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Environmental Noise Impact Assessment

For The

Proposed Ogilvie Residential Development

Prepared for:

The City of Edmonton

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Executive Summary

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of Edmonton to conduct an environmental noise impact assessment (NIA) for the proposed Ogilvie Residential Development (the Development) in Southwest Edmonton, AB. The purpose of this study was to compare the projected noise levels of residential receptor locations most impacted by the existing EPCOR Petrolia Substation to the most applicable noise criteria from the City of Edmonton and from the Alberta Utilities Commission (AUC). A site visit was conducted for aci on October 28, 2016 by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

The Future Case noise model results, with and without the cooling fans, indicated that the Future AUC Rule 012 PSL's for the Approved Site will be determined by Section 2 of AUC Rule 012 and not by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Approved Site will be below Bylaw 14600 PSL of 50 dBA at all locations for both future case scenarios. Therefore, noise mitigation will not be required for the Approved site.

The Future Case noise model results, with and without the cooling fans, indicated that the Future AUC Rule 012 PSL's for the Alternate Site will either be determined by Section 2 of AUC Rule 012 or by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Alternate Site were above Bylaw 14600 PSL of 50 dBA at certain locations for both future case scenarios. Therefore, noise mitigation will be required for the Alternate site. Noise mitigation in the form of acoustical barriers were provided for the Alternate site for both future case noise modelling scenarios.

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1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of Edmonton to conduct an environmental noise impact assessment (NIA) for the proposed Ogilvie Residential Development (the Development) in Southwest Edmonton, AB. The purpose of this study was to compare the projected noise levels of residential receptor locations most impacted by the existing EPCOR Petrolia Substation to the most applicable noise criteria from the City of Edmonton and from the Alberta Utilities Commission (AUC). A site visit was conducted for aci on October 28, 2016 by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

2.0 Location & Project Description

2.1. Location Description

The proposed Development is in Southwest Edmonton, as shown in Figure 1. The specific Study Area for this NIA includes the Approved Site and the Alternate Site as indicated in Figure 1. The current land on which the Development will be placed has been identified as a surplus school site and in accordance with City Policy C583 is to be medium density residential.

As previously mentioned, the EPCOR Petrolia Substation (EPCOR site) is within proximity of both potential sites. The EPCOR site currently has large transformers in the northeast and northwest corners of the site, as shown in Figure 2. Each transformer has vertical cooling fans in addition to a large concrete acoustical barrier. The barrier for the northeast corner wraps around the west, north and east portion of the transformer and is open to the south. The barrier for the northwest transformer wraps around the south, west and north sides and is open to the east. Due to the restricted access to this site, short term fence line sound level measurements were limited to being performed along the east and north perimeter of the site.

Topographically the land within the Study area has several changes in elevation. The Approved Site is approximately 2.0 m below the height of the northern boundary of the EPCOR site while the Alternate site which is approximately 0.5 m higher than the eastern boundary of the EPCOR site. Digital topographical information for the area was included in the model to account for the variations in elevation.

Vegetation within the area is composed primarily of field grasses. Periodically, there are sparse trees and bushes within the area, however, they are neither deep nor dense enough to provide significant vegetative sound absorption for any of the projected receiver locations.

3.0 Measurement & Modeling Methods

3.1. Site Sound Level Measurements

As part of the study, a site visit was conducted on October 28, 2016 in which fence-line measurements were conducted around the perimeter of the EPCOR Site. The sound power levels used in the noise model accurately reflect the existing noise sources observed within the study area. Any noise sources further away were subjectively insignificant and were not considered as part of the study. It should be noted that due to the outdoor temperature (and likely the electrical load) during the site measurements, the cooling fans were not in operation. However, aci has detailed acoustical data for fans of this type from previous measurements conducted on similar fan assemblies.

Sound level measurements were conducted using a Brüel and Kjær Type 2270 Precision Integrating Sound Level Meter (SLM). The distance from each noise source to the SLM was measured and the surrounding reflective conditions were noted. The sound pressure level data obtained was then used to determine the appropriate octave band sound power level data for the noise source. Refer to Appendix I for a detailed description of the measurement instrumentation used.

3.2. Modeling Methods

3.2.1. Computer Noise Modeling

The computer noise modeling was conducted using the CADNA/A (version 4.6.155) software package. CADNA/A allows for the modeling of various noise sources such as road, rail, and various stationary sources. In addition, topographical features such as land contours, vegetation, and bodies of water can be included. Finally, meteorological conditions such as temperature, relative humidity, wind-speed and wind-direction can be included in the calculations. Note that all modeling methods used exceed the requirements of the AUC Rule 012 on Noise Control.

The calculation method used for noise propagation follows the ISO standard 9613-2. All receiver locations were assumed as being downwind from the source(s). In particular, as stated in Section 5 of the ISO document:

> *"Downwind propagation conditions for the method specified in this part of IS0 9613 are as specified in 5.4.3.3 of IS0 1996-2:1987, namely*
> - *wind direction within an angle of ± 45^0 of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and*

- *wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.*

The equations for calculating the average downwind sound pressure level LAT(DW) in this part of IS0 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.

These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights".

3.2.2. Noise Modeling Scenarios

As part of the study, four (4) various scenario were modeled:

1) Future Case without Fans: This included all noise sources and buildings associated with the EPCOR site, without the cooling fans[1], in addition to residential receptor locations and structures associated with the Development.

2) Future Case with Fans: This included all noise sources and buildings associated with the EPCOR site, with the cooling fans, in addition to residential receptor locations and structures associated with the Development.

3) Future Case without Fans with Mitigation: This included all conditions associated with the Future Case without fans, along with the mitigation required to achieve the maximum noise levels specified in City of Edmonton Community Standards Bylaw 14600.

4) Future Case with Fans with Mitigation: This included all conditions associated with the Future Case with fans, along with the mitigation required to achieve the maximum noise levels specified in City of Edmonton Community Standards Bylaw 14600.

[1] The addition and subtraction of the cooling fans will be discussed in Section 4.2.

3.2.3. Noise Modeling Parameters

All noise sources have been modeled as point sources at their appropriate heights[1]. Sound power levels for all noise sources were modeled using octave-band information. Sound power levels for existing noise sources were determined based on sound level measurements conducted within the study area for specific noise producing items and are provided in Appendix II.

Due to the small amount of vegetation, and thus relative ineffectiveness to mitigate the noise climate, vegetation was not included in the model. Similarly, no snow cover was included since there can be variation in absorption/reflection caused by different snow conditions. A ground absorption coefficient of 0.5 was used along with a temperature of 10^0C and a relative humidity of 70%. As a result, all sound level propagation calculations are considered representative of summertime conditions for all surrounding residential receptor locations (as specified in AUC Rule 012).

The computer noise modeling results were calculated in two ways. First, sound levels were calculated at the specific residential receptor locations. The receptor locations were only implemented for residential receptor locations most impacted by the various facilities. These locations will have the highest projected noise levels due to their proximity to the facilities and due to the lack of shielding provided by other dwellings, structures, etc. In addition, AUC Rule 012 requires that the residential receptor locations be placed 15 m from the dwelling in the direction of the facility. However, the exact location of the dwellings is currently unknown, therefore all residential receptor locations were placed along the nearest property line to the EPCOR site. Next, the sound levels were calculated using a 2 m x 2 m grid over the entire study area. This provided color noise contours for easier visualization of the results.

3.2.4. Modeling Confidence

As previously mentioned, the algorithms used for the noise modeling follow the ISO 9613 standard. The published accuracy for this standard is ±3 dBA between 100 m – 1,000 m. Accuracy levels beyond 1,000 m are not published. Experience based on similar noise models conducted over large distances shows that, as expected, as the distance increases, the associated accuracy in prediction decreases. Experience has shown that environmental factors such as wind, temperature inversions, topography and ground cover all have increasing effects over distances larger than approximately 1,500 m. As such, since all receptors are within approximately 1,500 m of the proposed station, the prediction confidence is considered high.

Refer to Appendix III for a description of the acoustical terminology and Appendix IV for a list of common noise sources.

[1] The heights for many of the sources are generally slightly higher than actual. This makes the model more conservative.

4.0 Permissible Sound Levels

Environmental noise levels from various sources (industrial, roads, railways, etc.) are commonly described in terms of equivalent sound levels or L_{eq}. This is the level of a steady sound having the same acoustic energy, over a given time period, as the fluctuating sound. In addition, this energy averaged level is A–weighted to account for the reduced sensitivity of average human hearing to low frequency sounds. These L_{eq} in dBA, which are the most common environmental noise measure, are often given for day-time (07:00 to 22:00) L_{eq}Day and night-time (22:00 to 07:00) L_{eq}Night while other criteria use the entire 24-hour period as L_{eq}24. The criteria used to evaluate the noise in the study area include the City of Edmonton Community Standards Bylaw 14600 and the Alberta Utilities Commission Rule 012.

4.1. City of Edmonton Community Standards Bylaw 14600

The City of Edmonton Community Standards Bylaw 14600 (Bylaw 14600) sets maximum sound levels that may exist between various categories of land use. The maximum sound levels that may impinge upon a residential property at the shared boundary is **50 dBA** for the night-time (22:00 - 07:00) and 65 dBA for the day-time (07:00 - 22:00). While not explicitly stated, it is commonly assumed that these allowable levels are in dBA L_{eq}.

4.2. Alberta Utilities Commission Rule 012

AUC Rule 012 (2013) on Noise Control applies to all the energy-related facilities which includes electrical substations. The following is taken directly from AUC Rule 012 for the determination of Permissible Sound Levels (PSL) for a proposed dwelling in proximity to an existing or approved facility:

1. *Where a person builds a dwelling or receives a building permit within 1.5 km from the boundary of an existing or approved facility, or a wind turbine or substation in a wind project, the permissible sound level at the new dwelling, will be the greater of the cumulative sound level existing at the time of construction of the new dwelling, or the permissible sound level as determined in Section 2 of this rule.*

2. *When a licensee is notified that a person is proposing to build a dwelling within 1.5 km of the boundary of the facility property or a wind turbine or substation in a wind project, if requested by the person, the licensee must communicate information regarding existing noise levels to that person. Where a noise impact assessment for the facility or wind turbine project exists, the licensee must either provide it to that*

person or, in the alternative, the licensee may provide the existing sound level survey or modelling data interpolated to the person's proposed building site.

3. *A licensee must keep documentation of communication between the licensee and a person proposing to build a dwelling within 1.5 km of the boundary of the facility property or a wind turbine or substation in a wind project including a copy of the noise impact assessment or other data provided to that person.*

As indicated in Item 1, the determination of PSLs for the residential receptors will be the greater of the cumulative sound level existing at the time of construction of the new dwellings, or the PSL as determined in Section 2 of Rule 012.

As per Rule 012, the cumulative sound level is a representation of the typical noise climate of the area and not an unusually quiet time (non-frequent occurrence – less than 10 per cent of the time for a season) or a loud time. At the time of this report, the frequency of the operations of the cooling fans is unknown and therefore their occurrences as non-frequent/ frequent cannot be determined. Thus, as discussed in Section 3.2., a scenario for each case (with/without fans) has been investigated.

The PSL at the receiver location, as described in Section 2 of the AUC Rule 012, is based on population density and relative distances to heavily traveled road and rail as shown in Table 1. The various adjacent residential receptors are classified in Category 2, because they are all between 30 – 500 m from a heavily travelled road[1]. In addition, they all have a population density that is greater than 160 dwellings per quarter section. All receptors are considered not to be in an area with frequent aircraft flyovers and the facility will not be a seasonal operation.

The PSLs provided are related to noise associated with activities and processes at the facilities and are not related to vehicle traffic on nearby highways (or access roads). This includes all traffic related to construction and operations of the facilities. As such, their contributions will not be considered in this report.

[1] When comparing the traffic volumes (found within the City of Edmonton's 2014 AAWDT Report) along similar roads within proximity of Ogilvie Blvd NW, it would be anticipated that the AADT for Ogilvie Blvd would be approximately 1000. Assuming 10% of this traffic occurs during the night-time equates to approximately 11 vehicles per hour during the night time. This meets the AUC Rule 012 requirement of 10 vehicles per hour for the road to be considered Heavily Traveled.

Based on this information the AUC Rule 012, Section 2, the PSL will be an **L_{eq}Night of 51 dBA and an L_{eq}Day of 61 dBA** for all residential receptor locations. Refer to Appendix V for a detailed determination of the permissible sound levels.

Table 1. Basic Night-Time Sound Levels (as per the AUC Rule 012)

Proximity to Transportation	Dwelling Density per Quarter Section of Land		
	1-8 Dwellings	9-160 Dwellings	>160 Dwellings
Category 1	40 dBA	43 dBA	46 dBA
Category 2	45 dBA	48 dBA	51 dBA
Category 3	50 dBA	53 dBA	56 dBA

Category 1 Dwelling units more than 500m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

Category 2 Dwelling units more than 30m but less than 500m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

Category 3 Dwelling units less than 30m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

As stated in Item 2 (shown above), the developer should notify the various facilities of the construction of the Development. The existing noise levels for the Development are found within the tables and figures found in Section 5.2. Lastly, it is the responsibility of the facilities to keep documentation of communication between themselves and the Developer.

5.0 Results and Discussion

5.1. Short-term Sound Level Measurements

Short-term sound level measurements were conducted on October 28, 2016 at various locations around the EPCOR site to determine the contribution of the various noise sources found on-site. The results of each measurement are provided in Table 2. The 1/3 octave spectral data for each of the short-term measurements are provided in Appendix VI.

Table 2. Compressor Station Site Sound Level Measurement Results

Measurement Number	Description	Distance (m)	Sound Pressure Level (dBA)
1	Southeast of Transformer #1	52.8	60.0
2	Southeast of Transformer #1	27.8	57.3
3	Southeast of Transformer #1	27.8	57.1
4	Southeast of Transformer #1	27.8	57.0
5	East of Transformer #1	23.3	53.4
6	Northeast of Transformer #1	27.7	47.7
7	Northeast of Transformer #1	27.7	47.2
8	North of Transformer #1	20.5	49.7
9	Northwest of Transformer #1	27.1	46.4
10	East of Transformer #2	18.0	60.7
11	Northeast of Transformer #2	22.2	62.0
12	North of Transformer #2	18.3	51.1
13	North of Transformer #2	18.3	52.3
14	Northwest of Transformer #2	29.4	43.9

5.2. Noise Modeling Results

5.2.1. Future Case without Fans

The results of the Future Case without Fans noise modeling scenario are presented in Table 3a & Table 3b and illustrated in Figure 3. Tables 3a & 3b provide the projected noise levels at the Approved site and Alternate site from the EPCOR site (without the contributions of the cooling fans) in addition to a comparison to the City of Edmonton's Bylaw 14600 and the AUC's Rule 012.

Table 3a. Future Case without Fans Modeled Sound Levels & PSL Determination (Approved Site)

Receptor	Projected L_{eq}24 Noise Levels from Facility (dBA)	City of Edmonton Bylaw 14600 PSL	Compliant with City of Edmonton (Yes/No)		PSL as per AUC Rule 012 Section 2 (LeqNight dBA)	Future AUC Rule 012 LeqNight PSL (dBA)	Determined From
R-01	40.3	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-02	40.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-03	41.2	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-04	42.3	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-05	44.3	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-06	46.0	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-07	46.7	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-08	44.1	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-09	42.8	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2

Table 3b. Future Case without Fans Modeled Sound Levels & PSL Determination (Alternate Site)

Receptor	Projected L_{eq}24 Noise Levels from Facility (dBA)	City of Edmonton Bylaw 14600 PSL	Compliant with City of Edmonton (Yes/No)		PSL as per AUC Rule 012 Section 2 (LeqNight dBA)	Future AUC Rule 012 LeqNight PSL (dBA)	Determined From
R-10	42.2	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-11	44.4	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-12	47.1	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-13	50.2	50.0	No		51.0	51.0	AUC Rule 012, Section 2
R-14	53.6	50.0	No		51.0	53.6	Projected Noise Levels from Facilities
R-15	52.2	50.0	No		51.0	52.2	Projected Noise Levels from Facilities
R-16	50.5	50.0	No		51.0	51.0	AUC Rule 012, Section 2
R-17	48.6	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-18	46.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2

As indicated in Table 3a and Figure 3, the Future AUC Rule 012 PSL's are determined by Section 2 of AUC Rule 012 and not by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Approved Site will be below the Bylaw 14600 PSL of 50 dBA at all locations. Therefore, noise mitigation will not be required for the Approved Site under this scenario.

As indicated in Table 3b and Figure 3, apart from R-14 & R-15, the Future AUC Rule 012 PSL's for all residential receptors are determined by Section 2 of AUC Rule 012. The PSL's for receptors R-14 & R-15 are determined by the existing cumulative projected noise levels from the EPCOR site. The projected noise levels for the Alternate site will be below Bylaw 14600 PSL of 50 dBA at all locations, aside from R-14 & R-15. As a result, noise mitigation will be required for the Alternate site under this scenario.

5.2.2. Future Case with Fans

The results of the Future Case with Fans noise modeling scenario are presented in Table 4a & Table 4b and illustrated in Figure 4. Tables 4a & 4b provide the projected noise levels at the Approved site and Alternate site from the EPCOR site (with the contributions of the cooling fans) in addition to a comparison to the City of Edmonton's Bylaw 14600 and the AUC's Rule 012.

Table 4a. Future Case with Fans Modeled Sound Levels & PSL Determination (Approved Site)

Receptor	Projected L_{eq}24 Noise Levels from Facility (dBA)	City of Edmonton Bylaw 14600 PSL	Compliant with City of Edmonton (Yes/No)		PSL as per AUC Rule 012 Section 2 (LeqNight dBA)	Future AUC Rule 012 LeqNight PSL (dBA)	Determined From
R-01	43.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-02	44.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-03	46.2	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-04	47.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-05	49.4	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-06	49.9	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-07	47.8	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-08	46.3	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-09	47.1	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2

Table 4b. Future Case with Fans Modeled Sound Levels & PSL Determination (Alternate Site)

Receptor	Projected L_{eq}24 Noise Levels from Facility (dBA)	City of Edmonton Bylaw 14600 PSL	Compliant with City of Edmonton (Yes/No)		PSL as per AUC Rule 012 Section 2 (LeqNight dBA)	Future AUC Rule 012 LeqNight PSL (dBA)	Determined From
R-10	49.0	50.0	Yes		51.0	51.0	AUC Rule 012, Section 2
R-11	50.7	50.0	No		51.0	51.0	AUC Rule 012, Section 2
R-12	56.1	50.0	No		51.0	56.1	Projected Noise Levels from Facilities
R-13	62.2	50.0	No		51.0	62.2	Projected Noise Levels from Facilities
R-14	59.3	50.0	No		51.0	59.3	Projected Noise Levels from Facilities
R-15	56.5	50.0	No		51.0	56.5	Projected Noise Levels from Facilities
R-16	55.7	50.0	No		51.0	55.7	Projected Noise Levels from Facilities
R-17	53.8	50.0	No		51.0	53.8	Projected Noise Levels from Facilities
R-18	53.8	50.0	No		51.0	53.8	Projected Noise Levels from Facilities

As indicated in Table 4a and Figure 4, the Future AUC Rule 012 PSL's are determined by Section 2 of AUC Rule 012 and not by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Approved Site will be below the Bylaw 14600 PSL of 50 dBA at all locations. Therefore, noise mitigation will not be required for the Approved Site under this scenario.

As indicated in Table 4b and Figure 4, the Future AUC Rule 012 PSL's are determined by Section 2 of AUC Rule 012 for Receptors R-10 & R11. For all other residential receptor locations, the Future AUC Rule 012 PSL's are determined by the existing cumulative projected noise levels from the EPCOR site. With the exception of R-10, the projected noise levels for the Alternate site will be above Bylaw 14600 PSL of 50 dBA at all locations. Therefore, noise mitigation will be required for the Alternate site under this scenario.

5.2.3. Future Case without fans with Mitigation

The results of the Future Case without Fans noise modeling scenario are presented in Figure 5[1]. As indicated in Figure 5, all areas within the Approved site are below Bylaw 14600 PSL's of 50 dBA. Therefore, no further noise mitigation is required.

For the Alternate site, to achieve the noise levels shown Figure 5, a 1.83 m barrier was placed along the west residential boundary. Note that the barrier height is relative to the **existing grade** at the residential area boundary line (the location of the modeled barrier). It is also important to note that the barriers are modeled as continuous and must meet any adjacent segment with no holes or gaps. The barriers can either start/finish abruptly or slowly taper up/down after the required barrier lengths/heights are implemented.

5.2.4. Future Case with fans with Mitigation

The results of the Future Case with Fans noise modeling scenario are presented in Figure 6[1]. As indicated in Figure 6, all areas within the Approved site are below Bylaw 14600 PSL's of 50 dBA. Therefore, no further noise mitigation is required.

For the Alternate site, to achieve the noise levels shown Figure 6, a combination of 1.83 m (6 foot), 3.0 m and 4.0 m barrier heights are required along the west residential boundary. The location and length of each barrier height is shown in Figure 7. Note that the barrier height is relative to the **existing grade** at the residential area boundary line (the location of the modeled barrier). It is also important to note that the barriers are modeled as continuous and must meet any adjacent segment with no holes or gaps. The barriers can either start/finish abruptly or slowly taper up/down after the required barrier lengths/heights are implemented.

[1] A table has not been provided for the residential receptor locations since the location of the receptors are directly along the residential boundary which is also the location of the noise barrier.

5.3. Barrier Construction

Barrier construction can be either solid screen wood fences or masonry noise walls. If using wood materials, the fences should be, at a minimum, double boarded with no visible gaps through the fence or at the bottom and have a surface density of at least 20 kg/m^2. A sample schematic of fence construction is provided in Figure 8. For masonry noise walls, there should also be no visible gaps and the surface density must also be at least 20 kg/m^2.

If there are to be any walkways or roadways penetrating through the proposed barrier locations, then the barrier should either: a) wrap around on both sides of the opening on the inside for at least the distance from the rear property line to the structure or, b) wrap around past the opening for at least 3 equivalent opening dimensions. Both options are shown in Figure 9.

It should be noted that for any of barriers described above it is it is possible to exchange berm height for fence height and vice-versa, providing the centerline of the barrier does not change (i.e. it remains at the current proposed property line). The key is that the total height must be that listed above. For example, the barrier could either be a 2.83 m tall masonry wall or a combination of a 1.0 m berm + 1.83 m noise fence.

6.0 Conclusion

The Future Case noise model results, with and without the cooling fans, indicated that the Future AUC Rule 012 PSL's for the Approved Site will be determined by Section 2 of AUC Rule 012 and not by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Approved Site will be below Bylaw 14600 PSL of 50 dBA at all locations for both future case scenarios. Therefore, noise mitigation will not be required for the Approved site.

The Future Case noise model results, with and without the cooling fans, indicated that the Future AUC Rule 012 PSL's for the Alternate Site will either be determined by Section 2 of AUC Rule 012 or by the existing cumulative projected noise levels from the EPCOR site. In addition, the projected noise levels for the Alternate Site were above Bylaw 14600 PSL of 50 dBA at certain locations for both future case scenarios. Therefore, noise mitigation will be required for the Alternate site. Noise mitigation in the form of acoustical barriers were provided for the Alternate site for both future case noise modelling scenarios.

7.0 References

- Alberta Utilities Commission (AUC), *Rule 012 on Noise Control, 2013*, Calgary, Alberta
- City of Edmonton Community Standards Bylaw 14600, 2008
- International Organization for Standardization (ISO), *Standard 1996-1, Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures, 2003*, Geneva Switzerland.
- International Organization for Standardization (ISO), *Standard 9613-1, Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of absorption of sound by the atmosphere, 1993*, Geneva Switzerland.
- International Organization for Standardization (ISO), *Standard 9613-2, Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation, 1996*, Geneva Switzerland.

Figure 1. Development Plan

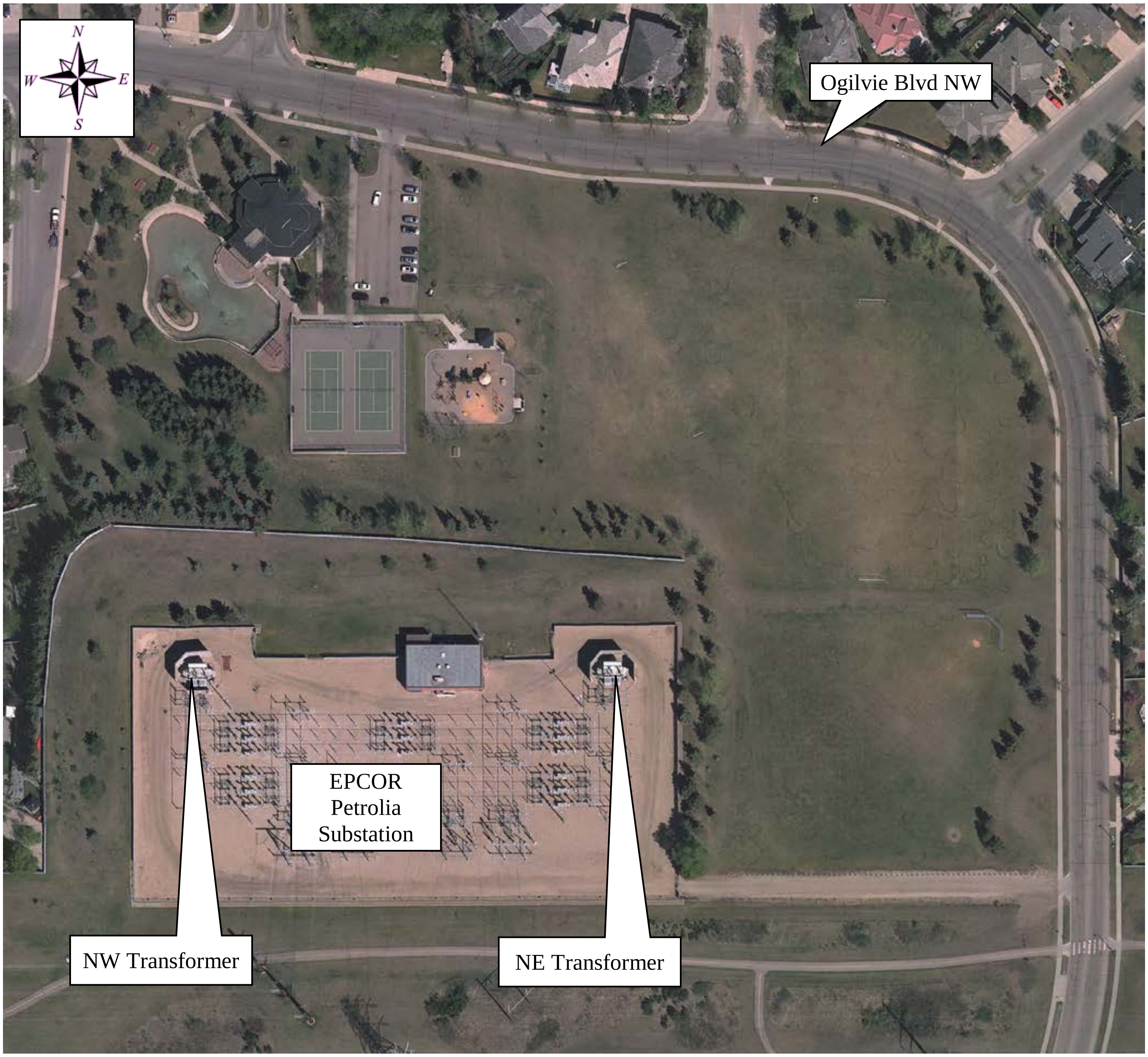

Figure 2. Study Area

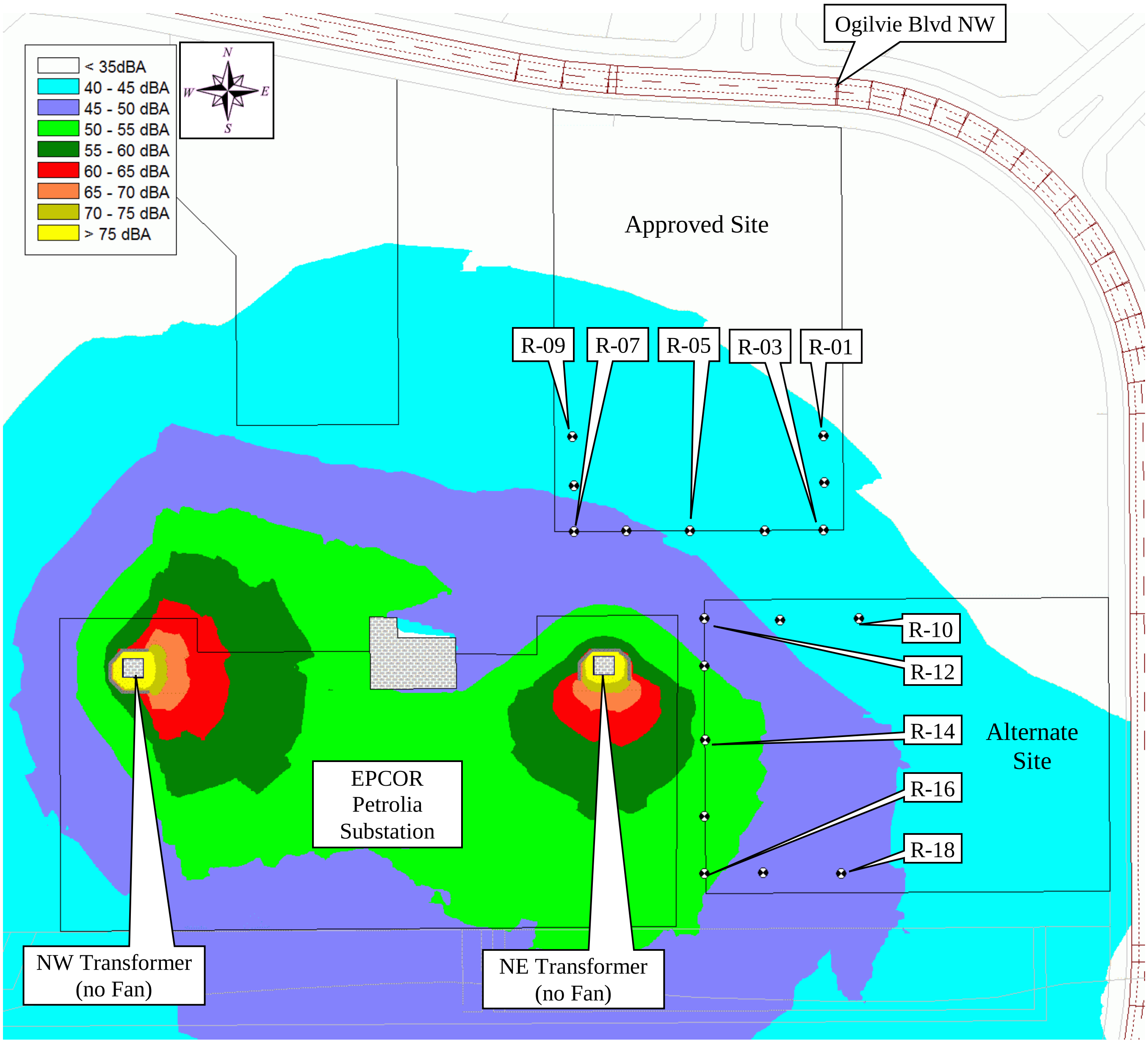

Figure 3. Future Case without Fans, L_{eq}24 Noise Levels

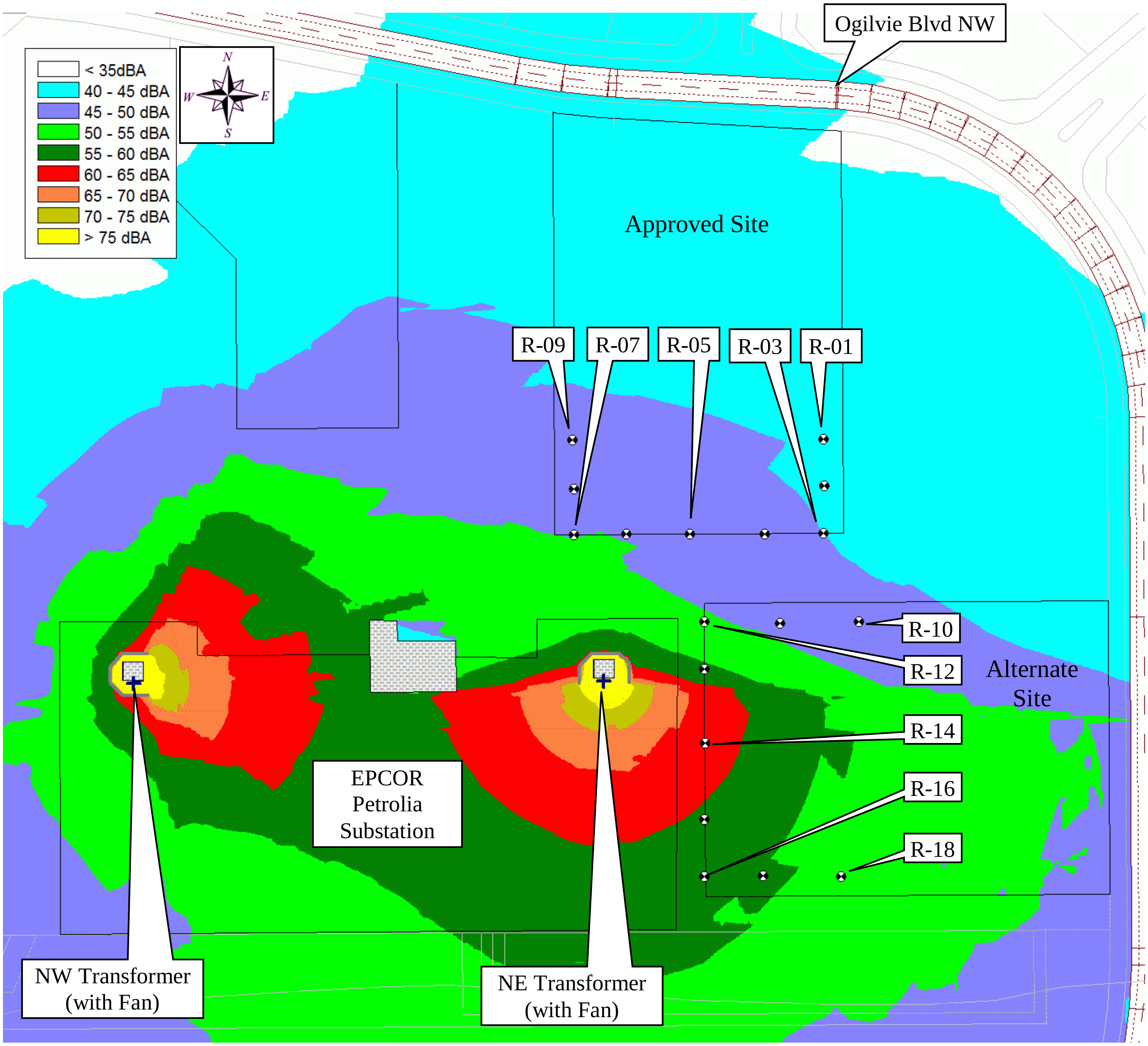

Figure 4. Future Case with Fans, L_{eq}24 Noise Levels

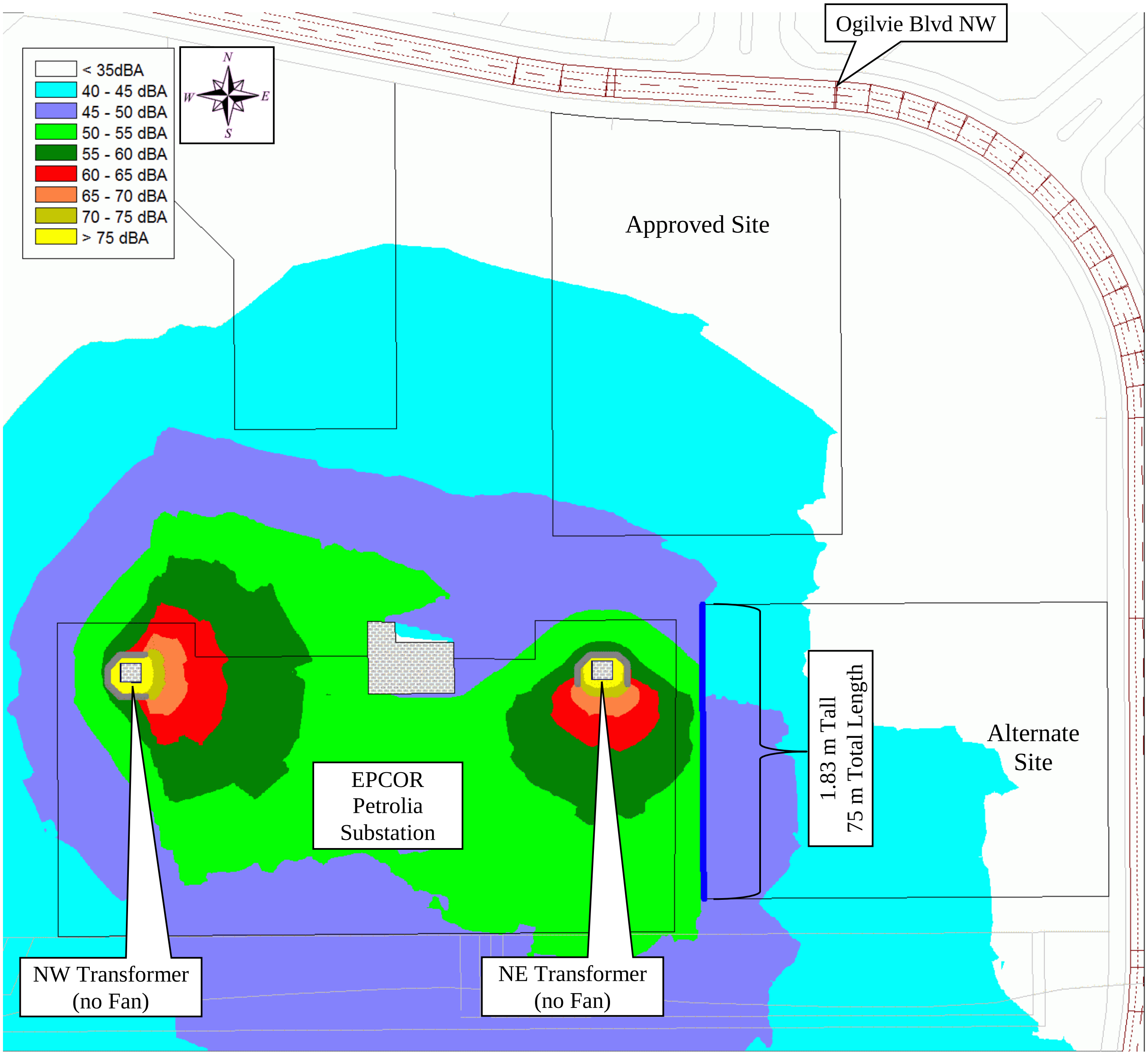

Figure 5. Future Case without Fans with Noise Mitigation, L_{eq}24 Noise Levels

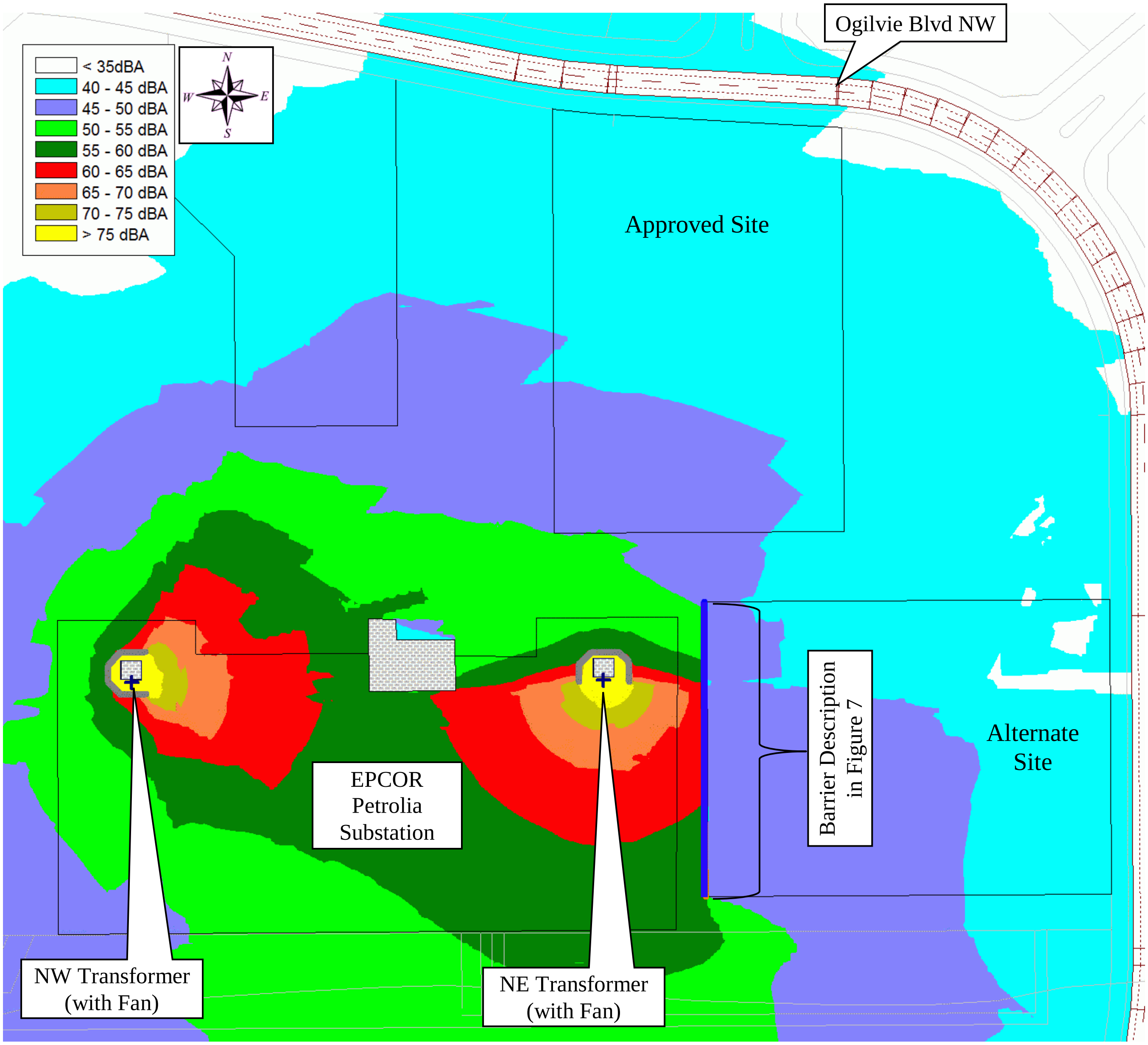

Figure 6. Future Case with Fans with Noise Mitigation, L_{eq}24 Noise Levels

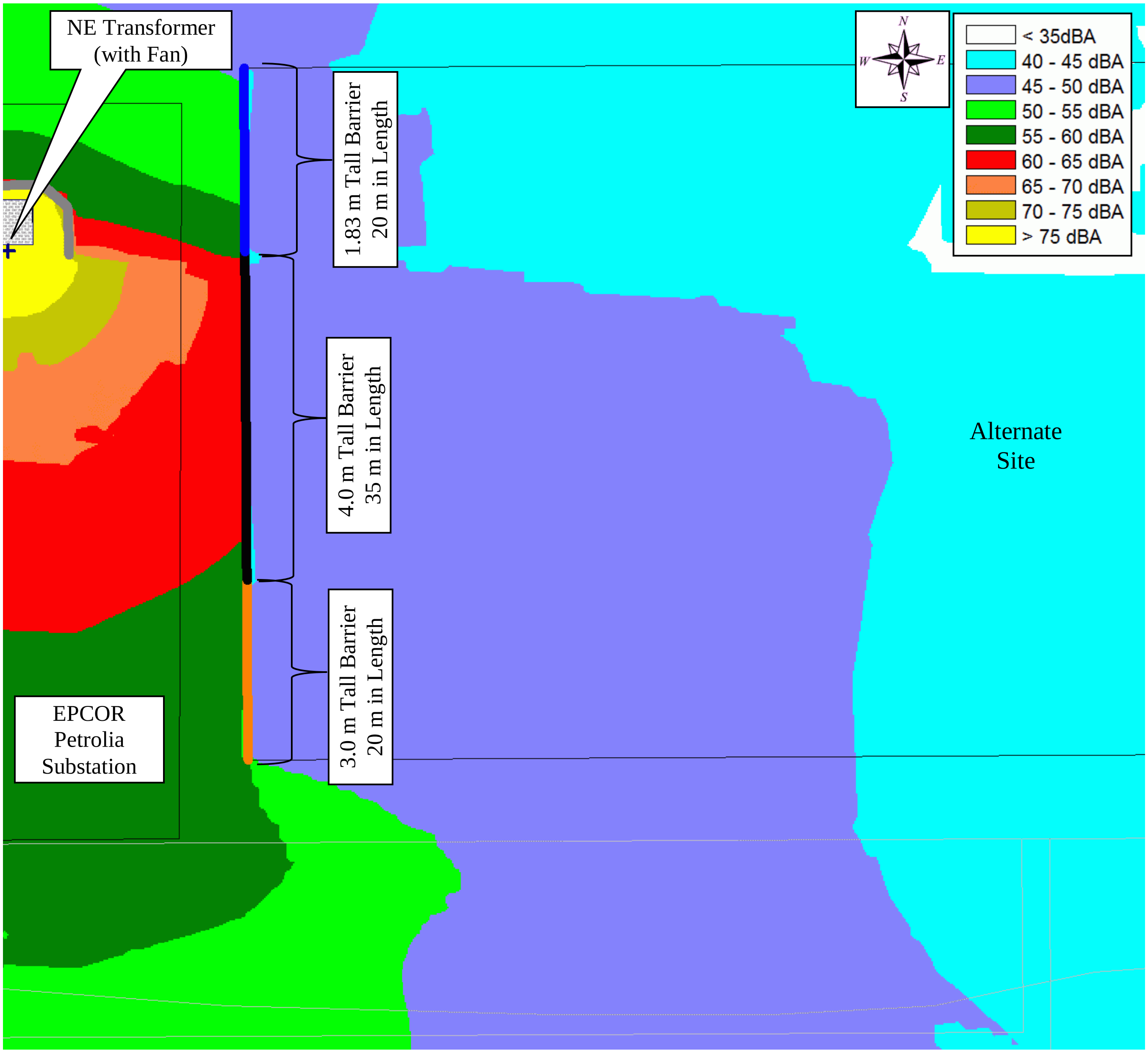

Figure 7. Barrier Description for Alternate Site

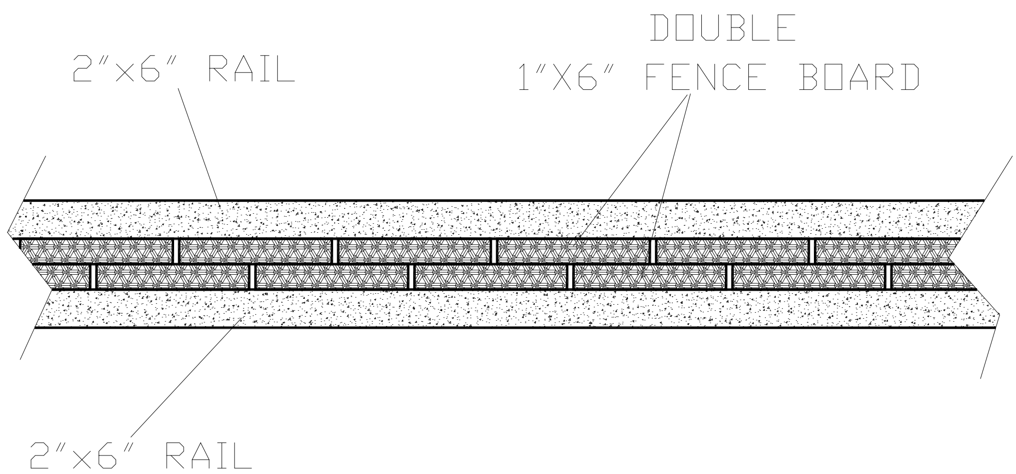

Figure 8. Minimum Recommended Wooden Fence Construction Sectional View

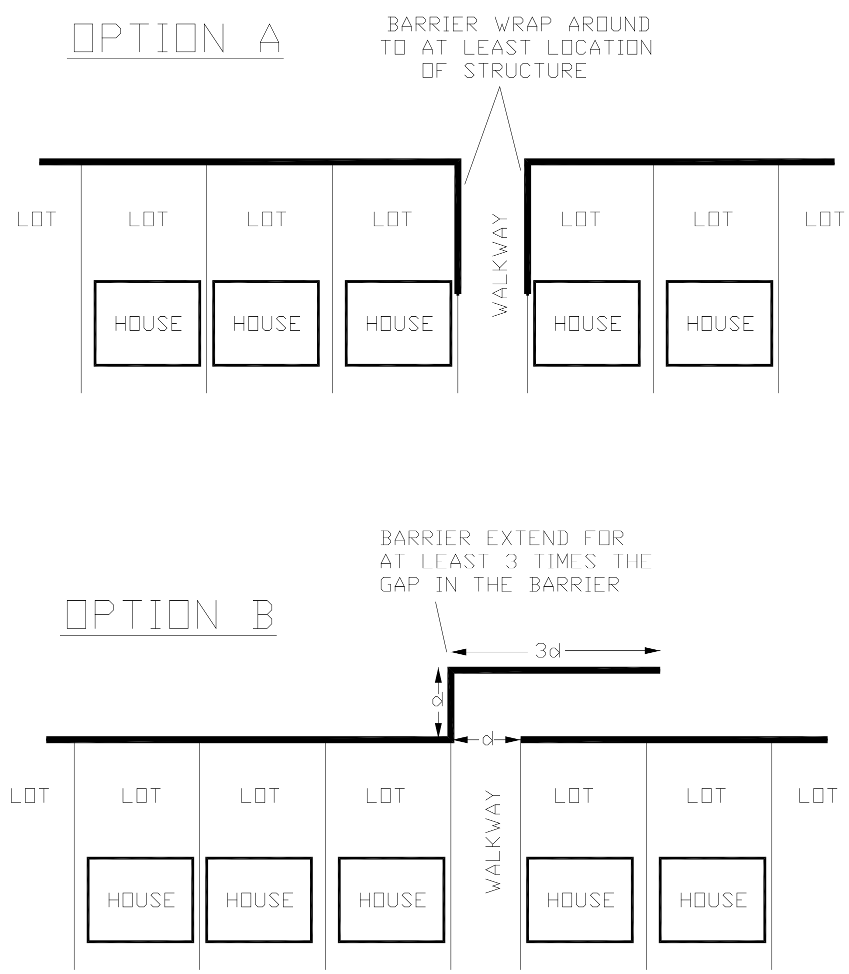

Figure 9. Minimum Recommended Walkway/Roadway Penetration Barrier Construction

Appendix I MEASUREMENT EQUIPMENT USED

The environmental noise monitoring equipment used consisted of a Brüel and Kjær Type 2270 Precision Integrating Sound Level Meter, a tripod, a weather protective microphone hood. The system acquired data in 15-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meter conforms to Type 1, ANSI S1.4, ANSI S1.43, IEC 61672-1, IEC 60651, IEC 60804 and DIN 45657. The 1/3 octave filters conform to S1.11 – Type 0-C, and IEC 61260 – Class 0. The calibrator conforms to IEC 942 and ANSI S1.40. The sound level meter, pre-amplifier and microphone were certified on December 15, 2014 October 9, 2014 and the calibrator (type B&K 4231) was certified on August 31, 2016 by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002:1994, ISO 9001:2000 and ANSI/NCSL Z540: 1994 Part 1. All measurement methods and instrumentation conform to the requirements of the AUC Rule 012. Simultaneous digital audio was recorded directly on the sound level meter using a 8 kHz sample rate for more detailed post-processing analysis. Refer to the next section in the Appendix for a detailed description of the various acoustical descriptive terms used.

Record of Field Calibration Results

Description	Date	Time	Pre / Post	Calibration Level	Calibrator Model	Serial Number
Pre-Calibration	October 28 2016	12:00	Pre	93.9 dBA	B&K 4231	2478139
Post-Calibration	October 28 2016	13:00	Post	93.9 dBA	B&K 4231	2478139

B&K 2270 SLM Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.32877

Instrument:	**Sound Level Meter**	*Date Calibrated:* **12/15/2014** *Cal Due:*		
Model:	**2270**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel and Kjær**	*In tolerance:*	**X**	**X**
Serial number:	**3002718**	*Out of tolerance:*		
Tested with:	**Microphone 4189 s/n 2850742** **Preamplifier ZC0032 s/n 18754**	*See comments:*		
		Contains non-accredited tests: __Yes _X_ No		
Type (class):	**1**	*Calibration service:* __ Basic _X_ Standard		
Customer:	**ACI Acoustical Consultants Inc.**	*Address:* **5031 - 210 Street** **Edmonton, Alberta** **CANADA T6M 0A8**		
Tel/Fax:	**780-414-6373 / -6376**			

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/22/2012
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 11, 2014	ACR Env./ A2LA	Nov11, 2016
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 11, 2014	ACR Env. / A2LA	Nov 11, 2015
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 18, 2014	ACR Env./ A2LA	Nov 18, 2016
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 10, 2014	Scantek, Inc./ NVLAP	Nov 10, 2015

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK).

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
24.0 °C	100.329 kPa	42.4 %RH

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	12/15/2014	Date	12/15/2014

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B&K 2270 Microphone Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.32878

Instrument:	**Microphone**	*Date Calibrated:* **12/13/2014** *Cal Due:*			
Model:	**4189**	*Status:*		**Received**	**Sent**
Manufacturer:	**Brüel & Kjær**	*In tolerance:*		X	X
Serial number:	**2850742**	*Out of tolerance:*			
Composed of:		*See comments:*			
		Contains non-accredited tests: __Yes _X_ No			
Customer:	**ACI Acoustical Consultants Inc.**	*Address:*	**5031 - 210 Street Edmonton, Alberta CANADA T6M 0A8**		
Tel/Fax:	**780-414-6373 / -6376**				

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 11/30/2010

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 11, 2014	ACR Env./ A2LA	Nov11, 2016
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 11, 2014	ACR Env. / A2LA	Nov 11, 2015
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 18, 2014	ACR Env./ A2LA	Nov 18, 2016
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Nov 10, 2014	Scantek, Inc./ NVLAP	Nov 10, 2015
1203-Norsonic	Preamplifier	14059	Jan 2, 2014	Scantek, Inc./ NVLAP	Jan 2, 2015
4180-Brüel&Kjær	Microphone	2246115	Oct 15, 2013	NPL-UK / UKAS	Oct 15, 2015

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature	[signature]	Signature	[signature]
Date	12/13/2014	Date	12/13/2014

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B&K 4231 Calibrator Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.36929

Instrument: **Acoustical Calibrator**
Model: **4231**
Manufacturer: **Brüel and Kjær**
Serial number: **2575493**
Class (IEC 60942): **1**
Barometer type:
Barometer s/n:

Date Calibrated: **8/31/2016** *Cal Due:*

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Customer: **ACI Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 / -6376**
Address: **5031 - 210 Street, Edmonton, Alberta, CANADA T6M 0A8**

Tested in accordance with the following procedures and standards:
Calibration of Acoustical Calibrators, Scantek Inc., Rev. 10/1/2010

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31061	Jul 27, 2016	Scantek, Inc./ NVLAP	Jul 27, 2017
DS-360-SRS	Function Generator	88077	Sep 9, 2014	ACR Env./ A2LA	Sep 9, 2016
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 24, 2015	ACR Env./ A2LA	Sep 24, 2016
HM30-Thommen	Meteo Station	1040170/39633	Oct 23, 2015	ACR Env./ A2LA	Oct 23, 2016
140-Norsonic	Real Time Analyzer	1403978	Mar 17, 2016	Scantek, Inc. / NVLAP	Mar 17, 2017
PC Program 1018 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
4192-Brüel&Kjær	Microphone	2854675	Nov 11, 2015	Scantek, Inc. / NVLAP	Nov 11, 2016
1203-Norsonic	Preamplifier	92268	Oct 14, 2015	Scantek, Inc./ NVLAP	Oct 14, 2016

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK)

Calibrated by:	Jeremy Gotwalt	**Authorized signatory:**	Valentin Buzduga
Signature	[signature]	Signature	[signature]
Date	9/1/16	Date	9/01/2016

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Appendix II NOISE MODELING PARAMETERS

Project and Existing Noise Source Sound Power Levels (Re 10^{-12} Watts)

Item	Qty	Source Height (m)	SWL (dBA)	32 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Transformer #1	2	2.5 - 5.5	95	97	94	110	85	89	74	67	61	57
Transformer #2	2	2.5 - 5.5	97	89	89	111	90	95	80	69	61	57
Cooling Fans (1 for each Transformer)	2	2.0	101	82	101	109	100	100	95	89	86	70

General Noise Modeling Parameters

Parameter	Value
Modeling Software	CADNA/A (Version 4.6.155)
Standard Followed	ISO 9613-2
Ground Sound Absorption Coefficient	0.5
Wind Speed	1 - 5 m/s (3.6 - 18 km/hr)
Wind Direction	Downwind from all sources to all receptors
Temperature	10 °C
Humidity	70%
Topography	Used Digital Terrain Model Contours

Appendix III. THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

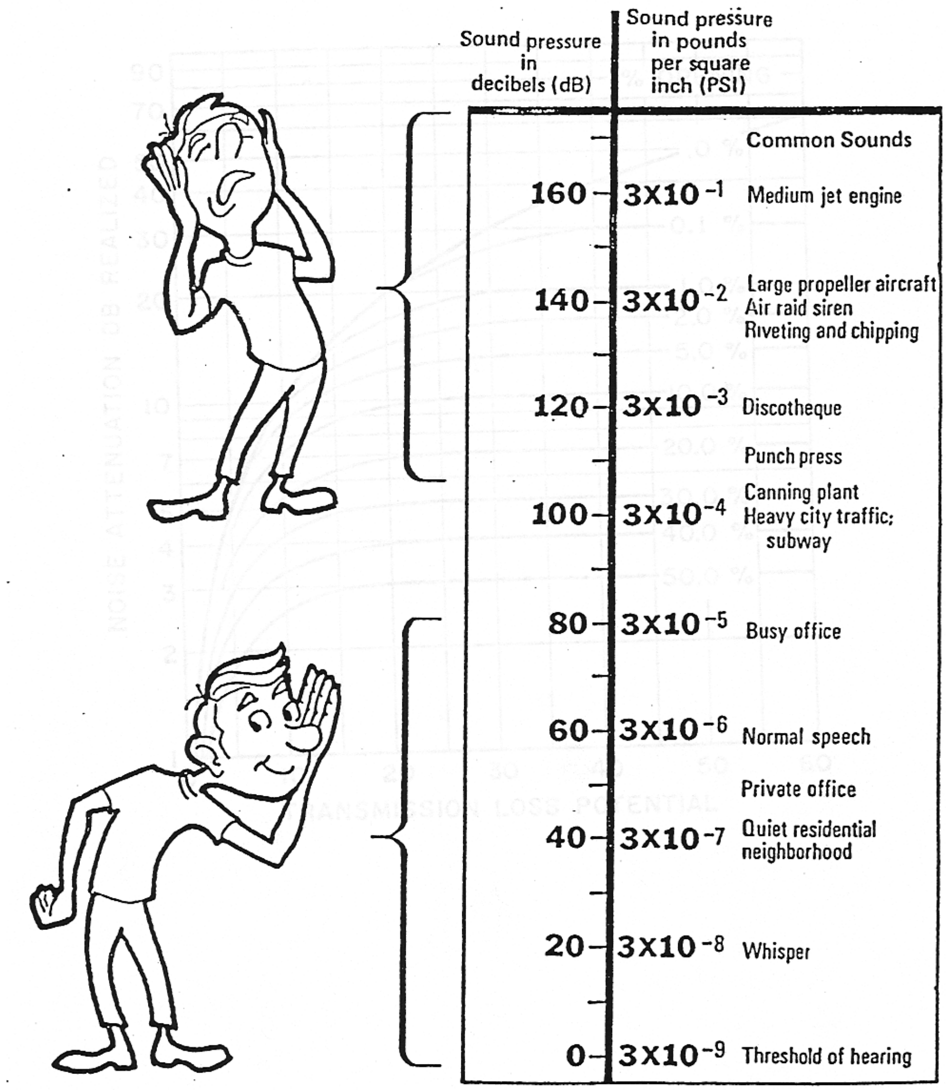
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we measure pressure we typically measure the RMS sound pressure.

$$SPL = 10\log_{10}\left[\frac{P_{RMS}^{2}}{P_{ref}^{2}}\right] = 20\log_{10}\left[\frac{P_{RMS}}{P_{ref}}\right]$$

Where: SPL = Sound Pressure Level in dB
P_{RMS} = Root Mean Square measured pressure (Pa)
P_{ref} = Reference sound pressure level ($P_{ref} = 2x10^{-5}$ Pa = 20 μPa)

This reference sound pressure level is an internationally agreed upon value. It represents the threshold of human hearing for "typical" people based on numerous testing. It is possible to have a threshold which is lower than 20 μPa which will result in negative dB levels. As such, zero dB does not mean there is no sound!

In general, a difference of 1 – 2 dB is the threshold for humans to notice that there has been a change in sound level. A difference of 3 dB (factor of 2 in acoustical energy) is perceptible and a change of 5 dB is strongly perceptible. A change of 10 dB is typically considered a factor of 2. This is quite remarkable when considering that 10 dB is 10-times the acoustical energy!


Sound pressure in decibels (dB)
Sound pressure in pounds per square inch (PSI)
Common Sounds
160 3X10^{-1} Medium jet engine
140 3X10^{-2} Large propeller aircraft Air raid siren Riveting and chipping
120 3X10^{-3} Discotheque
Punch press
100 3X10^{-4} Canning plant Heavy city traffic; subway
80 3X10^{-5} Busy office
60 3X10^{-6} Normal speech
Private office
40 3X10^{-7} Quiet residential neighborhood
20 3X10^{-8} Whisper
0 3X10^{-9} Threshold of hearing

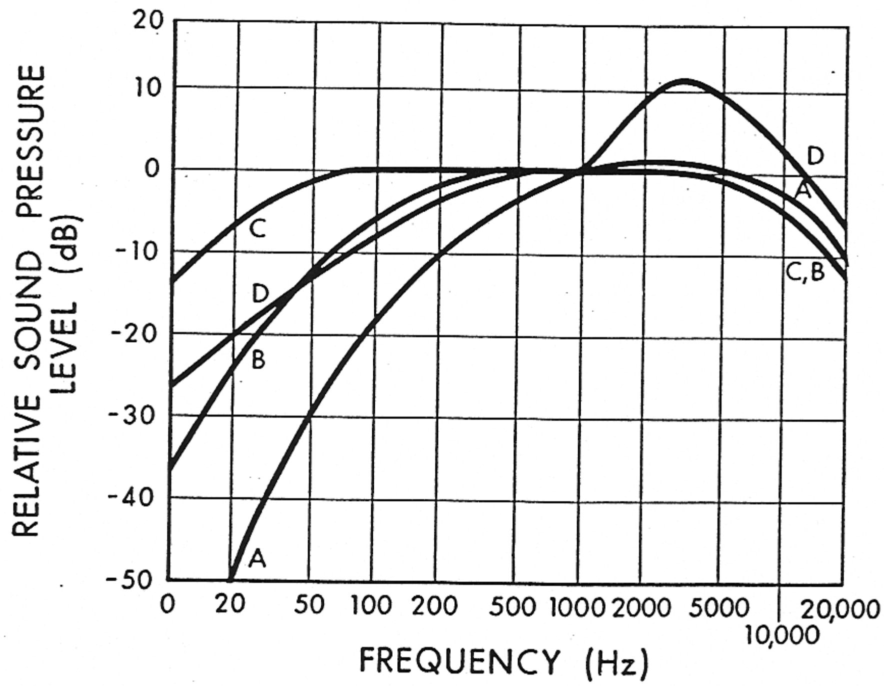
Frequency

The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low frequency sounds, is very sensitive to mid frequency sounds and is slightly less sensitive to high frequency sounds. Due to the large frequency range of human hearing, the entire spectrum is often divided into 31 bands, each known as a 1/3 octave band.

The internationally agreed upon center frequencies and upper and lower band limits for the 1/1 (whole octave) and 1/3 octave bands are as follows:

	Whole Octave			1/3 Octave	
Lower Band Limit	**Center Frequency**	**Upper Band Limit**	**Lower Band Limit**	**Center Frequency**	**Upper Band Limit**
11	**16**	22	14.1	**16**	17.8
			17.8	**20**	22.4
			22.4	**25**	28.2
22	**31.5**	44	28.2	**31.5**	35.5
			35.5	**40**	44.7
			44.7	**50**	56.2
44	**63**	88	56.2	**63**	70.8
			70.8	**80**	89.1
			89.1	**100**	112
88	**125**	177	112	**125**	141
			141	**160**	178
			178	**200**	224
177	**250**	355	224	**250**	282
			282	**315**	355
			355	**400**	447
355	**500**	710	447	**500**	562
			562	**630**	708
			708	**800**	891
710	**1000**	1420	891	**1000**	1122
			1122	**1250**	1413
			1413	**1600**	1778
1420	**2000**	2840	1778	**2000**	2239
			2239	**2500**	2818
			2818	**3150**	3548
2840	**4000**	5680	3548	**4000**	4467
			4467	**5000**	5623
			5623	**6300**	7079
5680	**8000**	11360	7079	**8000**	8913
			8913	**10000**	11220
			11220	**12500**	14130
11360	**16000**	22720	14130	**16000**	17780
			17780	**20000**	22390

Human hearing is most sensitive at approximately 3500 Hz which corresponds to the ¼ wavelength of the ear canal (approximately 2.5 cm). Because of this range of sensitivity to various frequencies, we typically apply various weighting networks to the broadband measured sound to more appropriately account for the way humans hear. By default, the most common weighting network used is the so-called "A-weighting". It can be seen in the figure that the low frequency sounds are reduced significantly with the A-weighting.



Combination of Sounds

When combining multiple sound sources the general equation is:

$$\Sigma SPL_n = 10\log_{10}\left[\sum_{i=1}^{n} 10^{\frac{SPL_i}{10}}\right]$$

Examples:

- Two sources of 50 dB each add together to result in 53 dB.
- Three sources of 50 dB each add together to result in 55 dB.
- Ten sources of 50 dB each add together to result in 60 dB.
- One source of 50 dB added to another source of 40 dB results in 50.4 dB

It can be seen that, if multiple similar sources exist, removing or reducing only one source will have little effect.

Sound Level Measurements

Over the years a number of methods for measuring and describing environmental noise have been developed. The most widely used and accepted is the concept of the Energy Equivalent Sound Level (L_{eq}) which was developed in the US (1970's) to characterize noise levels near US Air-force bases. This is the level of a steady state sound which, for a given period of time, would contain the same energy as the time varying sound. The concept is that the same amount of annoyance occurs from a sound having a high level for a short period of time as from a sound at a lower level for a longer period of time.
The L_{eq} is defined as:

$$L_{eq} = 10\log_{10}\left[\frac{1}{T}\int_0^T 10^{\frac{dB}{10}}\,dT\right] = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{P^2}{P_{ref}^2}\,dT\right]$$

We must specify the time period over which to measure the sound. i.e. 1-second, 10-seconds, 15-seconds, 1-minute, 1-day, etc**. An L_{eq} is meaningless if there is no time period associated**.

In general there a few very common L_{eq} sample durations which are used in describing environmental noise measurements. These include:

- L_{eq}24 - Measured over a 24-hour period
- L_{eq}Night - Measured over the night-time (typically 22:00 – 07:00)
- L_{eq}Day - Measured over the day-time (typically 07:00 – 22:00)
- L_{DN} - Same as L_{eq}24 with a 10 dB penalty added to the night-time

Statistical Descriptor

Another method of conveying long term noise levels utilizes statistical descriptors. These are calculated from a cumulative distribution of the sound levels over the entire measurement duration and then determining the sound level at xx % of the time.

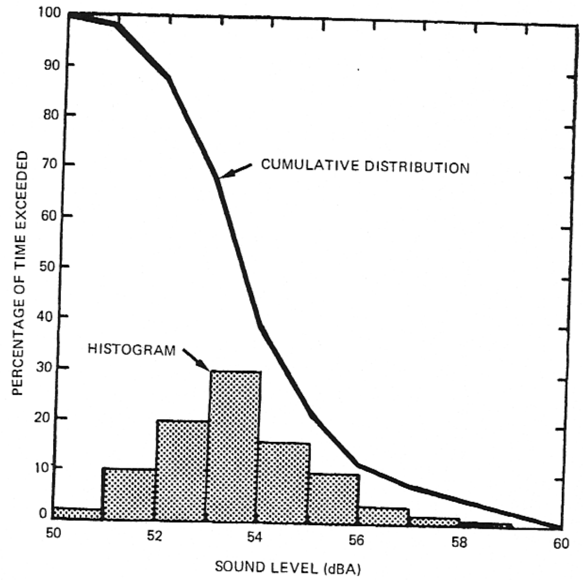


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

Industrial Noise Control, Lewis Bell, Marcel Dekker, Inc. 1994

The most common statistical descriptors are:

L_{min} - minimum sound level measured
L_{01} - sound level that was exceeded only 1% of the time
L_{10} - sound level that was exceeded only 10% of the time.
- Good measure of intermittent or intrusive noise
- Good measure of Traffic Noise

L_{50} - sound level that was exceeded 50% of the time (arithmetic average)
- Good to compare to L_{eq} to determine steadiness of noise

L_{90} - sound level that was exceeded 90% of the time
- Good indicator of typical “ambient” noise levels

L_{99} - sound level that was exceeded 99% of the time
L_{max} - maximum sound level measured

These descriptors can be used to provide a more detailed analysis of the varying noise climate:

- If there is a large difference between the L_{eq} and the L_{50} (L_{eq} can never be any lower than the L_{50}) then it can be surmised that one or more short duration, high level sound(s) occurred during the time period.
- If the gap between the L_{10} and L_{90} is relatively small (less than 15 – 20 dBA) then it can be surmised that the noise climate was relatively steady.

Sound Propagation

In order to understand sound propagation, the nature of the source must first be discussed. In general, there are three types of sources. These are known as 'point', 'line', and 'area'. This discussion will concentrate on point and line sources since area sources are much more complex and can usually be approximated by point sources at large distances.

Point Source

As sound radiates from a point source, it dissipates through geometric spreading. The basic relationship between the sound levels at two distances from a point source is:

$$\therefore SPL_1 - SPL_2 = 20\log_{10}\left(\frac{r_2}{r_1}\right)$$

Where: SPL_1 = sound pressure level at location 1, SPL_2 = sound pressure level at location 2
r_1 = distance from source to location 1, r_2 = distance from source to location 2

Thus, the reduction in sound pressure level for a point source radiating in a free field is **6 dB per doubling of distance**. This relationship is independent of reflectivity factors provided they are always present. Note that this only considers geometric spreading and does not take into account atmospheric effects. Point sources still have some physical dimension associated with them, and typically do not radiate sound equally in all directions in all frequencies. The directionality of a source is also highly dependent on frequency. As frequency increases, directionality increases.

Examples (note no atmospheric absorption):

- A point source measuring 50 dB at 100m will be 44 dB at 200m.
- A point source measuring 50 dB at 100m will be 40.5 dB at 300m.
- A point source measuring 50 dB at 100m will be 38 dB at 400m.
- A point source measuring 50 dB at 100m will be 30 dB at 1000m.

Line Source

A line source is similar to a point source in that it dissipates through geometric spreading. The difference is that a line source is equivalent to a long line of many point sources. The basic relationship between the sound levels at two distances from a line source is:

$$SPL_1 - SPL_2 = 10\log_{10}\left(\frac{r_2}{r_1}\right)$$

The difference from the point source is that the '20' term in front of the 'log' is now only 10. Thus, the reduction in sound pressure level for a line source radiating in a free field is **3 dB per doubling of distance**.

Examples (note no atmospheric absorption):

- A line source measuring 50 dB at 100m will be 47 dB at 200m.
- A line source measuring 50 dB at 100m will be 45 dB at 300m.
- A line source measuring 50 dB at 100m will be 44 dB at 400m.
- A line source measuring 50 dB at 100m will be 40 dB at 1000m.

Atmospheric Absorption

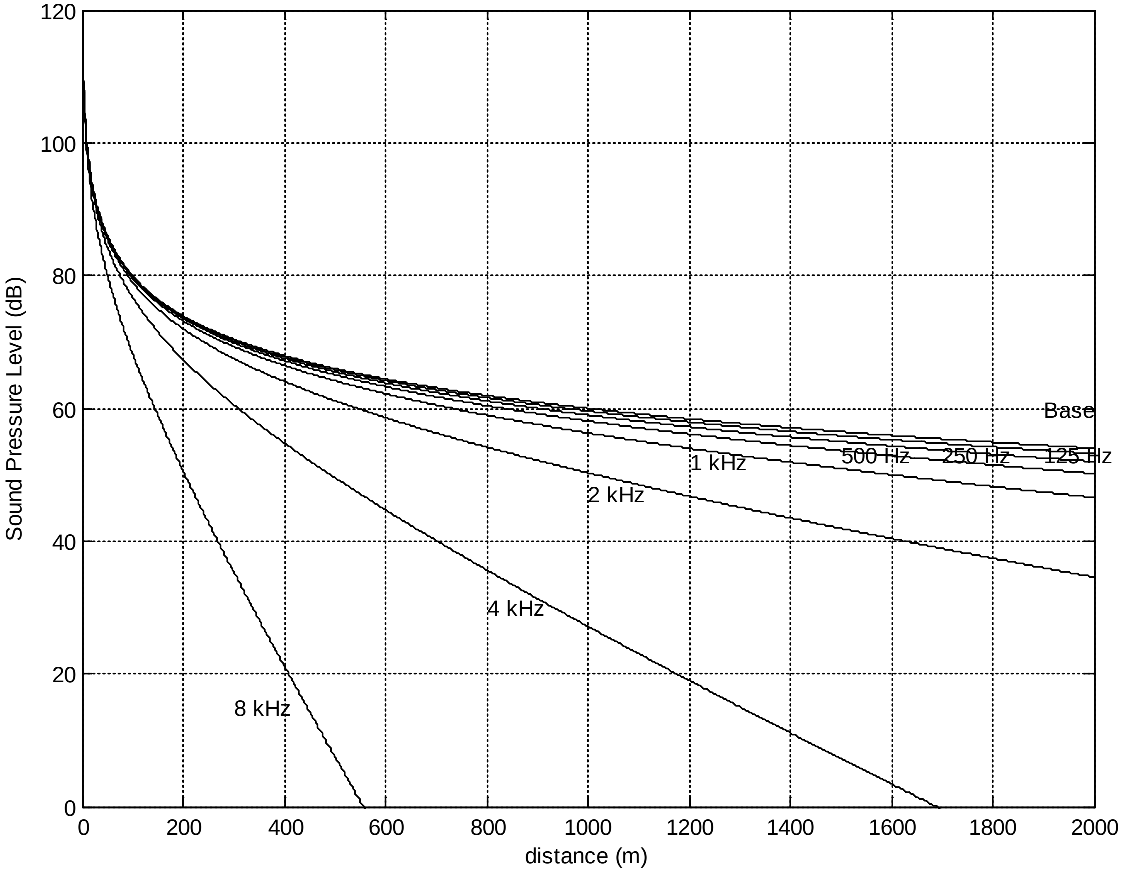
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

1) **Viscous Effects** - Dissipation of acoustic energy due to fluid friction which results in thermodynamically irreversible propagation of sound.
2) **Heat Conduction Effects** - Heat transfer between high and low temperature regions in the wave which result in non-adiabatic propagation of the sound.
3) **Inter Molecular Energy Interchanges** - Molecular energy relaxation effects which result in a time lag between changes in translational kinetic energy and the energy associated with rotation and vibration of the molecules.

The following table illustrates the attenuation coefficient of sound at standard pressure (101.325 kPa) in units of dB/100m.

Temperature °C	Relative Humidity (%)	Frequency (Hz) 125	250	500	1000	2000	4000
30	20	0.06	0.18	0.37	0.64	1.40	4.40
	50	0.03	0.10	0.33	0.75	1.30	2.50
	90	0.02	0.06	0.24	0.70	1.50	2.60
20	20	0.07	0.15	0.27	0.62	1.90	6.70
	50	0.04	0.12	0.28	0.50	1.00	2.80
	90	0.02	0.08	0.26	0.56	0.99	2.10
10	20	0.06	0.11	0.29	0.94	3.20	9.00
	50	0.04	0.11	0.20	0.41	1.20	4.20
	90	0.03	0.10	0.21	0.38	0.81	2.50
0	20	0.05	0.15	0.50	1.60	3.70	5.70
	50	0.04	0.08	0.19	0.60	2.10	6.70
	90	0.03	0.08	0.15	0.36	1.10	4.10

- As frequency increases, absorption tends to increase
- As Relative Humidity increases, absorption tends to decrease
- There is no direct relationship between absorption and temperature
- **The net result of atmospheric absorption is to modify the sound propagation of a point source from 6 dB/doubling-of-distance to approximately 7 – 8 dB/doubling-of-distance (based on anecdotal experience)**



Atmospheric Absorption at 10ºC and 70% RH

Meteorological Effects

There are many meteorological factors which can affect how sound propagates over large distances. These various phenomena must be considered when trying to determine the relative impact of a noise source either after installation or during the design stage.

Wind
- Can greatly alter the noise climate away from a source depending on direction
- Sound levels downwind from a source can be increased due to refraction of sound back down towards the surface. This is due to the generally higher velocities as altitude increases.
- Sound levels upwind from a source can be decreased due to a "bending" of the sound away from the earth's surface.
- Sound level differences of ±10dB are possible depending on severity of wind and distance from source.
- Sound levels crosswind are generally not disturbed by an appreciable amount
- Wind tends to generate its own noise, however, and can provide a high degree of masking relative to a noise source of particular interest.

Temperature
- Temperature effects can be similar to wind effects
- Typically, the temperature is warmer at ground level than it is at higher elevations.
- If there is a very large difference between the ground temperature (very warm) and the air aloft (only a few hundred meters) then the transmitted sound refracts upward due to the changing speed of sound.
- If the air aloft is warmer than the ground temperature (known as an *inversion*) the resulting higher speed of sound aloft tends to refract the transmitted sound back down towards the ground. This essentially works on Snell's law of reflection and refraction.
- Temperature inversions typically happen early in the morning and are most common over large bodies of water or across river valleys.
- Sound level differences of ±10dB are possible depending on gradient of temperature and distance from source.

Rain
- Rain does not affect sound propagation by an appreciable amount unless it is very heavy
- The larger concern is the noise generated by the rain itself. A heavy rain striking the ground can cause a significant amount of highly broadband noise. The amount of noise generated is difficult to predict.
- Rain can also affect the output of various noise sources such as vehicle traffic.

Summary
- In general, these wind and temperature effects are difficult to predict
- Empirical models (based on measured data) have been generated to attempt to account for these effects.
- Environmental noise measurements must be conducted with these effects in mind. Sometimes it is desired to have completely calm conditions, other times a "worst case" of downwind noise levels are desired.

Topographical Effects

Similar to the various atmospheric effects outlined in the previous section, the effect of various geographical and vegetative factors must also be considered when examining the propagation of noise over large distances.

Topography

- One of the most important factors in sound propagation.
- Can provide a natural barrier between source and receiver (i.e. if berm or hill in between).
- Can provide a natural amplifier between source and receiver (i.e. large valley in between or hard reflective surface in between).
- Must look at location of topographical features relative to source and receiver to determine importance (i.e. small berm 1km away from source and 1km away from receiver will make negligible impact).

Grass

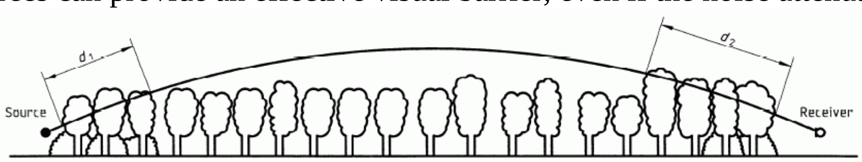
- Can be an effective absorber due to large area covered
- Only effective at low height above ground. Does not affect sound transmitted direct from source to receiver if there is line of sight.
- Typically less absorption than atmospheric absorption when there is line of sight.
- Approximate rule of thumb based on empirical data is:

$$A_g = 18\log_{10}(f) - 31 \qquad (dB/100m)$$

Where: A_g is the absorption amount

Trees

- Provide absorption due to foliage
- Deciduous trees are essentially ineffective in the winter
- Absorption depends heavily on density and height of trees
- No data found on absorption of various kinds of trees
- Large spans of trees are required to obtain even minor amounts of sound reduction
- In many cases, trees can provide an effective visual barrier, even if the noise attenuation is negligible.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f	Nominal midband frequency Hz							
m	63	125	250	500	1 000	2 000	4 000	8 000
	Attenuation, dB:							
$10 \leq d_f \leq 20$	0	0	1	1	1	1	2	3
	Attenuation, dB/m:							
$20 \leq d_f \leq 200$	0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

Tree/Foliage attenuation from ISO 9613-2:1996

Bodies of Water

- Large bodies of water can provide the opposite effect to grass and trees.
- Reflections caused by small incidence angles (grazing) can result in larger sound levels at great distances (increased reflectivity, Q).
- Typically air temperatures are warmer high aloft since air temperatures near water surface tend to be more constant. Result is a high probability of temperature inversion.
- Sound levels can “carry” much further.

Snow

- Covers the ground for approximately 1/2 of the year in northern climates.
- Can act as an absorber or reflector (and varying degrees in between).
- Freshly fallen snow can be quite absorptive.
- Snow which has been sitting for a while and hard packed due to wind can be quite reflective.
- Falling snow can be more absorptive than rain, but does not tend to produce its own noise.
- Snow can cover grass which might have provided some means of absorption.
- Typically sound propagates with less impedance in winter due to hard snow on ground and no foliage on trees/shrubs.

Appendix IV. SOUND LEVELS OF FAMILIAR NOISE SOURCES

Used with Permission Obtained from the Alberta Energy Regulator Directive 038 (2007)

Source[1]	Sound Level (dBA)
Bedroom of a country home	30
Soft whisper at 1.5 m	30
Quiet office or living room	40
Moderate rainfall	50
Inside average urban home	50
Quiet street	50
Normal conversation at 1 m	60
Noisy office	60
Noisy restaurant	70
Highway traffic at 15 m	75
Loud singing at 1 m	75
Tractor at 15 m	78-95
Busy traffic intersection	80
Electric typewriter	80
Bus or heavy truck at 15 m	88-94
Jackhammer	88-98
Loud shout	90
Freight train at 15 m	95
Modified motorcycle	95
Jet taking off at 600 m	100
Amplified rock music	110
Jet taking off at 60 m	120
Air-raid siren	130

[1] Cottrell, Tom, 1980, *Noise in Alberta*, Table 1, p.8, ECA80 - 16/1B4 (Edmonton: Environment Council of Alberta).

SOUND LEVELS GENERATED BY COMMON APPLIANCES

Used with Permission Obtained from the Alberta Energy Regulator Directive 038 (2007)

Source[1]	**Sound level at 3 feet (dBA)**
Freezer	38-45
Refrigerator	34-53
Electric heater	47
Hair clipper	50
Electric toothbrush	48-57
Humidifier	41-54
Clothes dryer	51-65
Air conditioner	50-67
Electric shaver	47-68
Water faucet	62
Hair dryer	58-64
Clothes washer	48-73
Dishwasher	59-71
Electric can opener	60-70
Food mixer	59-75
Electric knife	65-75
Electric knife sharpener	72
Sewing machine	70-74
Vacuum cleaner	65-80
Food blender	65-85
Coffee mill	75-79
Food waste disposer	69-90
Edger and trimmer	81
Home shop tools	64-95
Hedge clippers	85
Electric lawn mower	80-90

[1] Reif, Z. F., and Vermeulen, P. J., 1979, “Noise from domestic appliances, construction, and industry,” Table 1, p.166, in Jones, H. W., ed., *Noise in the Human Environment*, vol. 2, ECA79-SP/1 (Edmonton: Environment Council of Alberta).

Appendix V. PERMISSIBLE SOUND LEVEL DETERMINATION

Permissible Sound Levels for Category 2 Residential Receptors (> 160 Dwellings)

Basic Sound Level

Proximity to Transportation	Dwelling Density (Per Quarter Section of Land): 1 - 8 Dwellings	9 - 160 Dwellings	> 160 Dwellings	Night-Time	Day-Time
Category 1	40	43	46		
Category 2	45	48	51	51	51
Category 3	50	53	56		
Basic Sound Level (dBA)				51	51

Time of Day Adjustment

Time of Day	Adjustment (dBA)	Night-Time	Day-Time
Night-time adjustment for hours 22:00 - 07:00	0	0	n/a
Day-time adjustment for hours 07:00 - 22:00	+10	n/a	+10
Time of day adjustment (dBA)		0	+ 10

Class A Adjustments

Class	Reason for Adjustment	Adjustment (dBA)	Night-Time	Day-Time
A1	Seasonal Adjustment (Winter)	0 to +5	0	0
A2	Ambient Monitoring Adjustment	-10 to +10	0	0
Sum of A1 and A2 cannot exceed maximum of 10 dBA Leq				
Class A Adjustment (dBA)			0	0

Class B Adjustments

Class	Duration of Activity	Adjustment (dBA)	Night-Time	Day-Time
B1	≤ 1 Day	+ 15	0	0
B2	≤ 7 Days	+ 10	0	0
B3	≤ 60 Days	+ 5	0	0
B4	> 60 Days	0	0	0
Can only apply one of B1, B2, B3, or B4				
Class B Adjustment (dBA)			0	0

	Night-Time	Day-Time
Total Permissible Sound Level (PSL) [dBA]	51	61

Appendix VI 1/3 OCTAVE BAND SHORT-TERM SOUND LEVELS

Measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A-Weighted	60.0	57.3	57.1	57.0	53.4	47.7	47.2	49.7	46.4	60.7	62.0	51.1	52.3	43.9
20Hz	49.5	49.2	49.9	48.9	45.0	49.9	45.8	45.9	46.3	48.5	43.7	43.9	43.6	43.3
25Hz	53.2	50.9	51.6	49.5	47.4	49.6	47.7	48.5	47.2	47.4	46.7	46.0	45.9	45.1
31.5Hz	60.1	58.9	55.2	53.5	50.5	50.6	59.7	56.9	52.3	48.2	50.6	51.2	49.1	48.5
40Hz	57.1	60.2	54.3	51.1	50.9	50.3	56.4	56.0	50.2	46.9	52.7	47.4	48.5	46.8
50Hz	55.9	54.6	53.1	51.4	51.3	52.1	51.9	51.6	49.9	47.3	50.0	47.8	48.3	46.9
63Hz	52.7	54.2	53.5	51.6	54.4	52.9	51.2	52.9	52.3	50.8	49.7	48.4	49.2	48.1
80Hz	54.6	53.0	56.8	52.5	49.3	49.8	51.3	54.1	49.1	48.7	50.7	47.1	47.7	48.0
100Hz	62.4	53.6	52.7	48.6	54.2	51.1	49.0	51.6	47.1	61.1	62.8	49.4	48.7	45.9
125Hz	76.0	60.0	58.5	57.7	67.6	58.0	58.3	60.2	55.7	75.0	76.7	60.6	58.8	57.1
160Hz	52.1	50.0	46.6	41.9	45.5	42.7	44.3	43.5	40.0	49.8	51.8	39.5	42.6	37.3
200Hz	44.5	44.4	44.7	43.3	43.8	43.0	41.7	40.2	36.5	38.5	41.2	37.3	40.7	32.6
250Hz	45.4	51.2	52.4	52.8	56.5	50.2	49.3	44.2	38.5	41.2	52.1	42.3	45.1	33.0
315Hz	47.3	55.7	55.4	55.4	41.4	43.4	38.9	42.8	42.2	50.2	54.3	49.3	50.3	35.9
400Hz	51.0	59.6	59.3	59.3	43.7	42.6	39.5	45.8	45.4	54.3	58.3	53.1	54.1	39.0
500Hz	51.5	50.9	52.5	51.7	45.6	38.9	41.4	48.9	37.6	51.6	56.7	37.8	42.5	33.8
630Hz	36.5	42.3	40.7	42.0	40.6	38.0	36.0	35.8	35.7	50.5	46.5	37.1	40.0	33.1
800Hz	36.5	39.3	37.7	39.2	33.1	36.4	36.1	37.0	39.2	52.4	45.3	37.1	37.9	34.7
1kHz	34.3	40.1	39.4	40.3	30.9	33.5	34.3	34.9	33.6	50.7	39.0	31.2	34.3	30.4
1.25kHz	32.4	37.1	36.3	36.5	30.4	29.8	30.9	31.7	29.7	40.2	35.1	29.6	34.7	27.3
1.6kHz	30.1	34.3	34.3	34.4	28.8	28.1	28.9	28.8	27.9	37.8	33.1	27.8	35.9	26.7
2kHz	28.0	28.0	27.9	28.1	23.7	23.8	25.7	25.4	24.1	30.8	29.7	23.7	29.8	24.2
2.5kHz	26.3	25.4	24.5	24.5	20.9	21.4	23.3	22.3	22.3	26.4	25.2	20.7	30.1	23.0
3.15kHz	23.4	23.3	22.5	23.0	21.2	20.9	22.0	20.7	20.7	25.4	24.2	20.5	28.0	22.6
4kHz	21.9	21.5	19.4	20.7	18.6	21.9	21.5	20.7	18.6	25.5	21.8	19.4	25.6	21.6
5kHz	20.9	18.7	17.7	18.4	16.9	18.0	18.8	18.5	16.8	24.5	20.2	17.5	24.1	21.5
6.3kHz	19.6	17.7	16.6	17.5	16.8	16.5	17.2	17.3	14.9	23.7	19.2	16.4	23.3	20.8
8kHz	17.7	16.3	14.9	15.7	16.3	14.2	15.6	17.7	13.7	22.4	18.3	15.4	21.1	19.3
10kHz	15.4	15.3	14.3	15.0	16.4	13.0	14.3	15.4	12.0	22.1	18.2	14.5	19.8	17.7
12.5kHz	12.7	14.6	13.9	14.1	16.9	11.9	12.8	16.6	11.1	22.0	17.3	13.8	19.1	16.8
16kHz	10.2	13.7	13.3	13.5	15.0	10.9	10.9	11.2	10.0	19.0	15.4	12.5	15.9	14.0
20kHz	8.9	11.8	11.9	14.6	12.3	10.1	9.5	8.6	9.1	15.6	12.7	10.8	12.7	10.9