Attachment 1

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Traffic Noise Attenuation Policy

Review and Development

Prepared for:

City of Saskatoon

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1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of Saskatoon to assist in the development of a Traffic Noise Attenuation Policy (The Policy). The purpose of the work was as follows:

- Conduct a peer review of the traffic noise policies within other Canadian Jurisdictions.
- Summarize the current best practices in the field of noise attenuation engineering, including types of construction (i.e. types of materials used in walls).
- Summarize and highlight consistencies and inconsistencies, emerging technologies, and trends in policies and bylaws in order to determine the extent to which other jurisdictions are facing similar sound attenuation demands and the approaches they are using in terms of policy, bylaws, and technology.
- Provide a framework and technical information pertaining to a City Policy for Traffic Noise Attenuation, along with options and potential implications related to the allowable maximum sound levels. Recent noise modeling studies within the City of Saskatoon, conducted by aci, allowed for direct determination of noise attenuation to meet various criteria in various locations.

To that end, the information provided in the document is as follows:

- **Section 2.0**: Review of traffic noise attenuation policies within 12 jurisdictions in Canada (11 active policies and the historical policy within the City of Saskatoon. Each policy is reviewed in detail and comparisons are provided between the various policies to highlight consistencies and inconsistencies.
- **Section 3.0**: Review of the current Best Practices for transportation noise mitigation including planning, enforcement, education, barriers, pavement, and vegetation.
- **Section 4.0**: Traffic noise policy framework. This provides a detailed list of the information required and recommended for a traffic noise attenuation policy including the assessment criteria, conducting noise impact assessments, conducting noise monitoring, noise barrier specifications, and a glossary of terms.
- **Section 5.0**: Assessment of various noise attenuation criteria within the City of Saskatoon to determine the noise mitigation required to achieve each criteria target. The purpose for this was to provide a sense of sense of the scale required in order to meet the various assessment criteria which will help in the process of determining the specific assessment criteria.
- **Appendices**: Acoustic primer and list of various noise levels.

2.0 Other Jurisdictions Policy Review and Summary

2.1. General Discussion

As part of the process for developing a Traffic Noise Attenuation Policy, it is important to review the policies of other similar jurisdictions within Canada. Thus, a search was conducted for traffic noise policies within cities and municipalities across Canada. A total of 12 policies were reviewed (11 currently applicable polices and the historical policy within the City of Saskatoon). Table 2.1 provides an overall summary of all reviewed policies while Sections 2.2 to 2.13 provide a detailed summary for each policy. It is important to note that traffic noise polices were not found for some of the largest cities within Canada (including Vancouver, Winnipeg, Montreal). In general, it is at the discretion of each city or Municipality to determine if a traffic noise policy is required. One exception, however, is in Ontario in which there is a traffic noise policy that applies throughout the entire province. Also, traffic noise policies tend to be separate documents relative to noise bylaws which are intended for general noise nuisance issues such as noisy residential neighbours, or commercial/industrial development adjacent to residential areas. A review of noise bylaws was not conducted. Finally, although not formally reviewed as part of this assessment, it is worth noting the Alberta Energy Regulator (AER) Directive 038 on Noise Control (2007). The AER Directive 038 is specific to the energy industry within Alberta and not applicable to traffic noise. However, the AER Directive 038 has useful information pertaining to environmental noise measurement equipment and methods as well as a glossary of terms and a brief acoustic primer. Information contained within the AER Directive 038 was used in Section 4.0 of this report. For more information, refer to the following website: http://www.aer.ca/rules-and-regulations/directives/directive-038

2.1.1. Sound Level Criteria Comparison

Throughout the reviewed policies, the maximum allowable sound levels ranged from as low as 50 dBA (L_{eq}Night) to as high as 65 dBA L_{eq}24[1] [2] and various levels in between, with 65 dBA L_{eq}24 being the most common (used in 5 of the reviewed policies). All of the reviewed policies assess the noise at the exterior of the residential structure (even if that value is ultimately used to estimate an interior noise level). Refer to Appendix I for a description of the acoustical terms used and to Appendix II for a list of common noise sources.

The outdoor assessment location ranged from 2 m inside the property line to 3 m from the residential dwelling façade with 5 of the policies not specifically defining the location. The assessment height ranged from 1.2 m to 1.5 m (1.5 m being the most common with 5 policies) with 5 of the policies not specifically defining the height. Finally, the planning horizon for determining the need for noise attenuation ranged from 10-years to 20-years (10-years being the most common with 5 policies) with 2 policies not specifically defining the planning horizon and 1 policy specifying that the design capacity for the road be used for predictions.

None of the reviewed policies have criteria that are applicable to the second story of the residential structure and none have criteria that are applicable to multi-storey residential buildings (i.e. apartments and condominiums). Although not often stated within noise policies, traffic noise mitigation for second storey elevations is difficult and expensive to achieve and would typically require noise barrier heights that would be undesirable by the residents. Traffic noise mitigation for the higher elevations of multi-storey residential buildings is generally not possible through conventional means (i.e. noise berms and/or barriers) because of the inability to block the line-of-sight from the residential suite to the roadway and would need to be dealt with through the construction of the building itself.

In addition, none of the reviewed policies have assessment criteria for interior noise levels within the residential structure. Some of the reviewed policies make reference to desired interior noise levels with an assumed noise attenuation associated with the structure, but none have specific interior noise criteria

[1] The British Columbia Ministry of Transportation and Infrastructure Policy uses a sliding scale that depends on the noise level prior to the Project with no specific definable maximum allowable noise level, however, for areas with no new/upgraded roads a value of 65 dBA L_{dn} is considered to have a moderate impact which would trigger a noise mitigation assessment.

[2] Some jurisdictions use a maximum allowable noise level of 65 dBA L_{dn}, which is more restrictive than a level of 60 dBA L_{eq}24. The amount by which the two metrics differ is dependent on the difference between the day-time and night-time traffic noise levels.

that must be achieved. This is typical throughout environmental noise policies for transportation noise as well as industrial noise. The level of noise attenuation from exterior to interior will differ from structure to structure depending on the orientation relative to the noise source, the design and construction of the structure exterior, the geometries and design associated with the layout of the structure, and the sound absorptive materials (i.e. furniture, draperies, carpet) used within the structure. Plus, there are often noise sources within residential structures that can produce higher noise levels than typical interior criteria and yet the residents tend to not object to (i.e. furnace, refrigerator). Thus, it is common practice to assess noise levels at the exterior of the residential structure with an assumption of the typical structural noise attenuation (with all doors and windows closed). The most prevalent issue with this type of assessment is for residents who sleep with bedroom windows open. The exterior criteria in all of the reviewed policies (even in Ontario with the most stringent criteria of 50 dBA L_{eq}Night at the plane of the bedroom window) would generally result in nighttime noise levels above the published desired interior noise levels in residential bedrooms if the windows are open.

Finally, note that none of the reviewed polices have traffic noise criteria that are applicable to commercial or industrial development. Most of the time, this is not a significant concern since noise levels associated with industrial facilities and many commercial facilities are often at or above those associated with adjacent traffic noise and people are not living (i.e. sleeping) at these locations. The are some areas, however, where this can be a concern. For example, at commercial buildings that are located very near major roadways with large windows that face onto the roadway. It is common practice for any noise mitigation efforts associated with reducing interior noise levels to be assumed by the owner/operator of the commercial business. Other areas where this can cause concern are Hotels and other similar temporary lodgings where people are indeed sleeping. Again, a Hotel is considered a commercial business and it is common practice for any noise mitigation efforts associated with reducing interior noise levels to be assumed by the owner/operator of the commercial business.

2.1.2. Noise Monitoring Specifications Comparison

None of the reviewed policies have information pertaining to when noise measurements should be conducted (i.e. time of year, minimum duration, etc.) or the minimum noise measurement equipment requirements. With regards to the minimum equipment requirements and practices surrounding conducting a noise monitoring, this allows for the potential for vastly different noise monitoring results with little consistency or ability to conduct meaningful comparisons in the data. Similarly, none of the reviewed policies have information pertaining to what events or actions would trigger a noise measurement to be conducted for an existing roadway.

2.1.3. Funding Comparison

For all of the reviewed policies that specifically mention new residential development adjacent to existing transportation infrastructure, the cost associated with noise mitigation is the responsibility of the developer. Some of the reviewed policies do not specify this, however, the common practice is to assume that the developer would be responsible for the cost of achieving traffic noise levels within the criteria of the specific jurisdiction.

For all of the reviewed policies that specifically mention new/upgraded roadways, bus lanes, and LRT projects, the cost associated with noise mitigation is the responsibility of the City/Municipality. Typically, the cost for noise mitigation is included in the capital cost for the project. Some of the reviewed policies, however, have no information pertaining to new/upgraded transportation infrastructure and would then assess the need for and cost of noise mitigation on a case-by-case basis.

For all of the reviewed policies that specifically mention retrofit projects (i.e. building noise barriers in existing areas with known high traffic noise levels), the cost associated with noise mitigation is the responsibility of the City/Municipality and is assessed on a case-by-case basis. The City of Calgary has a ranked list (publicly available on the City website) with the locations, estimated noise barrier dimensions, and estimated cost. The actual construction of the barriers from year to year is contingent on funding within the City budget. The City of Edmonton has a similar process by which there are internally known areas that are likely candidates for noise mitigation retrofits, pending funding.

One important component with regards to the funding of noise barriers is the criteria that have been set (i.e. maximum allowable noise levels). Some of the reviewed policies have the same criteria for new residential development and for upgrade/retrofit projects. Others, however, have two different sets of criteria. As an example, Strathcona County (Alberta) has a criterion of 55 dBA $L_{eq}24$ for new residential development and 65 dBA $L_{eq}24$ for upgrade/retrofit locations. In terms of the required quantity and cost of noise mitigation, there is a significant difference between 55 dBA $L_{eq}24$ and 65 dBA $L_{eq}24$. In recent years, this has been a cause for concern with developers of new areas (55 dBA L_{eq}24 is often a difficult target to achieve) and residents in existing areas (65 dBA L_{eq}24 is seen by some as "too loud"). Similarly, in the City of Leduc, new residential development has a criterion of 55 dBA L_{eq}24 while there is no specific criterion for upgrade/retrofit projects. One reason for the lack of criteria for upgrade/retrofit projects is the high cost associated with achieving a maximum noise level of 55 dBA L_{eq}24. In recent years, a common practice in the City of Leduc is to provide the noise mitigation requirements to achieve a range of noise levels (55, 60, 65 dBA L_{eq}24) and then the City determines the actual mitigation that will be implemented based on need/benefit/cost. The result of this is criteria that can change from project to project, resulting in inconsistencies.

It is also important to note that some of the reviewed policies make reference to having a minimum 5 dBA reduction in sound level associated with implementing noise mitigation in order for the project to be considered "worth the cost". This concept of a minimum 5 dBA reduction is common for environmental noise assessments within transportation and industrial applications.

2.1.4. Policy Information Availability Comparison

Of the 11 currently applicable traffic noise policies reviewed, 4 are imbedded within municipal "engineering standards" or "development standards" documents, one was only available by phoning the City and requesting the document (after finding reference to it in a development standards document), and one was not available online at all (obtained through previous work involving the document). This often makes it difficult for the general public to locate through web-based searches unless they know specifically where to look.

2.1.5. Emerging Technologies and Trends in Policies

None of the reviewed policies make any reference to the use of emerging technologies. Specific noise mitigation measures are assessed on a project-by-project basis with noise berms and barriers being the primary method for noise mitigation. Many of the reviewed policies are several years old, and have not been recently updated. In terms of trends, there are no identifiable trends for the newer policies relative to the older policies.

Table 2.1 Summary of Reviewed Traffic Noise Attenuation Policies

City / Municipality	Policy Document	Source	Noise Level Criteria	Funding	Assessment Location	Assessment Height	Future Assessment Timeline
City of Saskatoon (Historical)	Historical information previously posted on the City of Saskatoon Website	Historical information previously posted on the City of Saskatoon Website	65 dBA Ldn (Historically)	No information for New Development City to pay for Retrofit Barriers based on need and budget	Not Defined	Not Defined	Not Defined
City of Regina	Regina Traffic Division Procedure Manual Section 6.0	Received via e-mail after calling City. Otherwise not available online.	65 dBA Ldn	Developers to pay for New Development City to pay for Retrofit Barriers based on need and budget City to pay for barriers as part of Capital Cost for new/upgraded roads where required	3 m from dwelling facade in direction of noise source	1.5 m above grade	20 year planning horizon
City of Edmonton	Urban Traffic Noise Policy (UTNP) C506A	City of Edmonton Website (easily found through Google Search)	65 dBA Leq24	Developers to pay for New Development City to pay for Retrofit Barriers based on need and budget City to pay for barriers as part of Capital Cost for new/upgraded roads where required	Private Backyards	1.5 m above grade.	20 year planning horizon
City of Calgary	Surface Transportation Noise Policy TP003	City of Calgary Website (easily found through Google Search)	60 dBA Leq24	Developers pay for New Development (up to 10-years planning for new roadways) City pay based on need and budget through specific Noise Barrier Retrofit Program City pay as part of Capital Cost for new/upgraded roads where required	Outdoor Leisure Area	Not Defined	10 year planning horizon
City of St. Albert	Municipal Engineering Standards, Section 3.9	City of St. Albert Municipal Engineering Standards Document available at City website	65 dBA Leq24	Developers to pay for New Development City to pay for Retrofit Barriers based on need and budget City to pay for barriers as part of Capital Cost for new/upgraded roads where required	Not Defined	Not Defined	Not Defined
Strathcona County	SER-009-027	Strathcona County Website (easily found through Google Search)	55 dBA Leq24 New Residential 65 dBA Leq24 Existing Residential	Developers to pay for New Development City to pay for Retrofit Barriers based on need and budget City to pay for barriers as part of Capital Cost for new/upgraded roads where required	5 m from dwelling facade in direction of noise source	1.5 m above grade	Future volumes based on design capacity of road
City of Leduc	Engineering Standards Section 1.15	City of Leduc Engineering Design Standards Document available at City website	55 dBA Leq24 New Residential No Criteria for Existing Residential	Developers to Pay for New Development No information/precedent regarding retrofits or new/updgraded road construction	5 m from dwelling facade in direction of noise source	Not Defined	Not Defined
Fort McMurray	Engineering Servicing Standards and Development Procedures, Section 4.9	RMWB Engineering Services Standards and Development Procedures document available at RMWB website	65 dBA Leq24 New Residential No Criteria for Existing Residential	Developers to Pay for New Development No information/precedent regarding retrofits	2 m inside residential property line, in direction of noise source	1.2 m above grade	10 year planning horizon
City of Red Deer	Engineering Services Design Guidelines, 2016 Edition. Section 13	City of Red Deer Engineering Services Design Guidlines Document available at City website	60 dBA Leq24 New Residential No Criteria for Existing Residential	Developers to Pay for New Development No information regarding retrofits	3 m from dwelling facade in direction of noise source. 4.5 m from Property Line if building unknown	1.5 m above grade	20 year planning horizon
Alberta Transportation	Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas	Website that is not directly accessable by the public	65 dBA Leq24	Developers to pay for New Development Alberta Transportation to pay for Retrofit Barriers based on need and budget Alberta Transportation to pay for barriers as part of Capital Cost for new/upgraded roads where required	2 m inside residential property line, in direction of noise source	1.2 m above grade	10 year planning horizon
British Columbia Ministry of Transportation and Infrastructure	Policy for Assessing and Mitigating Noise Impacts From New and Upgraded Numbered Highways	BC Ministry of Transportation and Infrastructure Website	Range based on comparison to the "pre-project" noise levels with maximum allowable noise limit	Applicable for retrofits/upgrades and paid for by the Province of BC. No specific information regarding new Development	Not Defined	Not Defined	10 year planning horizon
Ontario Ministry of the Environment	Publication NPC-300. Environmental Noise Guideline, Stationary and Transportation Sources - Approval and Planning	Ontario Ministry of the Environment Website (easily found through Google search)	55 dBA LeqDay for Outdoor Living Area 50 dBA LeqNight at Window for Bedrooms	Developers to Pay for New Development No information/precedent regarding retrofits	3m from dwelling façade for outdoor living area. Plane of window for indoor.	1.5 m above grade	10 year planning horizon

2.2. City of Saskatoon

In the past, the criteria used to evaluate the road noise and barrier design within the City of Saskatoon has been as follows[1]:

> *"Only existing residential sites with a rear or side lot abutting high traffic roadways would be considered for a sound attenuation barrier. In general, the outdoor area must experience a noise level standard of 65 dBA L_{dn} or higher without a sound attenuation wall to be considered for future installation.*
>
> *Sound attenuation walls will be constructed of City-approved composite materials with due consideration to streetscape and future maintenance requirements. A public meeting with property owners may be conducted prior to deciding on the type of wall to be constructed, however, the final decision regarding the type of wall to be constructed will be at the discretion of the City of Saskatoon. Sound attenuation barriers will be constructed on the City right-of-way only. Installation of the private side yard fencing is the sole responsibility of the property owner."*

For more current traffic noise information, refer to the following website:
https://www.saskatoon.ca/moving-around/driving-roadways/managing-traffic/traffic-noise

[1] Obtained from the previous City of Saskatoon Website discussion of noise barriers. Information is no longer available on the City of Saskatoon Website.

2.3. City of Regina

The City of Regina has a traffic noise attenuation policy imbedded within Section 6.0 of the Regina Traffic Division Procedure Manual for which there is no information available online and which was obtained by calling the City and requesting the document. The Regina policy specifies a maximum allowable noise level of 65 dBA L_{dn} (day-night average level), assessed within the outdoor living space at a height of 1.5 m and 3 m from the building façade. For future assessments, the following procedure and noise level standards are to be used, as taken directly from the Regina policy:

*6.0 **Noise Level Projection Procedure***

6.1 In the case of new residential development or in the evaluation of barriers, the twenty year projection of future traffic volumes will be used in noise studies.

6.2 Traffic volume projections will be provided by the Engineering & Works Department.

6.3 Vehicle speed shall be the proposed or posted speed.

6.4 Truck volumes shall be assumed to comprise 6% of the total projected traffic flow unless known by actual traffic count or by trip generation rates and land use.

6.5 Noise levels shall be calculated using traffic noise prediction methods approved by the City of Regina Engineering & Works Department Traffic Division. These methods include: The Alberta Surface Transportation Noise Attenuation Study Manual for the Prediction of Surface Transportation Noise, the Canada Mortgage and Housing Corporation method, the Federal Highway Administration method Stamina 2.0/Optima. Other technically accurate methods of noise prediction shall be subject to Engineering & Works Department approval. When appropriate, actual measurements with noise monitoring equipment shall be employed.

6.6 Noise levels shall be calculated as the A-weighted 24-hour day-night sound level Ldn (24) expressed in decibels (dBA).

*7.0 **Noise Level Standards***

7.1 The noise level standards of this policy shall apply to all existing or proposed transportation corridors with roadway classification "Freeway", "Expressway", or "Major Arterial".

7.2 For existing or proposed transportation corridors abutting residential land, a noise level standard of 65 dBA Ldn shall apply subject to a maximum barrier height of 5.0 m, a minimum barrier height of 2.0 m, and a reduction of 5 dBA Ldn by the installation of a noise barrier.

7.3 For future or existing transportation corridors where abutting lands are to be zoned industrial or commercial, with good expectation that commercial buildings will occupy these lands and with enforcement of such zoning: no noise barrier standard shall apply.

7.4 The requirement for barriers for other land uses or zoning classifications shall be at the discretion of the City of Regina Engineering & Works Department.

7.5 Where residential developments are being planned adjacent to existing or proposed transportation corridors, the developer shall be responsible for ensuring that noise levels in the ground level outdoor living space area do not exceed 65dBA Ldn based on 20 year traffic projections.

7.6 For residential development where the incident sound level at the façade of any dwelling unit is projected to exceed 55 dBA Leq (24), the City shall require as a condition of approval that the building construction standard shall be in accordance with Canada Mortgage and Housing Corporation recommendation for "adequate sound insulation".

The Regina policy also provides detailed minimum requirements for the construction of earth berms and noise barriers (materials, geometries, locations).

For new residential development, the assessment, design and construction cost for noise attenuation is the responsibility of the developer. For existing development, the following procedure is to be used, as taken directly from the Regina policy:

8.0 ***Prioritization of Candidate Sites – Existing Development***

8.1 Candidate sites for noise attenuation shall be those with noise sensitive land use where noise level exposure in the ground level outdoor living space area nearest the roadway noise source is greater than 65 dBA Ldn.

8.2 Areas where barrier installations would not be technically or economically feasible will not be candidate sites. Such sites will include, but will not necessarily be limited to those sites where barrier heights required to meet the noise level standard would exceed 5m or where property access requirements would prevent construction of an effective barrier.

8.3 Where noise level reduction due to a barrier is expected to be less than 5 decibels, a barrier is not considered to be cost effective. Such sites will not be candidate sites.

8.4 Where roadways are rescheduled to be upgraded within the next five years; noise attenuation will be addressed at the time of roadway construction.

8.5 Feasibility of barrier placement will respect future twenty year road right-of-way requirements.

8.6 Candidate sites will be prioritized using the Barrier Priority Index which is a relative measure of the noise attenuation cost benefit ratio for each site. The Barrier Priority Index is defined as:

$$BP1 = \frac{(ENL - DNL)N}{C} \quad \text{where}$$

BP1 = Barrier Priority Index
ENL= Estimated Noise Level in dBA Ldn based on current or projected traffic counts or actual noise measurement.
DNL = Design Noise Level in dBA Ldn or the minimum noise level for consideration in prioritization (65 dBA Ldn)
N = Number of first row ground level dwelling units which would be protected by barrier attenuation.
C = Barrier construction cost in thousands of dollars including all associated costs such as utility modifications.

The value of the index increases with the traffic noise level and number of residences protected, and decreases with the cost. The larger the value of the index the higher the relative priority of the site.

8.7 Implementation of attenuation of candidate sites will be dependent upon budget allocations, priority ranking and cost/benefit analysis.

In summary, the Regina Traffic Division Procedure Manual requires a maximum sound level of **65 dBA L_{dn}** for all residential outdoor living spaces, nearest to the roadways. For new residential development, the noise mitigation is the responsibility of the developer. For retrofit or new/upgraded road construction, the noise mitigation is the responsibility of the City, subject to economic and technical feasibility, which includes a minimum requirement of achieving a 5 dBA reduction and a maximum sound wall height of 5 m.

2.4. City of Edmonton

The City of Edmonton currently has the Urban Traffic Noise Policy (UTNP), C506A (February, 2013) which is available on the City of Edmonton website. The UTNP is applicable to residential land use adjacent to major transportation facilities such as arterial roadways, light rail transit and future high speed transit facilities. The UTNP accounts for "background" transportation noise only and does not deal with non-typical events such as loud mufflers, stereos, etc. These are dealt with under the City of Edmonton Community Standards Bylaw C14600. The following is taken directly from the UTNP:

Policy Statement:
Mitigating the impact of traffic noise in the urban environment is governed by the following:

The City of Edmonton will seek to ensure that no new residential development less than three storeys will be allowed adjacent to transportation facilities (arterial roadways, light rail transit) unless the developer proves to the satisfaction of the City that the projected noise level in the private back yards of residences abutting the transportation facility will not exceed 65 dBA Leq24. Construction of any noise attenuation measures necessary to achieve this threshold will be funded and undertaken by the developer of the adjacent property, unless specific site characteristics, such as topography or existing land uses, necessitate the consideration of relief from the requirement. Under these circumstances, the attenuated noise level in the abutting private back yards should be the lowest level technically and economically practicable.

The City of Edmonton will seek to achieve a projected attenuated noise level below 65 dBA Leq24 or as low as technically, administratively, and economically practicable, where any urban transportation facility (arterial roadways, light rail transit) is proposed to be built or upgraded through or adjacent to a developed residential area where private back yards will abut the transportation facility. Funding for noise attenuation, where appropriate, and subject to availability, is considered in the cost of the project.

Existing residential sites backing onto a transportation facility (arterial roadways, light rail transit) with measured noise levels exceeding 65 dBA Leq24 in the private back yard will be considered for noise attenuation by the City of Edmonton, where technically administratively, and economically practicable, and subject to the availability of funds and the endorsement of adjacent property owners.

The City of Edmonton will seek to minimize the impact of operational noise associated with the Light Rail Transit (LRT) system on adjacent noise-sensitive land uses while balancing the need for safety and security of road users and patrons at stations, including pedestrians at intersecting roadways.

The purpose of this policy is to:

1. *Seek to ensure that the negative impacts associated with the ongoing exposure to excessive traffic noise is mitigated in the City of Edmonton.*
2. *Assign the responsibility for traffic noise mitigation to the developers of new residential land uses as appropriate.*
3. *Assign the responsibility for traffic noise mitigation to the City of Edmonton where major transportation facilities are proposed or upgraded, subject to funding availability.*
4. *Govern the application of the City of Edmonton's "retrofit noise attenuation program", subject to funding availability.*

In addition to the 1-page UTNP C506A document, the City of Edmonton is currently working on a companion document detailing the noise measurement and modeling methodology including where measurements need to be conducted, etc. All of the details are not currently known, however, it is known that the UTNP C506A uses a 20-year planning horizon for traffic volume projections (AAWDT volumes) to predict future noise levels adjacent to new developments and new or upgraded transportation facilities. In addition, the previous version of C506A utilized a measurement and modeling height of 1.5 m above grade which will likely remain.

In summary, the UTNP requires a maximum sound level of **65 dBA L_{eq}24** for all private back yard locations adjacent to the transportation facility. For new residential development, the noise mitigation is the responsibility of the developer. For retrofit or new/upgraded road construction, the noise mitigation is the responsibility of the City, subject to economic and technical feasibility.

for more information, refer to the following website:
http://www.edmonton.ca/transportation/on_your_streets/traffic-noise.aspx

2.5. City of Calgary

The City of Calgary current has the Surface Transportation Noise Policy (STNP) TP003 (April 1988) which is available on the City of Calgary website. The following is taken directly from the STNP:

BACKGROUND

Many people are exposed to sounds which become annoying. Transportation noise, especially from vehicles, is part of our daily lifestyle. Cars and especially trucks are major sources of noise.

The City of Calgary is committed to reducing the impact of such noise sources in existing and future residential areas. As part of the planning process in Calgary, residential areas are examined to determine whether there is an existing or potential problem in outdoor rear leisure areas around the home.

The City of Calgary's Surface Transportation Noise Policy prescribes the conditions under which noise barriers are constructed adjacent to residential properties using guidelines established by the Federal Government.

PURPOSE

The intent of the Surface Transportation Noise Policy is to provide the design noise levels and descriptors, design criteria, and the responsibility for providing noise attenuation.

POLICY

DESIGN NOISE LEVEL GUIDELINES

The Design Noise Level (DNL) in residential areas for outdoor leisure areas is 60 dBA Leq 24.

In order to achieve acceptable noise levels in residential areas in a consistent and objective manner, it is necessary to utilize a guideline or target noise level. The descriptor dBA Leq 24 is defined as the daily unit of noise which condenses a full 24 hours worth of sound energy into a single number "A-Weighted" to correlate closely with human hearing. Generally, it has been found that a single number representing a 24 hour time period is a good measure of annoyance. The descriptor Leq24 has been used for a number of years and based on empirical research, has proven to be acceptable. The decibel level of 60 dBA for 24 hours has also proven to be acceptable from a benefit/cost point of view.

In residential areas it is specifically the outdoor leisure area in which target levels are to be achieved. This would include ground level areas such as yards and patios or common areas allocated outside multi-dwelling complexes. For buildings two stories or higher, where balconies are considered as the outdoor leisure area, protection should be provided on an individual basis through the use of architectural treatments.

With the achievement of the exterior DNL of 60 dBA Leq24, it is expected that the interior DNL of 45 dBA Leq24 should result with the use of standard construction materials. This level is acceptable, on an average, for most rooms inside dwellings.

In all cases, in order to maximize benefit/cost, noise attenuation should be constructed to achieve a minimum 5 decibel reduction, with a desirable target of 10 decibels. There may be instances where these criteria are not achievable and, therefore, the design noise level cannot be applied in all cases. The achievement of design noise levels must be technically, economically and administratively feasible. Therefore, feasibility is determined when the Administration reviews the details of the noise attenuation design and all alternative measures have been evaluated.

PROCEDURE

IMPLEMENTATION OF DESIGN NOISE LEVELS

In the process of implementing design noise level objectives, the roles of all participants involved in the planning, design and construction of residential subdivisions and adjacent roadways and associated noise attenuation, must be clearly defined. The general practice is that the provision of noise attenuation is dependent on the timing of the residential development and/or the transportation facility. The earlier in the planning process that noise is considered, the greater the flexibility that will be available in providing acceptable acoustical environments in residential areas.

POTENTIAL NOISE IMPACT

A Potential Noise Impact area consists of residential development proposed adjacent to major roads, expressways, freeways, light rail transit corridors, and other rail tires.

Residential development adjacent to a transportation corridor/facility may or may not experience traffic noise problems resulting from proximity to the corridor/facility. Based on field measurements and/or computer calculations, facilities are identified as having a potential noise problem and a noise impact analysis is required. In cases where residential development is proposed adjacent to existing or future transportation corridors/facilities, the developer is responsible for providing a noise impact analysis. This requirement and the analysis methodology is reviewed and approved by the Transportation Department.

RESPONSIBILITY FOR IMPLEMENTATION

The City's responsibility for achieving desirable noise levels is an ongoing process. As a general principle, the timing for providing noise attenuation is the most critical factor in determining responsibility for funding its implementation. When a developer constructs a residential development adjacent to a roadway which has a potential noise impact, if the expected noise levels exceed the City's Design Noise Level, the developer is responsible for providing noise attenuation at his expense. The choice of attenuation measure is left to the developer, subject to City approval. When the method chosen is the installation of a noise barrier, the City reimburses the cost of a 1.8 metre high chain link fence (which would have been required as a minimum) for the length of the noise barrier required.

There are four typical cases in which this responsibility can be categorized.

Case I: Residential development or redevelopment adjacent to an existing or imminent (within 10-years) transportation noise source.

The developer, at his cost, is responsible for providing noise attenuation necessary to achieve sound levels less than or equal to 60 dBA Leq24 where technically and economically feasible.

The method of attenuation should be initiated by the developer, and determined in consultation with the City in order to meet City specifications. Given the developer has maximized opportunities to provide an acceptable acoustical environment, the City will continue to accept the responsibility to further the achievement of the desired noise levels as part of the roadway design.

Example: Where there are existing transportation corridors/facilities, the future noise level is calculated based on the design year traffic volumes (10 years hence), and noise attenuation must be constructed by the developer at the time of development.

Case II: Residential development or redevelopment adjacent to a future (beyond 10-years) transportation noise source.

The developer is responsible for designing and constructing the residential area in such a way as to facilitate the necessary attenuation at the time of construction of the roadway. The City of Calgary would then be responsible for completing the required noise attenuation.

Example: Where there is a future transportation corridor, the future noise level is calculated, based on the design year (beyond 10 years). The developer shall design and construct the residential area in such a way as to accommodate the construction of noise attenuation by the City.

Case III: Upgrading of a roadway adjacent to existing residential developments:

The City is responsible for providing noise attenuation necessary to achieve the Design Noise Level where technically and economically feasible.

Example: When any upgrading takes place, such as reconstruction or new construction of roadways adjacent to an existing residential development, the City installs noise attenuation, as feasible.

Case IV: Present residential development, adjacent to an existing transportation noise source.

Problem locations are identified, and placed as a candidate on the Noise Barrier Retrofit Program for review by City Council.

Example: In situations where a noise problem has been identified, but where a roadway is not scheduled for upgrading within the foreseeable future, the City installs noise attenuation, as feasible. The process *involves a feasibility review of candidate locations, and ranking based on a benefit/cost analysis. Project priority and funding level is determined by City Council.*

In summary, the City of Calgary allows for a maximum sound level of **L_{eq}24 of 60 dBA** measured within the outdoor leisure area and uses a 10-year planning horizon for noise modeling. The responsibility of noise wall costs are as follows:

- For residential development adjacent to existing or imminent transportation noise (within 10 years), the developer is responsible. The city, however, reimburses the equivalent cost of a 1.8m chain-link fence (the minimum required fencing).
- For residential development adjacent to future transportation noise (beyond 10 years), the responsibility is the cities, but the developer has to ensure there is room for the barrier in the development.
- For upgrades to existing roadways adjacent to existing residential development, the city is responsible.
- For present residential development adjacent to existing roadways, the city will consider noise wall construction in accordance with the City Noise Barrier Retrofit Program. The City has a brochure detailing the Retrofit Program along with a list of the top 10 locations which qualify for the Program, pending funding availability by the City.

For more details, refer to the website:
http://www.calgary.ca/Transportation/TP/Pages/Environment/Noise-Barrier-Program.aspx

2.6. City of St. Albert

The City of St. Albert currently has the Municipal Engineering Standards, Section 3.9 on Noise Attenuation (2013) which is available on the City of St. Albert website. The following is taken directly from the document:

"*A Noise Impact Assessment, signed and sealed by a professional engineer, must be provided in cases where a major arterial roadway and/or railway runs through or adjacent to a proposed residential development. The assessment must list the current noise levels, estimate future noise levels, and identify and implement noise attenuation measures required to achieve a* ***maximum noise level of 65 dBA Leq over a 24-hour period****, and in accordance with the City's Noise Bylaw, Bylaw 31/2006.*"

There is no information pertaining to the specific noise assessment location (distance or height). There is also no specific information pertaining to the criteria for retrofit or new/upgraded road construction, although anecdotal information indicates that the City of St. Albert will consider noise mitigation to meet 65 dBA L_{eq}24 for retrofit areas on a case-by-case basis (pending funding) and will consider noise mitigation to meet 65 dBA L_{eq}24 for new/upgraded roads as part of the capital construction cost.

For more information, refer to the following website:
http://www.stalbert.ca/business/engineering/engineering-standards/

2.7. Strathcona County (Alberta)

Strathcona County currently has the Traffic Noise Policy SER-009-027 (June 12, 2007) which is available on the Strathcona County website. SER-009-027 is applicable to all existing or new residential neighborhoods. This policy serves as a guideline to assess and, as necessary, to attenuate forecasted or actual traffic noise in these residential neighborhoods. The sound level descriptor used in all assessments is an A-weighted L_{eq}24. The following is taken directly from SER-009-027:

Policy Statement

A consistent framework is necessary for the assessment and, as necessary, the attenuation of forecasted or actual traffic noise in residential neighborhoods.

Definitions

A. *Outdoor Criterion Sound Level for new residential development - 55 dBA.*
B. *Outdoor Trigger Criterion Sound Level for existing residential development - 65 dBA*
C. *Receiver location - 5 metres from the rear facade of the dwelling and 1.5 metres above the ground elevation at that point*
D. *Road Design Capacity – For the purpose of this Policy, projected traffic volumes to be used for the calculation of projected noise levels on arterial roads are:*
   - *4 lane arterial road - 27,000 vehicles per day*
   - *6 lane arterial road - 40,000 vehicles per day*
E. *Sound Level Descriptor - The sound level descriptor to be used in all assessments will be the 24 Hour Energy Equivalent Sound Level or Leq (24 Hour) expressed in A-weighted decibels or dBA. All sound levels in this policy are Leq (24 Hour).*
F. *Vicinity - the depth of 2 residential lots and will be the nearest residential lots to the roadway regardless of commercial, light industrial or green space screening*
G. *Residential Urban Village - compact, walkable, mixed-use neighbourhoods, as designated in the Area Concept Plans and Area Structure Plans.*

Guidelines

A. *Attenuation of Traffic Noise for Proposed New Residential Development*
   1) *A Noise Impact Assessment, satisfactory to the Manager of Engineering and Environmental Planning, is required for all residential development to be constructed within the vicinity of existing and proposed major roadways.*

2) *The assessment must address background noise levels, the impact of current traffic levels and the impact of traffic at projected road design capacity. The assessment will identify the attenuation measures necessary to meet the Outdoor Criterion Sound Level.*

B. *Attenuation of Traffic Noise for Existing Residential Areas*

1) *No measures will be undertaken for residential neighbourhoods until the measured noise levels 5 metres from the rear facade of the dwelling and 1.5 metres above the ground elevation at that point, exceed 65 dBA.*
2) *No protection will be provided for second or subsequent storeys of houses unless such protection can be achieved by a maximum of a 2.5 metre wall on the existing grades at the road right-of-way limit.*

C. *Attenuation of Traffic Noise for Residential Urban Villages*

1) *A Noise Impact Assessment, satisfactory to the Manager of Engineering and Environmental Planning, is required for all residential development to be constructed within the vicinity of existing and proposed major roadways.*
2) *Noise attenuation will be provided through building orientation and privacy walls and fences.*

Procedures

A. *Attenuation of Traffic Noise for Proposed New Residential Development*

1) *Developers will be required to provide a design for a 55 dBA maximum noise level. The Manager of Engineering and Environmental Planning, at his sole discretion, may relax the design in the interests of practicality, however, under no circumstances shall the attenuation measures as designed permit greater than 60 dBA at design road capacity 5 metres from the facade of the nearest dwellings and 1.5 metres above the ground elevation at that point.*
2) *Traffic noise levels will be estimated using the Strathcona County Traffic Noise Prediction Model. When traffic noise predictions are made, print-outs from the model containing the input data and predicted sound levels will be attached to the Noise Impact Statement for consideration and acceptance by the County. Electronic "reports" will also be acceptable if compatible with County equipment and systems.*
3) *The traffic volumes used for the noise prediction will be the Road Design Capacity traffic volumes. Percentages of medium and heavy trucks for use in the model will be based on existing traffic counts.*
4) *The Developer shall construct or provide funds for the construction of the attenuation measures to meet the road design capacity.*
5) *Where the predicted noise levels are below the 55 dBA level without the provision of a attenuation facility, the minimum requirement acceptable is a 1.8 metre high double board wood fence. At the sole discretion of the Manager of Engineering and Environmental*

Planning this may be relaxed in circumstances where the vicinity of the house is screened from the roadway by sufficient vegetation to provide a design noise level no greater than 55 dBA, 5 metres from the nearest dwelling's facade and 1.5 metres above the ground elevation at that point. The screening property must be municipal reserve, environmental reserve, public utility lot or other such designation or use that would not reasonably be expected to change during the design life of the dwellings.

6) *Wherever possible absorptive materials will be preferred over reflective noise attenuation measures. Developers are encouraged to explore the availability of alternative construction material for the construction noise attenuation facilities and use vegetation in the development for screening of the arterial from the residence.*
7) *Achievement of C.M.H.C. recommended noise levels inside buildings is not controllable by the County. Home owners concerned about these noise levels are expected to take their own mitigative measures and should refer to Part 11 of the Alberta Building Code that specifies the use of sound insulation for the interior living areas. If requested, the Manager of Engineering and Environmental Planning may authorize home interior testing for the determination of the building attenuation measures required.*
8) *The developers of any multi-storey residences planned for "the vicinity" of a major roadway must use sound insulation for the interior living areas that conform to Part II of the Alberta Building Code.*

B. *Attenuation of Traffic Noise for Existing Residential Areas*

1) *In areas where the Outdoor Trigger Sound Level Criterion of 65 dBA noise level is exceeded, Council will consider, on a priority and availability of funds basis, the construction of such noise attenuation measures that are determined by Administration to have the desired attenuating effect.*
2) *Where residents would prefer a more expensive attenuation measure than that proposed by the County, they may petition on a local improvement charge basis to pay the difference in cost for the enhanced facility.*
3) *Where residents would prefer a noise attenuation facility in advance of the County's ability to provide it, in accordance with the Municipal Government Act, RCA 2000, M-26, they may petition for the construction of such noise attenuation measures at any time on a 100% local improvement charge basis.*
4) *The residents will be assisted by Engineering and Environmental Planning staff in the determination of the design and estimated cost of such noise attenuation measures. In conjunction with the petition process, all residents adjacent to the property line on which the facility will be constructed must sign a working easement agreement prior to implementation of the project.*

C. *Attenuation of Traffic Noise for Residential Urban Villages*

1) *Developers will be required to provide a design for a 55 dBA maximum noise level to the outdoor amenity area and deck areas.*

2) *Traffic noise levels will be estimated using the Strathcona County Traffic Noise Prediction Model. When traffic noise predictions are made, print-outs from the model containing the input data and predicted sound levels will be attached to the Noise Impact Statement for consideration and acceptance by the County. Electronic "reports" will also be acceptable if compatible with County equipment and systems.*
3) *The traffic volumes used for the noise prediction will be the Road Design Capacity traffic volumes. Percentages of medium and heavy trucks for use in the model will be based on existing traffic counts.*
4) *Developers must use sound insulation for the interior living areas that conform to Part 11 of the Alberta Building Code.*

In summary, as described in SER-009-027, the Outdoor Criterion Sound Level for new residential development is **55 dBA L_{eq}24** which may be relaxed at the sole discretion of the Manager of Engineering and Environmental Planning. Under no circumstances shall the attenuation measures as designed permit **greater than 60 dBA L_{eq}24** at design road capacity 5 meters from the facade of the nearest dwellings and 1.5 meters above the ground elevation at that point. The Outdoor Criterion Sound Level for existing residential development is **65 dBA L_{eq}24**.

for more information, refer to the following website:
http://www.strathcona.ca/departments/transportation-and-agriculture-services/traffic-management/traffic-noise/

2.8. City of Leduc

The City of Leduc currently has the Engineering Standards – Section 1.15 Noise Abatement (2006) which is available at the City of Leduc website. The following section, which is most applicable to this study, is taken directly from the Criteria:

1.15 NOISE ABATEMENT

1. *Where an arterial roadway, Secondary Highway or Primary Highway abuts or passes through a development area, the Developer shall engage an independent consultant to conduct a noise study to forecast noise levels that would be experienced within the development area from the rail and/or roadway.*

2. *Where the noise study predicts a 24 hour L_{eq} of 55 dBA or less measured or calculated at a distance of 5.0 metres from the nearest dwelling facade adjacent to the rail and/or the roadway within the subdivision area, no further action by the Developer shall be required.*

3. *Where the noise study predicts a 24 hour L_{eq} in excess of 55 dBA, the Developer shall provide noise attenuation in a form that will reduce the noise level to 55 dBA or below. Under extenuating circumstances and at the discretion of the City Engineer, the design noise level may be relaxed.*

In summary, the City of Leduc allows for a maximum sound level of **L_{eq}24 of 55 dBA** measured at approximately 5m from the nearest dwelling in the direction of the noise source. There is no mention of the height of the receptor. There is no policy regarding noise level criteria for new/modified road construction or retrofit programs.

for more information, refer to the following website:
http://www.leduc.ca/City_Government/Departments/Engineering/Engineering_Design_Standards.htm

2.9. Regional Municipality of Wood Buffalo – Fort McMurray

The Regional Municipality of Wood Buffalo (RMWB) - Fort McMurray has the Engineering Servicing Standards and Development Procedures, Section 4.9 on Sound Abatement (2013) which is available at the RMWB website. The criteria are applicable to new developments that include and/or are adjacent to arterial roadways, highways and railways, or any other land use identified to generate noise. The following is taken directly from Section 4.9:

At the direction of the Municipality, a noise impact assessment may be required for all new developments that include and/or are adjacent to arterial roadways, highways, and railways, or any other land use identified to generate noise. The threshold requiring noise mitigation measures shall be an A-weighted 24 hour equivalent sound level of 65 dB[1], measured 1.2 meters above ground level and 2 m inside of the property line (i.e. outside of the road right-of-way), adjusted for the 10 year planning horizon of the traffic loads on the adjacent arterial roadway.

The mitigation of noise can include berms or elevated contoured embankments along arterial roadways, highways and/or railways. Sound barrier fences or equivalent means of noise abatement may also be accepted by the Municipality upon approval of design submittal.

The side slopes of the embankment shall have a maximum gradient of 4H:1V. Pedestrian connectivity via a PUL shall work with the grades, by reducing the gradient and placing retaining walls where required along the adjacent property lines on the subdivision side, and cutting a walkway diagonally along the embankment at a maximum 8% grade on the roadway side. The right-of-way may require widening to suit.

In summary, the criteria sets a threshold of **65 dBA L_{eq}24** measured 1.2 m above ground level and 2 meters inside the property line. There is also no specific information pertaining to the criteria for retrofit or new/upgraded road construction.

For additional information, refer to the following website:
http://www.woodbuffalo.ab.ca/living/Services-and-Utilities/Engineering-Servicing-Standards.htm

[1] Also typically written as 65 dBA L_{eq}24.

2.10. City of Red Deer

The City of Red Deer currently has the Engineering Services Design Guidelines, Section 13.13 Noise Study (2016) which is available at the City of Red Deer website. The following is taken directly from the document:

> *The City's Traffic Noise Attenuation (Council) Policy establishes the maximum design noise level at 60 dBA Leq (24) for new development areas adjacent to expressways and arterial roadways.*
>
> *When a Noise Study is required, typically at Area Structure Planning (Section 4) or Servicing Study (Section 5), to support a project or development the following criteria shall be used:*
>
> 1. *The maximum noise level of 60 dBA Leq (24) relates to the outdoor leisure area. The receiver is located 1.5 m above the ground and 3 m from the face of the building. If the location of the building is not known, the receiver should be located 4.5 m from the property line.*
> 2. *Noise levels are to be predicted for the 20-year traffic volume as forecast in the current City of Red Deer Transportation Study. Predicted traffic volumes for highways (i.e. Hwy. 2, Hwy. 2A, Hwy. 11 and Hwy. 11A) should be obtained from Alberta Transportation.*
> 3. *The Noise Study is to contain a report of the findings and scaled drawing(s) of the site including the following:*
>   a. *building location(s),*
>   b. *receiver location(s),*
>   c. *road alignment,*
>   d. *proposed noise barrier(s),*
>   e. *coordinate grid (for FHWA method),*
>   f. *scaled cross-section at each receiver location showing roadway, receiver, and ground elevation as required,*
>   g. *traffic volumes and percentage of heavy vehicles,*
>   h. *detailed calculations used to determine noise levels and barrier heights, and*
>   i. *table showing receiver noise levels with and without a barrier.*
>
> *The package of information provided shall include the construction specifications for the sound attenuation barrier, if the Study's results warrant one.*

In summary, the City of Red Deer allows for a maximum sound level of **L_{eq}24 of 60 dBA** measured at 3 m from the face of the dwelling in the direction of the noise source at a height of 1.5 m. For areas where the locations of the proposed dwellings are not yet known, the assessment location is 4.5 m from the property line. There is also no specific information pertaining to the criteria for retrofit or new/upgraded road construction. For more information, refer to the following website:

http://www.reddeer.ca/media/reddeerca/city-services/engineering/publications/Design-Guidelines-Full-Version.pdf

2.11. Alberta Transportation

Alberta Transportation has a document entitled *Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas (2002)*, which is difficult for the public to find since it is not on a published website or a website that is navigable through conventional means. Although this document does not apply to any specific Municipality, it does apply to some of the major highways operated by Alberta Transportation within major urban centers and provides a useful comparison. The following is taken directly from the document:

Definition:

Noise is defined as the sounds generated by vehicles operating on the highway. It includes but is not limited to engine/exhaust sounds and road contact sounds.

Guidelines:

- *For construction or improvements of highways through cities and other urban areas, Alberta Transportation will adopt a noise level of 65 dBA Leq24 measured 1.2 metres above ground the level and 2 metres inside the property line (outside the highway right-of-way). The measurements should be adjusted to the 10 year planning horizon value, as a threshold to consider noise mitigation measures.*
- *The mitigation of noise issues could include constructing noise walls and/or berms. The decision to implement noise mitigation must consider whether mitigation is cost-effective, technically practical, broadly supported by the affected residents, and fits into overall provincial priorities.*
- *Any accepted noise mitigation measures consistent with this guideline will be the responsibility of Alberta Transportation. Where established local noise mitigation policies are more stringent than this guideline, the local policy may be considered on a shared responsibility basis.*
- *Alberta Transportation will be responsible for noise attenuation, in accordance with this guideline, in areas where Alberta Transportation is undertaking widening (by at least one lane width) or major realignment of an existing road or constructing a new road adjacent to an existing residential development.*
- *In areas where a residential subdivision is constructed adjacent to an existing roadway, the development proponent will be responsible for noise attenuation consistent with these guidelines.*
- *In areas where a residential subdivision is constructed adjacent to a designated highway that has not been constructed, Alberta Transportation will request that the development proponent and approving authority address future noise concerns consistent with these guidelines.*

In summary, the criteria sets a threshold of **65 dBA L_{eq}24** measured 1.2 m above ground level and 2 meters inside the property line.

For additional information, refer to the following website:
http://www.transportation.alberta.ca/Content/docType490/Production/NoiseGuidelines.pdf

2.12. British Columbia Ministry of Transportation and Infrastructure

The British Columbia Ministry of Transportation and Infrastructure has the *Policy for Assessing and Mitigating Noise Impacts From New and Upgraded Numbered Highways,* April, 2014 (the BC Policy) which is available on the BC Ministry website. The BC Policy is applicable to new and existing numbered highways and freeways within the entire province, but is not specifically applicable to any other major arterial or collector roadways within the various cities and municipalities.

The BC Policy uses the day-night average sound level (L_{dn}) and, as stated in the Policy:

> *The Policy takes a "dual-threshold" approach to identifying noise impacts that warrant mitigation consideration so as to better address the range of possible impacts associated with highway projects and to provide greater flexibility in selecting mitigation measures consistent with the project degree of impact. These thresholds are shown in two forms in Figures 1 and 2. In Figure 1, baseline, or pre-project, noise levels (*L_{dn}*s) are plotted on the horizontal axis while total, post-project (10 years after project completion) noise levels are plotted on the vertical axis. Mitigation consideration shall be warranted for noise impact situations falling within the Moderate and Severe impact zones. Note that mitigation will only be carried out where total post-project noise levels are clearly dominated by highway traffic. In Figure 2, pre-project noise levels are shown on the horizontal axis while the project-related increases in total noise exposure required to warrant mitigation consideration are plotted on the vertical axis. The Moderate and Severe noise impact threshold values are presented in tabular form in Table 1.*

Figures 1 and 2 and Table 1 from the BC Policy, have been copied below.

Figure 1; Project-Related Traffic Noise Impact Thresholds

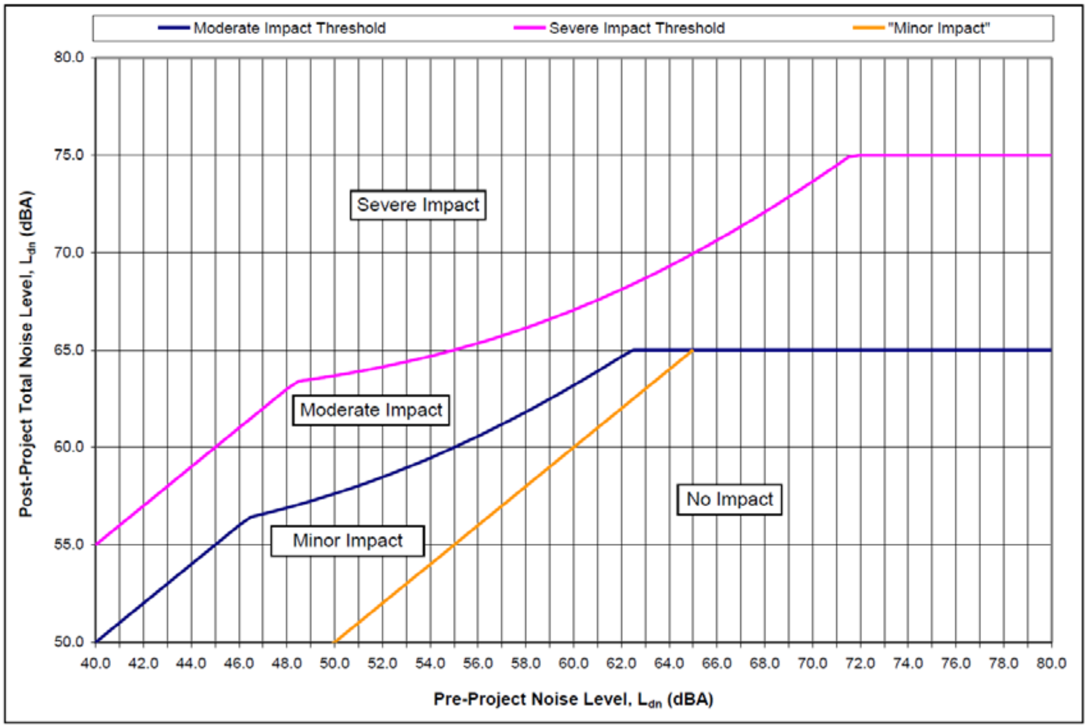
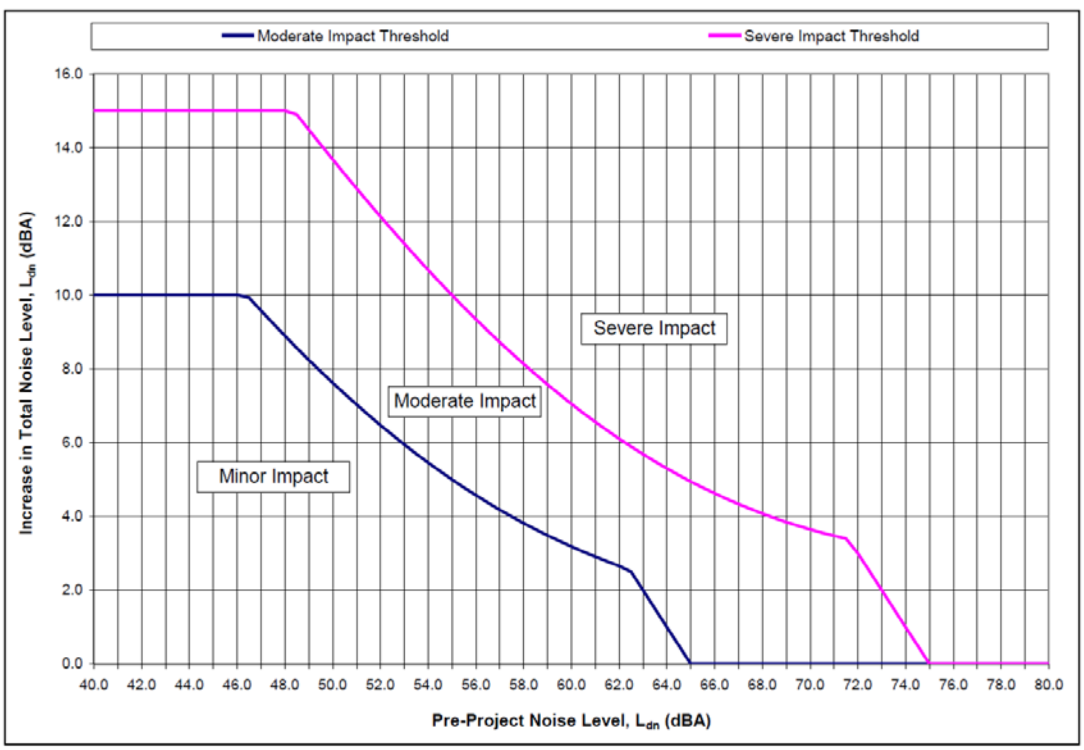


Figure 2; Increases in Total Noise Levels Permitted by Impact Thresholds of Figure 1.



B.C. MoTI Policy for Assessing & Mitigating Noise Impacts from New & Upgraded Numbered Highways

Table 1; Post-Project Total L_{dn} Values and Increases in Total L_{dn} Corresponding to Noise Impact Thresholds of Figures 1 and 2 Respectively.

Pre-Project L_{dn} (dBA)	Post-Project Total L_{dn} (dBA) (Figure 1)			Increase in Total L_{dn} (dBA) (Figure 2)		
	Minor Impact	Moderate Impact	Severe Impact	Minor Impact	Moderate Impact	Severe Impact
40.0	40.0	50.0	55.0	0.0	10.0	15.0
41.0	41.0	51.0	56.0	0.0	10.0	15.0
42.0	42.0	52.0	57.0	0.0	10.0	15.0
43.0	43.0	53.0	58.0	0.0	10.0	15.0
44.0	44.0	54.0	59.0	0.0	10.0	15.0
45.0	45.0	55.0	60.0	0.0	10.0	15.0
46.0	46.0	56.0	61.0	0.0	10.0	15.0
47.0	47.0	56.6	62.0	0.0	9.6	15.0
48.0	48.0	56.9	63.0	0.0	8.9	15.0
49.0	49.0	57.2	63.5	0.0	8.2	14.5
50.0	50.0	57.6	63.7	0.0	7.6	13.7
51.0	51.0	58.0	63.9	0.0	7.0	12.9
52.0	52.0	58.5	64.1	0.0	6.5	12.1
53.0	53.0	59.0	64.4	0.0	6.0	11.4
54.0	54.0	59.5	64.7	0.0	5.5	10.7
55.0	55.0	60.0	65.0	0.0	5.0	10.0
56.0	56.0	60.6	65.3	0.0	4.6	9.3
57.0	57.0	61.2	65.7	0.0	4.2	8.7
58.0	58.0	61.8	66.1	0.0	3.8	8.1
59.0	59.0	62.5	66.6	0.0	3.5	7.6
60.0	60.0	63.2	67.1	0.0	3.2	7.1
61.0	61.0	63.9	67.6	0.0	2.9	6.6
62.0	62.0	64.7	68.1	0.0	2.7	6.1
63.0	63.0	65.0	68.7	0.0	2.0	5.7
64.0	64.0	65.0	69.3	0.0	1.0	5.3
65.0	64.0	65.0	69.9	0.0	0.0	4.9
66.0	64.0	65.0	70.6	0.0	0.0	4.6
67.0	64.0	65.0	71.3	0.0	0.0	4.3
68.0	64.0	65.0	72.1	0.0	0.0	4.1
69.0	64.0	65.0	72.8	0.0	0.0	3.8
70.0	64.0	65.0	73.6	0.0	0.0	3.6
71.0	64.0	65.0	74.5	0.0	0.0	3.5
72.0	64.0	65.0	75.0	0.0	0.0	3.0
73.0	64.0	65.0	75.0	0.0	0.0	2.0
74.0	64.0	65.0	75.0	0.0	0.0	1.0
75.0	64.0	65.0	75.0	0.0	0.0	0.0
76.0	64.0	65.0	75.0	0.0	0.0	0.0
77.0	64.0	65.0	75.0	0.0	0.0	0.0
78.0	64.0	65.0	75.0	0.0	0.0	0.0
79.0	64.0	65.0	75.0	0.0	0.0	0.0
80.0	64.0	65.0	75.0	0.0	0.0	0.0

B.C. MoTI Policy for Assessing & Mitigating Noise Impacts from New & Upgraded Numbered Highways

In summary, unlike all of the other traffic noise policies reviewed, the BC Policy uses a scaled approach with a range of allowable increases in noise levels (relative to the pre-project noise levels) as well as a maximum allowable noise limit. The document does not specify how the allowable increases or maximum limits were determined and does not provide any references for the information.

The BC Policy is applicable to residences as well as Hospitals (on a case-by-case basis). There is also discussion of noise mitigation for educational facilities, libraries, churches, and museums, however unlike the rest of the document, the criteria used for these specific spaces is a L_{eq}(max-hour) of 40 dBA inside the structure and assumes a 20 dBA reduction through the building façade, resulting in an L_{eq}(max-hour) of 60 dBA at the exterior building façade. No other reviewed policy uses the metric of L_{eq}(max-hour).

It is important to note that the specific receptor locations (location and height) are not defined in the document. Also, unlike all of the other traffic noise policies reviewed, the BC Policy is intended to apply to new highway or retrofit highway construction in which the province of BC will pay for the noise attenuation. There is no specific discussion regarding the applicability of the noise criteria for new residential development adjacent to existing highways.

For additional information, refer to the following website:
http://www.th.gov.bc.ca/publications/eng_publications/environment/references/moti_noise_policy_april_23_2014.pdf

2.13. Ontario Ministry of the Environment

The Ontario Ministry of the Environment (MOE) has Publication NPC-300, Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning (2013) which is available on the MOE website. NPC-300 covers various noise sources such as stationary (mechanical equipment) and transportation including road, rail, and aircraft. Specific to road noise, NPC-300 is used as a framework throughout Ontario in place of road noise policies in each Municipality.

As discussed in NPC-300:

> *Section C3.2.1 Method*
> *The assessment of road traffic noise impact, if required by the land use planning authority, is evaluated by prediction using statistically averaged road traffic information, based on the higher of the AADT (Annual Average Daily Traffic) or SADT (Summer Average Daily Traffic). The commonly used prediction method for road traffic noise, as recommended by MOE, is a method entitled ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, published in 1989 by MOE, as amended from time to time. The descriptors are the 16-hour daytime* L_{eq} *(16) (07:00 – 23:00) and the 8-hour nighttime (23:00 – 07:00) equivalent sound levels.*
>
> *For complete description on assessing road traffic impacts, refer to ORNAMENT. Other traffic noise prediction models have been and are being developed by various authorities and may be adopted from time to time for use in Ontario by the MOE.*
>
> *In order to be consistent with MOE guidelines, the sound level should be assessed in an Outdoor Living Area (OLA), such as a rear yard or a patio, and in indoor living areas, such as bedrooms and living rooms. Where the noise impact exceeds the applicable sound level limits, mitigation measures such as site planning, architectural design, noise barriers, building envelope elements (windows, exterior walls, doors) with upgraded sound isolation performance and/or central air conditioning may be required. Noise control measures are not required if the sound level estimated in the OLA is 55 dBA or less during the daytime and 50 dBA or less in the plane of bedroom windows during either daytime or nighttime.*

For planning purposes, a 10-year planning horizon is used. Further, the Outdoor Living Area is defined in more detail as follows:

> *"Outdoor living area (OLA)" (applies to impact assessments of transportation sources) means that part of a noise sensitive land use that is:*
>
> - *intended and designed for the quiet enjoyment of the outdoor environment; and*
> - *readily accessible from the building.*
>
> *The OLA includes:*
>
> - *backyards, front yards, gardens, terraces or patios;*
> - *balconies and elevated terraces (e.g., rooftops), with a minimum depth of 4 metres, that are not enclosed, provided they are the only outdoor living area (OLA) for the occupant; or*

- *common outdoor living areas (OLAs) associated with high-rise multi-unit buildings.*

The following considerations apply to OLAs:

1. *For the purposes of noise impact assessment in an OLA at grade, the point of assessment is typically:*
   a. *3 metres from the building façade;*
   b. *1.5 metres above grade or floor level; and*
   c. *aligned with the midpoint of the subject façade.*
2. *For elevated OLAs or those at grade that are less than 6 metres in depth, the point of assessment is in the middle of the OLA at 1.5 metres above grade or floor level.*
3. *For the purposes of the noise impact assessment in an OLA at grade, the minimum areas that require protection/consideration are 56 m^2 for single family dwellings, 46 m^2 for semi-detached dwellings and 37 m^2 per unit for row housing (dwellings). If the total area of the OLA is smaller than the areas noted above, then the entire OLA, excluding the footprint of the dwelling needs to be protected.*
4. *The noise impact assessment at an OLA excludes the effect of sound reflection from the façade. In general, the point of assessment in the OLA is a point used for prediction (including extrapolation), rather than measurement, of sound levels.*

The Plane of Window is defined as follows:

> *A point in space corresponding with the location of the center of a window of a noise sensitive space. The noise impact assessment excludes the effect of sound reflection from the plane of the window on which it is located. In general, the plane of a window is a point used for prediction (including extrapolation), rather than measurement, of sound levels. The plane of door has the same meaning as the plane of window for the purposes of this guideline.*

The NPC-300 provides for a maximum *indoor* sound level of 45 dBA L_{eq} during the day-time or night-time in residential structures (other than bedrooms) as well as hospitals, nursing homes, schools, and daycare centers. Within residential bedrooms, the maximum indoor sound levels are 45 dBA L_{eq}Day (07:00 – 23:00) and 40 dBA L_{eq}Night (23:00 – 07:00). In most jurisdictions, it is commonly assumed that the building façade (with windows closed) will attenuate traffic noise by at least 15 dBA, if it has been built to meet the Building Codes. This would represent an *exterior* noise level at the plane of window of 60 dBA during the day-time and 55 dBA during the night-time, which exceeds the criteria previously listed. Based on the criteria within the NPC-300, it can be surmised that the document assumes only a 10 dBA reduction associated with the building façade with windows closed. This is a conservative assumption.

In terms of road noise mitigation, as discussed in Section C7.1:

C7.1.1 Outdoor Living Areas

If the 16-Hour Equivalent Sound Level, L_{eq} (16) in the OLA is greater than 55 dBA and less than or equal to 60 dBA, noise control measures may be applied to reduce the sound level to 55 dBA. If measures are not provided, prospective purchasers or tenants should be informed of potential noise problems by a warning clause Type A. If the 16-Hour Equivalent Sound Level, L_{eq} (16) in the OLA is greater than 60 dBA, noise control measures should be implemented to reduce the level to 55 dBA. Only in cases where the required noise control measures are not feasible for technical, economic or administrative reasons would an excess above the limit (55 dBA) be acceptable with a warning clause Type B. In the above situations, any excess above the limit will not be acceptable if it exceeds 5 dBA.

C7.1.2 Plane of a Window – Ventilation Requirements

C7.1.2.1 Daytime Period, 07:00 – 23:00 Hours
Noise control measures may not be required if the L_{eq} (16) daytime sound level in the plane of a bedroom or living/dining room window is less than or equal to 55 dBA. If the sound level in the plane of a bedroom or living/dining room window is greater than 55 dBA and less than or equal to 65 dBA, the dwelling should be designed with a provision for the installation of central air conditioning in the future, at the occupant's discretion. Warning clause Type C is also recommended.

If the daytime sound level in the plane of a bedroom or living/dining room window is greater than 65 dBA, installation of central air conditioning should be implemented with a warning clause Type D. In addition, building components including windows, walls and doors, where applicable, should be designed so that the indoor sound levels comply with the sound level limits (previously listed). The location and installation of the outdoor air conditioning device should comply with sound level limits of Publication NPC-216, and guidelines contained in Environmental Noise Guidelines for Installation of Residential Air Conditioning Devices, or should comply with other criteria specified by the Municipality.

C7.1.2.2 Nighttime Period, 23:00 – 07:00 Hours
Noise control measures may not be required if the L_{eq} (8) nighttime sound level in the plane of a bedroom or living/dining room window is less than or equal to 50 dBA. If the sound level in the plane of a bedroom or living/dining room window is greater than 50 dBA and less than or equal to 60 dBA, the dwelling should be designed with a provision for the installation of central air conditioning in the future, at the occupant's discretion. Warning clause Type C is also recommended.

If the nighttime sound level in the plane of a bedroom or living/dining room window is greater than 60 dBA, installation of central air conditioning should be implemented, with a warning clause Type D. In addition, building components including windows, walls and doors, where applicable, should be designed so that the indoor sound levels comply with the sound level limits (previously listed). The location and installation of the outdoor air conditioning device should comply with sound level limits of Publication NPC-216, and guidelines contained in

Environmental Noise Guidelines for Installation of Residential Air Conditioning Devices, or should comply with other criteria specified by the Municipality.

C7.1.3 Indoor Living Areas – Building Components

If the nighttime sound level outside the bedroom or living/dining room windows exceeds 60 dBA or the daytime sound level outside the bedroom or living/dining area windows exceeds 65 dBA, building components including windows, walls and doors, where applicable, should be designed so that the indoor sound levels comply with the sound level limits (previously listed). The acoustical performance of the building components (windows, doors and walls) should be specified.

Warning Clause Type C

> *"This dwelling unit has been designed with the provision for adding central air conditioning at the occupant's discretion. Installation of central air conditioning by the occupant in low and medium density developments will allow windows and exterior doors to remain closed, thereby ensuring that the indoor sound levels are within the sound level limits of the Municipality and the Ministry of the Environment."*

In summary, NPC-300 allows for a maximum *exterior* sound level in the outdoor living area (1.5 m elevation and 3m from the building façade) of 55 dBA during the day-time (07:00 – 23:00) and a maximum *exterior* sound level of 50 dBA at the plane of window for residential bedrooms and 55 dBA at the plane of window for all other residential rooms during the night-time (23:00 – 07:00). This assumes a 10 dBA reduction of sound across the building façade which will result in *interior* noise levels of 40 dBA for bedrooms and 45 dBA for all other residential spaces. A 10-year planning horizon is used. There is also no specific information pertaining to the criteria for retrofit or new/upgraded road construction.

For more information, refer to the following website:
https://www.ontario.ca/page/environmental-noise-guideline-stationary-and-transportation-sources-approval-and-planning

3.0 Current Best Practices

Another component in developing a Traffic Noise Attenuation Policy is to review the current noise mitigation practices and technologies employed in other cities and municipalities. In general, these practices and technologies tend to not be written into noise policies and the information provided below is based largely on the anecdotal experience of the author, having conducted numerous traffic noise studies across Western Canada.

3.1. Planning

The first best method for reducing traffic noise for residential areas is through appropriate neighbourhood planning. Where possible, residential areas should be separated from major transportation corridors by large distances with other development in between. For example, it is recommended to have commercial development that directly abuts the major transportation corridors and then have the residential development further-in, on the other side of the commercial development. This will provide greater distance between the major transportation corridor and the residential development and will also provide barriers in the form of the commercial buildings. Similarly, the use of natural buffers like storm water management facilities (SWMFs), parks, natural areas, and other public spaces can help to provide a “distance barrier” which will lower the traffic noise levels at the residential development.

Having specific designated heavy truck routes and bus routes that are separated from the residential developments can also help to reduce the overall traffic noise impact since these vehicles contribute the largest to the overall traffic noise level.

3.2. Enforcement and Education

One significant source of traffic noise annoyance for adjacent residents is associated with excessively loud vehicles on the roadway. In many situations, the excessive noise is caused by an illegal activity such as use of engine retarder brakes within City limits, street racing or other potentially subjectively annoying activities such as excessively loud stereos, vehicles with excessively loud exhaust noise, etc. Standard engineering mitigation methods such as noise barriers or earth berms do very little to reduce the noise from these types of events. In addition, excessive noise from such events are typically under the jurisdiction of local noise bylaws and are not covered by traffic noise attenuation policies. Thus, the solution for mitigating these types of noise sources is a program of enforcement of local bylaws and educating the public regarding the impacts of these noise sources.

3.3. Barriers

For areas where commercial and natural buffers are not feasible or for existing areas where the configuration of the road and adjacent residential locations are fixed, the next noise mitigation strategy is the use of noise barriers. Noise barriers generally come in the form of earth berms or noise walls or a combination of the two. It is common practice in many municipalities to stipulate that the noise barrier used for retrofit projects or new/upgraded roadways provide a minimum of 5 dBA of attenuation before the subjective noise reduction benefit is considered worth the cost of the installation. A traffic noise barrier that can provide 10 dBA of reduction is considered a good barrier and a 15 dBA reduction is nearing the practical limit for any traffic noise barrier.

3.3.1. Earth Berms

Earth berms can be an effective means for noise mitigation. In terms of a "barrier" effect, earth berms are similar to noise walls for any given height and location of the earth berm centerline. For example, an earth berm that is 1.83 m tall will act as a similar noise barrier to a 1.83 m noise wall if the wall was located at the same line as the centerline of the earth berm. Earth berms provide the required mass and continuity (i.e. no gaps or openings) to act as an appropriate noise barrier. In addition, relative to noise walls, earth berms naturally incorporate sound absorption through the dirt and the vegetation (typically grass and possibly bushes/shrubs). And earth berms tend to be subjectively more visually appealing than noise walls.

However, relative to noise walls, earth berms require a significant amount of land. Typical berms require slopes ranging from 3:1 to 4:1, depending on the specific municipal requirements. This means that, for a 3:1 slope, for every 1 m of height, 6 m of total width is required (3m on each side) plus the width of the top plateau. Thus, a berm that is 5 m tall would typically require at least 31 m total width (with a 1 m wide plateau) and even wider if it is desired to have a plateau that can be driven on with a vehicle for maintenance purposes. Plus, the vegetation on the berm requires maintenance (i.e. mowing grass, tending to shrubs and bushes) during the summer months which carries an associated cost. Finally, earth berms can present issues associated with water runoff and drainage.

In some municipalities, there are instances in which retrofit noise attenuation has been achieved through the use of an earth berm (or a larger earth berm than was previously there). The rear residential property line is shifted closer to the roadway (giving the resident more land), and the centerline of the earth berm is located at the new property line. This provides additional noise attenuation and gives the resident a larger lot, at the cost of having part of the lot encompass one half of an earth berm. The maintenance of that half of the earth berm is then the responsibility of the resident. Further, in some instances, the residents take it upon themselves to cut-in to the earth berm and install an appropriate retaining wall to give them more flat usable yard area.

3.3.2. Noise Walls

Noise walls are the most common form of traffic noise mitigation. Noise walls can be comprised of various materials including wood, masonry, metal, and even vegetative/living barrier walls. There are several important components required for a good noise wall, including:

- **Geometry:** The geometry associated with the noise wall is the single largest factor in determining the performance of the noise wall. The location of the noise wall (relative to the roadway and the receptors) and the height are what determine the amount of sound that will propagate over top of noise wall to the other side. In general, assuming relatively flat ground, it is better to locate the noise wall as close to the roadway or the receptors as possible with the least effective place being midway between the roadway and the receptors. The exception to this is if there is already an earth berm located in between the roadway and the receptors, in which case, it is typically best to locate the noise wall on top of the earth berm. Further, it is generally better to locate noise walls as close to roadways as possible so that all residential receptors on the "shadow" side receive similar noise reduction benefits (as opposed to locating the noise wall at the nearest rear residential property line which would largely benefit the nearest residents and then have a much lesser benefit for all other residents further-in). Also, as one would intuitively expect, a taller noise wall will attenuation the noise better than a shorter noise wall. Finally, the noise wall must be sufficiently long that it either extends well past the desired noise attenuation property OR wraps around to provide the necessary attenuation. Note that the geometry rules apply equally to noise walls and earth berms and combinations of the two.

- **Mass:** As sound propagates from the road towards the residential area with a noise wall in between, some of the sound will impact the noise wall and transmit directly through it, while some of the sound will propagate over the wall and diffract back down to the other side. It is important that the sound that transmits through the noise wall be sufficiently less than the sound that transmits over top of the noise wall. This can be accomplished by using building materials that have enough mass. For traffic noise barriers, the generally accepted minimum value is a noise wall with a surface density of at least 20 kg/m^2. This is readily achieved with a double board wood fence (if using wood materials) or any thickness of masonry materials that would commonly be used for noise wall construction.

- **Reflections:** The location of and the materials used for a noise wall can result in significant sound reflections off the wall towards the opposite direction which will increase the overall noise levels in that direction. Depending on what is located on the opposing side, these reflections and increased sound levels may be a concern. This is further compounded for situations where there are noise walls on each side of the roadway, resulting in multiple reflections and an overall increase in noise levels that limits the effectiveness of the noise walls. There are sound absorptive materials available for noise walls that can limit the amount of reflected sound. Further, it may be possible to adjust the location of the noise wall to reduce the reflected sound.

- **Gaps:** The noise wall needs to have no gaps throughout or along the bottom. Even very small gaps in the composition of the noise wall (i.e. small gaps with abutting single fence boards) will significantly compromise the performance of the noise wall, allowing too much of the sound energy to transmit directly through. This has significant implications when it comes to pedestrian pathways through the noise wall. For pedestrian pathways, it is important to install overlapping sections of wall such that there is no direct line-of-sight through the opening. Figure 3.1 provides a sample schematic of typical overlap methods. Note that these will vary for each situation and need to be reviewed by an experienced acoustical engineer.

- **Access:** For larger noise walls (typically taller than 2.44 m), access is often required to both sides of the noise wall so that the Municipality can maintain both sides. This affects the location of the noise wall as well as any vegetation that may be located nearby on either side. As mentioned previously, it is generally best to locate noise walls as close to the roadways as possible. In terms of noise attenuation, this would put the noise barrier right at the curb. However, there are traffic safety, visibility, snow build-up, drainage, and accessibility issues that prevent having the noise wall this close. In general, the recommendation is to locate the noise wall as close as feasible to the roadway, keeping in mind all of the various other restrictions.

- **Security:** Noise walls can provide security concerns. Long spans of tall walls can provide places for criminals to hide and little means of escape for potential victims of crime. Depending on the location, the available security lighting, and the access issues, security can be a significant concern and needs to be considered when implementing noise wall design.

When using wood materials for noise wall construction, the fence boards need to be doubled and overlapped with staggered joints to minimize the gaps. Figure 3.2 provides a sample schematic of a solid screen wood fence that will provide the required composition. Typically, the main issue associated with wood is that, in order for any barrier to provide appropriate noise attenuation, it must be in direct contact with the ground with no gap underneath. This provides a long-term maintenance issue with wood rotting. Note also that most municipalities will only allow a wood fence to be built with a maximum height of 2.44 m (8 ft) due to the structural integrity and maintenance issues.

When using masonry materials, the same rules and recommendations apply, particularly with regards to the gaps in between the masonry blocks. There are various materials available that provide interlocking or overlapping joints which, when combined with the mortar, eliminate or significantly reduce the gaps. These materials can come in the form of standard sized masonry blocks that are assembled in a staggered pattern in between masonry posts or in much larger pre-cast panels that fit in between large posts and need to be maneuvered with the use of a crane. Masonry walls can be built much taller than wood fences and are the most common material used for noise walls taller than 2.44 m.

Metal materials can also be used, subject to the same rules and recommendations as with the wood and masonry materials.

Plastics and other composite materials can be used, provided that they provide the minimum level of noise reduction such that the sound transmitting through the barrier is sufficiently less than the sound that propagates over the barrier. Typically, the use of such materials is assessed on a case-by-case basis, with the vendors providing laboratory tested results for the sound transmission loss of the barrier and the values reviewed and approved by an experienced acoustical engineer.

It is important to note the use of buildings as noise barriers. Given the significant mass and continuity (i.e. no gaps) associated with typical building construction, buildings will provide the same noise barrier performance as a noise wall with the same height and length. This is why long spans of commercial buildings (for example in strip malls or big box stores) can provide significant levels of noise attenuation.

Finally, one of the most recent materials/technologies available for wall barrier design is to use a so called "living wall". There are various versions that incorporate structural support, earth, and vegetative material to provide a barrier that looks more like a hedge row than a noise wall. One method that has been used in some Canadian municipalities incorporates a central core that is made up of approximately 0.5 m thick of earth, contained within a woven cloth-like container and a wooden structure. This provides the "barrier" required for noise attenuation. On the outside of the structure (on both sides) living plant material grows and provides sound absorption and visual appeal. Given that there is living plant material, this wall would require regular maintenance.

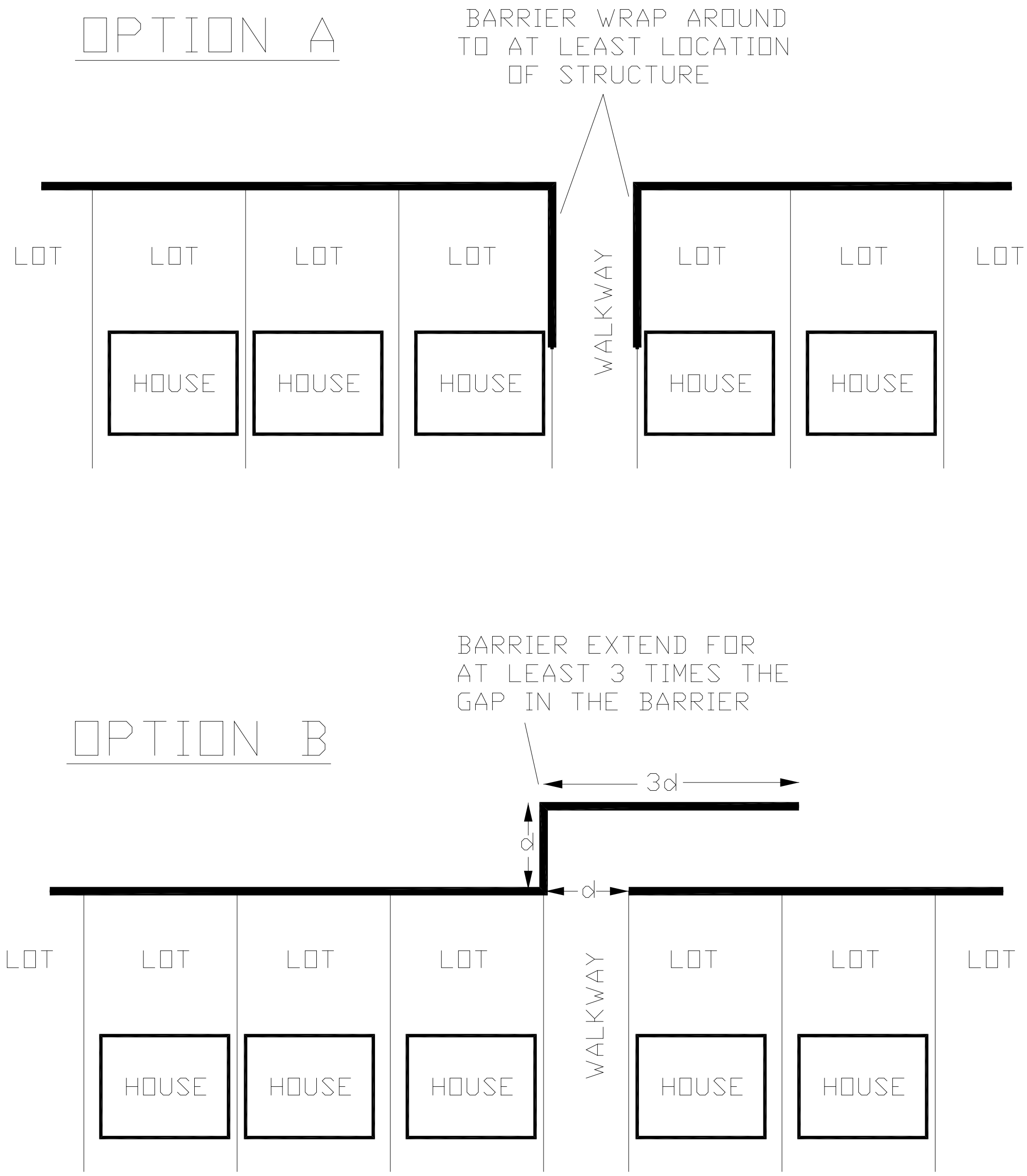


Figure 3.1. Sample Schematic of Noise Wall Walkway Overlap

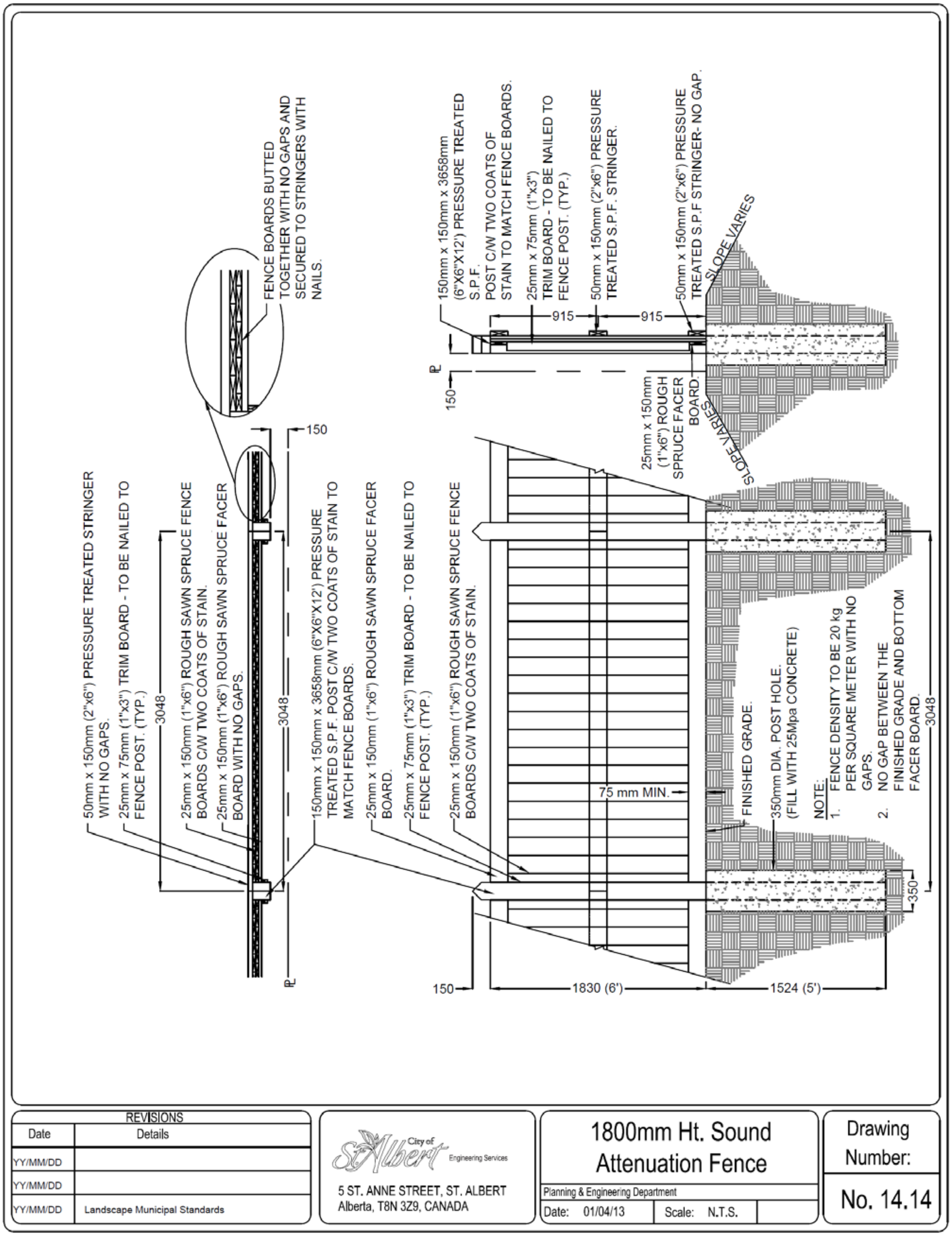


Figure 3.2. Sample Schematic of Solid Screen Wood Fence

Source: City of St. Albert, Engineering Services

3.4. Pavement / Tires

The largest contributor to traffic noise is the noise associated with the vehicle tires interacting with the road, in particular at speeds above approximately 40 – 50 km/hr. The factors that determine the level of tire noise are the composition of the tires themselves and the composition of the road. Tire manufacturers are always conducting research regarding tire noise, however, factors such as traction and durability are of prime importance relative to noise. Unfortunately, these are often at odds and noise ends up becoming a secondary or tertiary factor. Low environmental noise tires are not known to even be commercially available. Further, a municipality would likely have no jurisdiction over the use of vehicle tires.

With regards to the road surface, newer asphalt pavements tend to result in lower noise levels than older, rougher pavements. Similarly, rough surfaces such as chip-seal coatings tend to result in higher noise levels. Thus, road surface maintenance and updated paving materials can help to reduce noise levels. Further, there are various asphalt mixture options (including those which use crushed/recycled rubber tires) which can reduce the noise levels by providing a more “compliant” road surface that is not as hard and is slightly more sound absorptive than conventional asphalt. Long term tests conducted in Alberta (areas with similar road conditions and climate to Saskatoon) indicate that the noise reduction benefits associated with these materials are typically only present for the first year or two and then start to deteriorate (along with the road surface itself) through the winter/summer freeze/thaw cycle such that the noise levels are back to original after just a few years.

3.5. Vegetation

In terms of traffic noise mitigation, the factor which has the largest level of public misconception is related to vegetation. The myth is that planting a few rows of trees and bushes will result in notable noise reduction. The reality is that vegetation typically provides an insignificant level of sound attenuation. Only in situations with very large gaps between the roadway and the adjacent residential receptors (larger than 20 – 30 m) full of thick, dense vegetation, will the level of vegetative sound attenuation even start to become noticeable and still well below that of typical noise barriers. Installing such vegetation in areas where there is currently no vegetation would also be as expensive or more expensive than a noise wall with much less acoustic benefit. Further, if the vegetation is comprised of leafy trees and bushes, then for approximately half of the year, there is absolutely no noise attenuation because there are no leaves. In general, vegetation tends to provide a placebo (out of sight, out of mind) effect. The overarching recommendation is that if there is existing vegetation and it can be kept, then allow it to remain. But do not bother to install new vegetation in hopes of providing appropriate noise attenuation.

4.0 Traffic Noise Policy Framework

The information provided in this Section is intended to be used by the City of Saskatoon in developing the technical and detailed components required for a traffic noise attenuation policy. The information is based on components contained within the reviewed traffic noise policies as well as anecdotal experience of the author. The Section is divided into the following subsections:

- Assessment criteria
- Conducting noise impact assessments
- Conducting noise monitoring
- Noise barrier requirements
- Glossary of terms.

Each of the subsections is further divided in to various specific components. For some of the specific components the information and recommendations are provided without options and are based on the rationale provided. However, some of the components contain various options that would need to be reviewed and decided upon for implementation into the traffic noise attenuation policy. At the end of some of the components the various options are listed in bold, along with the recommended course of action (where applicable).

4.1. Assessment Criteria

The single most important component to a traffic noise attenuation policy is the assessment criteria (metric and value). The requirement for noise mitigation based on either noise monitoring or noise modeling depends on the assessment criteria. In addition, the noise monitoring and noise modeling methods and techniques need to be conducted in accordance with the assessment criteria.

4.1.1. Metrics

4.1.1.1. Decibel Scale and Weightings

The noise assessment criteria should use the metric of the A-weighted decibel sound level (dBA). This matches every other reviewed jurisdiction within Canada and is the most common metric world wide. Sound level measurements for road, rail, and industrial noise sources all use this metric. It is also worth noting that, for some industrial noise assessment policies/guidelines, the C-weighted (dBC) sound level is used as well. However, this is more applicable to situations where there is a sufficiently high likelihood of significant low frequency noise, such as that which may be associated with industrial applications. For typical vehicle traffic noise, however, low frequency noise does not tend to be a specific problem and none of the reviewed traffic noise policies use the dBC metric. In addition, some policies/guidelines make use of the frequency content of the noise in 1/1-Octave or 1/3-Octave bands. Although of interest and sometimes useful information to obtain when conducting a noise monitoring, use of the frequency content in setting criteria for a traffic noise policy is generally considered too onerous and is not typically done. Again, none of the reviewed traffic noise policies make use of the frequency content.

Options: dBA, dBC, frequency content

Recommendations: Use dBA only

City of Saskatoon Recommendations: Adopt dBA as the metric.

4.1.1.2. Timeframe and Value

The next component of the assessment metric is to determine the timeframe over which the assessment is to be conducted. As indicated in the review of other traffic noise policies within Canada, the most common timeframe is the $L_{eq}24$ followed by the L_{dn}. All but one jurisdiction uses one of these two timeframes. The only jurisdiction that does not is in Ontario, where the assessment timeframe is separated into day-time (07:00 – 23:00) and night-time (23:00 – 07:00). Given that traffic patterns are generally very repeatable and predictable, must jurisdictions elect to have a single criterion to cover the entire 24-hour period (i.e. $L_{eq}24$ or L_{dn}) instead of having a separate criterion for each of the day-time and night-time, respectively.

As its name implies, the $L_{eq}24$ is a logarithmic average conducted over an entire 24-hour period. Due to the nature of the logarithmic average and typical traffic patterns, the time periods which largely dictate the $L_{eq}24$ value are the morning and afternoon peak traffic times. The reduced traffic during the night-time does significantly impact the $L_{eq}24$.

The L_{dn} is very similar to the $L_{eq}24$, with one significant difference. The L_{dn} adds a 10 dBA penalty to the monitored or modeled noise during the night-time period (the specific night-time period needs to be defined as part of setting the assessment metric). Thus, the L_{dn} will always be higher than the $L_{eq}24$. The amount by which the two differ depends on the differences between the day-time and night-time traffic noise levels and the definition of the night-time period. Most jurisdictions define the night-time as the time period from 22:00 – 07:00 (9-hours). Typically, with night-time from 22:00 – 07:00, traffic noise within urban environments tends to result in the L_{dn} being 2 – 3 dBA higher than the $L_{eq}24$.

As part of the traffic noise policy review and development process a study was conducted to determine the relative noise barrier impact associated with various criterion levels of the $L_{eq}24$ (65, 60, 55 dBA) and the L_{dn} (65, 60, 55 dBA) at various locations within Saskatoon for the future (400k population) timeline. The specific assessment locations and the detailed results are provided in Section 5.0. A summary of the results is as follows:

- 65 dBA $L_{eq}24$ – Essentially no noise mitigation is required to achieve 65 dBA $L_{eq}24$
- 60 dBA $L_{eq}24$ – Barrier heights ranged from 0.0 m to 4 m with most barriers 1.83 m or 2.44 m
- 55 dBA $L_{eq}24$ – Barrier heights ranged from 1.83 m to 8.5 m with most barriers between 4.0 m to 6.0 m

- 65 dBA L_{dn} – Barrier heights ranged from 0.0 m to 2.44 m with most areas either requiring no barrier or just a 1.83 m solid screen wood fence.
- 60 dBA L_{dn} – Barrier heights ranged from 1.83 m to 6.5 m with most barriers between 3.0 m to 6.0 m
- 55 dBA L_{dn} – Barrier heights ranged from 3.0 m to 12 m with most barriers between 5.0 m to 8.0 m

Ultimately, the selection of the specific assessment timeframe and criteria value is a trade-off between having lower overall community noise levels (benefit to residents) and the costs associated with the noise mitigation required to achieve the desired values.

Options: L_{eq}24 (65, 60, 55 dBA), L_{dn} (65, 60, 55 dBA), L_{eq}Day/L_{eq}Night

City of Saskatoon Recommendations: Adopt L_{dn} 65dBA as the threshold.

4.1.1.3. Location

The next component of the assessment metric is to determine the location at which the noise level is to be measured or modeled. Firstly, none of the reviewed noise policies use an indoor receptor location. Some of the reviewed policies make reference to desired interior noise levels with an assumed noise attenuation associated with the structure, but none have specific interior criteria that must be achieved. This is typical throughout environmental noise policies for transportation noise as well as industrial noise. The level of noise attenuation from exterior to interior will differ from structure to structure depending on the orientation relative to the noise source, the design and construction of the structure exterior, the geometries and design associated with the layout of the structure, and the sound absorptive materials (i.e. furniture, draperies, carpet) used within the structure. Plus, there are often noise sources within residential structures that can produce higher noise levels than typical interior criteria and yet the residents tend to not object to (i.e. furnace, refrigerator). Thus, it is common practice to assess noise levels at the exterior of the residential structure with an assumption of the typical structural noise attenuation (with all doors and windows closed).

The next factor is to determine where the outdoor noise level should be assessed. Some of the reviewed policies specify a location that is 3 m from the residential structure while others specify 5 m from the residential structure. Yet, others specify a location that is 2 m within the residential property line. With regards to specifying an assessment location that is 3 m or 5m from the structure, the biggest issue is with the acoustic reflections off the structure. Placing a noise monitor so close to a large reflecting surface can result in increased noise levels (as much as +3 dBA). In addition, for noise modeling assessments of new developments, the location of the structure is often not known. Thus, it is not recommended to specify a location that is so close to the structure. With regards to the location 2 m inside the residential property line, this can also have issues and significant variances from property to property. If there is already a good noise reducing fence at the rear property line, then a measurement location so close to the fence can result in excessive acoustic shielding from the fence at the measurement/modeling location. Thus, it is recommended to specify a location that is approximately mid-yard to minimize both the structure reflection issues and the fence acoustical shielding issues. For most newer residential lots, a distance of 5 m from the property line that is adjacent to the road noise source is generally approximately mid-yard. In addition, most policies make reference to the backyard or the outdoor amenity or outdoor living space for the assessment. Most policies do not consider the front-yard of a residence to be an outdoor amenity or outdoor living space. Part of the issue with using the front-yard as the assessment location is that noise mitigation is generally not possible or desired because most residents are not amenable to installing a noise barrier in their front yard. Thus, even if the residential property "fronts" or "sides" onto the adjacent major roadway, the noise assessment is almost always conducted with the receptor in the backyard.

Adding to the discussion about the outdoor amenity space assessment locations is a discussion regarding multi-family buildings such as apartments or condominiums without a defined outdoor amenity space. None of the reviewed policies specifically discuss such situations and typically all upper floors (from 2nd floor and up) are not included in traffic noise policies because noise mitigation is generally not feasible for these locations due to the inability of noise barriers to block the line-of-sight between the residence and the adjacent roadway. Anecdotally, within most municipalities, if there are ground-floor apartments or condominium units, each with a defined (i.e. fenced-in) outdoor amenity space, then these would be considered for noise mitigation in the same manner as a single family detached residential structure.

The final factor for the assessment location is the height. Most of the reviewed policies have a height of 1.5 m above ground. Some use a value of 1.2 m above ground. Typically, the rationale for using an assessment height of 1.5 m above ground is that it is close to the average ear-level of a person standing within the yard. If using a height of 1.2 m, there could be some additional acoustical shielding associated with the fence that would not be as prevalent at a height of 1.5 m. Also, none of the reviewed policies assess the noise levels at a height of the 2nd story for 2-storey houses. This means that the noise levels are typically not assessed at the height of any 2nd storey bedroom windows. Although noise modeling calculations can be performed at this height, it is difficult to conduct a noise monitoring at this height. Further, if the idea is to assess the noise level within the outdoor amenity space, then the assessment height should match the typical use of that outdoor space. Thus, an assessment height of 1.5 m is recommended.

Two variants to the use of 1.5 m above ground within the outdoor amenity space include issues associated with decks and with walkout lots (and combinations of the two). Sometimes there are situations in which the rear deck is used by the homeowners exclusively as their "outdoor amenity space". Concurrently, there are situations in which the rear deck is elevated above grade by a sufficient amount that it can significantly impact the line-of-sight to the adjacent roadway (i.e. sitting on the rear deck and can see overtop of the fence with direct line-of-sight to the adjacent roadway and elevated noise levels compared to 1.5 m above ground). A similar but even more exageraged scenario can occur with rear walk-out lots in which the rear property line is significantly lower in elevation than the rear of the house. If such a house has a deck off the main floor, then this deck will almost certainly be elevated well above the fence and will allow for direct line-of-sight to the adjacent roadway. If the rear yard itself slopes down enough, even an assessment location mid-yard (or 5 m from the property line) can also result in direct line-of-sight to the adjacent roadway. For all of these situations, the result would be higher noise barriers than those which would be required with a flat backyard and an assessment height of 1.5 m above ground.

Options: Indoor vs. Outdoor, specific location within outdoor space, height of receptor, issues with rear decks and walk-out lots

Recommendations: Receptor in defined outdoor rear amenity space, 5 m from the adjacent property line, 1.5 m elevation. Applicable to ground floor apartments and condominiums if an outdoor amenity space is clearly defined (i.e. fenced-in)

City of Saskatoon Recommendations: Receptor in defined outdoor rear amenity space, 5 m from the adjacent property line, 1.5 m elevation, 3 m from any obstructions (i.e. a shed). Applicable to single family residential land use, and townhouse type (maximum of two storeys) multi-family land use.

4.1.1.4. Maximum Allowable Sound Level vs Relative Increase

Most of the reviewed policies provide for a maximum overall sound level and do not account for any increases in sound levels associated with new/upgraded roads relative to the sound levels that were present prior to the new/upgraded road. This is common for traffic noise attenuation policies as well as most industrial environmental noise policies. The only reviewed policy that included an assessment of the relative increase in sound level was in British Columbia for numbered highways. In addition, it is important to note that, within the United States, all major road projects that fall under the jurisdiction of the Federal Highways Administration (FHWA) have both the maximum allowable increase in sound levels (relative to the pre-construction sound levels) as well as an overall maximum value. The allowable increases and the maximum value are determined separately by each State, within the FHWA guidelines.

The intent with including both sets of criteria (maximum overall value and maximum allowable increase relative to pre-construction) is to minimize impacts associated with new/upgraded roads, in particular in areas where the new/upgraded roads will result in a potential significant increase in noise levels. A typical example of this is if a new highway or freeway is built in an area with nearby houses where there was previously only green space. Even though the overall noise levels associated with the highway may be below the maximum allowable limit used elsewhere in the City, the relative increase in noise levels could easily be in the range of 20 to 30 dBA[1], which would very likely be subjectively unacceptable to most of the adjacent residents and be received with strong opposition. Such has been the case with both the City of Edmonton and City of Calgary ring roads as well as sections of Circle Drive in Saskatoon.

Thus, it would seem reasonable to include both a maximum overall value and a maximum allowable increase within the assessment criteria. The difficulty with having both criteria is that, if the pre-construction noise levels are low enough, then the target criteria would be different for each new or upgraded road project. This will create different "acceptable" noise levels throughout the City which will constantly be evolving for each project and can change for any given area when the next project occurs. Further, in addition to the typical future noise modeling impact assessment that would typically be required for new/upgraded road projects, this method would also require detailed pre-project noise monitoring and pre-project noise modeling which adds cost and time.

Options: Either maximum overall sound level only OR maximum overall sound level plus maximum allowable increased sound level relative to pre-project sound level.

City of Saskatoon Recommendation: The maximum overall sound threshold is L_{dn} 65dBA.

[1] Most jurisdictions that include a maximum allowable increase use a range of 5 – 15 dBA.

4.1.2. Applicability

In all reviewed policies, the assessment criteria are applicable to residential areas and not intended for commercial or industrial developments. In general, traffic noise levels tend to be less of a concern for commercial and industrial areas since there are typically no people living/sleeping in these areas and there tend to be fewer outdoor amenity spaces where traffic noise is a nuisance.

The are some areas, however, where this can be a concern. For example, at commercial buildings that are located very near major roadways with large windows that face onto the roadway. It is common practice for any noise mitigation efforts associated with reducing interior noise levels to be assumed by the owner/operator of the commercial business. Another area where this can cause concern are Hotels and other similar temporary lodgings where people are indeed sleeping. Again, a Hotel is typically considered a commercial business and it is common practice for any noise mitigation efforts associated with reducing interior noise levels to be assumed by the owner/operator of the commercial business.

Other areas that may warrant consideration for noise mitigation include schools, hospitals, museums, libraries, churches, and park areas. For all of the structures included in this list, reducing the noise within the interior is achievable through appropriate design of the building envelope. However, some of these spaces (schools, hospitals, park areas) also tend to have outdoor spaces used for educational purposes or healing/relaxation that may warrant reduced traffic noise levels.

Options: Residential areas only or also include commercial, industrial, schools, hospitals, museums, libraries, churches, and park areas?

City of Saskatoon Recommendation: Residential areas only are available for traffic noise mitigation.

4.1.3. Mitigation Responsibility

In terms of designing and building noise mitigation (i.e. noise barriers) it is important to stipulate who is financially responsible. In essentially all of the reviewed policies, the responsibility is as follows:

- For new developments adjacent to existing or approved (but not yet built) transportation corridors (roads, bus lanes, LRT), determining the need for and then the implementation of required noise mitigation is the responsibility of the developer, pending review and approval by the City.

- For new or upgraded transportation corridors (roads, bus lanes, LRT) adjacent to existing developments, determining the need for and then the implementation of required noise mitigation is the responsibility of the City and is paid for as part of the capital cost of the associated transportation corridor project. Noise mitigation is included for locations where it is technically, economically, and administratively feasible.
- For retrofit areas with existing transportation corridors (roads, bus lanes, LRT) adjacent to existing developments, determining the need for and then the implementation of required noise mitigation is the responsibility of the City, for locations where it is technically, economically, and administratively feasible.

Some jurisdictions also include the possibility that residents pay themselves for noise mitigation for retrofit areas (pending City review and approval) where the City has deemed mitigation to be technically, economically, or administratively not feasible. The idea is that if residents are willing to pay for the mitigation themselves, then there is at least an opportunity for them to investigate and pursue that option.

Finally, for retrofit projects, some of the reviewed policies include the use of a cost vs. benefit calculation to quantify the rationale for the noise mitigation and to compare/rank various locations in which retrofit noise mitigation is being reviewed. The simplest form of this calculation is to divide the cost of the project by the number of impacted residential dwellings (i.e. $/dwelling) with a lower number better than higher. Another example is used by the City of Regina (below) in which the cost and the number of impacted residential dwellings are included along with the relative reduction in noise level associated with the proposed mitigation. This method not only determines the $/dwelling but also factors in the performance of the noise mitigation. Thus, if there are two similar projects costing the same and with the same number of impacted residents, the one with the better performing noise mitigation would rank higher than the other.

City of Regina Cost Benefit Calculation Method

$$BP1 = \frac{(ENL - DNL)N}{C}$$

Where:

BP1 = Barrier Priority Index
ENL = Estimated Noise Level in dBA Ldn based on current or projected traffic counts or actual noise measurement.
DNL = Design Noise Level in dBA Ldn or the minimum noise level for consideration in prioritization (65 dBA Ldn)
N = Number of first row ground level dwelling units which would be protected by barrier attenuation.
C = Barrier construction cost in thousands of dollars including all associated costs such as utility modifications.

Options: Developer responsible for new development, City responsible for new and upgraded transportation corridors as well as retrofit areas? Technically, economically, and administratively feasible? Allow residents to pay for mitigation themselves? Include a cost vs. benefit calculation?

City of Saskatoon Recommendation: Developers are responsible for traffic noise mitigation in new developments. The City is responsible for new and upgraded transportation areas as well as retrofit areas that are technically, economically, and administratively feasible.

4.2. Noise Impact Assessments

A significant component for a traffic noise attenuation policy is to provide the methods and reporting requirements for a noise impact assessment to allow for increased accuracy and more consistency in the assessments carried out by acoustical engineering consultants and the City.

4.2.1. Applicability

A traffic noise impact assessment will be required for the following:

- New developments adjacent to existing transportation corridors.
- New/Upgraded transportation corridors adjacent to existing developments
- Retrofit projects for existing transportation corridors and existing development where a study is being conducted to determine if noise mitigation is feasible and to what extent noise mitigation may be applied.

4.2.2. Methods and Software

- A traffic noise impact assessment must be carried out by a qualified and experienced Acoustical Engineer.
- The assessment calculations and modeling need to be conducted using any of the following acceptable software:
  - CADNA/A
  - SoundPlan
  - B&K Predictor
  - Traffic Noise Model (TNM)
  - Other software upon approval of the City
- The noise modeling software needs to account for the following conditions throughout the entire study area:
  - Topography of the study area (i.e. elevation contours) with a minimum 1 m vertical elevation resolution. Most elevation contour information is available from the City of Saskatoon.
  - Roadway alignment with lane dimensions or roadway width. Modeled roads should span well beyond the study limits of the model since road noise outside of the study limits still contributes to the overall area noise levels.
  - Property lines (residential, commercial, industrial)
  - Existing and proposed noise barriers.

- Existing and proposed buildings, where appropriate and applicable.
- Vegetation, where appropriate and applicable.

- It is recommended that the noise modeling software have the ability to make use of aerial imagery for increased accuracy of various topographical, vegetative, building, and barrier features.
- With regards to the traffic noise source data, the model needs to be able to account for the following minimum information for each road:
  - Traffic volumes (i.e. vehicles per hour) during the day-time and night-time.
  - Percentage of heavy vehicles during the day-time and night-time. Heavy vehicles essentially includes everything that is not a passenger vehicle.
  - Posted speed limits.
- The noise modeling for all projects needs to be conducted with a future planning horizon for traffic volumes. Does the City want to specify a minimum number of years (i.e. 10-years, 20-years), or a future City population (i.e. 400k population)?
- The noise levels need to be assessed at representative receptor locations (i.e. matching those associated with the assessment criteria) as well as using a calculation grid over the entire study area for generation of noise contour mapping. The height of the calculation grid needs to match the height associated with the assessment criteria.
- The noise modeling results need to be determined for the following scenarios:
  - Baseline conditions (if applicable)
  - Future conditions with all proposed area roadways and development and projected planning horizon traffic volumes and <u>*without*</u> any additional noise mitigation.
  - Future conditions with all proposed area roadways and development and projected planning horizon traffic volumes and <u>*with*</u> additional noise mitigation required to achieve the assessment criteria.

Options: Future planning horizon (10-years, 20-years, 400k population),

Recommendations: In terms of the planning horizon, it seems that the current standard and available traffic projections are for the 400k population, so it is reasonable to continue using that standard until it needs to be revised (i.e. as the population nears the 400k mark).

City of Saskatoon Recommendation: Use the 400k population horizon as the future planning horizon.

Additional questions that need to be addressed include:

- Is a baseline noise monitoring required for an existing transportation corridor that will be modified? It is recommended to conduct baseline noise monitoring for this scenario. The noise monitoring data can be used as a calibration/verification method for a baseline case noise model to ensure that the noise model is providing an accurate representation of the study area. Then, the noise model can be augmented with the modified roadway design and topography and the future projected traffic volumes and the results can be determined with a higher degree of certainty than if there was no baseline noise monitoring/modeling conducted. In addition, if the selected assessment criteria utilize a maximum overall sound level plus a maximum allowable increase in sound level (relative to baseline), conducting a baseline noise monitoring and using that information to calibrate/verify the noise model will increase the accuracy of the pre-project and post-project noise level comparison.

- Is a baseline noise monitoring required for a new transportation corridor? It is recommended that baseline noise monitoring *not* be conducted for this scenario, unless the selected assessment criteria utilize a maximum overall sound level plus a maximum allowable increase in sound level (relative to baseline). Otherwise, there is no advantage to obtaining the baseline noise levels and it is likely that a baseline case noise model will not be generated.

- Is a baseline noise monitoring required for a new development that is being built adjacent to an existing transportation corridor? It is recommended to conduct baseline noise monitoring for this scenario. The noise monitoring data can be used as a calibration/verification method for a baseline case noise model to ensure that the noise model is providing an accurate representation of the study area. Then, the noise model can be augmented with the addition of the development, any proposed development related transportation corridors, and the future projected traffic volumes. The results can be determined with a higher degree of certainty than if there was no baseline noise monitoring/modeling conducted.

4.2.3. Report Information

In order to allow for consistent review of noise impact assessment reports and to allow for data to be used in subsequent noise studies, the following information must be included in all noise impact assessment reports:

- Detailed description of the study area with all area topography, vegetation, roads, receptors, commercial and industrial areas identified along with any other information pertinent to the noise study.
- Maps and (where applicable) imagery of the study area indicating all area roads, receptors, commercial and industrial areas, property lines, and any other information pertinent to the noise study.
- Description of the noise modeling software and/or calculation standards used along with the various input parameters.
- Description of noise modeling receptor locations.
- Detailed traffic volumes used for the study including:
  - Roadway name
  - Day-time and night-time traffic volumes
  - Day-time and night-time percentage of heavy vehicles
  - Posted speed limits
- Table of noise receptors and modeled sound levels for the various assessment cases and comparison to the assessment criteria.
- If applicable, description of the noise mitigation required to achieve the assessment criteria. Noise mitigation information must include (at minimum):
  - Description of the location of noise barriers
  - Graphical representation of the location of the noise barriers (i.e. location of noise barriers drawn on a map)
  - Geometry of noise barriers (height and length)
  - Minimum noise barrier construction recommendations

4.3. Noise Monitoring

There are minimum requirements that should be established for conducting noise monitoring. This will allow for increased accuracy, better continuity for data collected by various acoustical engineering consultants and the City, and the ability to compare data obtained at the same locations at different time periods (i.e. comparing data from one year to the next, etc.).

4.3.1. Measurement Rationale

None of the reviewed policies have information pertaining to the process that triggers the need for a noise monitoring. It is recommended to have some guidelines in this regard. The main questions to ask are as follows:

- **What triggers the need for a noise monitoring adjacent to an existing roadway?**
  - This could be based on residential complaints.
  - This could be based on historical information (i.e. the area is known to have relatively high traffic noise levels based on previous noise monitoring).
  - This could be based on a City wide pro-active program for obtaining traffic noise levels in areas that are likely to have high traffic noise levels, even if residents have not complained.

- **How often is noise monitoring to be conducted adjacent to existing roadways?** For example, if the area is known to have high noise levels (but lower than the noise mitigation criteria), is there a specific interval (perhaps annually or every 2 years) at which the noise monitoring is to be conducted to track the noise levels?

- **Should all new/upgraded transportation projects and new developments include a pre-project (baseline) noise monitoring program?**
  - One benefit of such a program is to obtain the pre-project noise levels for use in comparing to any potential post-project noise monitoring.
  - Another benefit of such a program is that the baseline noise level data can be useful in calibration / verification of any computer noise modeling for the upgraded Project.
  - New transportation corridors (where none had existed before) will likely not benefit from conducting a baseline noise monitoring unless the selected assessment criteria includes a maximum overall sound level plus a maximum increase in sound level, relative to the baseline conditions.

- **Should all new/upgraded transportation projects include a post-project noise monitoring program to ensure that noise levels are within the assessment criteria?**
  - Most jurisdictions do not require post-project noise monitoring.
  - If the noise impact assessment results indicated that the noise levels would be well below the assessment criteria (at least 5 dBA lower), then a post-project noise monitoring program is likely not warranted.
  - If the noise impact assessment results indicated that the noise level would be near the assessment criteria (within a few dBA, to be determined by the City), then a post-project noise monitoring program may be warranted.

Options: **What triggers the need for noise monitoring adjacent to an existing roadway?**
How often should a noise monitoring be conducted adjacent to an existing roadway?
Should pre-project (baseline) noise monitoring be conducted?
Should post-project noise monitoring be conducted?

Recommendations: Pre-project noise monitoring is recommended for upgraded transportation corridors as well as new development and is recommended for new transportation corridors only if the assessment criteria allow for a maximum allowable increase in sound level relative to the baseline condition. Post-project noise monitoring should be conducted if the noise impact assessment results indicate that the noise levels would be near the assessment criteria (within a few dBA, to be determined by the City).

City of Saskatoon Recommendations: Pre-project noise monitoring is recommended for upgraded transportation corridors as well as new development. Post-project noise monitoring may be conducted on a case by case basis.

4.3.2. Measurement Location

The noise monitoring measurement location should match the requirements defined in the assessment criteria. This includes the location within the yard and the height. In addition, there are some important factors to consider for the noise monitor location, including:

- **Adjacent Structures:** The noise monitor should be located at least 5 m from any structure. This includes the house and any garage or shed or fence or similar broad-surfaced structures that are located within the yard. Locating the noise monitor near a structure will allow for acoustic reflections (reflecting off the structure) to influence the noise monitoring data and can result in higher than normal noise levels. Further, whenever possible, the noise monitor should be placed at an angle relative to any nearby structures such that, if there are any sound reflections, the angle of the reflection will not significantly impact the noise monitoring results.

- **Non-Transportation Noise Sources:** The noise monitor should be placed in a location where the dominant noise sources are those associated with the adjacent transportation corridors. If there are other non-transportation noise sources nearby, they may impact the noise monitoring data and result in noise levels that are higher than those associated with the transportation corridor. When determining a noise monitoring location, the potential site must be reviewed for non-transportation noise sources. If other noise sources are audible, then it is recommended to not conduct the noise monitoring at that location. If other potential noise sources are not audible at the time of setup, but may be turned on during the noise monitoring period, then the location should be avoided. Examples of common non-transportation noise sources include (but are not limited to):
    - Air conditioner condensers
    - Outdoor hot tubs
    - Building ventilation fans
    - Furnace intake/exhaust
    - Hot water heater intake/exhaust
    - Industrial or commercial facilities located very near the residential property
    - Electrical transformers from adjacent electrical substations
    - Power lines and power poles
    - Transformer "hum" from large yard lights
    - Pets or other animals nearby. Typically, this would include dogs that tend to bark

In general, there will be situations in which the prescribed noise monitoring location (i.e. the location defined in the assessment criteria) will not be feasible. In those cases, the acoustical practitioner should have the discretion to place the noise monitor in an "acoustically logical" location that will provide results indicative of the noise levels associated with the adjacent transportation corridor and that will minimize external influences.

4.3.3. Measurement Equipment

The Instrumentation used to conduct the noise monitoring must be able to measure the A-weighted (dBA) continuous energy equivalent sound level (L_{eq}) of steady, intermittent, and fluctuating sounds. It must be able to accumulate the data and calculate the L_{eq} values with a sample interval of no longer than 1-minute and run continuously for at least 24-hours. The instrumentation must meet the minimum technical specifications in the IEC 61672-2 Ed.01.0 2003 (or latest version), for Type/Class 2 (or Type/Class 1) sound level meters. Use of sound level meters less than Type/Class 2 is not allowed and Type/Class 1 is recommended for increased accuracy.

Noise monitors must be field calibrated immediately prior to the measurement using a sound calibrator meeting the requirements of EN/IEC 60942 (2003) Class LS, and ANSI S1.40-2006 (latest revision) for Class 1 calibrators. Noise monitors must have their calibration checked immediately after the measurement using the same calibrator and a record of the pre- and post-measurement calibration results must be included in the report.

Noise monitors must be calibrated by the instrument manufacturer, an authorized instrument calibration facility, or another agency acceptable to the City within a three-year period immediately preceding the measurements. Records of calibration must be maintained and the calibration certificates must be provided with the noise monitoring report. Noise monitors which fail a pre-use or post-use calibration test (e.g. the noise monitor does not read within ±1 dBA) must not be used until re-calibrated for accuracy, applicability and the cause of deviation has been removed. Data collected from noise meters that fail a pre-use or post-use field calibration test (e.g., the noise monitor does read within ±1 dBA) must not be used.

Field calibrators must be recertified in accordance with ANSI publication SI.40-1984 (or latest revision), which requires that a calibrator be recalibrated at least once a year. The calibrator may be used for a one-year period dated from the manufacturer certificate prior to requiring recalibration. Records of calibration must be maintained and the calibration certificates must be provided with the noise monitoring report.

The noise monitor must incorporate an appropriate outdoor measurement windscreen to minimize wind noise. The microphone must be a "direct-incidence" or "direct-field" type and be oriented in the vertical position.

The noise monitoring instrumentation must be capable of conducting a digital audio recording for the entire duration of the noise monitoring period. This can be accomplished either with recording capability directly on the noise monitor or with a separate recording device connected to the noise monitor with time-stamp capability. The digital audio recording is to be used during the post-processing data assessment for identification and isolation (i.e. removal) of abnormal or non-transportation corridor related noise events.

4.3.4. Measurement Conditions

4.3.4.1. Duration and Settings

The noise monitoring must be conducted for a minimum duration of 24-hours. Longer durations are recommended to allow for more flexibility in using a 24-hour window with appropriate weather conditions. The noise monitoring must be conducted with a maximum 1-minute L_{eq} sample period, with shorter sample periods recommended for less overall data time removal during the post-processing isolation analysis.

4.3.4.2. Weather Conditions

One of the most important factors in determining when a noise monitoring can be conducted is the weather conditions. The various acceptable weather conditions are as follows:

- **Wind:** Ideally, the noise monitoring should be conducted with a light wind (5 – 15 km/hr) in the direction from the adjacent transportation corridor towards the noise monitor location. Alternatively, calm wind conditions are acceptable as are light cross-wind conditions. The noise monitoring must not be conducted with upwind conditions (i.e. wind in the direction from the noise monitor towards the transportation corridor). The maximum allowable sustained wind speed is

15 km/hr (regardless of the direction) since any higher wind speeds will result in wind generated noise at the microphone or excessive leaf rustling on nearby vegetation. An even lower wind speed may be necessary if there are large leafy trees near the noise monitor which could result in a significant leaf-rustling noise level in even moderate wind speeds. If there are brief periods of excessive wind or wind from the wrong direction, then that data may be isolated (removed) from the overall data set provided that sufficient data remain for an appropriate analysis. In all cases, an appropriate outdoor windscreen must be used for the noise monitoring.

- **Precipitation:** There cannot be precipitation during the noise monitoring. Wet or snow covered road surfaces result in different noise levels and frequency content compared to dry road surfaces. In addition, significant rainfall can produce noise that will add to the noise from the transportation corridor. Finally, freshly fallen snow on the ground in between the transportation corridor and the noise monitor can change the ground level sound absorption significantly in a short period of time which will impact the noise monitoring results. If there are brief periods of precipitation, then that data may be isolated (removed) from the overall data set provided that sufficient data remain for an appropriate analysis. However, if snow falls and persists on the ground, then the noise monitoring data may not be useable.

- **Season:** It is recommended that noise monitoring adjacent to transportation corridors be conducted in the summer months when there is foliage and no snow covering the ground. This generally precludes winter-time noise monitoring. Early Spring and late Fall are also not recommended, unless specific circumstances warrant these time periods. The reason for the summer-time noise monitoring is that, typically, most residents have greater concerns for traffic noise in the summer months when residential windows are being left open overnight and when people tend to make more use of their outdoor amenity spaces. In addition, the ground and vegetative sound absorption and barrier conditions in the summer months tend to be consistent from day-to-day, introducing minimal variability with these parameters. In the winter, however, there can be large changes in the ground cover within just a few hours due to fresh snow fall (acoustically absorptive) versus hard-packed snow conditions (acoustically reflective). Finally, frozen pavement and cold tires (with a significant number of winter tires) produce different noise levels and frequency characteristics than during warm summer conditions with summer tires.

Local weather data for the duration of the noise monitoring must be obtained and provided within the noise monitoring report. At a minimum, hourly weather data is available for the Saskatoon Airport from the Environment Canada or Weather Network websites. However, it is recommended that even more localized weather data be obtained through the use of a portable weather station in the vicinity of the noise monitor. A portable weather station will be capable of collecting data in intervals much finer than 1-hour and will give a more accurate representation of the conditions local to the noise monitor. If using a portable weather station, some key elements include:

- Measurement of wind direction and wind speed with average and peak wind speed values.
- Measurement of air temperature
- Measurement of relative humidity
- Measurement of barometric pressure
- Measurement of precipitation
- Weather sensor height between 5 m to 10 m above the ground
- Weather monitor located in open area that is generally unobstructed from the wind for increased accuracy for the wind speed and wind direction measurements.

4.3.4.3. Traffic Conditions

It is important that the traffic conditions on the adjacent transportation corridor be appropriate for the intended noise monitoring period. Typically, this means that the noise monitoring needs to be conducted during a weekday (Monday-Tuesday, Tuesday-Wednesday, Wednesday-Thursday, Thursday-Friday) and not on a weekend or a holiday. In addition, there cannot be any road construction or other such occurrences on the adjacent transportation corridors that will hinder the flow of traffic in any way (i.e. lane closures, etc.). Finally, there cannot be any significant unplanned traffic disruption from traffic accidents or other similar occurrences. Depending on the severity of such a disruption in traffic, the noise monitoring results may be invalidated. The intent is to conduct a noise monitoring during normal daily traffic flow.

4.3.5. Isolation Analysis

Within a duration of 24-hours, it is highly likely that there will be non-transportation related or abnormal noise events within the vicinity of the noise monitor that will result in adversely affected monitored noise levels. Such non-transportation corridor related noise events include (but are not limited to):

- Noise from animals such as dogs barking, birds chirping (common in the morning), frogs and crickets.
- Noise from human activity nearby such as people talking, mowing lawns, etc.
- Noise from construction activity nearby.
- Noise from emergency vehicle sirens.
- Noise from abnormally loud vehicles such as loud motorcycles near the noise monitor, engine retarder brakes from heavy trucks, street racing or excessive speeding.
- Excessive wind-noise during periods of high wind speeds.
- Periods of precipitation that either result in precipitation noise or vehicle tire noise that has changed in amplitude and frequency content.
- Aircraft flyovers.

These non-transportation related or otherwise abnormal noise events should be identified and isolated (removed) from the noise monitoring data such that the remaining data more accurately reflect the noise levels associated with the adjacent transportation corridors. In order to appropriately isolate the noise monitoring data, a simultaneous digital recording must be conducted along with the noise monitoring. The audio needs to be time synchronized with the noise monitoring data for use in the post-processing analysis. Within the noise monitoring report, the isolated noise data needs to be identified, including the start/stop times for the data removal, the time duration of the removed data, and the reason for the data removal. The time duration for the remaining useful data also needs to be identified. The time duration for the remaining data needs to be sufficient such that the overall 24-hour assessment value is still considered valid and applicable.

4.3.6. Noise Monitoring Report Information

In order to allow for increased accuracy, better continuity for data collected by acoustical engineering consultants and the City, and the ability to compare data obtained at the same locations at different time periods (i.e. comparing data from one year to the next, etc.), the following information must be included in all noise monitoring reports:

- Detailed description of noise monitoring location with measured distances from reference locations (i.e. property lines and buildings), an aerial view schematic and photos of the equipment within the measurement location. This information is necessary for use in computer noise modeling exercises as well as for conducting follow-up noise monitoring at a subsequent time period.
- Description of the area surrounding the noise monitor including structures, noise sources, vegetation.
- Start/stop times/dates for the noise monitoring equipment and the defined time period used for the data assessment.
- Quantitative and (if available) subjective weather data for the noise monitoring period and the source of the quantitative weather data (i.e. website data or portable weather monitor).
- Discussion of results and comparison to the assessment criteria.
- Graphical form of the noise monitoring data with monitored dBA L_{eq} sound level vs. time for the entire assessment period.
- Detailed list of isolated (removed) noise data with the start/stop times, the duration of the data removed, the reason for the data removal, and the quantity of remaining data used for the data assessment.
- Calibration certificates for the noise monitoring equipment and field calibrators.

4.4. Noise Barriers

With regards to the design and construction of noise barriers, there are a number of items that need to be addressed or specified within the traffic noise attenuation policy, including:

- The general construction of noise barriers should be as follows:
    - The construction of any noise barriers (walls and/or earth berms) needs to adhere to all specific City requirements (is there a specific City document for noise barrier or noise fence construction?).
    - The design and construction of noise barriers need to consider appropriate surface water runoff drainage and maintenance access.
    - Barriers must be constructed with no visible gaps throughout the span of the barrier or at the bottom of the barrier. If the barrier is in the form of a solid screen wood fence, the fence must extend all the way to the ground wherever possible.
    - Barriers must be constructed of material that has enough mass to sufficiently reduce the sound transmitting through the barrier, relative to the sound transmitting over the barrier. For typical traffic noise sources, the minimum barrier surface density is 20 kg/m^2.
    - Any openings within barriers (for pedestrian access) must be designed to minimize sound transmission through the opening by using overlaps or other similar methods.

- For the situation where a noise barrier is installed at the residential or commercial or industrial property line, the maintenance responsibility needs to be clearly defined in the traffic noise policy. For locations where the noise barrier is installed solely on public land, it is typically the responsibility of the City to maintain both sides of the barrier. When the barrier is installed at the shared property line, however, access for maintenance on the private property side of the barrier is difficult and there are numerous potential issues associated with maintenance. It may be appropriate to specify that the resident is responsible for maintenance of the barrier on their side of the property. This applies to both noise walls and earth berms.

- For new/upgraded transportation corridor projects or for retrofit projects, it is recommended to install a clause within the traffic noise policy stating that the City will only build noise mitigation when it is shown to be technically, economically, and administratively feasible, as determined by the Engineering or Transportation Department Manager. There may be situations where achieving noise levels below the assessment criteria requires noise mitigation that is considered too expensive or has other factors which may preclude it from being built such as minimal public approval. Thus, it is recommended to review noise mitigation implementation on a case-by-case basis for new/upgraded/retrofit projects and assess based on more than just the noise levels.

- With regards to the performance of noise barriers, it is common to specify a minimum sound level reduction of target of 5 dBA. A noise barrier than cannot achieve a sound level reduction of at least 5 dBA is generally considered to not be worth the associated cost since the subjective reduction in noise levels will be only minimally subjectively noticeable. Indeed, this should be a good minimum design target, but this level of attenuation may not always be attainable (depending on the geometry) and should not prevent noise mitigation from being installed. The level of noise mitigation attained should be reviewed and compared to the cost of the mitigation on a case-by-case basis. For retrofit areas, the absolute minimum should be at least a 3 dBA reduction. Any less will not even be subjectively noticeable to the residents and the associated cost of the mitigation will be essentially wasted.

- For new developments adjacent to existing transportation corridors, there should not be a minimum noise barrier performance target. The barrier should be designed to meet the assessment criteria, regardless of the noise level reduction that would have been attained without the noise barrier in place.

Options:

- **Who is responsible for maintaining noise barriers after construction?**
- **What is the minimum level of noise mitigation?**

Recommendations:

- **Maintenance for barriers (walls and/or earth berms) on private property should be the responsibility of the property owner while maintenance for barriers on public property should be the responsibility of the City.**
- **Minimum recommended noise attenuation should be 5 dBA where possible but the performance for noise barriers for new/upgraded/retrofit projects should be assessed on a case-by-case basis. The absolute minimum attenuation for retrofit projects should be 3 dBA.**

City of Saskatoon Recommendations:

- **Maintenance for barriers (walls and/or earth berms) on private property should be the responsibility of the property owner while maintenance for barriers on public property should be the responsibility of the City.**
- **Minimum recommended noise attenuation should be a goal of 5 dBA where possible but the performance for noise barriers for new/upgraded/retrofit projects should be assessed on a case-by-case basis. The absolute minimum attenuation for retrofit projects should be 3dBA.**

4.5. Glossary of Terms

It is recommended to include a glossary of terms within the traffic noise attenuation policy. Those terms that specifically pertain to noise are as follows:

A-Weighted Sound Level – A-weighted sound level is measured on a sound level meter, using a setting that emphasizes the middle frequency components similar to response of the human ear. The A-weighted sound level is found to correlate well with subjective assessments of the annoying or disturbing effect of sounds.

Abnormal Noise Events – Noises that are sufficiently infrequent as to be uncharacteristic of an area or that occur so close to the microphone as to dominate the measurements in an unrealistic manner. Consideration must be given to deleting occurrences of abnormal noise from the measurements to obtain a reasonably accurate representation of the sound environment. Examples of abnormal noises include a dog barking close to the microphone, people talking in the vicinity of the microphone in a quiet environment, or a passing road grader.

Absorption – Absorption is a property of materials that reduces the amount of sound energy reflected. Thus, the introduction of an "absorbent" onto the surfaces of a noise barrier will reduce the reflected sound pressure level. The amount of sound absorption is denoted by the sound absorption coefficient which is a unit less number between 0 and 1 with 0 being completely reflective and 1 being completely absorptive.

Attenuation – A reduction in sound level in travelling from a source to a receiving point.

Barrier – A solid physical obstruction between the roadway and the observer, which interrupts the line of sight between them. Barriers can take the form of walls, berms, or buildings.

Barrier Attenuation – The reduction in level of sound travelling over hard ground resulting from a barrier being inserted between the noise source and the receiving point.

Berm (Earth Berm)– A mound of earth that interrupts the line of sight between the noise source and the receiving point, thus acting as a barrier.

Calibration – The procedure used for the adjustment of a sound level meter using a reference source of a known sound pressure level and frequency. Field calibration takes place before and after the sound level measurements.

Day-Night Average Sound Level (L_{dn}) – Day-night sound level in dBA is derived by performing a logarithmic average of the time varying sound energy equivalent over the daytime (L_{eq}Day) with the time varying sound energy equivalent over the night time (L_{eq}Night) and adding a 10 decibel "penalty" to the L_{eq}Night.

Day-Time – Defined as the hours from 07:00 to 22:00.

dBA – The decibel (dB) sound pressure level filtered through the A-weighting filtering network to approximate human hearing response at low intensities. Also see *dB* and *A-weighted sound level.*

Decibel (dB) – One tenth of a Bel. Sound is measured in decibels. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Decibels are not linear units, rather they are expressed using a base-10 logarithmic scale. An increase of 10 decibels represents 10-times the acoustical energy. An increase of 20 decibels represents 100-times the acoustical energy.

Energy Equivalent Level (L_{eq}) – The L_{eq} is the logarithmic average sound level over a specified period of time. It is a single-number representation of the cumulative acoustical energy measured over a time interval, T. The time interval must be specified in order for the L_{eq} to be valid. If a sound level is constant over the measurement period, the L_{eq} will equal the constant sound level.

L_{eq}24 – The energy equivalent sound level (L_{eq}) assessed for a 24-hour time period.

Night-Time – Defined as the hours from 22:00 to 07:00.

Noise Monitor – A self contained sound level meter installed in a weather protective case that can measure environmental noise levels for extended periods of time. Typically, the sound level meter is installed in a case while the microphone is mounted to a tripod and incorporates an outdoor windscreen and rain protection hood.

Propagation – The passage of sound energy from a noise source to a receiver.

Sound Insulation – The use of structures and materials designed to reduce the transmission of sound from one room or area to another or from the exterior to the interior of a building.

Sound Level Meter – An instrument designed and calibrated to respond to sound and to give objective, reproducible measurements of sound pressure level. It normally has several features that would enable its frequency response and averaging times to be changed to make it suitable to simulate the response of the human ear.

Sound Pressure Level (SPL) – The decibel equivalent of the pressure of sound waves at a specific location, which is measured with a microphone. Because human reaction and material behaviors vary with frequency, the sound pressure level may be measured using frequency bands or with an overall weighting scale such as the A-weighting system. The sound pressure level depends on the noise sources, as well as on the location and environment of the measurement path. *See also dB (decibel)*

Windscreen – A specialized piece of porous sponge or foam that fits over the microphone in order to reduce the noise generated by the wind blowing around the microphone. Useful in moderately low wind speeds. Generally, outdoor measurements are not recommended when wind speeds exceed 15 km/hr, as the wind-induced noise on the microphone becomes of the same magnitude as the levels of noise being measured.

5.0 Assessment of Various Noise Level Criteria

The singular most important component to any traffic noise attenuation policy is the selection of the specific assessment criteria that will determine the need for and the quantity of noise mitigation. In an effort to provide assistance with the selection of the specific assessment criteria, various assessment criteria have been evaluated for various roadways within the City of Saskatoon. Five completely separate areas within Saskatoon were evaluated, each with different roadway configurations and future traffic volumes, different distances between the roadways and adjacent residential receptors, and different topography. For each study area, a noise model (previously generated as part of a noise barrier study project within Saskatoon) was used to determine the required noise barrier heights and lengths to meet various assessment criteria including 65, 60, 55 dBA L_{eq}24 and 65, 60, 55 dBA L_{dn} at the adjacent residential receptor outdoor amenity spaces for the future conditions (400K population). The intent is to provide a sense of the scale required in order to meet the various assessment criteria. For more information regarding the specific study areas with detailed description of the geometries and topography as well as the traffic volumes, refer to the reports entitled:

- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for College Drive Between Central Avenue to CPR Bridge & McKercher Drive Between Boychuk Drive and College Drive*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.
- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Boychuk Drive Between Taylor Street and Heritage Crescent*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.
- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Circle Drive Between Highway 16 and Taylor Street*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.
- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for 22 Street Between Michener Crescent and Haviland Crescent*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.
- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Circle Drive Between Milton Street and 33 Street West*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

5.1. College Drive Between Central Avenue and McKercher Drive

This specific study area spans the south side of College Drive from the intersection at Central Avenue to the interchange with McKercher Drive and then follows McKercher Drive south to Boychuk Drive. The residential receptors are all comprised of single family detached houses which back onto Central Avenue and McKercher Drive.

- 65 dBA $L_{eq}24$ – No noise mitigation required to achieve 65 dBA $L_{eq}24$
- 60 dBA $L_{eq}24$ – Barrier height from 3.0 m to 3.5 m tall (approximately 1,100 m length)
- 55 dBA $L_{eq}24$ – Barrier height from 5.0 m to 6.0 m tall (approximately 1,100 m length)

- 65 dBA L_{dn} – Barrier height 2.44 m tall (approximately 1,100 m length)
- 60 dBA L_{dn} – Barrier height 4.5 m tall (approximately 1,100 m length)
- 55 dBA L_{dn} – Barrier height from 7.5 m to 8.5 m tall (approximately 1,100 m length)

5.2. Boychuk Drive Between Taylor Street and Heritage Crescent

This specific study area spans the west side of Boychuk Drive from the intersection at Taylor Street to the intersection at Heritage Crescent. The residential receptors are all comprised of single family semi-detached houses which back onto Boychuk Drive. The following noise barriers are required to meet the various assessment criteria:

- 65 dBA $L_{eq}24$ – No noise mitigation required to achieve 65 dBA $L_{eq}24$
- 60 dBA $L_{eq}24$ – No noise mitigation required to achieve 60 dBA $L_{eq}24$
- 55 dBA $L_{eq}24$ – Barrier height from 1.83 m to 2.44 m tall (approximately 280 m length)

- 65 dBA L_{dn} – No noise mitigation required to achieve 65 dBA L_{dn}
- 60 dBA L_{dn} – Barrier height 1.83 m tall (approximately 280 m length)
- 55 dBA L_{dn} – Barrier height 3.0 m tall (approximately 280 m length)

5.3. Circle Drive Between Highway 16 and Taylor Street

This specific study area spans the east and west sides of Circle Drive from the interchange at Highway 16 to the interchange with Taylor Street. The residential receptors are all comprised of single family detached houses which back onto Circle Drive. There are also multi-family residential structures to the south of Taylor Street on the west side of Circle Drive which have not been included in the noise mitigation assessment. It should be noted that Circle Drive within this area is flanked on both sides by an earth berm approximately 3 m tall with the houses on the other side of the berm. The following noise barriers are required to meet the various assessment criteria:

- 65 dBA $L_{eq}24$ – Most of study area requires no noise mitigation to achieve 65 dBA $L_{eq}24$, just a short span (approximately 130 m) with a 1.83 m tall barrier to the northwest of the intersection between Circle Drive and Highway 16.
- 60 dBA $L_{eq}24$ – Barrier height from 1.83 m to 3 m tall (approximately 2,600 m length)
- 55 dBA $L_{eq}24$ – Barrier height from 3.5 m to 7.0 m tall (approximately 2,600 m length)

- 65 dBA L_{dn} – Barrier height from 0 m to 2.44 m tall (approximately 2,600 m length)
- 60 dBA L_{dn} – Barrier height from 1.83 m to 4.5m tall (approximately 2,600 m length)
- 55 dBA L_{dn} – Barrier height from 7 m to 10+ m tall (approximately 2,600 m length)

5.4. 22 Street Between Michener Crescent and Haviland Crescent

This specific study area spans the north side of 22 Street from approximately Michener Crescent to approximately Haviland Crescent. The residential receptors are all comprised of single family detached houses which back onto 22 Street. The following noise barriers are required to meet the various assessment criteria:

- 65 dBA $L_{eq}24$ – No noise mitigation required to achieve 65 dBA $L_{eq}24$
- 60 dBA $L_{eq}24$ – Barrier height 1.83 m tall (approximately 650 m length)
- 55 dBA $L_{eq}24$ – Barrier height from 4.0 m to 4.5 m tall (approximately 1,700 m length)

- 65 dBA L_{dn} – No noise mitigation required to achieve 65 dBA L_{dn}
- 60 dBA L_{dn} – Barrier height 3.0 m tall (approximately 1,700 m length)
- 55 dBA L_{dn} – Barrier height from 3.5 m to 7.0 m tall (approximately 1,700 m length)

5.5. Circle Drive Between Milton Street and 33 Street West

This specific study area spans the north and south sides of Circle Drive from approximately Milton Street to the interchange with 33 Street West. The residential receptors are all comprised of single family detached houses which back onto Circle Drive. It should be noted that Circle Drive within this area is flanked on the north side by an earth berm approximately 2 m tall with the houses on the other side of the berm. The following noise barriers are required to meet the various assessment criteria:

- 65 dBA L_{eq}24 – No noise mitigation required to achieve 65 dBA L_{eq}24
- 60 dBA L_{eq}24 – Barrier height from 1.83 m to 4 m tall (approximately 1,800 m length)
- 55 dBA L_{eq}24 – Barrier height from 4.5 m to 8.5 m tall (approximately 1,800 m length)

- 65 dBA L_{dn} – Barrier height from 1.83 m tall (approximately 350 m length)
- 60 dBA L_{dn} – Barrier height from 1.83 m to 6.5 m tall (approximately 1,800 m length)
- 55 dBA L_{dn} – Barrier height from 7.5 m to 12 m tall (approximately 1,800 m length)

6.0 References

- City of Regina *Traffic Division Procedure Manual, Section 6.0*
- City of Edmonton *Urban Traffic Noise Policy (C506A),* 2013
- City of Calgary *Surface Transportation Noise Policy (TP003)*
- City of St. Albert *Municipal Engineering Standards, Section 3.9*
- Strathcona County *SER-009-027 (Traffic Noise)*
- City of Leduc *Engineering Standards Section 1.15*
- Regional Municipality of Wood Buffalo *Engineering Services Standards and Development Procedures, Section 4.9*
- City of Red Deer *Engineering Services Design Guidelines, Section 13*
- Alberta Transportation *Noise Attenuation Guidelines for Provincial Highways under Provincial Jurisdiction Within Cities and Urban Areas.*
- British Columbia Ministry of Transportation and Infrastructure *Policy for Assessing and Mitigating Noise Impacts From New and Upgraded Numbered Highways*
- Ontario Ministry of the Environment *Publication NPC-300, Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning*
- Alberta Energy Regulator (AER), *Directive 038 on Noise Control, 2007*, Calgary, Alberta
- Canadian Mortgage and Housing Corporation (CMHC), *Road and Rail Noise: Effects on Housing*, 1981
- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for College Drive Between Central Avenue to CPR Bridge & McKercher Drive Between Boychuk Drive and College Drive,* Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Boychuk Drive Between Taylor Street and Heritage Crescent*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Circle Drive Between Highway 16 and Taylor Street*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for 22 Street Between Michener Crescent and Haviland Crescent*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

- *Environmental Traffic Noise Modeling and Traffic Noise Barrier Recommendations for Circle Drive Between Milton Street and 33 Street West*, Prepared for the City of Saskatoon, by aci Acoustical Consultants Inc., November, 2015.

- 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.

Appendix I THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

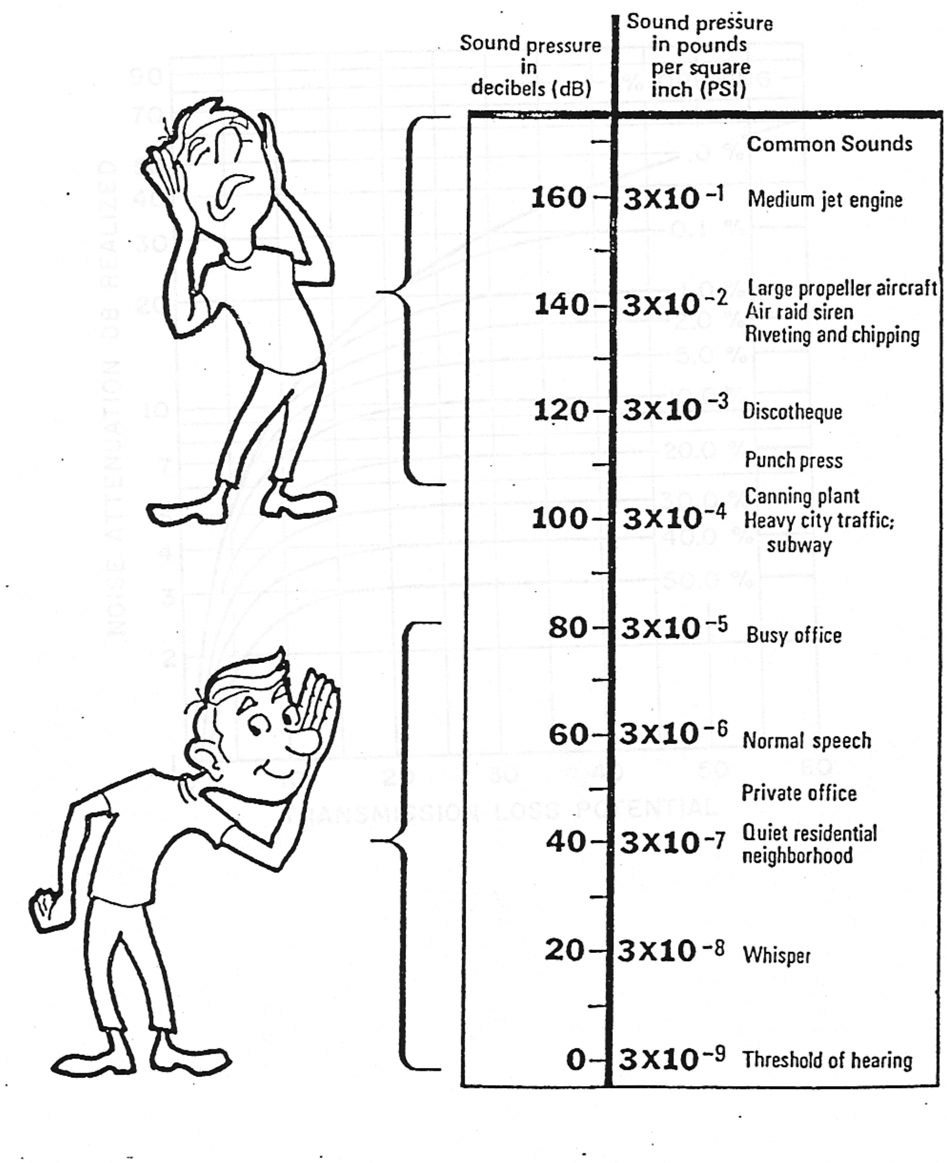
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we 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 ($P_{ref} = 2\text{x}10^{-5}$ 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
Canning plant
100 3X10-4 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

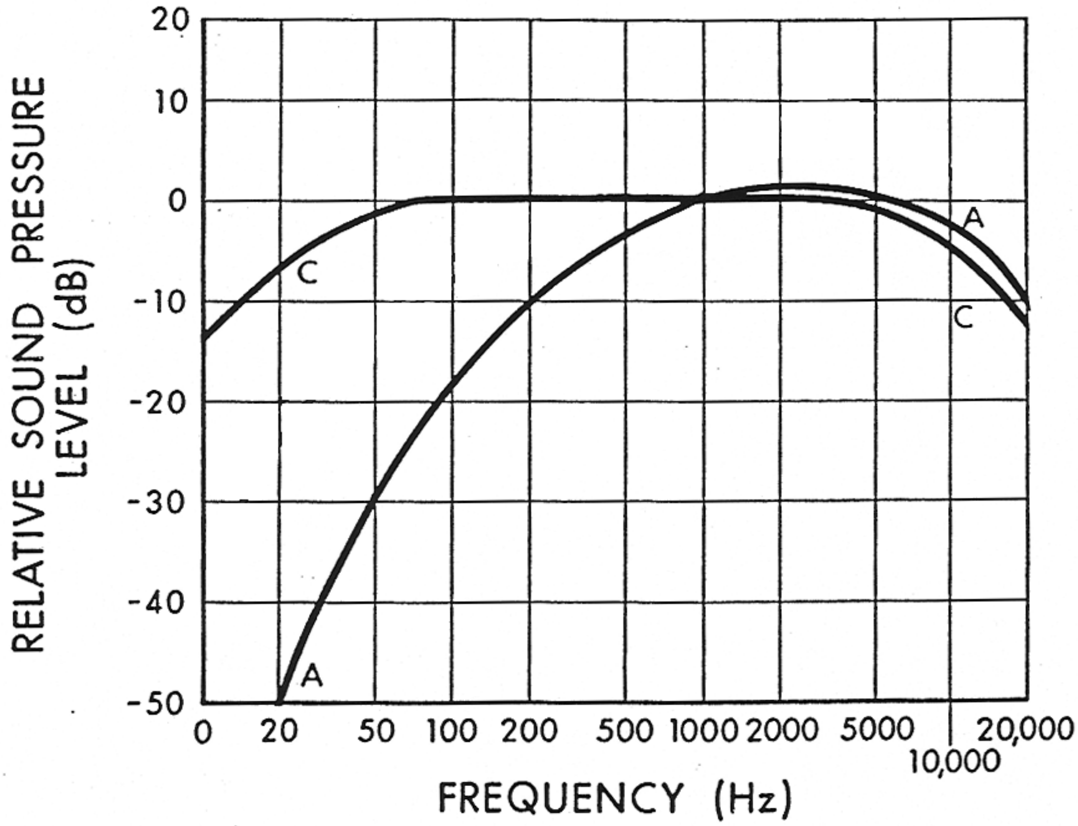
Frequency

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.

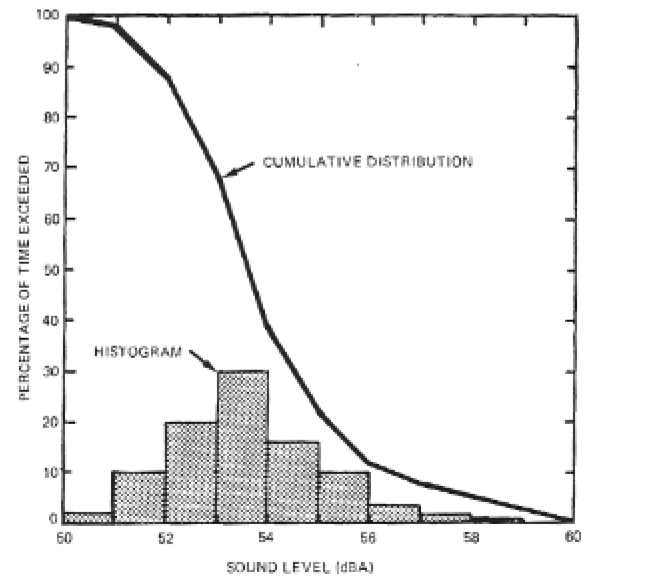


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

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

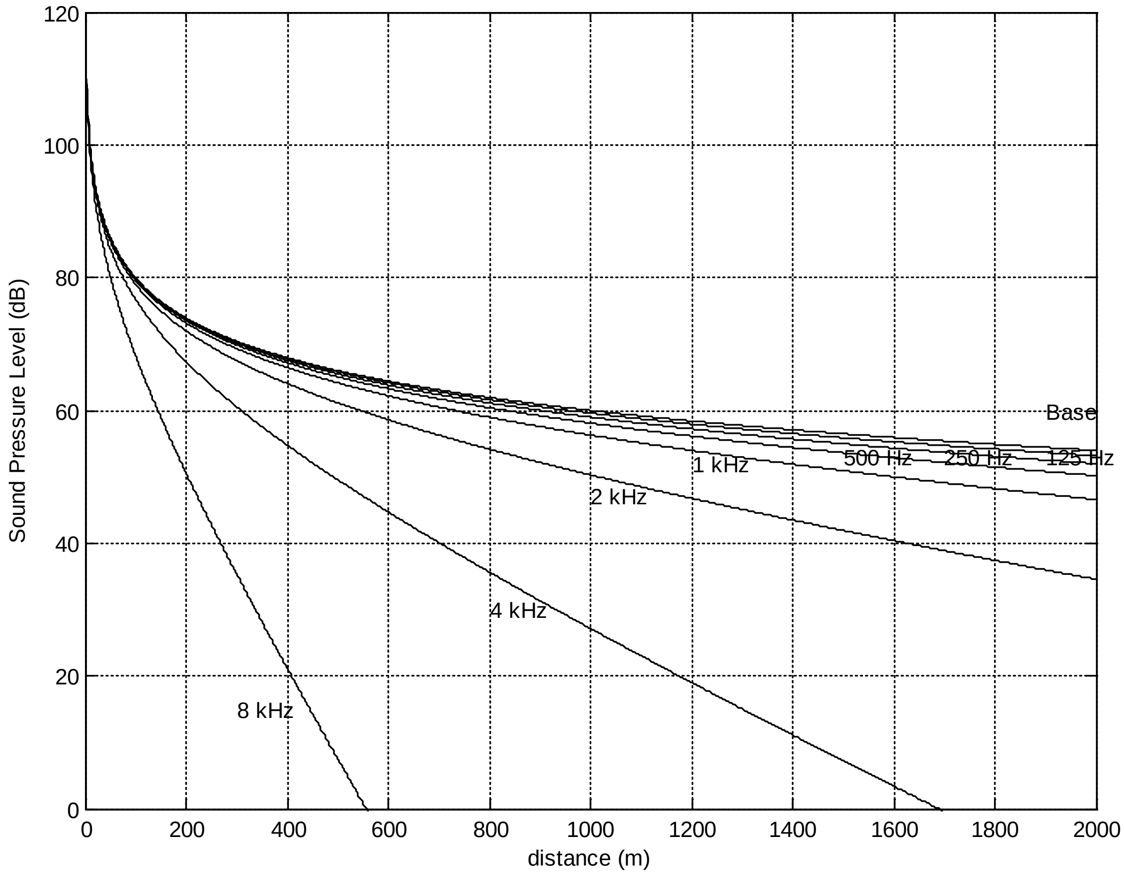
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

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 10°C 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.

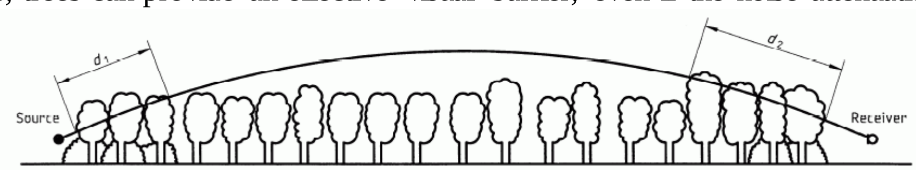
Topography
- One of the most important factors in sound propagation.
- Can provide a natural barrier between source and receiver (i.e. if berm or hill in between).
- Can provide a natural amplifier between source and receiver (i.e. large valley in between or hard reflective surface in between).
- Must 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 m	**Nominal midband frequency** Hz							
	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.

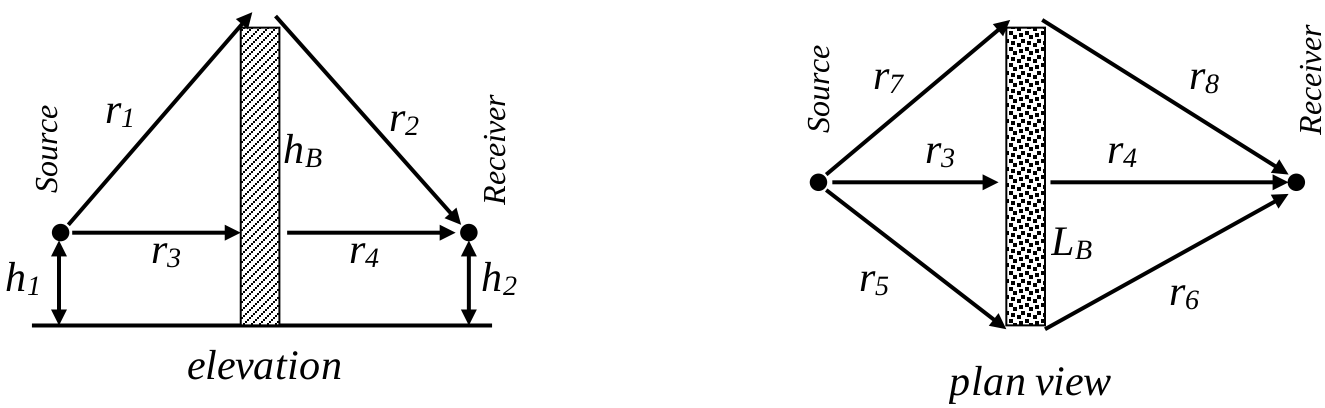
Road Noise Barriers

One of the most common methods for noise mitigation is through the use of a physical barrier. Noise travels over the barrier and is refracted down to the other side. The general formula for the Insertion Loss (level of noise attenuation) for a noise barrier is:

$$\therefore\ IL = -10\log_{10}\left[\sum_{i=1}^{3}\left(\frac{\lambda}{3\lambda + 20\delta_i}\right)\right]$$

Where: λ = the wavelength of the sound

δ_i = the pathlength difference between the i[th] diffracted path and the direct path



$$\delta_1 = (r_1 + r_2) - (r_3 + r_4)$$
$$\delta_2 = (r_5 + r_6) - (r_3 + r_4)$$
$$\delta_3 = (r_7 + r_8) - (r_3 + r_4)$$

Note that the preceding was derived with a point source. The attenuation due to a barrier in a free field for a line source is slightly less than that for a point source. The following table illustrates the differences

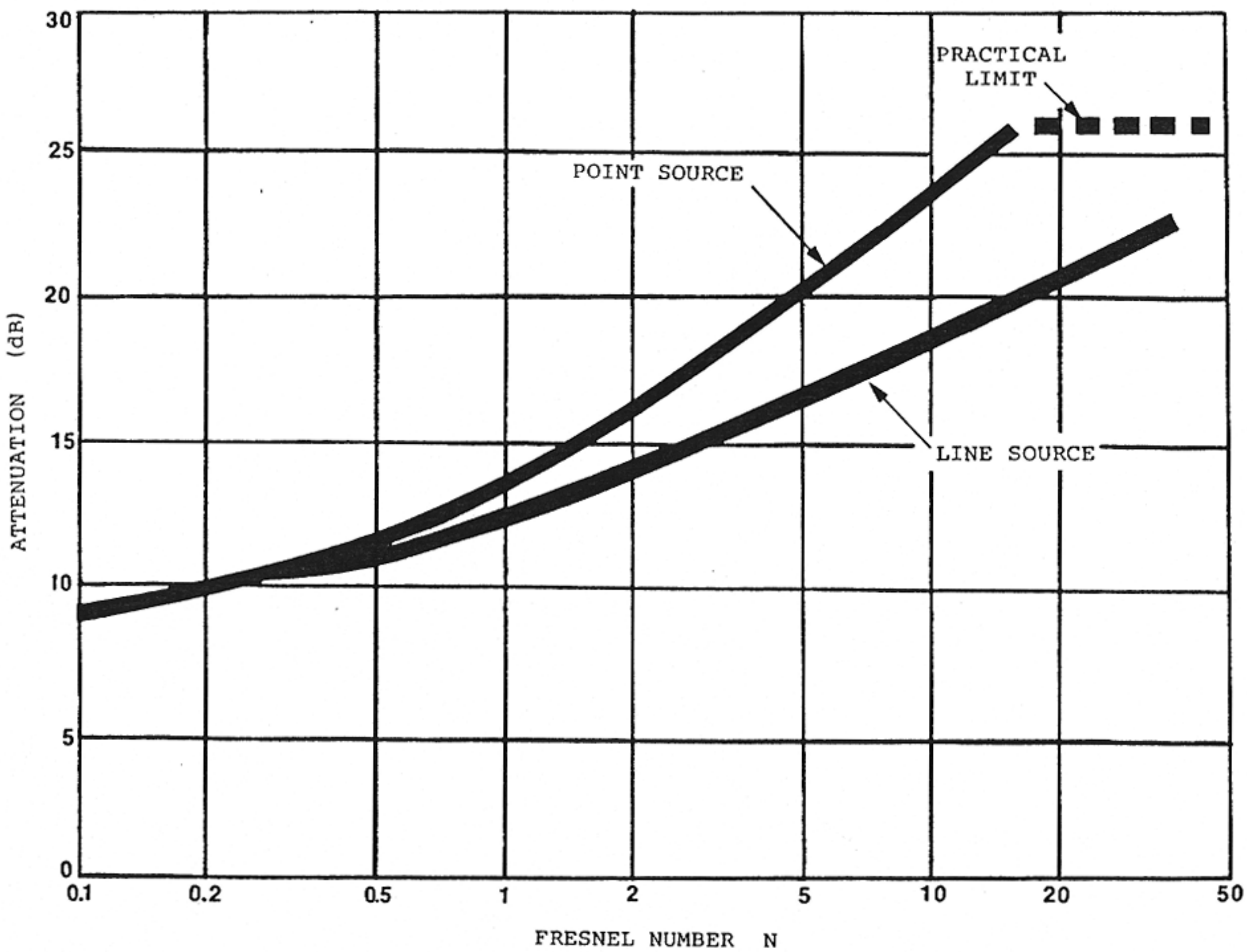
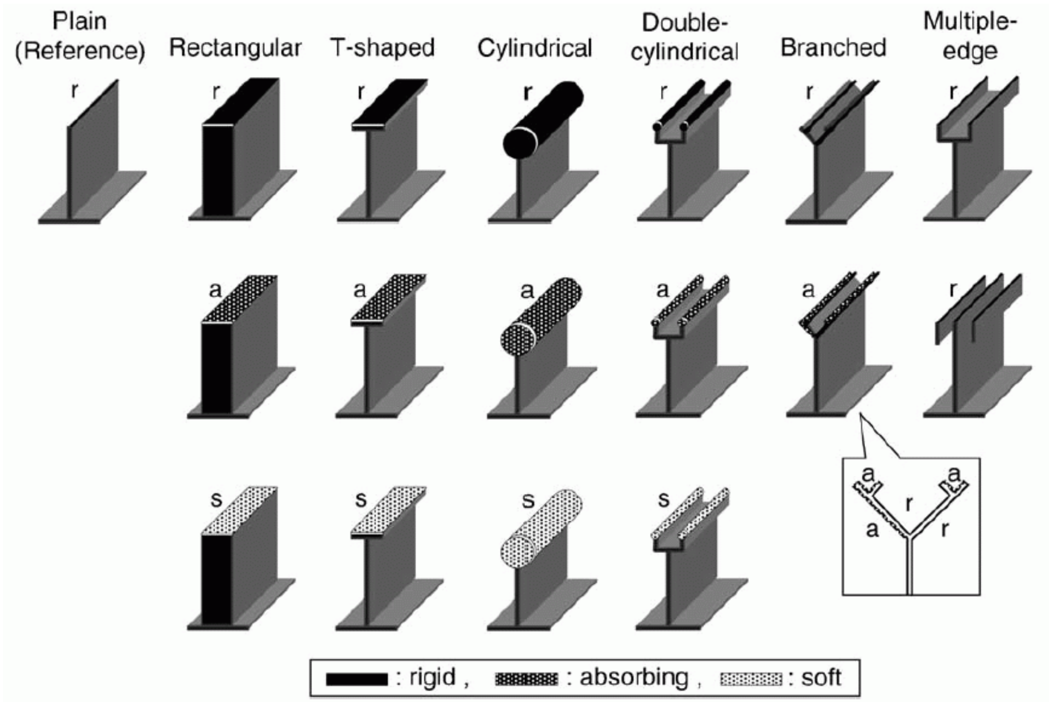


Figure 4.12 Attenuation due to a partial barrier for point and line sources.

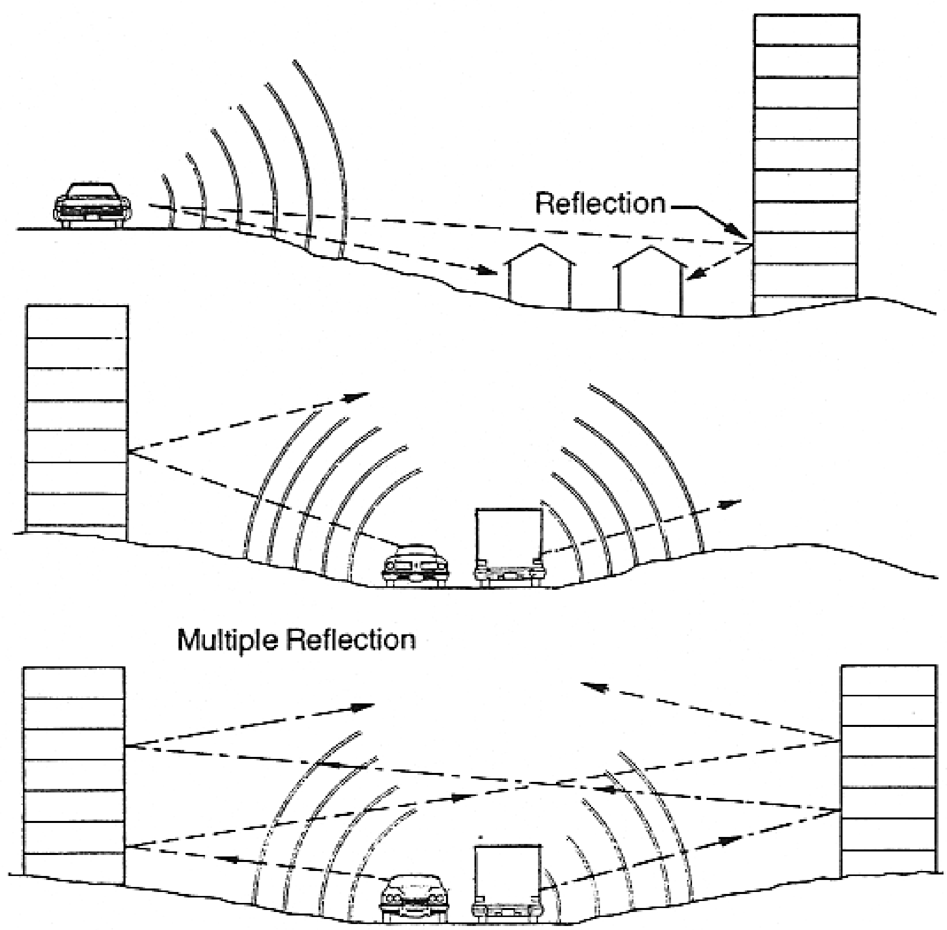
Industrial Noise Control, Lewis Bell, Marcel Dekker, Inc. 1994

- Barriers are least effective when placed in the middle between source and receiver (smallest path length difference).
- Barriers are most effective when located near the source or receiver.
- Most road noise barriers are placed as close as possible to the road for this reason
- Barrier attenuation is VERY dependent on the frequency of noise attenuated (Example of mouse and giant).
- Practical limit of about 20 dB of attenuation.
- Attenuation depended on barrier construction. If the materials used are only good for 5 dB of reduction (light weight or many holes) then that is the practical limit of the barrier.
- Materials need to be selected such that the noise transmitted through the barrier is at least 10 dB less than the noise transmitted over the barrier (typically use concrete / masonry / heavy steel).
- Recent barrier designs have incorporated various toppings in an attempt to alter the amount of sound refracted from the top. *(T. Ishizuka, et. al., Applied Acoustics 65 (2004) 125-141)*



Plain (Reference)
Rectangular
T-shaped
Cylindrical
Double-cylindrical
Branched
Multiple-edge
r
a
s
: rigid , : absorbing , : soft

- Barriers can provide adequate attenuation from one side to another but will also act as a reflector for the opposite side (increasing the sound level as much as 3 dB).
- This can be a problem depending on what is on the opposite side.
- Multiple parallel barriers can result in the "swimming pool effect"
- Can incorporate absorption into the barrier (fibrous materials, concrete, etc.)



Road and Rail Noise: Effects on Housing, Canadian Mortgage and Housing Corporation, 1981

Appendix II SOUND LEVELS OF FAMILIAR NOISE SOURCES

Used with Permission Obtained from the Alberta Energy Regulator Directive 038 (February, 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 (February, 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).