Traffic Noise Analysis Guidance Manual

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NEBRASKA

Good Life. Great Journey.

DEPARTMENT OF TRANSPORTATION

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Acronyms and Terms

Acronym or Term	Definition
Acoustic Feasibility	NDOT has established that a minimum of 60 percent of front-row impacted receptors directly behind the noise barrier (noise barrier must extend entirely across impacted receptor's property line) must achieve a 5 dB(A) noise reduction for noise abatement to be feasible.
Benefited Receptor	The recipient of an abatement measure that receives a noise reduction at or above the minimum threshold of 5 dB(A).
CFR	Code of Federal Regulations
dB(A)	A-weighted sound level in decibels
Date of Public Knowledge	The approval date of the Categorical Exclusion (CE), the Finding of No Significant Impact (FONSI), or the Record of Decision (ROD), defined in 23 CFR part 772
Design Year	The future year used to estimate the probable traffic volume for which a highway is designed.
Existing Noise Levels	The worst noise hour resulting from the combination of natural and mechanical sources and human activity usually present in a particular area.
Feasibility	The combination of acoustical and engineering factors considered in the evaluation of a noise abatement measure.
FHWA	Federal Highway Administration
Impacted Receptor	The recipient that has a traffic noise impact. For levels of impact determination, see Noise Abatement Criteria (NAC) Table 1.
Modeling Point	Refers to receivers and may be representative of one or more receptor.
Multi-family Dwelling	A residential structure containing more than one residence. Each residence in a multi-family dwelling will be counted as one receptor when determining impacted and benefited receptors.
NDOT	Nebraska Department of Transportation
NDOT Noise PQS	NDOT Noise Professionally Qualified Staff
NEPA	National Environmental Policy Act
Noise Abatement Criteria (NAC)	Traffic noise levels set by the FHWA to determine a traffic noise impact, or the absolute levels where abatement must be considered. Based on the land use adjacent to traffic noise, the NAC is organized by activity categories A–G each with a specific noise level that determines an impact. (See 23 CFR 772.)
Noise Analyst	Qualified person conducting the noise analysis. May be consultant or NDOT staff.
Noise Barrier	A physical obstruction that is constructed between the highway noise source and the noise sensitive receptor(s) that lowers the noise level, including standalone noise walls, noise berms (earth or other material), and combination berm/wall systems.

Acronym or Term	Definition
Noise Reduction Design Goal (Reasonable)	NDOT has established that a minimum of 50 percent of front-row benefited receptors directly behind the noise barrier (noise barrier must extend entirely across benefited receptor's property line) must achieve a 7 dB(A) noise reduction for noise abatement to be reasonable.
Noise Study Area (NSA)	A group or grouping of receptors into common areas of similar noise influences throughout the entire project limits.
Permitted	A definite commitment to develop land with an approved specific design of land use activities as evidenced by the issuance of a building permit.
Property Owner	An individual or group of individuals that holds a title, deed, or other legal documentation of ownership of a property or a residence.
Reasonableness	The combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure.
Receptor	A discrete or representative location of a noise sensitive area(s), for any of the land uses listed in the NAC table contained in the attachment to the NDOT Noise Analysis and Abatement Policy.
Residence	A single-family dwelling or a unit in a multi-family dwelling.
ROW	right-of-way
Traffic Noise Impacts	Design year build condition noise levels that approach or exceed the NAC listed in the attachment to the NDOT Noise Analysis and Abatement Policy for the future build condition; or design year build condition noise levels that create a substantial noise increase over existing noise levels. For reporting purposes, all noise levels should be rounded to the nearest whole number.
TNM	Traffic Noise Model

Acronym or Term	Definition
Type I Project	FHWA regulations (23 CFR 772.5) defines a Type I Project as: (1) The construction of a highway on new location; or, (2) The physical alteration of an existing highway where there is either: (i) Substantial Horizontal Alteration. A project that halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or, (ii) Substantial Vertical Alteration. A project that removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or, (3) The addition of a through-traffic lane(s), including the addition of a through-traffic lane that functions as a HOV lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or, (4) The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or (5) The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange; or, (6) Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or, (7) The addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot, or toll plaza. (8) If a project is determined to be a Type I Project under this definition then the entire project area as defined in the environmental document is a Type I Project.

1. Introduction

1.1 Purpose

This guidance manual describes the Nebraska Department of Transportation (NDOT) program to implement 23 Code of Federal Regulations (CFR) 772. Where the Federal Highway Administration (FHWA) has given NDOT flexibility in implementing the standard, this manual describes the NDOT approach to such implementation. As a supplement to the NDOT Noise Analysis and Abatement Policy, the purpose of this guidance manual is to provide technical information and procedures to assist consultants, local public agencies, and others in conducting noise analysis for NDOT projects.

This guidance manual was developed by NDOT and reviewed and concurred with by FHWA.

1.2 References and Resources

The following reference materials provide useful information both on the regulatory requirements at the state and federal levels as well as best practices for using the FHWA Traffic Noise Model (TNM). It should be noted that new guidance documents are occasionally issued by FHWA, and it is recommended that noise analysts check the FHWA's website frequently to ensure they have the latest information. This list is not inclusive of all guidance and should only be used as a starting point if additional guidance is necessary.

- Highway Traffic Noise: Analysis and Abatement Guidance, FHWA-HEP-10-025 December 2011
- The Audible Landscape: A Manual for Highway Noise and Land Use, FHWA, November 1974
- Entering the Quiet Zone: Noise Compatibility Land Use Planning, FHWA, May 2002
- Construction Noise Handbook, FHWA-HEP-06-015, August 2006
- Measurement of Highway Related Noise, FHWA, May 1996
- NDOT Noise Analysis and Abatement Policy, NDOT, 2018

Project-specific questions that arise during development of a noise analysis should be directed to the NDOT Noise Professionally Qualified Staff (PQS).

1.3 Applicability and Limitations

As noted in the NDOT Noise Analysis and Abatement Policy, this guidance manual applies uniformly and consistently to all Type I federal highway projects in Nebraska, including federal projects that are administered by local public agencies as well as NDOT. If there are any questions about whether a project is subject to the NDOT Noise Analysis and Abatement Policy or FHWA Noise Standards (23 CFR 772.3), contact the NDOT Noise PQS.

This guidance manual is not intended to provide a detailed instruction on the use of the FHWA TNM software or the fundamentals of noise nor is it intended to discuss in detail every scenario that may be encountered during a typical traffic noise analysis. NDOT expects that noise analysts use professional judgement and best practices when conducting a noise analysis on NDOT projects and coordinate with the NDOT Noise PQS when necessary.

It should also be noted that some topics discussed in the NDOT Noise Analysis and Abatement Policy (i.e., construction noise and viewpoints of property owners and renters) are covered in sufficient detail in the policy and therefore do not require additional discussion in this guidance manual.

1.4 Required Qualifications for Noise Analysts

Only qualified individuals may conduct a traffic noise analysis for NDOT transportation projects. To be considered qualified, staff must not only have successfully completed the required trainings but also have experience conducting transportation noise analysis and the demonstrated ability to apply professional judgment when necessary. Specific training and experience requirements are listed on NDOT's website http://dot.nebraska.gov/media/6077/cert-instruc-nepa-studies.pdf and are listed below for reference.

- Certificate(s) of training from a noise modeling course. Training must include TNM 2.5 (or a later version of TNM), and the firm must possess the software to run the model.
- Demonstrated experience completing U.S. Department of Transportation and/or NDOT-approved noise studies on transportation projects.

It should be noted that these requirements apply to the noise analysts and senior reviewers completing the work and are not intended as general requirements of consulting firms. Similarly, NDOT expects that consultants use a sufficient quality assurance/quality control process throughout the duration of the noise analysis to ensure quality and adherence to NDOT's standards. NDOT reserves the right to remove those individuals from the approved list of persons qualified to perform highway traffic noise analyses when deemed appropriate.

2. Traffic Noise Prediction

2.1 Worst Noise Hour

Highway traffic noise analyses should begin by determining the worst hourly noise level resulting from the combination of natural and mechanical sources and human activity usually present in an area. The worst noise hour is generally defined as the loudest noise condition and typically occurs when the highest volume of traffic is traveling at the highest possible speed. For simplicity, this often occurs during a Level of Service of C or D. NDOT typically uses Design Hourly Volume as the worst noise hour unless traffic conditions are congested. The traffic characteristics should be adequately discussed to determine the worst-case highway traffic noise hour(s). To help facilitate this, hourly traffic volume, speed, and vehicle mix (i.e., autos, medium trucks, heavy trucks) data shall be prepared using acceptable engineering practices to the extent such data are available. There are several alternative techniques to help determine the worst noise hour for projects where traffic congestion prohibits the use of peak-hour data, including the following strategies:

1. Evaluation of Peak and Off-Peak Traffic Data: The peak traffic hour may coincide with the worst noise hour of the day. However, on occasion, conditions such as capacity or higher than normal off-peak truck percentages may cause the worst noise hour of the day to be different from the peak traffic hour. For example, peak-hour congestion on major commuter routes, which lowers vehicle speeds and noise levels, may shift the worst noise hour to an off-peak traffic period.
2. 24-Hour Monitoring Sites with Evaluation of Diurnal Traffic Patterns: If there is some question as to the worst noise hour, it may be necessary to conduct 24-hour monitoring to determine the worst noise hour. Note, long-term (i.e., 24-hour) monitoring is typically not necessary and requires coordination with the NDOT Noise PQS to develop a monitoring plan prior to conducting long-term monitoring.

2.2 TNM Inputs and Data Needs

The accuracy of the TNM depends on the quality of the input data and the careful replication of real-world features within the available objects in the TNM. Except for a few TNM objects, the user has a multitude of three-dimensional inputs (e.g., roadways, modeling points, existing and proposed noise barriers, terrain lines, etc.) that should be considered when developing a noise model for a project. The use of field visits, aerial photography, survey data, and digital computer-aided design and drafting software will assist the user in developing accurate and defensible noise studies. Additionally, the user must consider the traffic volume, composition, and speed for each roadway being modeled. Close coordination with the project traffic engineers is required.

For more information on the TNM inputs, refer to the TNM Users Guide, which can be found on the FHWA's website, for instructional guidance and additional information on the TNM parameters. Additionally, the FHWA's final report on the *Recommended Best Practices for the Use of the FHWA Traffic Noise Model (TNM)* should be referenced as well as the National Cooperative Highway Research Program Report 791, *Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM)*, which provides details on modeling scenarios for which there is limited or no technical guidance.

2.2.1 Traffic Data

As noted in Section 2.1, information regarding traffic volumes, speeds, and vehicle mix (i.e., autos, medium trucks, heavy trucks) are required to determine both existing year and design year (build and no-build noise levels. It should be noted that although modeling the no-build scenario is not required as part of the FHWA noise standard, it is a requirement of the National Environmental Policy Act (NEPA) for federally funded projects. Projects funded entirely with State funds may not require the no-build noise level to be modeled, but coordination with the NDOT Noise PQS is required. Typically, peak-hour or design-hour traffic volumes are used to complete a noise analysis. The directional design hour volumes (i.e., volume per hour) can be derived from the annual average daily traffic using the Directional Distribution (D) factor and the K factor (percent of annual average daily traffic during the peak hour). A 50/50 directional split can be used in the absence of more detailed traffic data. Similarly, if detailed medium and heavy truck splits are not available, the national average can be used (i.e., 72 percent heavy trucks/28 percent medium trucks). In both instances, coordination with the NDOT Noise PQS is required.

The posted speed should be used to predict highway traffic noise levels unless data suggests operating speeds deviate substantially from the actual posted speed.

2.2.2 Roadway Data

The horizontal and vertical roadway data can be obtained through the digital computer-aided design files including the survey, profile, and cross-section files for the project. When digitizing roadways for noise modeling, it is suggested that the analyst space the roadway data points at the station locations for more complex projects (e.g., multiple grades, tight curves, etc.). For less complex projects with little terrain or few or larger curves, the noise analyst's professional judgement can be used to determine the spacing of these data points; however, the analyst must be aware of the effect the roadway grade has on the TNM results. Therefore, TNM roadway segments should not exceed 500 feet in length. Additionally, the analyst must consider the number lanes a TNM roadway object should represent. NDOT allows one TNM roadway to represent up to three travel lanes (including the paved shoulder width). If specialized lanes such as dedicated bus lanes are part of the project, the analyst should coordinate with the NDOT Noise PQS and consider splitting these vehicles and lanes out as separate TNM roadways for more accurate results.

2.2.3 Existing Barriers and Topography

As NDOT continues to expand its current facilities, it is likely that existing noise barriers as well as safety barriers will be encountered. As such, existing noise barriers, including top and bottom elevations, should be included in the modeling effort. Conversely, median jersey barriers should not be included in the model.

Additionally, survey files, cross sections, and even field measurement data should be carefully reviewed to determine any dominant terrain features that may affect noise levels. These topographical features should be included in the TNM. If available, ground contours of 2 feet or less should be modeled.

3. Analysis of Traffic Noise Impacts

3.1 Noise Monitoring and Model Validation

3.1.1 Noise Monitoring

As noted in the NDOT Noise Analysis and Abatement Policy, all noise monitoring shall be performed in accordance with methodology presented in FHWA's *Measurement of Highway Related Noise*. Typically, three, 15-minute measurements at each field monitoring location are sufficient to gather data for validating the TNM or determining the existing noise levels for projects on a new alignment. In some instances, two readings may be sufficient if the terrain is relatively flat and noise levels are consistent. Long-term (i.e., 24-hour) monitoring is typically not necessary and requires coordination with the NDOT Noise PQS to develop a monitoring plan prior to conducting long-term monitoring.

Measurements should be taken at locations representative of the types of receptors located within the project area, such as residences, schools, churches, libraries, etc.; however, not all locations included in the TNM need to be field monitored. Concurrent traffic counts should be documented as part of the field monitoring effort by manually counting traffic on adjacent streets in addition to the roadway under study. High traffic volume roadways may require the use of video recording for counting of traffic at a later date. The counts should include the number of automobiles, medium trucks, and heavy trucks and note if traffic is generally flowing at posted speeds.

When conducting noise measurements, the analyst should take photos of the location and document any pertinent terrain features and any non-traffic noise sources that may interfere with model validation. Other site conditions that should be documented include but are not limited to time of day, number and length of measurement periods, traffic count/speed methodologies, and weather and pavement conditions and constraints. An example noise monitoring data sheet is included in the attachment to this document.

In some instances, field monitoring may be required to determine the existing noise levels. For example, projects on a new alignment may require field monitoring to establish the ambient levels due to an absence of an existing roadway network to generate noise levels. Relying on the TNM to accurately predict existing levels in this instance would likely result in very low levels that would not accurately reflect the existing noise environment. Coordination with the NDOT Noise PQS in these instances should occur prior to field monitoring.

3.1.2 Model Validation

Federal regulation [23 CFR 772.11(d)(2)] requires validation of the traffic noise model to verify the accuracy of noise models used to predict the existing and future year noise levels for a project. To validate the noise model created for the proposed project, noise levels monitored in the field shall be compared to the FHWA TNM noise level predictions for the traffic conditions observed during the monitoring period. For model validation purposes, modeled and field-measured noise levels will be reported to the 10^{th} of a decibel.

Specifically, traffic data (volumes, composition, and speed) collected during the noise monitoring should be input into the existing model and run to make the comparison. In general, noise monitoring results should be within +/-3 A-weighted decibels [dB(A)] of the TNM-generated results for the model to be considered validated. If results are outside this range, the noise analyst should verify that the model inputs accurately reflect the data collected during field monitoring and review the monitoring data for potential non-traffic noise sources that may have affected the measured noise levels. Typically, adjustment factors should not be used to account for the discrepancy in the model validation. It should be noted, however, that in some instances adjustment factors may be required. For example, if the pavement condition along a roadway is sufficiently deteriorated and is causing higher than normal tire noise, adjustment factors may be applied to the model results but require prior approval from the NDOT Noise PQS. Other factors to consider within the TNM include adjustments to ground cover, building rows, ground zones, or terrain lines. All these have the potential to affect noise that may need to be accounted for in TNM.

If the monitored results are still not within 3 dB(A) of the computer-generated results, the analyst shall document the reason for the discrepancy in the traffic noise report, and, in some instances, may need to conduct additional monitoring at the locations of concern in coordination with the NDOT Noise PQS.

To ensure model validation is documented accurately, the noise report must contain the monitored and modeled noise level for each noise monitoring location in table format, with reported differences in noise level between the monitored and modeled values reported to the nearest tenth of a decibel to avoid rounding errors. In addition, if adjustment factors were used in the validation of the model (with prior coordination with the NDOT Noise PQS) they should also be included in the table.

3.2 Noise Study Area

The limits of the area included in a noise analysis are determined based not only on the extent of project improvements but also on the adjacent development and land use and must include all areas to be affected by project activities.

Specifically, the length of the study area should generally be consistent with the logical termini used for the overall environmental analysis of the project. However, in some instances the limits may need to be extended to allow for a comprehensive analysis. For example, project limits in an urban setting may need to be extended if the proposed improvements terminate in the middle of a housing row as shown in Figure 3-1. In these instances, the study area should be extended to the end of the housing row for continuity. Conversely, it may be sufficient to rely on logical termini for interstate projects located in sparsely populated rural areas, and, as such, no extended study area would be necessary.

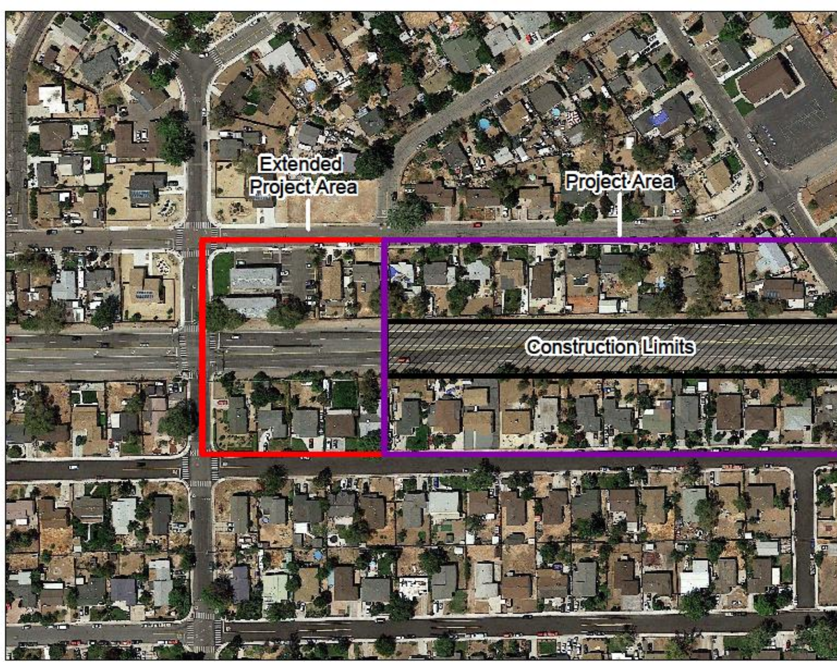

Figure 3-1. Noise Study Area

In addition, as noted in the NDOT Noise Policy, the minimum distance to look for receptors will extend at least 300 feet radius from the edge of pavement. If an impact is identified at 300 feet, the modeling area must be extended until a distance where impacted receptors are no longer identified is reached. Additionally, the noise modeling area must also account for any receptors that may be benefitted from any evaluated noise abatement measures. If no receptors are located within 300 feet, place a receptor at 300 feet. If impacts are found, the modeling area will be extended until impacts are no longer identified.

NDOT is required to identify all expected highway traffic noise impacts from the project. In cases where the roadway is on fill, the analysis area may need to be extended to ensure that all impacts are identified.

3.3 Modeling Point Placement

3.3.1 Activity Category A

As noted in the NDOT Noise Analysis and Abatement Policy, Activity Category A lands require prior coordination with the NDOT PQS before being included in the noise analysis. Designating a land use as Category A ultimately requires approval from FHWA.

3.3.2 Activity Category B

Modeling point placement for single-family residential uses should occur in an area of frequent use and face the noise source to represent the worst-case noise condition. In addition, modeling points must be within 20 feet of the dwelling unit regardless of whether there are structures such as pools, swing sets, etc., located in other areas of the yard that may be closer to the noise source.

For example, Figure 3-2a shows modeling point placement both in backyards and side yards depending on the location of the noise source and location of frequent human use. Similarly, Figure 3-2b shows modeling point placement at the front of

Figure 3-2a. Residential Example (Back and Side yards)

Figure 3-2b. Residential Example (Front yards)

the residences to reflect the noise source occurring to the front of the noise sensitive land use.

In the case of multi-family dwellings such as duplexes, townhomes, etc., each dwelling unit will be counted as a receptor, and several receptors may be represented by a single modeling point. Modeling point placement should be consistent with that described above for single-family residences. Regarding apartment buildings, modeling points should be placed on every floor that contains balconies until impacts are no longer predicted. It should be noted, however, that unique situations will require coordination with the NDOT Noise PQS to identify modeling point placement.

3.3.3 Activity Category C

Modeling point placement for Activity Category C uses such as schools, parks, cemeteries, etc., will be based upon the average density of the adjacent Activity Category B developments within the project limits. Specifically, the Activity Category C use will be divided into similarly sized segments as the adjacent Activity Category B development for purposes of determining the number of receptors. The receptor locations represented by modeling points will be areas of frequent human use within 600 feet of the edge of the roadway. If impacts occur farther than 600 feet from the roadway, the study area will extend to include the farthest impacted receptor. The area of frequent human use that is the most noise sensitive will be chosen first as a modeling point, followed by the next most noise sensitive area of frequent human use. This process will continue until all the modeling points have been placed. Doubling of modeling points will be used if there are fewer areas of frequent human use than the number of receptors needed by the frontage calculation. The doubling of modeling points will follow the order in which the modeling points were initially placed, with the most noise sensitive area being doubled first, never tripling modeling points before all points have been doubled.

In the example shown below in Figure 3-3, the average residential lot frontage of the homes adjacent to the park is 100 feet, and the park has a frontage of 700 feet. In this case, a total of 7 receptors would be analyzed in the park. Modeling points will be placed at areas of frequent human use (e.g., picnic tables, playground equipment, bleachers at baseball diamonds and soccer fields, etc.) and will be located in the area that best represents the worst-expected traffic noise condition as to prevent shielding by objects or buildings.

Figure 3-3. Park Example

With regard to trails, any recreational trail fully contained within the park such as a scenic route or bike/jogging trail that is a feature of the park will be analyzed. However, sidewalks and pathways serving a transportation purpose by connecting areas of frequent human use within the Activity Category C property are excluded and will receive zero receptors. A recreational trail that passes through (enters and exits) the park is considered a separate Section 4(f) property and may undergo additional analysis to determine whether a constructive use occurs (23 CFR 774.15). Any preliminary findings that suggest a Section 4(f) constructive use may occur would trigger consultation with FHWA Nebraska Division as well as FHWA Headquarters prior to FHWA making a formal determination. If an alignment shift or new roadway brings a new noise source to the area then consultation with NDOT is required.

As shown in Figure 3-3, trails fully contained within the park area (only applies to trails within Category C properties) will be represented by three receptors. Two modeling points will be placed near the ends of the trail and the third will be placed near the middle of the trail. For trails that wind away from the roadway, the farthest modeling point on the trail will be placed 600 feet from the roadway or the distance of the farthest impacted area of frequent human use along the trail. The remaining modeling points for the activity category will be in other areas of frequent human use within the limits to be studied, as noted above.

If no areas of frequent use are distinguishable (such as open park land or cemeteries without benches, playground, etc.), a grid system will be used to determine modeling point placement.

Figure 3-4. Cemetery Example

In the example shown in Figure 3-4, the average residential lot frontage of the homes adjacent to the cemetery is 75 feet, and the cemetery has a frontage of 700 feet. Consistent with the methodology for determining the number of receptors in the park shown in Figure 3-3, a total of nine receptors would be analyzed in the cemetery. In this example, the cemetery does not contain areas of frequent use such as benches and other gathering areas so a grid system will be required to determine modeling point placement.

The cemetery would be divided into two rows, with each row consistent with the depth of the adjacent lots and modeling points placed accordingly. In this example, the nine modeling points were distributed between the first and second rows at a setback distance from the roadway similar to the adjacent Activity Category B uses.

3.3.4 Activity Category D

As noted in the NDOT Noise Analysis and Abatement Policy, an indoor analysis will only be done after exhausting all outdoor analysis options. An indoor analysis also requires advance coordination with NDOT.

3.3.5 Activity Category E

The number of receptors analyzed in this category will be based upon the length of the property frontage adjacent to the roadway. Specifically, for every 200 feet of frontage that an Activity Category E occupies, a modeling point will be analyzed at a place of frequent human use. For example, an Activity Category E development with a frontage width of 1000 feet would analyze five modeling points representing receptors at areas of frequent human use.

3.3.6 Activity Category F

As noted in the NDOT Noise Analysis and Abatement Policy, no highway noise analysis is required for Activity Category F.

3.3.7 Activity Category G

Land that is permitted for development (that is, a building permit has been issued on or before the date of public knowledge), modeling point placement should be consistent with the Activity Category for that type of development.

For land that is not permitted for development by the date of public knowledge, the highway agency will determine future noise levels pursuant to 23 CFR 772.17(a). The results will be documented in the project environmental documentation and in the noise analysis report. At a minimum, the analysis should report the distance measured from the proposed edge of the traveled way to the noise abatement criteria (NAC) for all exterior land use categories. Any noise abatement for such lands will not be eligible for federal-aid participation. Refer to Chapter 5, Information for Local Officials, for further guidance on determining noise levels on undeveloped lands.

4. Analysis of Noise Abatement Measures

4.1 Noise Barriers

As noted in the NDOT Noise Analysis and Abatement Policy, the most common type of noise barrier implemented by NDOT is noise walls. Although earthen berms are allowed with prior approval by NDOT and are typically more cost effective than walls if sufficient space is available, noise walls are oftentimes the most suitable measure due to space constraints, availability of materials, etc.

4.1.1 Placement

In general terms barriers are considered most effective when blocking the "line of sight", but also must be placed in close proximity to either the noise source or receptor for optimal performance. Typically, on transportation projects, noise barriers are placed near the source (roadway) which in most cases is near the right-of-way (ROW) boundary as shown in Figure 4-1. Locating barriers near the ROW boundary also helps maintain clear zones and alleviates drainage concerns. However, in some instances, placement along the edge of shoulder may be required to adequately break the line of sight as described below.

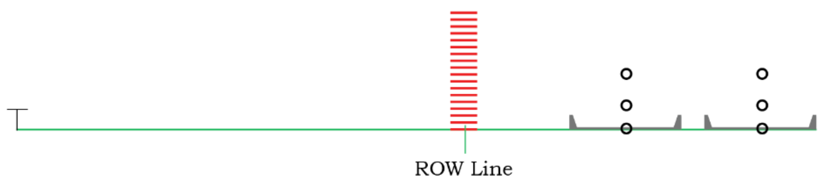

Figure 4-1. Noise Barrier Placement near ROW Line

Figure 4-2 illustrates a typical scenario in which the noise receptor is located at a much lower elevation than the roadway. In this instance, placing a shorter noise barrier along the edge of shoulder would be much more effective in blocking the line of site than a taller barrier placed along the ROW line.

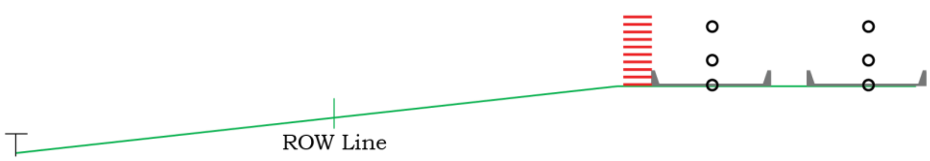

Figure 4-2. Noise Barrier Placement Along Edge of Shoulder

Another factor when considering placement of noise barriers, in addition to changes in elevation between the source and receptor, is proximity. In addition to breaking the line of sight, barrier effectiveness improves in relation to how closely it can be placed to either feature. Typically, the ROW boundary is adjacent to nearby homes, etc. but in some instances, such as that depicted in Figure 4-2, the ROW boundary may be located at a midpoint between noise sensitive land uses and the roadway rendering barrier placement along the ROW boundary ineffective when compared to placement along the edge of shoulder.

As with other aspects of conducting a noise analysis, professional judgement should be used when evaluating barrier placement, and several iterations may be required to determine the most effective scenario. Although not required to be discussed in detail, the noise technical report should provide sufficient documentation of these iterations to justify barrier placement.

4.1.2 Optimization

Although the goal of a noise abatement analysis is to achieve a design that meets the feasibility and reasonableness criteria established by NDOT, benefitting every impacted noise sensitive receptor is not always possible. As a result, the noise analysis should strive to determine the most cost-effective scenario that satisfies the feasibility and reasonableness criteria while protecting as many receptors as possible.

The relationship between noise barrier cost and performance is non-linear. Noise reductions typically increase with increased barrier height and/or length; however, at some point, further increases in barrier height and/or length result in smaller and smaller increases in reductions until a point of diminishing returns is reached. A point can be identified where a potential noise barrier provides the best balance between cost and benefit.

To achieve the most cost-effective scenario, a barrier with varying heights is often required as opposed to simply evaluating a continuous height along the length of the barrier. Transitions in height along the length of the barrier should also be balanced to improve constructability. In most instances, transitions between different barrier segments should be limited to 2- to 4-foot transitions if possible.

4.2 Feasibility

4.2.1 Acoustic Feasibility

As noted in the NDOT Noise Analysis and Abatement Policy, noise abatement is considered acoustically feasible when 60 percent of the front-row impacted receptors located directly behind the noise wall achieve a minimum 5 dB(A) noise reduction.

It should be noted that although satisfying the NDOT acoustic feasibility criteria requires a minimum 5 dB(A) reduction in noise levels, there is no requirement that the resultant levels with abatement should be below the NAC. For instance, if the build noise level at a receptor location is predicted to be 76 dB(A) and the noise barrier is effective in reducing the noise levels by 5 dB(A) down to 71 dB(A), the barrier would be considered acoustically feasible. Conversely, if a noise barrier reduces the build noise level from 68 dB(A) to 65 dB(A), the barrier would not satisfy the feasibility criteria even though levels would be reduced to below the NAC.

4.2.2 Engineering Feasibility

In addition to being considered acoustically feasible, noise barriers are also required to meet the engineering feasibility criteria. This includes a consideration of both constructability and safety elements. The following items will be considered in determining engineering feasibility:

1. **Can the barrier be designed to fit the topography and existing/designed highway barriers and still be maintained?**

   Noise barrier design and placement should include consideration of potential drainage and utility conflicts as well as future maintenance requirements. Consideration should also be given to how a proposed noise barrier fits within existing safety and noise barriers that may be present within the study area. In most cases, minor design refinements are sufficient to accommodate drainage and utility requirements. However, in those rare cases where more complicated design measures are required that may result in additional construction or ROW costs, those costs may be included in the overall barrier cost-effectiveness calculation and require coordination with the NDOT Noise PQS.

In regard to maintenance concerns, noise walls need to be repaired in the event of damage or deterioration and landscaping planted near the wall may need to be maintained. As a result, placement of the noise barrier, both along the ROW line and along the edge of the shoulder, should allow sufficient space and access for maintenance activities such as mowing and barrier repair. A setback distance of 10 feet from both the roadway edge of shoulder as well as the ROW line is preferred if space allows. However, if sufficient space isn't available, a minimum 5-foot permanent easement would be required.

2. **Can the exposed height of a noise barrier be built at 25 feet high or less?**

   As noted in the NDOT Noise Analysis and Abatement Policy, NDOT has limited the maximum height for noise barriers to 25 feet. Noise barriers beyond this height are typically not cost effective and present additional structural and aesthetic considerations.

3. **Safety concerns:**

   The two primary factors to consider when evaluating a noise barrier for safety include maintaining both the clear zone and sufficient sight distance at intersections.

   A. Can the barrier be located beyond the clear recovery zone (i.e., unencumbered roadside recovery area for errant vehicles)?

Figure 4-3. Safety Barrier

A clear zone is an unobstructed area adjacent to the roadway that provides sufficient space for a driver to stop safely or regain control of a vehicle. Clear zone requirements may vary depending on the location and classification of the roadway. A noise barrier needs to be located outside the clear zone so that errant vehicles have sufficient opportunity to recover thus reducing the potential for collision with the noise wall. However, when the noise barrier cannot be placed outside the clear zone, for instance along the edge of shoulder, because of site constraints, a safety barrier such as a guardrail or Jersey barrier must be designed as part of the noise wall. (See Figure 4-3.) The noise analyst should coordinate with the project roadway design team to determine when safety barriers are necessary and to also determine what additional costs may be attributed to safety barriers required specifically for noise walls. It should be noted that if safety barriers are required at a specific location independent of a noise barrier being installed, those costs may not be included in the reasonableness determination. The cost of any such measures, required specifically to protect a noise barrier, may be included in the total cost of the noise barrier as part of the cost-effectiveness analysis to determine reasonableness as discussed in Section 4.3.2 below.

B. Does the barrier allow for sufficient sight distance at intersections?
Adequate sight distance should also be evaluated as part of the feasibility analysis to determine if a noise barrier would restrict the line of sight near intersections or other points of access such as driveways. Sight distance specific to intersections is typically defined as the distance a motorist can see approaching vehicles before their line of sight is blocked by an obstruction such as a noise barrier. (See Figure 4-4.) Poor sight distance can increase the potential for crashes at intersections as motorists are unable to see and react to approaching vehicles. As a result, a noise barrier may not be located within the intersection sight distance triangle for any approach.

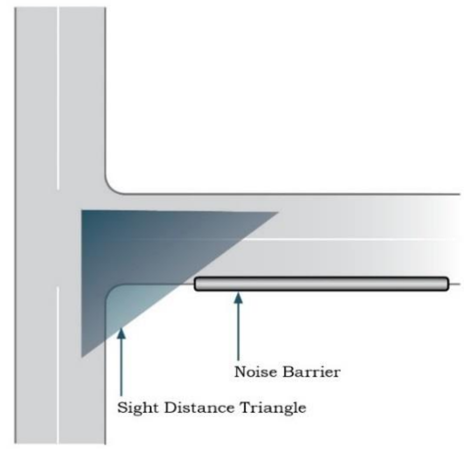

Figure 4-4. Example Sight Distance

The noise analyst should coordinate with the project roadway design team to determine if the proposed barrier maintains sufficient sight distance at intersections.

As noted in the NDOT Noise Analysis and Abatement Policy, if any of the feasibility items discussed above are checked "NO," the noise barrier will be considered not feasible, and a reasonableness analysis will not be completed. It is important that the results of both the feasibility and reasonableness analysis (if needed) be adequately documented in the noise technical report to provide sufficient justification for barrier recommendations.

4.3 Reasonableness

4.3.1 Noise Reduction Design Goal

To satisfy the NDOT noise reduction design goal, a minimum of 50 percent of benefited front-row receptors directly behind the noise barrier must achieve a 7 dB(A) noise reduction in order for noise abatement to be reasonable. Receptors can be considered benefited regardless of being impacted, although in most instances they may be both impacted and benefited.

4.3.2 Cost Effectiveness

Determining cost effectiveness as part of a barrier reasonableness evaluation includes an evaluation of unit costs, number of benefited receptors, and allowable costs per benefited receptor. The estimated build cost of each noise abatement measure may not exceed the allowable noise abatement cost based on a cost per benefited receptor comparison.

Unit Costs

As noted in the NDOT Noise Analysis and Abatement Policy, NDOT will use a unit cost of $52 per square foot (re-evaluated every 5 years) for barrier heights up to and including 16 feet based on construction price estimates for 2021. The unit cost increases by 40 percent to $73 per square foot for wall heights that exceed 16 feet up to 25 feet to account for additional structural considerations.

In some cases, a noise barrier may include segments both above and below the 16-foot threshold thereby requiring the noise analyst to use both unit costs when determining the total barrier cost.

For example, assume a barrier of 800 feet in total length is being evaluated and varies in height between 12 and 18 feet. (See Figure 4-5.)

Segment of noise barrier <16 feet -

Area: 200 feet x 12 feet = 2,400 square feet

Area: 200 feet x 14 feet = 2,800 square feet

Area: 200 feet x 16 feet = 3,200 square feet

Cost: 8,400 square feet x $52 per square foot = $436,800

Segment of noise barrier >16 feet -

Area: 200 feet x 18 feet = 3,600 square feet

Cost: 3,600 square feet x $73 per square foot = $262,800

Estimated total build cost of noise barrier = $436,800 + $262,800 = $699,600

Figure 4-5. Example Barrier

Determining Benefited Receptors

It should be noted that if representative modeling points are used in the TNM to determine impacts (no more than three receptors may be represented by a single modeling point and coordination with NDOT Noise PQS is required), additional modeling points will need to be added to the TNM as part of the barrier analysis to account for every noise sensitive receptor adjacent to the wall that may be benefited. This ensures an accurate estimate of the performance of each barrier being evaluated.

In terms of determining benefited receptors for trails contained within Activity Category C lands, if any of the receptors are impacted, the property will be analyzed for noise abatement. All receptors will be considered as "front row" for purposes of abatement, regardless of their distance from the roadway.

Allowable Cost Per Benefited Receptor

The allowable cost per benefitted receptor is determined by design year noise level and the height of the adjacent barrier. NDOT allows for adjustments based on the design year noise level as shown in Tables 4-1a and 4-1b. The average noise level of all impacted receptors adjacent to a barrier is used to determine the design year noise level. In addition, if any receptor behind a proposed barrier experiences a substantial increase in build noise levels, the allowable cost per benefitted receptor would be increased by $3,000 and would apply to all benefitted receptors behind that specific barrier where the substantial increase is experienced. Furthermore, the allowable cost per benefitted receptor will be increased if any part of the adjacent barrier is 16-25 feet in height, and the increased cost would apply to all receptors benefitted by that specific barrier (Table 4-1b). It should be noted that the adjusted allowable costs are specific to the receptors adjacent to a particular barrier and are calculated for each barrier independent of other barriers within the study area. Therefore, a study area containing four barriers may have different adjusted allowable costs for each. In addition, in some instances, breaks or gaps in a barrier may be required to facilitate drainage or allow access to a residence, etc., and would not result in each segment of the barrier being evaluated individually. Conversely, barriers on either side of a street intersection, for example, would be considered individual barriers and could not be evaluated as a single barrier.

Table 4-1a. Allowable Costs per Benefited Receptor (0-16 feet tall barrier)

Design Year Noise Level*	Allowed Cost per Benefited Receptor	Allowed Cost per Benefited Receptor with Substantial Increase**
66-67 dB(A)	$41,600	$44,600
68-69 dB(A)	$44,600	$47,600
70-71 dB(A)	$47,600	$50,600
72-73 dB(A)	$50,600	$53,600
74+ dB(A)	$53,600	$56,600

*Average noise level for all impacted receptors adjacent to a barrier.

** If any receptor behind a proposed barrier experiences a substantial increase in build noise levels, the allowable cost per benefitted receptor would be increased by $3,000 and would apply to all benefitted receptors behind that specific barrier where the substantial increase is experienced.

Table 4-1b. Allowable Costs per Benefited Receptor (16 – 25 feet tall barrier)

Design Year Noise Level*	Allowed Cost per Benefited Receptor	Allowed Cost per Benefited Receptor with Substantial Increase**
66-67 dB(A)	$58,400	$61,400
68-69 dB(A)	$61,400	$64,400
70-71 dB(A)	$64,400	$67,400
72-73 dB(A)	$67,400	$70,400
74+ dB(A)	$70,400	$73,400

*Average noise level for all impacted receptors adjacent to a barrier.

** If any receptor behind a proposed barrier experiences a substantial increase in build noise levels, the allowable cost per benefitted receptor would be increased by $3,000 and would apply to all benefitted receptors behind that specific barrier where the substantial increase is experienced.

Determining the adjusted allowed cost per benefited receptor is based on the design year noise level for all impacted receptors adjacent to a specific noise barrier and the highest point of that barrier. For example, in Figure 4-6 the average design year noise level for the four impacted receptors is 71 dB(A). As shown in Tables 4-1a and 4-1b, the corresponding adjusted allowable cost per benefited receptor is $47,600 for a barrier 0-16 feet tall or $64,400 for a barrier 16-25 feet tall, which would be the adjusted cost to be used for all benefited receptors adjacent to that noise barrier. In addition, one of the receptors also experiences a substantial increase, which raises the adjusted allowable cost per benefited receptor by $3,000, to $50,600 for a barrier 0-16 feet tall or $67,400 for a barrier 16-25 feet tall.

The estimated build cost of noise abatement per benefited receptor is determined by dividing the overall estimated build cost (square footage of the wall multiplied by the unit cost) by the number of benefited receptors. If the cost per benefited receptor is greater than the adjusted allowable cost shown in Table 4-1a or 4-1b, the abatement will be considered not reasonable.

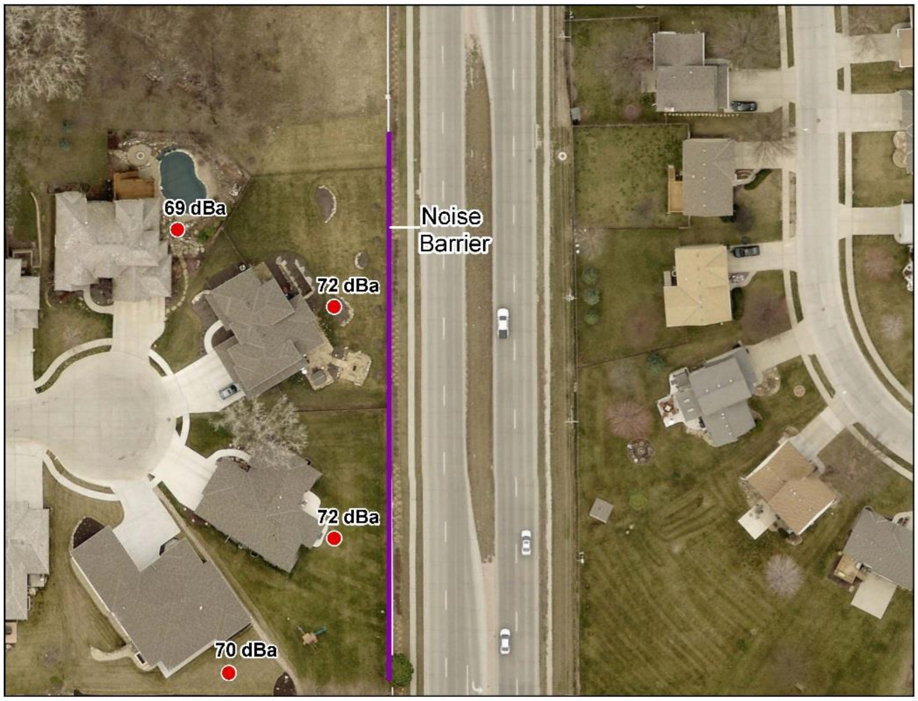

Figure 4-6. Adjusted Cost Example Barrier

To continue with the evaluation of the example barrier, the calculations below show how the reasonableness determination is made.

Estimated build cost of noise barrier = $699,600

Number of benefited receptors = 4

Cost per benefited receptor = $174,900

Adjusted <u>allowable</u> cost per benefited receptor = $50,600 / benefited receptor if the barrier is 0-16 feet tall or $67,400 / benefited receptor if the is barrier 16-25 feet tall

In this example, the cost per benefited receptor exceeds the adjusted allowable cost. As a result, this noise barrier would not be cost effective and would therefore not be recommended for further evaluation.

As noted in the NDOT Noise Analysis and Abatement Policy, the cost of utility relocation, drainage control, and ROW acquisition may be factored into the cost effectiveness of noise abatement with prior approval by NDOT. For instance, costs for ROW acquisition can be included in the overall barrier cost if the barrier must be placed outside the project ROW to satisfy the feasibility and reasonableness criteria. In addition, utility relocation and drainage costs can only be factored into the cost effectiveness if the conflicts are due to construction of noise abatement alone and not due to the project. If the noise abatement design can be modified to avoid the utility or drainage conflicts and still meet the feasibility criteria and the noise reduction design goal, these additional costs cannot be applied.

Although using aesthetic treatments on noise barriers is allowed, it cannot be factored into the cost-effectiveness evaluation. In addition, cost averaging of noise abatement (i.e., averaging several barriers together that otherwise would not meet the cost-effectiveness criteria individually) is not allowed.

4.4 Final Barrier Design

For some projects, a final barrier design may be required during the Final Design Phase of the project depending on the potential for design changes that may affect the noise analysis results. As a project progresses from Preliminary to Final Design, refinements to roadway alignments, retaining walls, slope/fill limits, etc., have the potential to alter the effectiveness of preliminary noise abatement schemes that may have been recommended as part of the approved Noise Technical Report. A final barrier design provides an opportunity to evaluate these design refinements. It should be noted, however, that not all refinements between preliminary and final design require additional noise modeling. Coordination with NDOT should occur to determine the extent of analysis required during final design.

Similar to a noise analysis conducted during the NEPA phase, a final barrier design follows a similar noise barrier analysis process with the main difference being the level of design information being used. As a result, the more advanced design data may provide additional opportunity to further refine and verify the barrier performance within the limits of the NDOT feasibility and reasonableness criteria.

The barrier runs created for the project from the approved TNM model should be used as a starting point, with any changes to alignments, etc., incorporated into the model. Additional detail not available during the original analysis should also be incorporated and may include new retaining walls, additional cut/fill slopes, ramps, etc. Similarly, the noise analyst should also verify that the land use in the project area has not changed (i.e., house converted to a commercial property). In some cases, and in coordination with the NDOT Noise PQS, the barrier segment lengths can also be subdivided into smaller segments of approximately 20 feet in length to provide greater detail and opportunity to further refine the barrier heights. Transitions in height along the length of the barrier should also be smoothed out to improve constructability. In most instances, transitions between different barrier segments should be limited to 2 to 4 feet or less if possible.

It should be noted that any revisions to traffic data should be coordinated with the NDOT Noise PQS prior to inclusion in the TNM, as such revisions may need to be evaluated in the larger context of NEPA as well. Similarly, a final barrier design does not typically include revisiting the determination of impacts unless such project changes have occurred to require a formal reevaluation of the NEPA document.

With regard to barrier materials, concrete precast panels are preferred and are what the barrier unit cost is based on as presented in the NDOT Noise Analysis and Abatement Policy, although other materials may be accepted with prior approval from the NDOT Noise PQS.

5. Information for Local Officials

As noted in the NDOT Noise Analysis and Abatement Policy, NDOT strives to prevent future traffic noise impacts on currently undeveloped lands by informing local officials of estimated future noise levels in the immediate vicinity of the transportation facility. Such information is useful to local communities to protect future land development from becoming incompatible with anticipated highway noise levels.

To provide useful data, estimated future noise levels (for various distances from the proposed highway improvement) for undeveloped lands or properties in the immediate vicinity of the project that are not permitted should be generated. Specifically, distances from the edge of pavement to the traffic noise impact limits [i.e. 66 dB(A), 71 dB(A)] should be provided in tabular or graphic format in the noise technical report. Urban projects may have only limited undeveloped areas that need to be analyzed and may be effectively shown graphically using contours. Conversely, undeveloped lands along extensive corridors in rural areas may be broken out by intersection and the data presented in a table format.

6. Documentation of Traffic Noise Analysis

6.1 Report Requirements

Although NDOT allows flexibility in how a noise analysis is documented, technical reports should include information regarding the modeling point selection, model validation, noise modeling methodology, noise modeling results, impact analysis, and evaluation of abatement. As a result, NDOT recommends that preparers of noise technical reports generally follow the outline shown below to provide consistency in reporting.

The recommended sections for noise technical reports include the following:

- Executive Summary
- Introduction
- Project Background
- Methodology
- Noise Sensitive Land Uses in the Study Area
- Model Validation
- Existing Noise Environment
- Future Noise Environment and Impact Analysis
- Noises Abatement Analysis
- Construction Noise
- Information for Local Officials
- Conclusion
- Appendices

It should be noted that the outline shown above is simply a recommended guideline and is not intended to represent the only approach to documenting the analysis. Specific questions regarding noise technical report formats should be directed to the NDOT Noise PQS.

6.2 TNM Files and Supporting documentation

All TNM files, noise monitoring data sheets, and other supporting documentation should be submitted with the draft noise technical report to the NDOT Noise PQS for review. Following approval of the final noise technical report, all final TNM files and other supporting documentation specific to the noise analysis should be submitted to the NDOT Noise PQS for inclusion in the project files. All information should be provided in electronic format (e.g., pdf, NDOT Sharefile).

7. Public Outreach

As part of the public involvement process, the results of the traffic noise analysis should be presented at the noise abatement stakeholder meeting, which includes benefitted receptors and others that may be affected by noise abatement as decided by the Environmental Section. Information typically presented includes project purpose and need, impact analysis, evaluated noise barrier locations, noise barriers likely to be implemented as part of the project. The purpose of the meeting is to provide an opportunity for the public to vote on recommended noise abatement measures. An example ballot is included in the attachment to this document. NDOT staff, including the project engineer, ROW staff, and Noise PQS, as well as consultant staff if applicable, should be available to answer questions. The NDOT Noise PQS should also present the Interactive Sound Information System to demonstrate to the public what various noise level reductions as a result of abatement sound like (i.e., hear in real time what a 5, 7, and 10 dB(A) reductions should sound like). Additional details on stakeholder meeting, meeting format and logistical requirements can be found in the *NDOT Public Involvement Procedure* (Chapter 9 of the *Environmental Procedures Manual*) and in the *NDOT Noise Analysis and Abatement Policy*. If requested by the NDOT Noise PQS, the noise analyst who completed the study should be present at the stakeholder meeting.

8. References

Code of Federal Regulations. 23 CFR 772.

Federal Highway Administration. Traffic Noise Model (TNM).

Federal Highway Administration. 2011. *Highway Traffic Noise: Analysis and Abatement Guidance*, FHWA-HEP-10-025. December.

Federal Highway Administration. 2006. *Construction Noise Handbook*. FHWA-HEP-06-015. August.

Federal Highway Administration. 2002. *Entering the Quiet Zone: Noise Compatibility Land Use Planning*. May.

Federal Highway Administration. 1996. *Measurement of Highway Related Noise*. May.

Federal Highway Administration. 1974. *The Audible Landscape: A Manual for Highway Noise and Land Use.* November.

National Cooperative Highway Research Program. *Report 791 Supplemental Guidance on the Application of FHWA's Traffic Noise Model (TNM).*

Nebraska Department of Transportation. 2020. *NDOT Public Involvement Procedures*.

Nebraska Department of Transportation. 2021. *Noise Analysis and Abatement Policy*.

Attachment: 1
Example Noise Monitoring Data Sheet

Noise Measurement Record

Project Name:		**Project No.**:
Site ID:		**Measurement No.**:
Conducted by:		**Date**:
Start Time:	**Stop Time**:	**L_{eq} Range**:
Length of Measurement:		**Microphone Height**:

Site Address: ______________________________

	Sound Level Meter	Microphone	Calibrator
Model:			
Serial No.:			

Calibration Check: ______________________

Winds	Temperature	Humidity	Precipitation

Noticeable Events

Source	dBA	Source	dBA

Optional

L_{eq} at 5 minutes:	dBA	L_1:	dBA
L_{eq} at 10 minutes:	dBA	L_{10}:	dBA
L_{eq} at 15 minutes:	dBA	L_{50}:	dBA
L_{eq} at 20 minutes:	dBA	L_{90}:	dBA

Overall L_{eq}:

Traffic (Optional)

	Roadway:		Roadway:		Roadway:	
	Counted	**Hr. Equiv.**	**Counted**	**Hr. Equiv.**	**Counted**	**Hr. Equiv.**
Autos	=		=		=	
Medium Trucks	=		=		=	
Heavy Trucks	=		=		=	
Speed						

Noise Sources Other than Traffic Noise: ______________________________

Elevation of Roadway in Relation to Elevation of Ground at Measurement Site: ____________

SKETCH OF SITE

(Show distances to important features, e.g., centerline, buildings, driveways, etc.)

Supplementary Information

Comments:

____

____

____

____

____

Attachment 2:
Noise Ballot

BALLOT

NAME (PLEASE PRINT): ____

PROPERTY ADDRESS (PLEASE PRINT): _________________________________

VOTE FOR ONE:

_________Accept noise barrier

_________Reject noise barrier

75% of the votes from returned ballots must be a YES (Accept) vote in order for your area to qualify for noise abatement. Voting rules are outlined in the Nebraska Department of Transportation Noise Analysis and Abatement Policy. This policy can be found online at the following location https://dot.nebraska.gov/projects/environment/noise-air/. If less than 75% of the tallied votes are in favor of the proposed noise barrier, the Nebraska Department of Transportation (NDOT) will not reconsider constructing a noise barrier at this location unless another Type I Project is proposed for the area or if there is a re-evaluation on the current project.

Abatement consisting of noise walls will be constructed of precast concrete panels of a predetermined pattern and color.

You will be given 15 days after the public information meeting date to return the ballot. If the ballot is not returned another identical ballot will be mailed. If the second ballot is not returned after an additional 15 days, you will not have a vote. Disregard this Ballot if you have already returned a ballot.

______________________________ ______________________________

(Signature) (Date)

Under Title VI of the Civil Rights Act of 1964 and related statutes, the NDOT ensures that no person shall, on the grounds of race, color, national origin, age, disability, or sex, be excluded from participation in, denied the benefits or services of, or be otherwise subjected to discrimination in all programs, services or activities administered by the NDOT.

Materials can be provided in alternative languages or formats such as large print, Braille, audio recording, or on computer disk for people with disabilities by calling **[insert name of responding official]** of the **[insert office name]** at [**insert telephone number**].

Materiales pueden suministrarse en lenguajes alternativos o formatos tales como grabación de audio de letra grande, Braille, o en disco de computadora para personas con discapacidades llamando a [**name**] el [**Agency**] en **[phone number].**