

REVISED POLICY FOR MITIGATING THE EFFECTS OF TRAFFIC NOISE FROM FREEWAYS AND EXPRESSWAYS

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Province of
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Ministry of Transportation
and Highways

HIGHWAY ENVIRONMENT BRANCH

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REVISED POLICY FOR
MITIGATING THE EFFECTS OF TRAFFIC NOISE
FROM FREEWAYS AND EXPRESSWAYS

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1 ADDRESSING THE NOISE IMPACTS OF MoTH PROJECTS

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1.1 Assessing/Mitigating Impacts of New and Upgraded Freeways and Expressways

Traffic on streets, roads and highways is the dominant source of intrusive noise in most British Columbia communities. Traffic noise can interfere with essential human activities such as speech communication, relaxation, recreation and sleep, and as a result can create annoyance and diminish the use and enjoyment of property (Appendix A describes in more detail the nature of traffic noise impacts on people).

The B.C. Ministry of Transportation & Highways (MoTH), is charged with the upgrading of existing highway facilities and the building of new ones in response to the province's needs for increased transportation capacity and safety. The MoTH recognizes that, without proper planning, design and control measures, such major improvements to the highway system may be accompanied by excessive noise impacts on adjacent communities.

Policy 1.1

The potential community noise impacts of all MoTH projects involving the new construction or substantial upgrading of controlled-access highways (i.e., freeways or expressways) will be evaluated and mitigation will be carried out where warranted, cost-effective and desired by the majority of the affected community.

Active mitigation measures will be carried out within the MoTH right-of-way and will generally involve the construction of roadside noise barrier walls, earth berms or combinations of these elements.

1.2 Avoiding Noise Impacts Through Land-Use Controls

It is also recognized that any effective strategy for minimizing the negative effects of highway noise must include the avoidance of future impacts through the appropriate control of land use along existing and planned highway corridors.

Policy 1.2

The MoTH will promote the avoidance of highway noise impacts through the co-operative implementation of appropriate land-use controls and/or design requirements for properties adjacent to existing or planned highway corridors.

2 MITIGABLE HIGHWAY NOISE IMPACTS AND MITIGATION OBJECTIVES

ISSUES ▼

POLICIES ▼

2.1 *Two Forms of Noise Impact*

Communities can be impacted by intrusive noise from highways and other sources in two fundamentally different ways:

- absolute noise levels may exceed recognized thresholds for significant interference with essential activities such as speech communication and sleep,
- increases in overall community noise levels due to a highway project may be sufficient to cause significant annoyance and negative community reaction due to the perception that environmental quality has been degraded; this can occur even when absolute traffic noise levels are not considered excessive.

Policy 2.1

Mitigation will be considered whenever projected increases in traffic noise levels due to a MoTH freeway or expressway project would cause excessive impacts, by interfering with essential human activities such as speech and sleep or by substantially elevating overall community noise levels above pre-project ambient levels.

2.2 *Project Impacts versus Traffic Volume Growth Impacts*

Gradual increases in highway noise levels associated with steadily growing populations and traffic volumes are being experienced throughout B.C.. While it would be desirable to address this growing noise problem through a retrofit noise mitigation program for existing highways, the scope of such a program exceeds the MoTH's current capabilities. Where current MoTH projects are expected to produce mitigable noise impacts, mitigation costs can be included in overall project budgets. It is such project-related impacts that the policy is intended to address.

Policy 2.2

The noise policy does not apply to noise impact situations which have arisen gradually over many years. It does apply to the relatively sudden impacts which can accompany new highway construction, upgrading or traffic management projects for which the MoTH is directly responsible, including:

- *highway construction along new alignments,*
- *upgrading of existing highways involving alignment changes, addition of new traffic movements or increases in numbers of through lanes.*

2.3 Noise Impact Mitigation Criteria for Residences

The Canada Mortgage and Housing Corporation (Ref. 1) recognizes a 24-hour equivalent sound level, or $L_{eq}(24)$, of 55 decibels (dB) as the threshold of concern for traffic noise impacts in residential areas. At $L_{eq}(24)$ 65 dB, traffic noise is subjectively twice as noisy and substantial speech and sleep interference would be expected at residences as normally constructed.

Subjective impressions of loudness/noisiness tend to increase and decrease quite uniformly with the level of a given noise, regardless of the baseline (or ambient) noise level. However, the interference of noise with speech and sleep begins to increase more rapidly with noise level once certain threshold levels of outdoor $L_{eq}(24)$ are reached - typically 55 to 60 dB. It is not then equitable to subject residents already exposed to noise levels at or above this "threshold" range to the same noise increases as those with ambient levels well below this range.

¹ See the glossary for definitions of acoustical/highway noise terminology.

Policy 2.3

Mitigation will not be considered where predicted $L_{eq}(24)$'s, ten years after project completion, are less than 55 dB. Impact avoidance, however, will be considered in such situations where feasible.

Mitigation is warranted, and will be carried out where cost-effective, practical and broadly supported by the directly-affected residents, wherever the exterior $L_{eq}(24)$ at the ground floor levels of adjacent residences, ten years after project completion, is predicted to be:

1. *from 55 to 65 dB inclusive and exceed pre-project, or ambient, noise levels by a minimum amount which progressively decreases from 10 dB at a pre-project level of 45 dB to 3 dB at a pre-project level of 62 dB (see Figure 2.1 for illustration), or*
2. *over 65 dB and exceed pre-project noise levels by 3 dB or more.*

2.4 Mitigation Objectives for Residences

The considerable expense associated with highway noise mitigation works can only be justified if a significant noise reduction can be achieved. A change of 5 dB (typically judged as a 40% change in loudness of a given noise) is considered the smallest, non-immediate change in average community noise levels that can be consistently perceived and appreciated. A 10 dB change is readily apparent and is typically considered to correspond to a halving of subjective noisiness.

Policy 2.4

Mitigation works must be able to achieve a minimum reduction in project $L_{eq}(24)$ of 5 dB when averaged over the worst-impacted locations - typically the first abutting row of residences.

Where site topography and highway/noise receiver geometry are favourable, efforts should be made to achieve larger reductions.

2.5 *Noise Impact Mitigation Criterion for Educational Facilities*

The primary function of schools and other educational facilities is communication, largely through the spoken word. Excessive levels of intrusive noise within classrooms can interfere with this function by masking or interrupting speech and by distracting the attention of students. Peak noise events such as may be produced by heavy trucks, are particularly disruptive. For busy highways, the severity of such peak noise events can be indicated by the L_{10} for the noisiest daytime hour. L_{10} is that noise level which is exceeded 10% of the time.

While speech interference in classrooms can be caused by intrusive noise at levels as low as 45 dBA, a reasonable threshold for the onset of significant general interference is a worst daytime hour L_{10} of 50 dBA inside the classroom. For typical highway traffic this corresponds to an indoor $L_{eq}(1 \text{ hour})$ of 47 dBA.

The level of outdoor traffic noise necessary at a school facade to produce $L_{eq}(1 \text{ hour})$ 47 dB indoors could range from approximately 60 to 75 dB depending on the construction and condition of the facade - particularly the type and size of windows.

2.6 *Mitigation Objectives for Educational Facilities*

As with residential noise impacts, a 5 dB reduction in traffic noise levels within school classrooms is considered to be necessary to achieve a significant improvement in speech intelligibility.

Policy 2.5

Highway noise mitigation measures will be considered - and implemented where cost-effective and practical - for educational facilities where it is projected that, ten years after project completion, daytime (typically 8:30 am to 3:30 pm) traffic noise levels inside classrooms will exceed $L_{eq}(1 \text{ hour})$ 47 dB and will have increased by 3 dB or more over pre-project levels.

Mitigation measures will, where feasible, be carried out within the MoTH right-of-way, thereby potentially providing noise reductions in outdoor play areas as well as in classrooms. Where effective mitigation of classroom noise levels through measures taken within the right-of-way may not be feasible (e.g. for multi-storey schools), consideration will be given to the treatment of the school facade(s).

Policy 2.6

Mitigation works at educational facilities must be able to achieve a minimum 5 dB reduction in daytime $L_{eq}(1 \text{ hour})$ within impacted classrooms. Where existing conditions of the site and/or school facade lend themselves to effective mitigation, efforts should be made to achieve larger reductions, and in particular to avoid exceeding $L_{eq}(1 \text{ hour})$ 47 inside classrooms.

3 AVOIDING HIGHWAY NOISE IMPACTS

ISSUES ▼

ACTIONS ▼

3.1 *Impact Avoidance Through Highway Location and Design*

Minimizing noise impacts on sensitive land uses is one of many factors that must be considered in the location of a new highway. Rural residential areas with very low ambient noise levels are particularly sensitive to noise intrusion. Fortunately, such areas tend to have widely dispersed populations so that there is often opportunity to avoid significant highway noise impacts through horizontal and/or vertical alignment selection.

Action 3.1

Noise impact avoidance/minimization should always be considered in locating new highways and carried out where practical. However, particular efforts should be made where projected highway noise levels are below 55 dB (and therefore not directly mitigable) but will exceed pre-project, ambient levels by 10 dB or more. (See Figure 2.1)

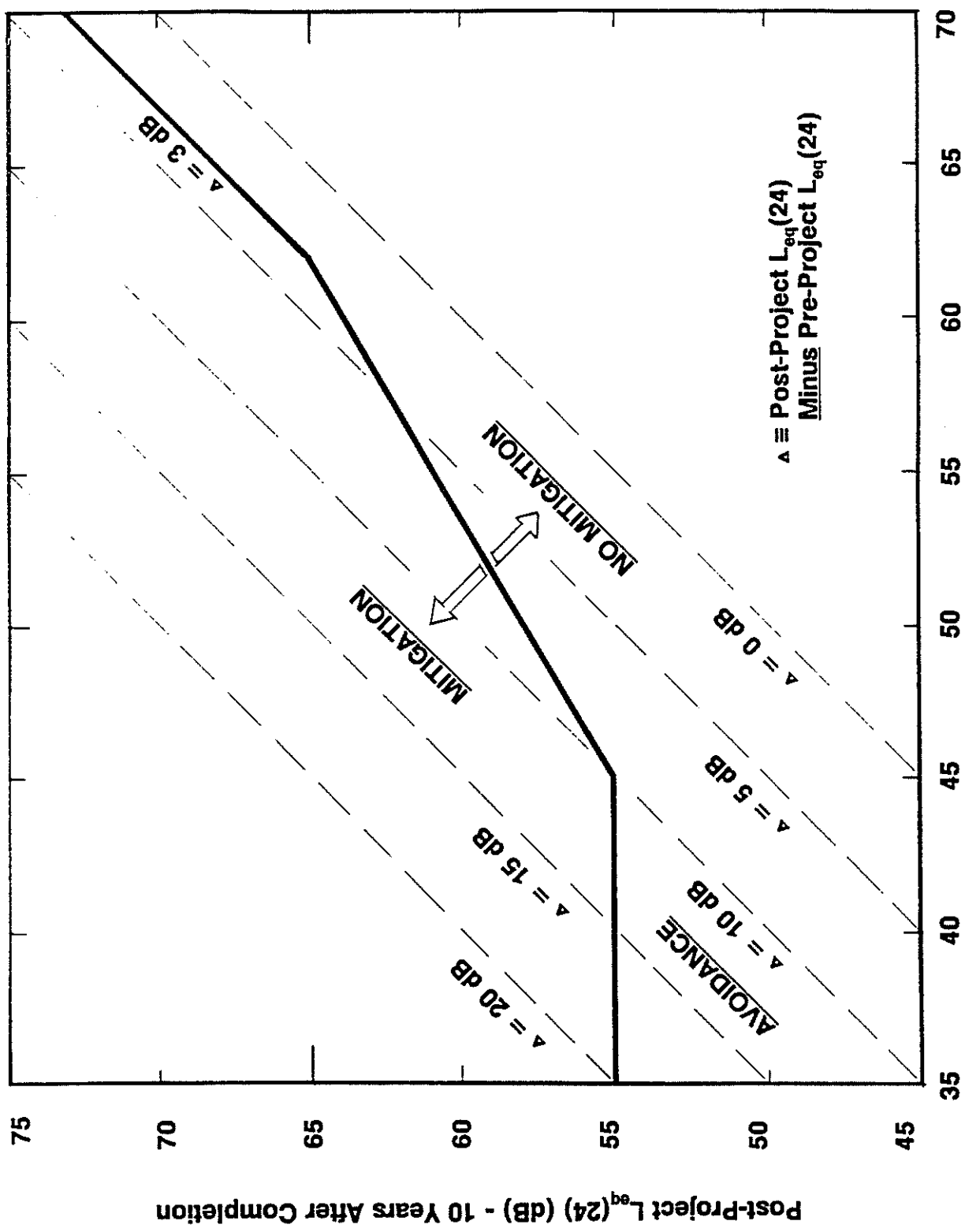
3.2 *Impact Avoidance Through Land Use Controls*

Where lands adjacent to planned or existing highways are undeveloped or are likely to be redeveloped, future noise impact situations can be avoided through land use controls. This could take the form of zoning restrictions which either limit such lands to relatively noise-insensitive uses (commercial, industrial or active recreational), or require that any noise-sensitive uses (residential, institutional, passive recreational) be designed so as to limit noise impacts on future occupants/users to acceptable levels.

Action 3.2

Since in organized areas, zoning controls are enacted and enforced by local municipal planning and building approval authorities, the MoTH, with the co-operation of the Ministry of Municipal Affairs, will encourage municipalities to incorporate noise impact avoidance strategies into their zoning regulations and Official Community Plans (OCP's).

In unorganized areas, the MoTH, through its District Approving Officers, will make efforts to expand its zone of development control (currently limited to areas within 700 ft. of an intersection or interchange) to include a strip of appropriate width on either side of the highway.



≤	45	55.0	≥10.0
	46	55.6	9.6
	47	56.2	9.2
	48	56.8	8.8
	49	57.4	8.4
	50	58.0	8.0
	51	58.5	7.5
	52	59.1	7.1
	53	59.7	6.7
	54	60.3	6.3
	55	60.9	5.9
	56	61.5	5.5
	57	62.0	5.0
	58	62.6	4.6
	59	63.2	4.2
	60	63.8	3.8
	61	64.4	3.4
	62	65.0	3.0
	63	66.0	3.0
	64	67.0	3.0
	65	68.0	3.0
	etc...		

Figure 2.1: Graphical Representation of MoTH Noise Policy Criteria for Residences

4 POLICY RESTRICTIONS

ISSUES ▼

POLICIES ▼

4.1 *Development Must Precede MoTH Project Announcement*

Noise-sensitive developments which are permitted to be constructed adjacent to existing or officially designated future highway corridors can be configured, designed and constructed so as to effectively avoid, in all but the most extreme cases, excessive noise impacts on the occupants/users. Greater noise reductions (particularly indoors) can generally be achieved through such site design techniques than through the construction of noise barriers within the highway right-of-way.

Policy 4.1

The MoTH will not mitigate highway noise impacts at residences or educational facilities for which planning approvals were not issued by the appropriate municipal authority prior to the first public announcement of the highway project or the designation (through gazetting) of the affected lands as potential future highway right-of-way, whichever occurs first. For this purpose, the first public announcement is considered to be the formal notification, by the Minister or a Ministry spokesperson, of the municipalities involved and the public (through the media) that the highway project design process has commenced or is about to commence.

For multi-phased projects, which are planned to be developed over a number of years depending on traffic demand or other factors, the first public announcement is considered to be that which accompanies the initial project phase.

4.2 *Height Limitation for Noise Barrier Walls*

Highway noise mitigation within the highway right-of-way may take the form of vertical or near-vertical walls of various materials, earth berms or combinations of these two elements. Landscaped earth berms, because of their natural appearance, are less visually dominant and tend to be met with broader public approval than noise barrier walls. Earth berms also have the advantage of not reflecting traffic noise back towards homes on the opposite side of the highway as do hard, vertical walls.

Policy 4.2

Earth berms, when used as roadside noise barriers, may be of any reasonable height, subject to soil conditions and the availability of adequate right-of-way and fill materials. However, to limit visual impacts and shading effects of vertical walls and to control their costs, which tend to increase rapidly with height, vertical or near-vertical barrier walls are limited to 3 m in height.

4.3 Guidelines for Mitigation Costs

The cost of noise mitigation per residence or classroom protected can vary substantially depending on site topography, the nature and height of noise barrier required to achieve the 5 dB minimum mitigation objective and the spacing of impacted residences or arrangement of school buildings along the highway.

In some situations, the cost of the noise mitigation works could be considered to be out of proportion with the benefits to be received by the affected community or with the overall cost of the highway project.

Policy 4.3

The assessment of whether obtainable noise mitigation benefits justify their costs must be made on a project by project basis - in recognition of overall project costs and the severity of the noise impact situation. However, to provide some guidance, a benchmark maximum cost has been established of \$15,000 per directly-fronting residential unit.

This benchmark is representative of 1993 costs associated with relatively widely-spaced (25 m), front-facing, residences and either an exceptionally high barrier (i.e., a berm/wall combination) or an exceptionally expensive wall type (eg. sound absorbing) or wall foundation. In many cases, mitigation cost per residence will be substantially less than this benchmark figure.

4.4 Restriction of Mitigation to Controlled-Access Highways

For a variety of reasons, mitigation of noise impacts with roadside barriers is generally not practical or effective along uncontrolled access highways and urban arterials. The need to preserve private driveway access, pedestrian security and utility services would generally preclude the construction of the long, continuous noise barriers necessary to achieve effective traffic noise attenuation.

Policy 4.4

Mitigation of MoTH project noise impacts will be considered only for controlled-access highways (freeways and expressways), except as indicated below.

Mitigation will be considered along non-controlled access roads in the immediate vicinity of intersections or interchanges with controlled-access highways where, as part of a freeway or expressway project, the arterial or minor highway has been modified in such a way as to create mitigable noise impacts. Here mitigation would be limited to those portions of the affected arterial or minor highway along which, for reasons of traffic control or realignment, direct access is no longer permitted.

5 POLICY INTERPRETATION AND APPLICATION

ISSUES ▼

INTERPRETATION/APPLICATION ▼

5.1 *Interpretation of Mitigation Criteria*

The criteria for mitigation at residences and schools (See Sections 2.3 and 2.5) represent approximate thresholds for the onset of substantial noise impacts in typical situations. This is not to say that impacts cannot result from traffic noise below these thresholds, but impact severity increases more rapidly as noise levels rise above them. For several reasons, including the inherent uncertainties in the measurement and prediction of traffic noise levels and the forecasting of traffic volume growth, these criteria should not be considered rigid boundaries between "mitigable" and non-mitigable" situations.

Interpretation 5.1

In view of the "softness" of the thresholds for significant highway noise impacts at residences and schools and the inherent uncertainties in highway noise measurement and prediction, mitigation should be considered - and its cost-effectiveness assessed in terms of the noise attenuation achievable, the number of residents/classrooms to benefit and overall project costs - whenever the criteria of Sections 2.3 and 2.5 are approached or exceeded.

5.2 Eligibility of Residences/Schools For Mitigation

The cost effectiveness of highway noise mitigation can vary considerably from project to project and from location to location depending on topography and highway alignment. It can also be substantially affected by the numbers of residences impacted and their locations relative to the highway - typically the denser a residential development and the closer it is to the highway, the more cost-effectively it can be shielded from traffic noise. However, small groups of residences or those not located immediately adjacent to the highway should not be precluded from potential mitigation efforts.

In some case an upgrading project may result in and increase in the setback distance of some residences from the highway. The generally beneficial effects of this increased setback distance could however be offset by the combined negative effects of increased traffic speed and volume growth facilitated by the highway upgrading.

Application 5.3

There are no restrictions on the eligibility of residences or schools for mitigation consideration provided the policy criteria are met and the residences/schools precede the highway project (see Section 4.1). More particularly:

- *there is no minimum number of residences which must be impacted by project noise,*
- *there is no specific number of housing rows or highway setback distances within which impacted residences must lie,*
- *residences which have, as a result of a project, had their setback distances increased, may still be eligible for mitigation.*

Whether or a not a particular residential area or school, which is eligible for mitigation under Policies 2.3 or 2.5 respectively, should receive mitigation is to be decided on the following bases:

- *can the minimum mitigation objective of 5 dB be achieved ?*
- *will mitigation costs per protected residence/classroom be reasonable (see Section 4.3) ?*
- *will total mitigation costs be in reasonable proportion with overall project costs ?*

TECHNICAL NOTES

TN 1 Establishing Pre-Project Noise Levels

TN 1.1 Definition of Pre-Project

To predict the change in community noise levels to result from a highway project, the pre-project or ambient noise levels in the community must first be established as accurately as possible. It is desirable to obtain the pre-project levels at a time as close as possible to the actual start of project construction. However, more typically this information is needed quite early in the highway design process in order to facilitate comparison of alternatives or to estimate the potential scope for mitigation. This is not generally a problem since the increase in $L_{eq}(24)$ with total traffic volume is very gradual (approximately 3 dB per doubling of volume for freely flowing traffic - which would take 20 years at a compounded annual growth rate of 3.5%). Therefore if traffic volume growth rates are known, noise level adjustments can be made to account for any substantial delay between project design and construction start-up.

TN 1.2 Measurement Versus Prediction

Pre-project noise levels can be established through either direct measurement in the community or through prediction - typically using the same highway noise model that will provide post-project noise projections (see Section 6.2.3). Each method has its advantages and disadvantages.

Where the pre-project noise environment in the affected community is clearly dominated by ground traffic noise (either from the highway to be upgraded or from other nearby roads) it is possible to employ either measurement or prediction. Where other non-traffic sources (aircraft, industrial or commercial operations, domestic activities, or natural sources) are judged to dominate or contribute significantly to overall noise levels in the community, pre-project noise levels must be established through measurement. If significant seasonal variations in ambient community noise levels are expected, emphasis should be placed on summer levels since it is then, with windows being open and more time being spent outdoors, that residents are typically most sensitive to traffic noise impacts. This increased outdoor activity also tends to elevate ambient community noise levels.

TN 1.3 Pre-Project Noise Measurements

Pre-project noise measurements should, where possible, involve continuous, 24-hour monitoring for one or more days, depending on the anticipated variability of the noise environment, and should yield the 24-hour equivalent sound level, or $L_{eq}(24)$. Measurement locations should be selected to adequately represent the range of potential noise impact situations throughout the affected community.

Measurements should, if possible, be made at ground floor level (1.5 m above ground) in utilized outdoor spaces directly associated with the residence(s) of concern. Measurement positions should be selected so as to be representative of the facade of the residence which will be most directly impacted by the highway project, but should not be less than 3 m from any building facade or other large, sound-reflecting surface.

TN 1.4 Establishing Highway Noise Levels Inside Classrooms

Traffic noise levels within classrooms can be predicted based on measured or projected exterior levels after accounting for the estimated noise reduction provided by the school's facade. Alternatively, and preferably, interior noise levels can be measured directly provided other sources of interior noise are adequately suppressed. Such measurements should be carried out on a warm day during peak traffic hours, with windows open or closed as would be the usual practice and ideally with the room occupied as usual but with the students engaged in reading or some other quiet activity. Simultaneous measurement of traffic noise levels just outside the classroom would permit the noise reduction of the facade to be directly evaluated for use in predicting post-project interior noise levels.

TN 2 Predicting Post-Project Noise Levels

TN 2.1 Definition of Post-Project

In assessing the need for highway noise impact mitigation, two distinct post-project time frames should be considered for new or upgraded highways:

1. ***Opening Day (year one):***

Prediction of project noise levels on opening day (year one) allows the accuracy of the highway noise model to be assessed (through comparison with follow-up measurements) and adjusted as necessary to account for local ground cover and/or terrain conditions.

2. ***Ten Years After Completion:***

Future highway noise levels are based on traffic projections which are in turn based on general economic and population growth projections. More confidence can therefore be placed in noise levels predicted ten years in the future than in the project design year (20 to 25 years on). ***The need for mitigation at the time of construction should then be based on projected noise levels ten years after project completion.***

While traffic volumes will likely continue to grow between the tenth and 20th/25th years, the effects of this growth on overall noise levels would be expected to be minor. At the outside this noise increase could be 2 to 3 dB for a 5% compounded annual traffic volume increase. However, as the highway approaches capacity and the Level of Service (LOS) begins to deteriorate from B or C to D and E, the associated reduction in average vehicle speed produces an offsetting decrease in overall noise output from the traffic stream - about 1 dB at LOS D and 2 to 3 dB at LOS E. (See Section TN 2.2)

TN 2.2 Traffic Parameters for use in Predicting Post-Project Noise Levels

Highway noise $L_{eq}(24)$'s increase slowly with total traffic volume but relatively sharply with average vehicle speed. Therefore, as long as a highway continues to operate under free-flowing conditions, noise levels will steadily, if gradually, increase over time as traffic volumes grow. Eventually further increases in volume will result in reductions in average speed - the Level of Service (LOS) will be degraded and average noise levels will tend to decrease. Highest noise levels are typically reached when the highway is operating at LOS B/C. Therefore *if projected traffic volumes indicate that a highway will be operating at LOS D or worse, noise levels should not be assumed to continue to rise above those reached at LOS B/C.*

Post-project highway noise levels should be based on the following traffic parameters:

- Projected summer average daily traffic (SADT) volumes - if not available use annual (AADT),
- Posted Speed Limits - assuming freely-flowing traffic,
- Recent directional vehicle classification data for the highway in question where available - particularly heavy truck percentages.
- the most current and accurate motor vehicle noise data base to incorporate any trends in vehicle noise emissions resulting from technological changes.

TN 2.3 Highway Noise Prediction Models

The highway noise model used in the application of this policy should be appropriate for the complexity of the highway project under consideration and the use to which the projected noise levels are to be put:

- For the preliminary assessment of noise impacts from simple, essentially straight highways or the comparison of alternatives prior to detailed analysis and mitigation design, the manual model contained in the Canada Mortgage and Housing Corporation's *"Road and Rail Noise: Effects on Housing"* (Ref. 1) will often be adequate.
- For the analysis of complex highway configurations such as interchanges or depressed highways, or where extensive mitigation works are likely to be involved, the U.S. Federal Highways Administration's *STAMINA 2.0 Highway Noise Prediction Model* (Ref. 2), or an equivalent, validated three-dimensional computer model, should be used.
- For roadways of intermediate complexity or where mitigation is considered likely, but only along an essentially straight and level road, a simplified version of STAMINA 2.0 developed by Ontario MTC and known as *ORNAMENT*, may be appropriate (Ref. 3).

All of the above highway noise models assume freely-flowing traffic. Where traffic will not be free-flowing, such as at a signalized intersection, appropriate interrupted flow or "stop and go" corrections should be applied. A recent, rigorous assessment of these effects is to be found in *NCHRP Report 311, "Predicting Stop and Go Traffic Noise Levels"* (Ref. 4).

TN 2.4 Adjustment of Post-Project Noise Levels for the Presence of On-going Ambient Noise Sources

When pre-project, or ambient, noise levels in a community are controlled by a noise source or sources which will continue operating after project completion (i.e., the source, say local street traffic or a factory, will not be replaced or displaced by the highway project) and are within 10 dB of post-project noise levels due to the new/upgraded highway, *then these ambient levels should be combined (logarithmically) with the project noise levels to obtain the overall post-project noise levels in the community.* If this is not done, post-project noise levels and projected related noise levels increases will be underestimated. For example, at a given residential location, traffic on an existing urban arterial creates an $L_{eq}(24)$ of 56 dB, while a new highway to be built nearby is projected to create 59 dB at the same location. Without combining the ambient arterial and future highway noise levels, the post project noise level would be taken as 59 dB and the associated increase in noise as 3 dB (59 dB - 56 dB). When the arterial (56 dB) and highway (59 dB) noise levels are combined logarithmically, the post-project noise level to be compared to policy criteria becomes 61 dB and the associated $L_{eq}(24)$ increase would become 5 dB (61 dB - 56 dB).

TN 3 Follow-Up Monitoring and Verification

TN 3.1 Verification of Projected Noise Levels

For new highways and major upgrading projects, follow-up noise monitoring in noise sensitive areas (where possible at the same locations used for pre-project ambient noise monitoring) should be conducted during the first year after project completion to verify the accuracy of the opening-day noise level projections. This is particularly important where the projected "ten-year after" noise levels were not mitigable but were within 2 or 3 dB of being so. Any significant discrepancy found in opening day noise levels would then be applied to the ten-year levels to determine whether mitigation is in fact warranted.

TN 3.2 Evaluation of Mitigation Performance

Where mitigation has been carried out in conjunction with a highway construction project, follow-up monitoring should be carried out to evaluate its effectiveness and to assess the accuracy with which the mitigation effects were modelled. This will provide field-rated performance results for the noise barrier products and configurations used and so aid in the development of realistic noise mitigation expectations for future projects.

REFERENCES

1. Road and Rail Noise: Effects on Housing, Canada Mortgage and Housing Corporation, NHA 5156 08/86.
2. Noise Barrier Cost Reduction Procedure STAMINA 2.0/OPTIMA: User 's Manual, U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-DP-58-1, April, 1982.
3. ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation, Technical Document, Noise Assessment and Systems Support Approvals Branch, Ministry of the Environment, October, 1989.
4. Predicting Stop and Go Traffic Noise Levels, National Cooperative Research Program Report No. 311, U.S. Transportation Research Board, 1989.

GLOSSARY

Avoidance	The design and location of a highway so as to minimize to the potential for creation of noise impacts on adjacent sensitive areas.
dB	The abbreviation for "decibel", which is the unit for measuring Sound Pressure Level, or noise.
dBA	The abbreviation for "A-weighted decibel", which is the unit for measuring Sounds Pressure Level when an "A-weighting" is used to approximate the frequency response of the human ear to sound.
Design Year	The year in which a new or upgraded highway is expected to reach its design capacity, generally 20 to 25 years after project completion.
L_{eq}	The abbreviation for "equivalent sound level" or equivalent continuous noise level; i.e., that <u>continuous, steady</u> noise level which over a given time period, would result in the same sound energy exposure as would the actual <u>time-varying</u> community noise level.
$L_{eq}(1 \text{ hour})$	The equivalent continuous noise level during any 1 hour period; when applied to the highway noise exposure of educational facilities, the hour should be between 8:30 am and 3:30 pm.
$L_{eq}(24)$	The equivalent continuous noise level over a 24-hour period; used for measurement of noise exposures at residences and prediction of highway noise exposures.
L_n	The abbreviation for "Exceedance Level", i.e., that noise level which is exceeded for "n" percent of a given monitoring or prediction period.
L_{10}	That noise level which is exceeded for 10% of the measurement or prediction time period - a reasonable representation of the peaks noise levels associated with heavy truck pass-bys on a busy highway.
LOS	Abbreviation for "Level of Service", which is a six-point scale (from A to F) traffic mobility scale indicative of average maintainable speed and freedom to change lanes. At LOS A, traffic is totally free-flowing while at LOS F, it is approaching stall or "jam" conditions.
Mitigation	The reduction of potential highway noise impacts through the construction of roadside noise barriers, or , potentially at schools, the enhancement of the sound insulating capabilities of buildings.

APPENDIX A

THE NATURE OF HIGHWAY NOISE IMPACTS

A.1 *General*

Since noise is an unavoidable by-product of virtually all mechanized forms of transportation, all urban dwellers, and even most residents of rural areas, are routinely exposed to a certain level of intrusive noise from motor vehicles and aircraft. However, when community noise levels from these and other sources become high enough, or when a new or modified noise source causes a large increase in noise levels, negative health and welfare effects can occur. These negative effects of intrusive noise can be grouped into two broad categories:

A.2 *Land Use Incompatibility/Activity Interference*

The noise-sensitive land uses of primary concern here are residential and educational. When highway noise reaches certain levels (variously considered to be a 24-hour equivalent sound level, or $L_{eq}(24)$, of from 55 to 65 dBA), land is no longer considered to be fully compatible with residential use - for residences as normally configured and constructed. In the case of educational facilities, the acceptable noise level outdoors depends on the degree of sound insulation provided by the building's facade, but could range from approximately 60 to 75 dB. Highway noise at these levels can begin to significantly interfere with essential activities. For residents, this primarily relates to speech interference outdoors and sleep disturbance, while in schools, speech interference and attention distraction are the main impacts of intrusive noise. The resulting negative effects on the health and welfare of residents and on communication in schools increase steadily with noise level above these thresholds.

A.3 *Environmental Degradation/Annoyance*

When a new source of intrusive noise increases overall community noise levels, but not to the point of incompatibility with residential land use, environmental degradation is considered to occur. If the increase is substantial enough, this degradation of the quality of life in the community can be expected to produce widespread annoyance and negative public reaction. The degree of negative reaction to be expected for a given level of intrusive noise depends on the ambient noise levels in the community, the prior experience of residents with the particular noise and their attitudes towards the noise-maker. However, it is generally observed that, for noises, such traffic noise, which have neither adverse frequency content (tonality) nor an impulsive nature, the threshold for observed negative responses is about 5 dB and that a concerted reaction can be expected when the increase in overall community noise level approaches 10 dBA. A 10 dBA increase corresponds approximately to a doubling of perceived loudness or noisiness.

APPENDIX B

HIGHWAY TRAFFIC NOISE LEVELS AND NOISE LEVEL INCREASES

B.1 Impressions of Various Levels of Highway Noise

The following will assist those not familiar with highway noise measurement and the decibel scale of noise intensity to better appreciate subjectively what the noise levels and criteria discussed herein represent. The measure of community noise used throughout is the 24-hour equivalent sound level or L_{eq} (24). This is a single number descriptor representing that steady noise level (expressed in A-weighted decibels or dBA) which would result in the same sound energy exposure as the actual time-varying community sound level. It has been shown to correlate well with subjective impressions of, and public reactions to intrusive noise from a variety of sources and over the wide range of intensities encountered in the community.

- 30 - 40 dBA - ambient noise level range in a rural area far from main roads, or a quiet living room,
- 50 dBA - ambient noise level in a typical suburban area away from main roads, or, a general office.
- 55 dBA - ambient noise level in a typical urban residential area, not directly on main road: the CMHC's threshold for noise concerns.
- 60 dBA - noisy urban area (30 m from centreline of a busy street carrying 10,000 vpd), or, about 70 m from centreline of 30,000 vpd highway,
- 65 dBA - very noisy urban area, or, about 35 m from centreline of 30,000 vpd highway,
- 70 dBA - about 15 m from centreline of a 30,000 vpd highway, or about 6 m from the edge of pavement.

B.2 Impressions of Noise Level Increases

The following are indicative of the of increases in average community noise levels that might result from the upgrading or new construction of a highway and the community responses that might typically be expected to them:

- 5 dBA - about a 40% increase in subjective loudness; the "threshold" of significant change and possible negative reaction (at moderate ambient levels),
- 10 dBA - about a 100% increase in subjective loudness; a "substantial" increase which is likely to produce a significant negative public reaction,
- 15 dBA - about a 140% increase in subjective loudness or noisiness; a "major" increase which would likely result in concerted community demands for mitigation.

APPENDIX C

THREE APPROACHES TO HIGHWAY NOISE CONTROL

C.1 General

The reduction of community exposure to any intrusive noise can be approached in three ways:

- control at the noise source(s),
- control along the noise path(s), and
- control at the noise receiver(s) - residences, schools.

C.2 Highway Noise Control at the Source

The noise to which a community near a highway is exposed is the aggregate of the noise produced by each individual vehicle using that highway. Reduction of highway noise would then ideally be focused on the reduction of the noise emitted by each vehicle. Transport Canada regulations limit permissible noise emissions from all new passenger vehicles and trucks sold in Canada. In the past, the B.C Motor Vehicles Branch identified vehicles with excessively-noisy engines or exhausts through noise tests done in conjunction with regular vehicle safety inspections at the Branch's testing stations in Vancouver, Victoria and Nanaimo.

At highway speeds, the dominant source of noise from both passenger vehicles and heavy trucks in good running condition is the interaction of their tires with the roadway surface. Much effort has gone into reducing the noise produced by passenger vehicle and truck tires and it is unlikely that further substantial reductions will be achieved. The scope for reducing overall highway noise levels at the source is therefore limited to the following:

- use of pavements, such as open-graded asphalt, which, due to their surface characteristics, are inherently quieter (by up to about 3 dB) than standard asphalt or concrete surfaces,
- the control of vehicle speed - tire noise being a strong function of speed,
- the limitation of highway gradient - heavy truck noise in particular increases with grade,
- the prohibition of heavy truck from sensitive routes, particularly at night.

Some of the above measures (local speed reductions and truck prohibitions) would generally not be feasible given the MoTH's mandate to provide for the safe and efficient movement of people and goods on the provincial highway system. Achievement of minimum gradients (6% or less on freeways and expressways) is always a key objective of highway route selection. The use of "quiet" pavements may be considered for use in situations where roadside barriers are not feasible.

C.3 Control Along the Noise Path

Along its path from source (traffic) to receiver (residences or school), highway noise can be attenuated in various ways:

- by increasing the length of the path (i.e. setback distance from highway to residences),
- by adjusting the highway's vertical and horizontal alignments so that cut tops, fill shoulders or natural terrain features provide noise shielding for adjacent sensitive areas,
- by erecting walls, earth berms or combinations thereof within the highway right-of-way to provide noise shielding for adjacent residences or schools.

The first two of these path treatment types can be considered to constitute noise impact "**avoidance**" through appropriate highway location and design. The third constitutes active "**mitigation**" since these elements would be purposefully built to limit the spread of noise from the highway. The potential of both noise control techniques should be assessed for each highway project. Avoidance and mitigation techniques should then be employed, individually or in combination, so as to achieve the required traffic noise reductions in a manner which is both cost-effective and compatible with the visual character of community.

C.4 Control at the Noise Receiver

In situations where the noise receivers are few and/or widely spaced or where they overlook the highway (as from a hillside or the upper floors of a school building), it will often not be cost-effective or even possible to mitigate their noise impacts with roadside noise barriers. Here mitigation at the noise receiver - through the construction of a barrier close to the receiver and/or the acoustical upgrading of the building facades (windows and doors) - can be more effective. However, for jurisdictional and practical administrative reasons, noise mitigation outside the highway right-of-way is, with the exception of schools and, in some cases, other institutional buildings, not permitted under the noise policies of the MoTH and most other highway agencies.