-54.7	-253.5	24.3
17 Dist to POR = 2248 m	13.2	14.8	19.7	19.4	15.7	-0.8	-54.7	-253.5	24.3
22 Dist to POR = 2301 m	13.0	14.6	19.5	19.1	15.3	-1.6	-56.6	-259.9	24.0
21 Dist to POR = 2336 m	12.9	14.4	19.3	18.9	15.0	-2.0	-57.9	-264.0	23.9
23 Dist to POR = 2336 m	12.9	14.4	19.3	18.9	15.0	-2.0	-57.9	-264.0	23.9
20 Dist to POR = 2436 m	12.5	14.0	18.9	18.3	14.3	-3.4	-61.5	-276.2	23.3
24 Dist to POR = 2436 m	12.5	14.0	18.9	18.3	14.3	-3.4	-61.5	-276.2	23.3
10 Dist to POR = 2485 m	12.4	13.8	18.6	18.1	13.9	-4.0	-63.3	-282.1	23.1
18 Dist to POR = 2485 m	12.4	13.8	18.6	18.1	13.9	-4.0	-63.3	-282.1	23.1
19 Dist to POR = 2595 m	12.0	13.4	18.2	17.5	13.1	-5.4	-67.3	-295.3	22.6
25 Dist to POR = 2595 m	12.0	13.4	18.2	17.5	13.1	-5.4	-67.3	-295.3	22.6
Total	28.2	29.8	34.9	34.8	31.7	17.6	-22.3	-161.0	39.7

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

107 dBA 10 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 1202 m	18.8	20.7	26.2	26.8	25.0	14.7	-14.9	-125.7	31.6
2 Dist to POR = 1267 m	18.3	20.2	25.7	26.2	24.3	13.7	-17.5	-133.7	31.0
3 Dist to POR = 1267 m	18.3	20.2	25.7	26.2	24.3	13.7	-17.5	-133.7	31.0
4 Dist to POR = 1444 m	17.2	19.0	24.4	24.8	22.5	10.8	-24.5	-155.6	29.5
5 Dist to POR = 1444 m	17.2	19.0	24.4	24.8	22.5	10.8	-24.5	-155.6	29.5
14 Dist to POR = 1602 m	16.3	18.0	23.3	23.6	21.0	8.4	-30.5	-174.9	28.3
13 Dist to POR = 1651 m	16.0	17.7	23.0	23.2	20.5	7.6	-32.4	-180.9	28.0
15 Dist to POR = 1651 m	16.0	17.7	23.0	23.2	20.5	7.6	-32.4	-180.9	28.0
6 Dist to POR = 1699 m	15.7	17.4	22.7	22.9	20.1	6.9	-34.2	-186.7	27.7
7 Dist to POR = 1699 m	15.7	17.4	22.7	22.9	20.1	6.9	-34.2	-186.7	27.7
Total	27.2	28.9	34.3	34.7	32.5	21.1	-11.1	-124.5	39.5

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

107 dBA 5 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 953 m	20.8	22.8	28.5	29.3	27.9	19.2	-4.7	-94.5	34.1
2 Dist to POR = 1034 m	20.1	22.1	27.7	28.5	26.9	17.7	-8.1	-104.6	33.2
3 Dist to POR = 1034 m	20.1	22.1	27.7	28.5	26.9	17.7	-8.1	-104.6	33.2
4 Dist to POR = 1244 m	18.5	20.3	25.9	26.4	24.5	14.0	-16.6	-130.9	31.2
5 Dist to POR = 1244 m	18.5	20.3	25.9	26.4	24.5	14.0	-16.6	-130.9	31.2
Total	26.9	28.7	34.3	35.0	33.3	24.0	-1.6	-93.7	39.8

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

105 dBA 25 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 1252 m	15.3	18.3	25.6	27.0	20.9	8.8	-25.0	-135.5	30.4
2 Dist to POR = 1315 m	14.9	17.8	25.1	26.4	20.3	7.8	-27.5	-143.2	29.9
3 Dist to POR = 1315 m	14.9	17.8	25.1	26.4	20.3	7.8	-27.5	-143.2	29.9
4 Dist to POR = 1486 m	13.8	16.7	23.9	25.0	18.6	5.1	-34.2	-164.3	28.5
5 Dist to POR = 1486 m	13.8	16.7	23.9	25.0	18.6	5.1	-34.2	-164.3	28.5
14 Dist to POR = 1652 m	12.9	15.7	22.8	23.8	17.0	2.5	-40.5	-184.6	27.3
13 Dist to POR = 1699 m	12.6	15.4	22.5	23.5	16.6	1.8	-42.3	-190.4	27.0
15 Dist to POR = 1699 m	12.6	15.4	22.5	23.5	16.6	1.8	-42.3	-190.4	27.0
6 Dist to POR = 1734 m	12.5	15.2	22.3	23.2	16.3	1.3	-43.7	-194.7	26.8
7 Dist to POR = 1734 m	12.5	15.2	22.3	23.2	16.3	1.3	-43.7	-194.7	26.8
12 Dist to POR = 1835 m	12.0	14.7	21.7	22.5	15.4	-0.2	-47.5	-207.0	26.1
16 Dist to POR = 1835 m	12.0	14.7	21.7	22.5	15.4	-0.2	-47.5	-207.0	26.1
8 Dist to POR = 2032 m	11.0	13.8	20.6	21.3	13.8	-3.0	-54.8	-230.9	24.9
9 Dist to POR = 2032 m	11.0	13.8	20.6	21.3	13.8	-3.0	-54.8	-230.9	24.9
11 Dist to POR = 2042 m	11.0	13.7	20.6	21.2	13.8	-3.1	-55.2	-232.1	24.9
17 Dist to POR = 2042 m	11.0	13.7	20.6	21.2	13.8	-3.1	-55.2	-232.1	24.9
22 Dist to POR = 2051 m	11.0	13.7	20.5	21.2	13.7	-3.2	-55.5	-233.2	24.8
21 Dist to POR = 2090 m	10.8	13.5	20.3	20.9	13.4	-3.8	-56.9	-237.9	24.6
23 Dist to POR = 2090 m	10.8	13.5	20.3	20.9	13.4	-3.8	-56.9	-237.9	24.6
20 Dist to POR = 2202 m	10.3	13.0	19.8	20.3	12.5	-5.3	-61.1	-251.5	24.0
24 Dist to POR = 2202 m	10.3	13.0	19.8	20.3	12.5	-5.3	-61.1	-251.5	24.0
10 Dist to POR = 2300 m	9.9	12.6	19.3	19.7	11.8	-6.6	-64.7	-263.3	23.5
18 Dist to POR = 2300 m	9.9	12.6	19.3	19.7	11.8	-6.6	-64.7	-263.3	23.5
19 Dist to POR = 2377 m	9.7	12.3	18.9	19.3	11.2	-7.7	-67.5	-272.6	23.1
25 Dist to POR = 2377 m	9.7	12.3	18.9	19.3	11.2	-7.7	-67.5	-272.6	23.1
Total	26.2	29.0	36.0	37.0	30.1	16.0	-21.1	-134.2	40.5

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

105 dBA 10 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 1003 m	17.3	20.3	27.8	29.4	23.8	13.2	-14.9	-104.3	32.8
2 Dist to POR = 1080 m	16.6	19.7	27.1	28.6	22.8	11.8	-18.1	-114.0	32.0
3 Dist to POR = 1080 m	16.6	19.7	27.1	28.6	22.8	11.8	-18.1	-114.0	32.0
4 Dist to POR = 1283 m	15.1	18.1	25.4	26.7	20.6	8.3	-26.2	-139.2	30.1
5 Dist to POR = 1283 m	15.1	18.1	25.4	26.7	20.6	8.3	-26.2	-139.2	30.1
14 Dist to POR = 1402 m	14.3	17.2	24.5	25.7	19.4	6.4	-30.9	-154.0	29.2
13 Dist to POR = 1458 m	14.0	16.9	24.1	25.3	18.8	5.5	-33.1	-160.9	28.7
15 Dist to POR = 1458 m	14.0	16.9	24.1	25.3	18.8	5.5	-33.1	-160.9	28.7
6 Dist to POR = 1564 m	13.4	16.2	23.4	24.5	17.8	3.9	-37.2	-173.8	27.9
7 Dist to POR = 1564 m	13.4	16.2	23.4	24.5	17.8	3.9	-37.2	-173.8	27.9
Total	25.3	28.2	35.5	36.9	30.8	19.1	-11.5	-103.5	40.3

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

105 dBA 5 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 853 m	18.7	21.8	29.4	31.1	25.7	16.0	-8.6	-85.5	34.4
2 Dist to POR = 942 m	17.8	20.9	28.4	30.0	24.5	14.3	-12.4	-96.7	33.4
3 Dist to POR = 942 m	17.8	20.9	28.4	30.0	24.5	14.3	-12.4	-96.7	33.4
4 Dist to POR = 1170 m	15.9	18.9	26.3	27.7	21.8	10.2	-21.7	-125.2	31.1
5 Dist to POR = 1170 m	15.9	18.9	26.3	27.7	21.8	10.2	-21.7	-125.2	31.1
Total	24.5	27.5	34.9	36.5	31.0	20.6	-5.7	-84.9	39.9

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

104 dBA 25 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 853 m	19.3	18.3	23.5	25.7	27.1	20.0	-1.7	-82.6	31.3
2 Dist to POR = 942 m	18.4	17.4	22.5	24.6	25.9	18.3	-5.5	-93.8	30.2
3 Dist to POR = 942 m	18.4	17.4	22.5	24.6	25.9	18.3	-5.5	-93.8	30.2
4 Dist to POR = 1170 m	16.5	15.4	20.4	22.3	23.2	14.2	-14.8	-122.3	27.8
5 Dist to POR = 1170 m	16.5	15.4	20.4	22.3	23.2	14.2	-14.8	-122.3	27.8
14 Dist to POR = 1252 m	15.9	14.8	19.7	21.6	22.3	12.8	-18.1	-132.6	27.0
13 Dist to POR = 1315 m	15.5	14.3	19.2	21.0	21.7	11.8	-20.6	-140.3	26.4
15 Dist to POR = 1315 m	15.5	14.3	19.2	21.0	21.7	11.8	-20.6	-140.3	26.4
6 Dist to POR = 1472 m	14.5	13.3	18.1	19.7	20.1	9.3	-26.8	-159.7	25.0
7 Dist to POR = 1472 m	14.5	13.3	18.1	19.7	20.1	9.3	-26.8	-159.7	25.0
12 Dist to POR = 1486 m	14.4	13.2	18.0	19.6	20.0	9.1	-27.3	-161.4	24.9
16 Dist to POR = 1486 m	14.4	13.2	18.0	19.6	20.0	9.1	-27.3	-161.4	24.9
22 Dist to POR = 1652 m	13.5	12.2	16.9	18.4	18.4	6.5	-33.6	-181.7	23.7
21 Dist to POR = 1699 m	13.2	11.9	16.6	18.1	18.0	5.8	-35.4	-187.5	23.3
23 Dist to POR = 1699 m	13.2	11.9	16.6	18.1	18.0	5.8	-35.4	-187.5	23.3
11 Dist to POR = 1734 m	13.1	11.7	16.4	17.8	17.7	5.3	-36.8	-191.8	23.1
17 Dist to POR = 1734 m	13.1	11.7	16.4	17.8	17.7	5.3	-36.8	-191.8	23.1
8 Dist to POR = 1813 m	12.7	11.3	16.0	17.3	17.0	4.1	-39.7	-201.4	22.5
9 Dist to POR = 1813 m	12.7	11.3	16.0	17.3	17.0	4.1	-39.7	-201.4	22.5
20 Dist to POR = 1835 m	12.6	11.2	15.8	17.1	16.8	3.8	-40.6	-204.1	22.4
24 Dist to POR = 1835 m	12.6	11.2	15.8	17.1	16.8	3.8	-40.6	-204.1	22.4
10 Dist to POR = 2032 m	11.6	10.3	14.7	15.9	15.2	1.0	-47.9	-228.0	21.1
18 Dist to POR = 2032 m	11.6	10.3	14.7	15.9	15.2	1.0	-47.9	-228.0	21.1
19 Dist to POR = 2042 m	11.6	10.2	14.7	15.8	15.2	0.9	-48.3	-229.2	21.0
25 Dist to POR = 2042 m	11.6	10.2	14.7	15.8	15.2	0.9	-48.3	-229.2	21.0
Total	28.9	27.7	32.6	34.4	35.1	26.1	1.3	-82.0	39.8

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

104 dBA 10 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 704 m	20.9	20.6	25.0	27.7	29.2	23.3	5.1	-63.1	33.4
2 Dist to POR = 810 m	19.7	19.2	23.7	26.3	27.5	21.1	0.4	-76.7	31.9
3 Dist to POR = 810 m	19.7	19.2	23.7	26.3	27.5	21.1	0.4	-76.7	31.9
4 Dist to POR = 1066 m	17.2	16.7	21.0	23.4	24.2	16.2	-10.4	-109.0	28.8
5 Dist to POR = 1066 m	17.2	16.7	21.0	23.4	24.2	16.2	-10.4	-109.0	28.8
14 Dist to POR = 1103 m	16.9	16.4	20.7	23.1	23.8	15.6	-11.9	-113.6	28.4
13 Dist to POR = 1173 m	16.4	15.8	20.1	22.4	23.0	14.3	-14.7	-122.4	27.7
15 Dist to POR = 1173 m	16.4	15.8	20.1	22.4	23.0	14.3	-14.7	-122.4	27.7
12 Dist to POR = 1362 m	15.1	14.4	18.6	20.7	21.0	11.2	-22.3	-145.9	25.9
16 Dist to POR = 1362 m	15.1	14.4	18.6	20.7	21.0	11.2	-22.3	-145.9	25.9
Total	27.9	27.4	31.8	34.3	35.3	28.3	7.6	-62.8	39.7

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

104 dBA 5 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 605 m	22.2	22.0	26.4	29.2	30.8	25.6	9.6	-50.2	35.0
2 Dist to POR = 725 m	20.6	20.3	24.7	27.4	28.8	22.9	4.1	-65.8	33.1
3 Dist to POR = 725 m	20.6	20.3	24.7	27.4	28.8	22.9	4.1	-65.8	33.1
4 Dist to POR = 1003 m	17.8	17.2	21.6	24.1	25.0	17.4	-7.8	-101.1	29.5
5 Dist to POR = 1003 m	17.8	17.2	21.6	24.1	25.0	17.4	-7.8	-101.1	29.5
Total	27.2	26.8	31.2	33.9	35.3	29.3	11.7	-49.9	39.6

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

102 dBA 25 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 754 m	18.5	20.6	25.1	28.0	26.5	19.1	-3.2	-76.1	32.2
2 Dist to POR = 853 m	17.4	19.4	24.0	26.8	25.0	17.0	-7.5	-88.9	30.9
3 Dist to POR = 853 m	17.4	19.4	24.0	26.8	25.0	17.0	-7.5	-88.9	30.9
4 Dist to POR = 1099 m	15.2	17.1	21.5	24.1	21.9	12.4	-17.8	-119.8	28.2
5 Dist to POR = 1099 m	15.2	17.1	21.5	24.1	21.9	12.4	-17.8	-119.8	28.2
14 Dist to POR = 1152 m	14.8	16.6	21.0	23.6	21.3	11.5	-19.9	-126.5	27.6
13 Dist to POR = 1220 m	14.3	16.1	20.5	23.0	20.6	10.3	-22.6	-134.8	27.0
15 Dist to POR = 1220 m	14.3	16.1	20.5	23.0	20.6	10.3	-22.6	-134.8	27.0
12 Dist to POR = 1403 m	13.0	14.8	19.1	21.4	18.7	7.4	-29.8	-157.5	25.4
16 Dist to POR = 1403 m	13.0	14.8	19.1	21.4	18.7	7.4	-29.8	-157.5	25.4
6 Dist to POR = 1417 m	12.9	14.7	19.0	21.3	18.5	7.1	-30.4	-159.2	25.3
7 Dist to POR = 1417 m	12.9	14.7	19.0	21.3	18.5	7.1	-30.4	-159.2	25.3
22 Dist to POR = 1552 m	12.1	13.9	18.1	20.2	17.2	5.0	-35.6	-175.8	24.3
21 Dist to POR = 1603 m	11.9	13.6	17.7	19.9	16.8	4.3	-37.6	-182.0	23.9
23 Dist to POR = 1603 m	11.9	13.6	17.7	19.9	16.8	4.3	-37.6	-182.0	23.9
11 Dist to POR = 1664 m	11.5	13.2	17.3	19.4	16.2	3.3	-39.9	-189.5	23.4
17 Dist to POR = 1664 m	11.5	13.2	17.3	19.4	16.2	3.3	-39.9	-189.5	23.4
20 Dist to POR = 1746 m	11.1	12.8	16.8	18.8	15.5	2.1	-43.0	-199.5	22.9
24 Dist to POR = 1746 m	11.1	12.8	16.8	18.8	15.5	2.1	-43.0	-199.5	22.9
8 Dist to POR = 1769 m	11.0	12.7	16.7	18.7	15.3	1.8	-43.9	-202.3	22.7
9 Dist to POR = 1769 m	11.0	12.7	16.7	18.7	15.3	1.8	-43.9	-202.3	22.7
19 Dist to POR = 1962 m	10.1	11.7	15.6	17.4	13.7	-1.0	-51.1	-225.8	21.5
25 Dist to POR = 1962 m	10.1	11.7	15.6	17.4	13.7	-1.0	-51.1	-225.8	21.5
10 Dist to POR = 1972 m	10.0	11.6	15.6	17.4	13.6	-1.1	-51.5	-227.0	21.4
18 Dist to POR = 1972 m	10.0	11.6	15.6	17.4	13.6	-1.1	-51.5	-227.0	21.4
Total	27.6	29.5	33.8	36.3	34.0	24.7	-0.5	-75.7	40.4

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

102 dBA 10 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 654 m	19.7	21.9	26.5	29.4	28.1	21.2	1.3	-63.3	33.7
2 Dist to POR = 767 m	18.3	20.4	25.0	27.9	26.3	18.8	-3.7	-77.8	32.1
3 Dist to POR = 767 m	18.3	20.4	25.0	27.9	26.3	18.8	-3.7	-77.8	32.1
4 Dist to POR = 1034 m	15.7	17.7	22.1	24.8	22.7	13.6	-15.1	-111.6	28.8
5 Dist to POR = 1034 m	15.7	17.7	22.1	24.8	22.7	13.6	-15.1	-111.6	28.8
14 Dist to POR = 1053 m	15.6	17.5	21.9	24.6	22.5	13.3	-15.9	-114.0	28.6
13 Dist to POR = 1126 m	15.0	16.9	21.3	23.8	21.6	12.0	-18.9	-123.2	27.9
15 Dist to POR = 1126 m	15.0	16.9	21.3	23.8	21.6	12.0	-18.9	-123.2	27.9
12 Dist to POR = 1322 m	13.5	15.4	19.7	22.1	19.5	8.7	-26.7	-147.5	26.1
16 Dist to POR = 1322 m	13.5	15.4	19.7	22.1	19.5	8.7	-26.7	-147.5	26.1
Total	26.6	28.6	33.0	35.8	34.0	26.0	3.7	-63.0	39.9

WIND TURBINE SOUND LEVEL AT MINIMUM SETBACKS

102 dBA 5 Turbines

Source	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	dBA
1 Dist to POR = 555 m	21.2	23.5	28.0	31.1	29.9	23.6	6.0	-50.2	35.4
2 Dist to POR = 684 m	19.3	21.5	26.0	29.0	27.6	20.6	0.0	-67.2	33.2
3 Dist to POR = 684 m	19.3	21.5	26.0	29.0	27.6	20.6	0.0	-67.2	33.2
4 Dist to POR = 974 m	16.2	18.2	22.7	25.4	23.4	14.7	-12.6	-104.1	29.5
5 Dist to POR = 974 m	16.2	18.2	22.7	25.4	23.4	14.7	-12.6	-104.1	29.5
Total	26.0	28.1	32.6	35.5	34.1	27.1	7.8	-50.1	39.8

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