

Guidance for Noise Modeling Using FHWA's Traffic Noise Model (TNM) 2.5 For Projects in Washington State



*September 1,
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Available online: [Traffic Noise Model \(TNM\) Guidance](#)

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1.0 Introduction

1.1 Background

The Washington State Department of Transportation (WSDOT) *Traffic Noise Policies and Procedures* require use of the most current Federal Highway Administration (FHWA) Traffic Noise Model (TNM) for traffic noise analysis. TNM modeling requires numerous inputs and modeling assumptions so WSDOT developed “*TNM Modeling Guidance*” to promote consistency and facilitate comparisons of modeling results between projects and project alternatives. WSDOT guidance is based on TNM modeling guidelines developed for the Tennessee Department of Transportation and modified to address WSDOT’s TNM noise modeling experiences for projects in Washington State as well as the NCHRP 25-34 Supplemental Guidance (2014) and FHWA Best Practices (2015).

The WSDOT guidance shall apply to all projects that must comply with the 2020 WSDOT Noise Policies and Procedures. Deviation from the guidance may be appropriate in some situations. Deviations must be approved by the WSDOT Noise Program and documented by the noise analyst in the noise study report or through supplemental information.

1.2 Audience

The guidance provides supplementary information to analysts with existing TNM modeling experience. It is not intended to serve as a training tool or supersede analyst qualification requirements listed in the WSDOT *Traffic Noise Policies and Procedures*.

Guidance is not provided for all of the TNM input items. The document focuses on areas where WSDOT feels that additional guidance is needed to ensure modeling consistency for projects in Washington State.

1.3 Guidance Updates

WSDOT guidance will be updated periodically to address changes in best practices. Traffic noise modeling guidance provided by FHWA (2015) or NCHRP (2014) may supersede this guidance document. Consult with the WSDOT Noise Program on questions regarding the WSDOT guidance.

**Check WSDOT [Noise webpage](#) to confirm that you are using the most current version of the modeling guidance.*

1.4 Additional Resources

Analysts are encouraged to frequently check the TNM modeling guidelines developed by the United States Department of Transportation’s Volpe Center that are provided online:

- [Highway Traffic and Construction Noise - Regulation and Guidance](#)

Additional noise modeling best practices are clarified in the National Cooperative Highway Research Program (NCHRP 25-34) report on [Supplemental Guidance on the Application of FHWA's Traffic Noise Model \(TNM\)](#) (2014).

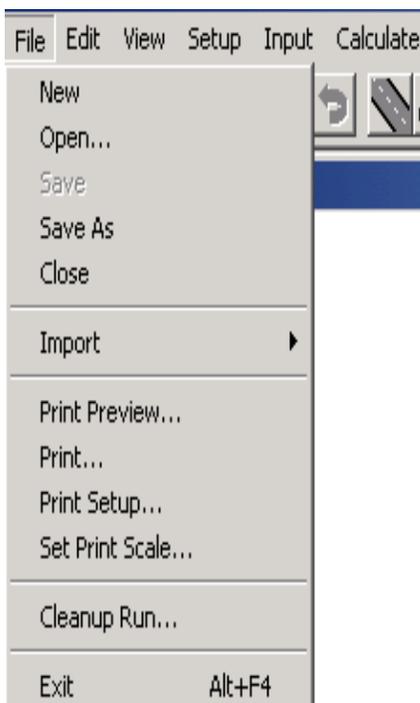
1.5 Organization

The guidance provided in this report follows the TNM 2.5 input toolbar (shown below) from left to right.



Information is provided by way of either “tips” in blue type or “guidance” in red type. Tips are intended to help analysts navigate TNM more efficiently. Guidance provides information regarding how WSDOT expects the TNM modeling to be conducted.

2.0 File



2.1 Open

Tip: TNM will not open a run if the combined path and run name exceed 87 characters in length.

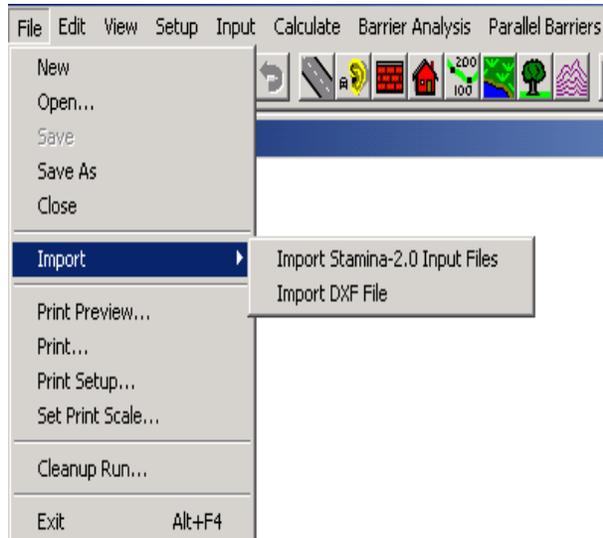
2.2 Import

2.2.1 Import DXF File

2.2.2 DXF Import as Background

TNM DXF Import has some limitations. TNM has an internal CAD package based on AutoCAD 2000. Arcs are brought into TNM as straight lines, sometimes with chords that are too long. TNM does not bring in DXF point objects, and TNM does not have any kind of raster display capability. TNM often has trouble with complex DXF files, newer DXF file formats or DXF files that are larger than about 6,000 KB in size.

Tip: Before importing a DXF file as a background, remove the following: all unneeded layers/levels, references. Separate contours and divide into separate DXF files. If necessary, divide DXF files into separate project quadrants or areas. Try to keep the DXF file size <6,000 KB. Also, DXF files should comply with AutoCAD 2000 or earlier. When using MicroStation to convert a .dgn file to a .dxf file format save the .dxf file as the oldest file format available.



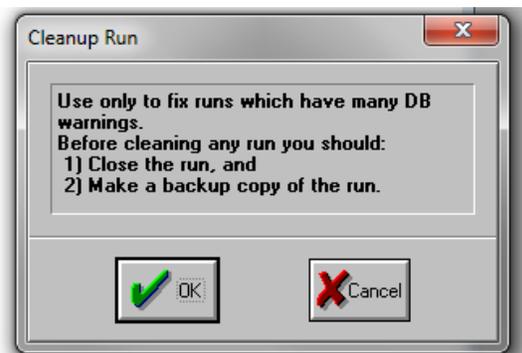
2.2.1.2 DXF Import as Objects

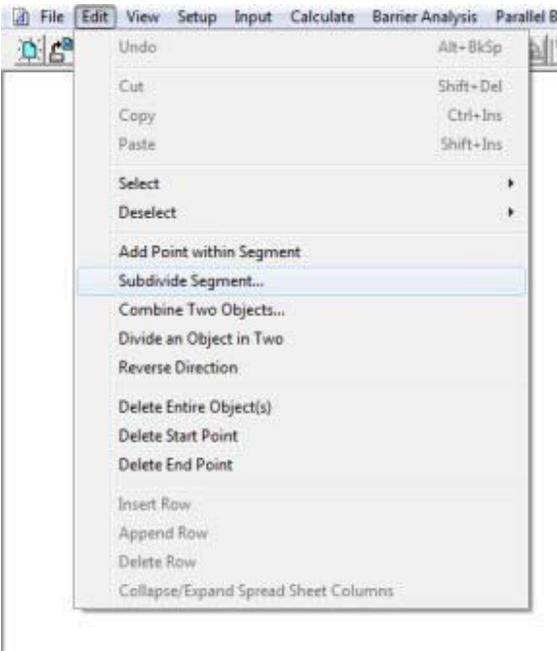
Tip: With the "Import as Objects" method, DXF lines are objects that can be selected, snapped to and converted into TNM objects, such as roadways. TNM may crash, leave out lines, or need the user to take action after every zoom or pan to redraw all of the imported objects. TNM functions more efficiently with smaller DXF files that only use the levels/layers needed.

2.3 Set Print Scale

Tip: "1 inch" (or "1 cm") is the distance between tick marks on the plot axes, not 1-inch (or 1-cm) on the paper. Also, note that Printer Margins do not affect the location of the axes, which are fixed, just the size of the plotted objects.

2.4 Cleanup Run





3.0 Edit

3.1 Subdivide Segment

Tip: TNM allows you to subdivide segments of TNM objects. This can be useful when you need to create smaller noise barrier segments which could allow for fine tuning the optimization of a noise barrier. This feature also shows you the exact length of a specific segment prior to subdivision which can be useful when reviewing final noise wall plan sheets to see how the modeled panels relate to the panels on the plan sheets.

3.2 Divide an Object in Two

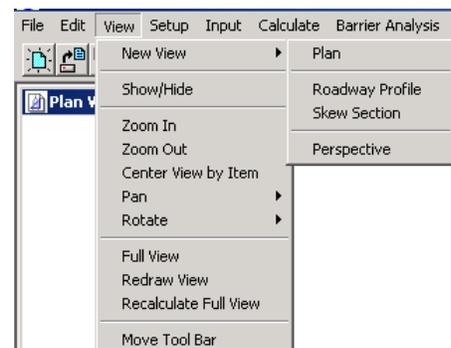
Tip: TNM allows you to divide a TNM object into two separate objects. This can be useful when you need to create a roadway object that has different traffic volumes on each roadway object or dividing a noise barrier into smaller panel segments that can help to optimize the noise wall height/length.

4.0 View

Guidance: Use the Skew and Perspective Views to check your model before calculating results or conducting a barrier analyses. Look for anomalous elevations, receiver/source relationships, etc.

4.1 New View, Roadway Profile

Tip: TNM 2.5 has a bug that draws the arrows as double-headed and shows the name of the last point, which the Plan View does not do.



4.2 New View, Skew Section

Tip: TNM 2.5 will not draw a Skew Section (cross section) or partial cross section if the Plan View is zoomed in too close to the project. Try zooming out from the Plan View and redrawing the cross section.

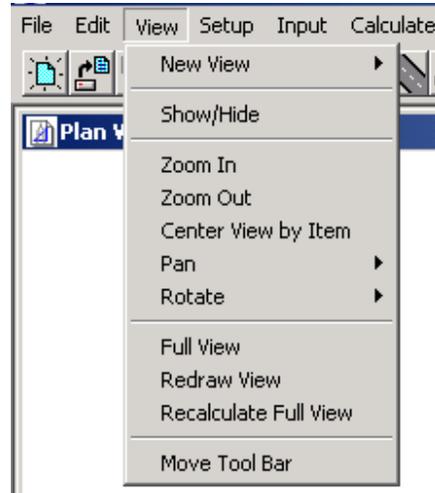
4.3 New View, Perspective

Tip: TNM 2.5 Perspective View will allow you to rotate and view the plan view from

different angles. This can be very helpful in reviewing TNM models to see if any TNM objects have missing or incorrect elevations or if elevations are inconsistent with other objects nearby.

4.4 View, Show/Hide

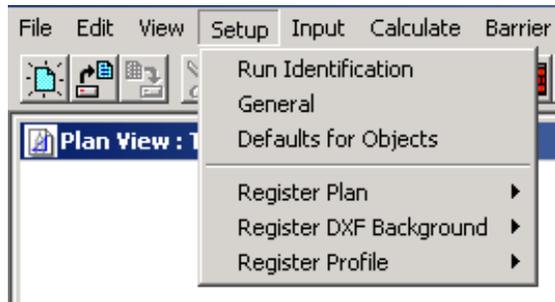
Tip: Uncheck the DXF background under “Show Objects” for quicker screen navigation. Re-check DXF background after locating the desired section of the model. Checking receivers under “Show Text” turns on receiver names in “Plan View,” “Perspective,” or “Barrier Analysis,” which helps to identify specific receivers to troubleshoot issues or verify results.



5.0 Setup

5.1 Run Identification

Guidance: Include the title, organization, project/contract and analysis for each run using terms that clearly indicate what the results represent.



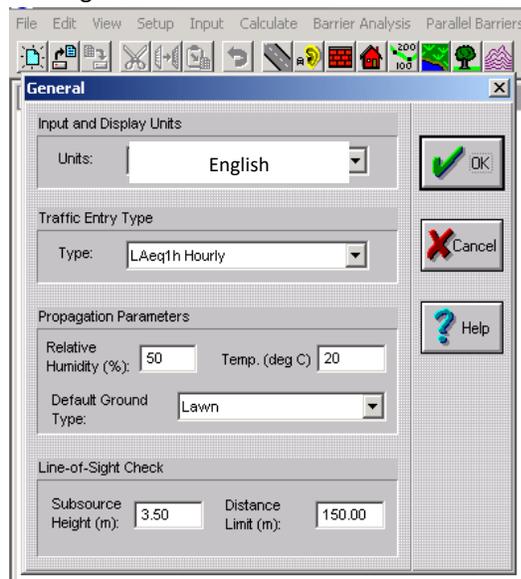
5.2 General

Guidance:

- Make sure to make the following changes prior to creating any objects
- Use English modeling units
- Use LAeq(1h) for traffic entry type
- Do not modify default values for Relative Humidity, Temperature or Line-of-Sight Check unless you feel your project will be challenged in court.
- Otherwise consult with WSDOT. These inputs have

minimal effect on outputs.

- Consult WSDOT if using a default ground type other than lawn.
- Ground zones can be used to simulate site-specific conditions instead.



5.3 Defaults for Objects

TNM has built-in default values for every parameter of every input type. The user may set up custom defaults using the “Defaults for Objects” menu command.

For newly created TNM 2.5 runs, the defaults for receivers are 1 for Dwelling Units and 4.92 feet (1.5 meter) for Height Above Ground. The four Levels/Criteria parameters’ defaults are 0 (existing sound level), 8 (noise reduction goal), 66 (noise impact criterion), and 10 dB (substantial impact criterion).

Guidance: Model receivers at a height of 4.92 feet above ground. Set the noise reduction goal to 7 dB for noise barrier analyses (reasonableness design goal).

5.4 Register Plan Sheet

Tip: While registering plan sheets, TNM computes the expected coordinates of the third point and shows them in the computed cells of the verification box. If you decide that computed and target coordinates are close enough, click “OK.” You will then receive a registration accuracy warning if the computed coordinates are off by more than 0.05 % (5 feet in 10,000 feet). The warning is only a guide and you may feel that a larger difference is acceptable.

5.5 Register Profile

Tip: TNM was intended to allow Z coordinates to be digitized from paper highway profile sheets after using the “register profile” function. However, TNM profile registration currently requires a 1:1 horizontal to vertical scale for profiles. All highway profiles have exaggerated vertical scales and, thus cannot be used for digitizing Z coordinates by TNM.

6.0 Input

6.1 User-Defined Vehicles

Guidance: User-defined vehicles should not be modeled without consultation with and approval from WSDOT.

6.2 Roadways

6.2.1 Roadway Length

Guidance: Extend roadways beyond all first row receivers by a distance of at least four times the distance from the receiver to the roadway centerline. For example, the TNM roadway would extend 400 feet beyond the last first row receiver located 100 feet from the road centerline.



6.2.2 Number of TNM Roadways

Guidance: Model each direction of traffic for a roadway and model each roadway lane individually when:

- Eight lane or greater facilities, or
- Receptors are located below the elevation of the roadway, or
- There are intervening objects in the sound propagation path that block the line of sight between the roadway and the receiver, or
- It is necessary to consider the super-elevation of the highway,

Provide an overlap of 0.1 to 1.0 feet between travel lanes and between travel lanes and the shoulder. Use a “dummy lane” to model the shoulder of a roadway.

If the roadway is a 4 lane facility or less or if it is a minor arterial with low volumes and low speeds lanes can be grouped into a single road object for each direction of travel. Model additional roadways within the project area that affect noise levels or validation at receivers within the project, including interchange ramps and local roads.

Tip: Your model may not validate using minor roads without using significant terrain features, particularly for elevated receivers or elevated roadways.

6.2.3 Roadway Horizontal Coordinates

Guidance: Locate modeled roadways within ± 3 feet of the actual horizontal alignment of the road/lane.

Tip: Using X, Y and Z coordinates from the design profiles in the TNM roadway input provides a more accurate roadway alignment.

6.2.4 Roadway Elevations

Guidance: When modeling roadways on fill, always include a terrain line along the toe of slope of the roadway fill. When modeling roadways on structure, always include a terrain line at ground level just off the edge of structure. Failure to do this can result in a 2 to 5 dB under prediction by TNM with increased under prediction at receivers at increasing distances.

When available, use current roadway profiles and cross sections to determine roadway elevations. Elevations along the roadway should be less than ± 1 -2 feet from the actual roadway elevation. See also section 6.6 for use of terrain lines with roadways.

For projects on new alignment where roadway profiles and cross-sections are not available, use and document reasonable assumptions about the future roadway profile.

6.2.5 Roadway Width

Guidance: For highways that are greater than 4 lane facilities model each lane individually using the actual width of each lane and include the outside and inside shoulders in the outside and inside lane widths or use a “dummy lane” for the shoulders (Section 6.2.2). There should be 0.1 to 1.0 foot of overlap of the individual modeled roadway lanes.

For highway facilities with low speeds and /or facilities with 4 lanes or less or local arterials you can group two lanes together into one modeled lane in each direction but must include the total roadway widths including travel lanes and shoulders. There should be overlap of 0.1 to 1.0 feet of modeled roadway lanes unless there is an unpaved median.

For example, in the 4 lane divided highway shown below, the upper roadway has two 12-foot travel lanes and a 2-foot outside and 2-foot inside shoulder. The lower road has two 12-foot travel lanes, a 12-foot outside shoulder and a 2-foot inside shoulder for a total pavement width of 28 feet and 38 feet, respectively. Therefore, a minimum grouped pavement width of 28 ft. should be modeled for the upper roadway and 38 feet should be modeled for the lower. The median separation between the two roadways should also be modeled.



6.2.6 Pavement Type

FHWA Policy states:

"TNM defaults to "AVERAGE" for pavement type. The use of any other pavement type must be substantiated and approved by the FHWA...." It is very difficult to forecast pavement surface condition into the future. Therefore, unless definite knowledge is available on the pavement type and condition and its noise generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels.

Guidance: Use "Average" pavement type for all TNM runs, unless otherwise justified and approved by WSDOT and FHWA.

6.2.7 Traffic Volumes

Guidance:

- For existing and design year conditions, use peak hour volumes, unless otherwise directed by WSDOT. If forecasted traffic volumes are not available, develop future peak hour volumes based on existing traffic volumes (e.g., 10% of existing AADT) and using a reasonable growth factor provided by the WSDOT Traffic Office.
- For NEPA noise studies, it is not necessary to model non-uniform traffic distributions for multiple-lane highways up to 12 lanes wide.
- Non-uniform traffic distributions can be considered for final noise abatement design studies if all of the following conditions are met:
 - The facility is 8 general-purpose lanes or more;
 - Sound propagation occurs over soft ground;
 - There is a high percentage of heavy trucks (20% or more); and
 - The freeway is either elevated or depressed, such that intervening terrain blocks the line of sight between any number of lanes and receivers of interest.
- 10% of AADT is an acceptable surrogate for peak hour traffic volumes, when peak hour traffic is not available.

- **Include buses in the medium truck category. Do not include motorcycles unless they are a significant percent of total volumes.**

6.2.8 Traffic Speeds

Guidance: Use existing posted speeds for existing models. For future conditions, use design year posted speeds with the design peak hour volumes, unless otherwise directed by WSDOT.

Tip: The analyst should be aware sound levels change with speed and that propagation, barrier attenuation, ground attenuation and tree zone attenuation are sensitive to speed.

6.2.9 Roadway Flow Control

For TNM roadways with a traffic control device, TNM puts the flow control at the beginning of the roadway and computes accelerating speeds along the roadway's length as a function of vehicle type and roadway grade until the final speeds are attained or the end of the roadway is reached. For the next roadway, TNM begins anew with that roadway's input speeds. In other words, while TNM tracks speeds from one roadway segment to the next, it does not link speeds from one roadway to the next.

At a traffic-control device, TNM reduces vehicle speeds to your "speed constraint," for your "percentage of vehicles affected," and then accelerates this percentage of vehicles away from the device.

Acceleration continues until the vehicles come back up to your input speed, or until they reach the end of that TNM roadway. As vehicles accelerate, their noise emissions increase as compared to cruising vehicles at the same speed. The speed constraint is generally zero for all devices except on-ramp start points, where vehicles sometimes enter the on-ramp without completely stopping first.

Guidance: A reasonable start speed (speed constraint) for such on-ramps is 16 km/hr (10 mph).

If vehicles will continue to accelerate past the endpoint of the TNM traffic control roadway, the road must be extended to allow the vehicles to continue accelerating. For example, if heavy truck acceleration will continue past the physical merge point of an on-ramp with the mainline, the on-ramp should be extended past this physical merge point, parallel to the mainline, so that heavy trucks will approach the input speed before the end of the on-ramp roadway. Use Figure 45 from Appendix B of the [TNM Technical Manual](#) to compute this length.

The need to extend a ramp roadway to its full acceleration length depends on the number of trucks on the ramp compared to the mainline and the proximity of receivers.

Guidance: Model on-ramps and traffic control devices, including signals, stop signs and toll booths, and roundabouts using appropriate flow control as necessary. Extend the traffic-control roadway where heavy

truck acceleration is anticipated beyond the merge point with the mainline. If no flow control is used for on-/off-ramps these should be modeled with a speed of 45 mph or the posted advisory speed limit along their entire length.

6.2.10 Roundabouts

The key elements of modeling a roundabout are entry, circulation and exit speeds. Roundabouts are designed using yield signs instead of traffic signals for entry into the roundabout. Roundabouts are designed to move vehicles smoothly into and through or around before exiting and then accelerating away. Thus, in the TNM model the acceleration roadway should start after the vehicles have exited the roundabout.

Approach leg

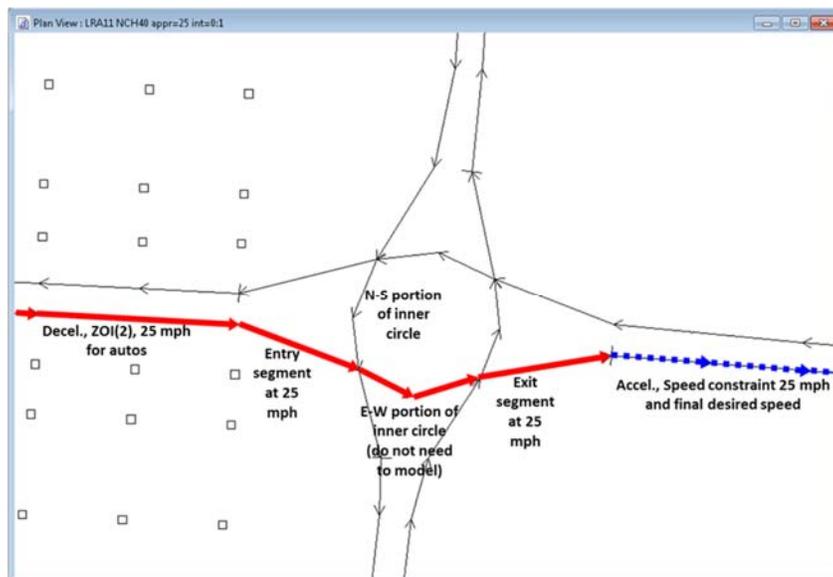
For a one lane inner circulatory road the approach to the roundabout may be modeled by a constant speed equal to the posted speed up to the beginning of the splitter island/crosswalk. Then, one 25-mph segment would be used to represent the entry leg, ending at the entry point to the circulatory road.

Inner circulatory road

The traffic on the inner circulatory road does not need to be modeled. The noise from the accelerating traffic departing the roundabout will dominate the overall sound levels.

Departure leg

For the departure leg, a one-segment constant-speed roadway would be modeled at a speed of 25 mph. It would start at the exit point from the inner circulatory road and end at the end of the reverse curve typically at the end of the splitter island/crosswalk. Then, a flow control acceleration roadway would be modeled from the point downstream to the end of the modeled site. The roadway would have a Speed Constraint of 25 mph and 100% Vehicles Affected with the posted or operating speed as final desired speed.



A roundabout with a two-lane inner circulatory road may be modeled essentially the same way as described for the one-lane inner circulatory road.

Because of the slightly higher speed typical of the two-lane case – on the order of 20-25 mph instead of 15-20 mph on the smaller diameter one-lane road and the greater circumference – there might be a desire to model the inner circulatory road, especially if receivers are immediately adjacent. However, if the inner roads' entry and approach legs are modeled for each leg, then it is unlikely that the inner road itself needs to be modeled, especially because of the noise of vehicles accelerating away from the roundabout

6.2.11 Additional Roadway Modeling Guidance

Guidance: Use stationing to name roadway points if possible. Alternatively you could name all roadway points so the direction and milepost or stationing are clear. For example, a point on eastbound I-90 at STA 335+00 could be named I90EB335.

If the project does not yet have stationing, roadway point names should reflect the direction of travel, differentiate one roadway point from another, and give some indication of where along the project the roadway point is located.

Tip: Exercise caution when modeling super-elevated roadways, since super-elevation can significantly affect predicted sound levels and the design of noise barriers. One method might be to model each lane separately with each lane having a slightly different elevation to represent the superelevation.

6.3 Receivers

Model receivers according to WSDOT's 2020 Noise Policies and Procedures available online: ([WSDOT Noise Policy \(2020\)](#))

Guidance: Include all impacted receivers within the traffic noise study area. The traffic noise study area will extend beyond the project limits the same distance as it extends out from the edge of the nearest travelled lane when the project limit ends within a residential community. If the project limits end within a commercial zone the noise study area will terminate at the project limit.

6.3.1 Dwelling Units and Sound Level Criteria

Guidance: The number of Dwelling Units/Residential Equivalents in the models must be consistent with the number of Dwelling Units/Residential Equivalents within the final discipline report.

Tip: Changing receiver Dwelling Units or any of the Sound Level Criteria values in TNM 2.5 after calculation incorrectly invalidates calculated results.

6.3.2 Adjustment Factors

Adjustment factors were originally designed to convert shielding

factors (such as building rows, terrain features and ground zones) in Stamina into adjustment factors in TNM. However, TNM 2.5 can include elements such as building rows, terrain lines and ground zones.

Guidance: Do not use adjustment factors, unless approved by WSDOT. Use shielding elements such as building rows, terrain lines and ground zones in TNM instead.

6.4 Barriers

Two types of proposed barriers can be modeled in TNM: Barrier and Berm. Barrier attenuation is *not* in the “no barrier” LAeq1h, so the “no barrier” and “with barrier” LAeq1h are different.

- 1. *Perturb-able height barrier:*** Set “# Up,” “# Down,” and “Increment” to non-zero values except for private or existing walls with fixed heights. For existing noise barriers with impacts in the future build scenario set the height at the existing height and the number of down perturbations to zero. Set the increment to two feet and the number of up perturbations to 10 or less. This will allow the analyst to evaluate whether raising the height of the existing barrier can reduce noise levels behind the wall to below impact and then determine if that extended height barrier is feasible and reasonable to build.

Pnt.Name	Pnt.No	X (ft)	Y (ft)	Z(bottom) (ft)	Height (ft)	Increment (ft)	#Up	#Dn
	12	0.0	180.0	80.00	16.00	2.00	0	0
	1	100.0	180.0	80.00	16.00	2.00	0	0
	2	200.0	180.0	80.00	16.00	2.00	0	0
	3	300.0	180.0	80.00	16.00	2.00	0	0
	4	400.0	180.0	80.00	16.00	2.00	0	0
	5	500.0	180.0	80.00	16.00	2.00	0	0
	6	600.0	180.0	80.00	16.00	2.00	0	0
	7	700.0	180.0	80.00	16.00	2.00	0	0
	8	800.0	180.0	80.00	16.00	2.00	0	0
	9	900.0	180.0	80.00	16.00	2.00	0	0
	10	1,000.0	180.0	80.00	16.00	2.00	0	0

2. **Fixed height barrier** (noise barrier with a single height or existing/planned safety-barrier next to roadway): Leave “# Up,” “# Down” at zero, but make “Increment” size non-zero.

Pnt.Name	Pnt.No	X (ft)	Y (ft)	Z(bottom) (ft)	Height (ft)	Increment (ft)	#Up	#Dn
	12	0.0	180.0	80.00	16.00	2.00	2	5
	1	100.0	180.0	80.00	16.00	2.00	2	5
	2	200.0	180.0	80.00	16.00	2.00	2	5
	3	300.0	180.0	80.00	16.00	2.00	2	5
	4	400.0	180.0	80.00	16.00	2.00	2	5
	5	500.0	180.0	80.00	16.00	2.00	2	5
	6	600.0	180.0	80.00	16.00	2.00	2	5
	7	700.0	180.0	80.00	16.00	2.00	2	5
	8	800.0	180.0	80.00	16.00	2.00	2	5
	9	900.0	180.0	80.00	16.00	2.00	2	5
	10	1,000.0	180.0	80.00	16.00	2.00	2	5

Guidance: Follow WSDOT standard specs for stepping the modeled noise barrier (no more than 2 feet increment steps, sections 6-12.3(5) and 6-12.3(6)) and/or the Urban Design Criteria, where appropriate.

Avoid the ‘saw toothed’ effect of the top of wall during barrier optimization caused by using too few modeled receivers behind the noise wall which tends to result in higher noise wall panels at the modeled receivers and shorter panels in-between modeled receivers

The wall should remain a relatively constant height between receivers except during substantial changes in terrain and modeling receivers at every home or at a minimum every other home can minimize this effect. Be sure to evaluate if receivers can see over the top of the wall in front of them and to the left/right and recommend using the line-of-sight check feature in TNM if the top of wall elevation is close to the line of sight from receiver to traffic.

Tip: For modeled barriers with long panel widths over steeply changing grade, it may be advantageous to divide the panels into smaller panel lengths (e.g., approximately 12 foot lengths) and step them according to standard specs or to the Urban Design Criteria for stepping requirements in a particular corridor.

According to FHWA Supplemental TNM Guidance TNM has a large L_{eq} sensitivity whenever sound paths just graze across diffracting edges such as terrain lines and the outer edge of roadways.

Guidance: When conducting a Barrier Analysis in TNM do not include other noise walls or terrain lines in the barrier analysis unless the second noise wall is an adjacent existing noise barrier or is being analyzed as part of a noise barrier 'system'.

Types of barriers that exist or will be constructed as part of the project but not as noise barriers might include:

- Median or shoulder safety barriers
- Masonry block walls/fences
- Large buildings
- Parapet walls
- Crash barriers

Model these objects as fixed height barriers for validation and "no-build" conditions, where appropriate. Existing barrier attenuation *is* included in the "no barrier" $L_{Aeq}(1h)$ column. If no other barriers are present, Noise Reduction would be zero in the Results table. Set all perturbation values to zero for these fixed height barrier types.

6.4.1 Optimizing Noise Barriers

Consider using the FHWA Noise Barrier Optimization Tool (NBOT). Otherwise, noise barriers should be evaluated to determine if they are highly cost effective according to our 2020 Noise Policies and Procedures and/or to determine which wall height will benefit the most noise sensitive receivers while still meeting the reasonableness criteria. If the noise wall cost and reasonableness allowance are relatively close optimization can sometimes help to meet the reasonableness criteria.

6.4.2 Median Barriers

Guidance: For receptors within 500 feet of the center of the nearest travel lane and below the elevation of the highway, model the median barrier. For receptors beyond 500 feet and below the elevation of the highway model the median barrier and use the appropriate reflected barrier technique in the TNM Supplemental Guidance (2014, Appendix D). For receptors that are between 50 and 500 feet of the highway and less than 6 feet above the highway elevation model the median barrier and if more than 6 feet consider reflections

Distance From Middle of Near Travel Lane	Height of Receptor With Respect to Roadway	
	Receptor Below to 6 Feet Above Roadway	Receptor More Than 6 Feet Above Roadway
50	Model Median Barrier and Ignore Reflections	Model Median Barrier and Consider Reflections
100		
200		
500		
1000	Model Median Barrier and Consider Reflections	

6.4.3 Building Shielding

Guidance: If the building is large (e.g., warehouses, large retail buildings and multifamily buildings), located between a receiver and a roadway and is not incorporated into a building row (Section 6.5), model the building as a fixed height barrier with a minimum of three sides which are facing the source and zero perturbations.

6.4.4 Parapet Walls

Guidance: If a roadway on an overpass is shielded by an existing parapet wall, model the parapet wall to include shielding in the validation model if it is required to validate the model. If it is included in the validation model also include the parapet wall in the existing and no-build models. Include in the build model unless it is removed as part of the project. Model the parapet wall as a fixed height wall with zero perturbations.

6.4.5 Crash Barriers

Guidance: If a roadway, or roadway on an overpass, includes an existing crash barrier include it in the validation model if it is required to validate the model. If included in the validation model also include the crash barrier in the existing and no-build model and the build alternative if it is not removed by the project. If a crash barrier is planned to be an element of the project design, model the crash barrier in the “build” alternative model. Model the crash barrier as a fixed height wall with zero perturbations.

6.4.6 Noise Barrier Points

Guidance: Noise barrier points should generally be located near the right-of-way line and line up with nearby modeled roadway points on the adjacent roadway to ensure consistency of vertical geometry between the roadway and barrier.

Barrier points should be modeled at least every 200 feet for situations where the barrier will be located near the edge of pavement (EOP) and/or where the roadway is at-grade or on fill. Where the barrier will be located near the top of cut, model barrier points at least every 100 feet and at smaller intervals, where appropriate, such as where there are significant changes in bottom of wall elevations.

For barrier point names, indicate the direction and station of the adjacent roadway. For example, a barrier point at the EOP of eastbound I-90 at STA

335+00 could be called EB335. If barrier points are not located at a whole station, then expand the barrier point name to identify the location of the barrier point. For example, a barrier point at the EOP of eastbound I-90 at STA 335+30 could be called EB335.3.

If project stationing has not yet been developed, then develop a generic barrier point labeling system.

6.4.7 Berms

To create a berm within the TNM model using terrain lines the toe of the berm (bottom of slope) cannot overlap a roadway or receiver or you will cause an “invalid results” modeling error, instead of sound levels, in the Sound Level Results table after calculations. The top width of the berm must be entered into the program as zero.

Guidance: To simplify modeling, model berms as noise walls with the noise wall aligned along the centerline of the berm and with the assumption that there is sufficient right-of-way for the berm. If a berm is modeled using terrain lines only place one terrain line representing the top of the berm and one representing each toe of slope of the berm and insure that the distance between terrain lines is more than four feet in all areas.

The wall-on-berm feature in TNM does not work properly. Only use a wall to model a wall-on-berm for proposed abatement. If modeling an existing wall-on-berm combination, use the base of the wall to define the top of the berm and terrain lines to define the toes of the berm.

Guidance: The feasibility of berms highly depends on available right-of-way, current and proposed slopes, and drainage issues. Consult with WSDOT before modeling berms as noise abatement.

6.4.8 Barrier Unit Costs

Guidance: WSDOT provides unit costs for all noise barrier analyses in the WSDOT Noise Policies and Procedures, (2020), Exhibit 11, available online: [WSDOT Noise Policy \(2020\)](#)

Tip: Barrier unit costs on the “More” tab of the “Barrier” input dialog box apply to all segments of the barrier. If barrier costs vary on different sections of the barrier (e.g., barrier on a bridge), these costs can be computed outside of TNM.

6.4.9 Barrier Segments on Structure

WSDOT does not typically model noise barriers on structure because it is understood that the cost to construct a noise barrier on an existing structure can be very expensive and the noise barrier will not be reasonable. However, if a noise wall on structure is required for the project, follow the following procedure.

Structure barrier segments may shield both *structure* roadway segments and *non-structure* roadway segments.

Guidance: All roadways on structure that are potentially shielded by the barrier should be included in the shielded list.

Tip: The graphical method of assigning shielded roadway segments to a structure barrier segment is the most straightforward input method.

Modifying roadway segments in the shielded list for structure barriers can corrupt the entire shielded list. WSDOT recommends developing the shielded lists late in the TNM run process and checking it thoroughly before running TNM.

6.5 Building Rows

Attenuation from a building row is much less than from a noise barrier of the same height and length. In the case of multiple building rows, TNM first calculates the most effective building row attenuation at a frequency of 630 Hz. Exact values are calculated only for the building row with the highest attenuation at 630 Hz. For all remaining rows that block the line-of-sight, attenuation of 1.5 dB is assigned to each 1/3 octave band, regardless of building height and gap. As a result, TNM may over-predict sound levels back into a community, particularly where there is a high density of intervening structures. Building rows also define terrain. Therefore, validation of receivers back into a community to the point where noise impacts no longer occur is important.

Guidance: Model all intervening building rows between a source and a receiver, but recognize that TNM may over-predict sound levels at locations two or more rows back into a community. Validate the noise model with noise measurements two or more rows back into a community to reduce potential for over-prediction.

6.5.1 Average Building Height

Guidance: ± 2 m (6 feet) is precise enough for average height when buildings are within a single story of one another and the road is not on fill, where the building height is critical.

6.5.2 Building Percentage

It is not necessary that building spacing be highly regular. The analyst does not have to be overly precise in this parameter.

Guidance: Model all intervening building rows with a building percentage between 20% and 80% to an accuracy of $\pm 10\%$. Generally, older neighborhoods should use a building percentage of 20% and newer neighborhoods/condos should use a building percentage of 80%. Model the building row as a fixed-height barrier when building percentage exceeds 80%.

6.6 Terrain Lines

6.6.1 General Modeling

The TNM web site FAQ notes: *“TNM has shown some weaknesses in the diffraction algorithms, which would be invoked when computing the effects of terrain lines; thus, it is recommended that terrain lines only be used to locate substantial changes (± 3 feet) in terrain elevation.”* Terrain lines

should be used on elevated roadways at the toe of slope adjacent to the roadway and for roadways on structure placed at the ground just off the edge of the structure and never be located less than four (4) feet apart. Otherwise, terrain lines should only be used when necessary to validate the noise model.

The August 2002 TNM Validation Report, in referring to a particular study site, states that: "...undulations of this size (+5 to -20 feet) should not be ignored."

Then in the Conclusions, it states that you should model undulations of " ± 5 feet or more."

Guidance: Any terrain lines used during validation shall be included in all modeled conditions/alternatives unless altered in the Build alternative. Do not model terrain lines closer than 4 feet apart and only use terrain lines when necessary for validation. Study ground contours to determine where terrain changes break the line-of-sight between a source and a receiver and model terrain lines that break line-of-sight.

Tip: Receivers do not define the terrain, except for themselves.

Use caution when placing terrain lines close to noise barriers as the diffraction caused by the combination of the barrier and terrain line could lead to erroneous results.

Guidance: Do not place terrain lines closer than 4 feet from a noise barrier.

6.7 Ground Zones

6.7.1 General Ground Zone Modeling

The effective flow resistivity values are similar for loose soil, lawn, and field grass.

Guidance: Only model pavement, water, or hard soil ground zones, not tree zones. Do not use custom effective flow resistivity values

TNM can have problems handling multiple diffraction points when a grassy median is modeled between roadways. In cases where the grass median is < 10 feet (3 m) wide, increase pavement widths so the pavements overlap slightly.

Guidance: When a grass median is less than 10 feet wide, increase the modeled widths of the adjacent roadways to slightly overlap.

Use a ground zone to model the median if a median is ≥ 10 feet and the median is a ground type other than the default. For ground zone medians, avoid overlapping or matching edges with the adjacent roadways.

6.8 Tree Zones

Per FHWA guidance, only use tree zones when vegetation meets the following condition:

"...sufficiently dense to completely block the view along the propagation path;i.e., it is

impossible to see a short distance through the foliage.”

Tree zones use the default ground type. To define a new ground type for the tree zone, you must create a ground zone. FHWA recommends the following for ground zones within tree zones:

“If you want a ground type other than the default, you must use a ground zone to define the type of ground inside tree zones. If you are using a tree zone, surround the tree zone with a ground zone of loose soil to account for the ground effects of that tree zone.”

***Guidance:** Only model tree zones where trees are coniferous and density is sufficient to block the view from the receiver to the source. Do not model tree zones with depths less than 66 feet and predominantly deciduous trees.*

6.9 Contour Zones

TNM has difficulties modeling noise contours and FHWA policy states the following on contours: *“TNM allows the user to model contour zones. However, calculating noise contours with TNM greatly increases run time. It is strongly recommended that this feature of TNM only be utilized for land-use planning activities and/or performing screening analyses to determine the number of impacted receivers in an area.”*

***Guidance:** Do not produce TNM generated contours on WSDOT projects, unless authorized by WSDOT.*

6.11 Input Check

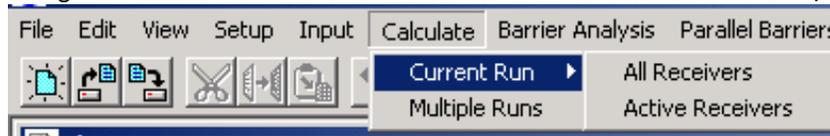
Input Check finds some, but not all, input errors in TNM. For example, Input Check will not find incorrect elevations for receivers, barriers, building rows, terrain lines, or tree zones and will only find incorrect roadway elevations when they cause the road to have a grade above a pre-defined limit. Errors not found in the input check are sometimes easily detected in the various TNM views or input tables during the normal review process.

***Guidance:** Review input tables and views before calculating.*

TNM will give Input Check errors for vehicle types with speed but no volume, or volume but no speed. However, if none of the roadways in a TNM 2.5 run have traffic volumes or speeds, TNM 2.5 may give a "log10: argument singularity error" during the calculation phase, and not calculate further. This error only occurs when all TNM roadways are without traffic. If just one TNM roadway segment contains a single vehicle, and the remaining roadways have no traffic, TNM 2.5 will calculate results for this single vehicle. If some roadways have traffic and some roadways have no traffic, sound level results may look plausible but will be incorrect.

***Guidance:** Review traffic table before calculating.*

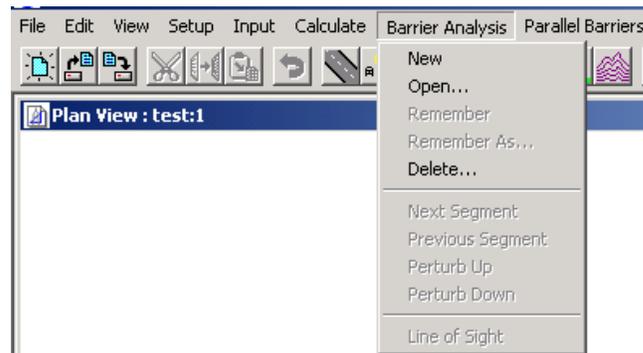
7.0 Calculate



TNM indicates the progress of the calculations in a Calculate Sound Levels window. The time “to go” feature is not particularly accurate.

7.1 Current Run, Active Receivers

Tip: Calculating newly “active” receivers invalidates previous active receiver results. If you run TNM with some receivers “active”, then add more as “active”, TNM will invalidate results for previously calculated receivers when you try to calculate for newly activated receivers. Exception: if you calculate “All” receivers using the “Calculate,” “Current Run,” “All Receivers” command after calculating only some receivers using the “Calculate,” “Current Run,” “Active Receivers” command. In this case, TNM will generate a message box asking if you want to re-calculate 1) already-calculated receivers or if 2) you want to skip re-calculating those receivers with results.



8.0 Barrier Analysis

8.1 New

Tip: At least one barrier and one receiver must be selected to create a Barrier Analysis design. A Barrier Analysis design may also contain roadways and building rows. Include any adjacent existing noise barriers in your new barrier analysis but do not include other noise walls in your barrier analysis unless you are analyzing them as a ‘system’.

8.2 Remember and Remember As...

“Remember” saves a barrier design to its current name specified in the last Remember As command. (If no current design name, Remember saves design as “unsaved.”)

“Remember As” means “create a new design name for upcoming changes.” That is, Remember Next Design As.

“Remember As” also saves the current design under the current name while creating a new name for an upcoming design. Unlike “Save As” in word processors and spreadsheets, “Remember As” does not save any edits just completed under the name about to be entered.

Tip: When starting a Barrier Analysis, use “Remember As” and provide a design name.

After the first design, use Remember to save the design to that name. Then, use “Remember As” to create a new design name for upcoming changes. Use “Remember As” conservatively so as not to create too many different barrier design names which can become confusing. Name barrier designs clearly and delete any barrier designs that will not move forward.

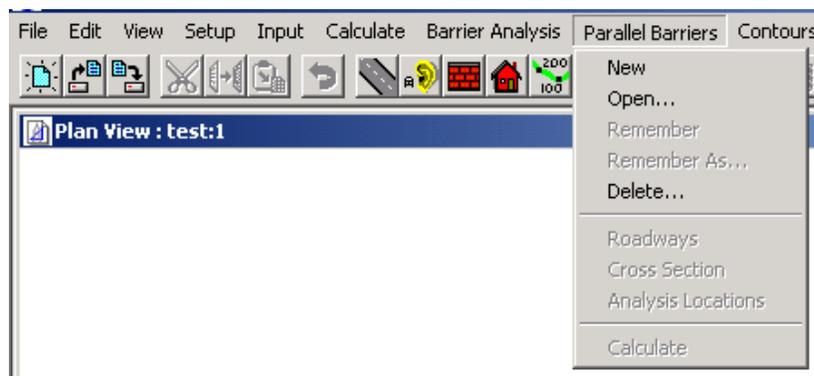
8.3 Line of Sight Check

When a barrier is present, the TNM “Line-of-Sight” function checks for a line-of-sight between a receiver and a source. Sources can include the pavement (tire noise), engine and elevated truck stacks. Check the source height and the distance from the receiver to the farthest point on the roadway and specify in the “Setup,” “General” dialog box. These terms, sub-source height and distance limit, default to 11.48 feet and 492.13 feet, respectively, and should not be adjusted. The source height of 11.5 feet is based on a Caltrans study of 1,000 trucks in 1979.

The 50th percentile of the stack height data was 11.5 feet. A recent NCHRP study on the contribution of heavy truck stacks indicates that TNM may be over predicting the contribution of the stack noise (NCHRP, 2017).

***Guidance:** Perform a line-of-sight check on noise barriers. This is especially important to prevent construction of barrier panels that are too low for barriers with varying panel heights and/or with receivers on elevated slopes behind a barrier. Additionally, even when noise levels are below impact, residents may perceive a barrier as being less effective when there is a line-of-sight from receivers to truck stacks. However, taller walls to block the truck stacks may not meet the reasonableness criteria so a balance must be found.*

9.0 Parallel Barriers



9.1 FHWA Policy on Parallel Barriers

FHWA policy on parallel barriers states the following: *“TNM allows the user to model parallel barriers. Studies have suggested that to avoid a reduction in the performance of parallel reflective noise barriers, the width-to-height ratio of the roadway section to the barriers should be at least 10:1. The width is the distance between the barriers, and the height is the average height of the barriers above the roadway. This means, that two parallel barriers 3 meters tall should be at least 30 meters apart. Accordingly, it is recommended that parallel plane surfaces not be modeled with TNM unless the width-to-height ratio of the surfaces is less than 10:1 (note that modeling parallel plane surfaces greatly increases TNM run time).”*

The actual increase in sound level due to reflections varies with receiver horizontal and vertical position, intervening shielding, and source location. Reflection problems due to parallel barriers can occur in cross-sections with a width-to-height ratio greater than 10:1.

Additionally, the effect of reflections can vary significantly from location to location in the same area. The site geometry should be reviewed to ensure that all potentially affected areas are identified and assessed. This may require modeling additional TNM receivers.

Guidance: Use the TNM parallel barrier module to assess potential noise barrier degradation from reflections. Model in the TNM parallel barrier module and verify results in the field.

9.2 General Parallel Barrier Modeling

“Open,” “Remember,” “Remember As,” and “Delete” work the same for “Parallel Barrier” designs and “Barrier Analysis” designs.

This module cannot be used for single wall reflections, and each wall must be at least 6 feet tall.

When a parallel barrier section contains two separate vertical surfaces offset on the same side of a road (e.g., a retaining wall near the edge-of-pavement and a barrier at the right-of-way), TNM completely ignores the lower inside surface (e.g., retaining wall), leading to erroneous results.

Changes to “Parallel Barrier” input data after calculations do not invalidate parallel barrier results. Instead, the program states that the current data is valid after you have made a change to the parallel barrier input data and try to recalculate the parallel barrier results.

The TNM User’s Guide suggests the use the calculated increases as “Adjustment Factors” in the main part of TNM for those receivers represented by the “Analysis Locations.”

Guidance: Do not enter the parallel barrier increases as adjustment factors. Instead, use the Parallel Barriers module as a design module, where you may do one of the following:

- 1. Analyze the effects of sound absorbing materials on barrier faces by changing the NRC of the Parallel Cross Section input dialog box*
- 2. Analyze tilting the walls outward by adjusting the horizontal values for the wall tops (either graphically or in the “Parallel Cross Section” input dialog box).*

9.3 Roadways

If more than half of the lowest sub-source circle is below the road line, the lower source will not be computed properly.

Guidance: Make sure that the position of new Parallel Barrier roadways are slightly above the road surface.

9.4 Cross Section

The initial “cut” heights of parallel barriers are based on Input Heights entered into the Barrier input dialog box. If a parallel barrier analysis is completed for other heights, then adjust input heights graphically or in the Parallel Cross Section input dialog box. It is incorrect to assume that the calculated multiple reflections sound level increase will be the same for two different sets of barrier heights.

9.5 Analysis Locations

After the Parallel Barriers calculations are completed, the Parallel Analysis Locations table is automatically updated to show the computed increases in $L_{Aeq}(1h)$. For TNM receivers being represented by Parallel Barrier Analysis Locations, these values are increases to the “With Barrier” $L_{Aeq}(1h)$ values shown in the main Sound Level Results table. However, TNM does not automatically add these increases to those “With Barrier” levels.

Tip: Analysis location Z values are for the ear height, not the ground height.

Guidance: Beware of computed increases in $L_{Aeq}1h$ of 0.0; sometimes, when the receiver Z is below the roadway Z, the result may be incorrectly calculated as zero.

10.0 Tables

10.1 Input Tables

Tip: The default ground type is not shown on any of the input tables. Future versions of TNM will have default ground type on the ground zone input table.

10.2 Barrier Design

The following tables may be helpful in the barrier design process:

1. “Sound Level Results” table
2. “Diagnosis by Barrier Segment” table
3. “Barrier Descriptions” table tracks total barrier cost
4. “Barrier Segment Descriptions” table helps track segment heights

Setting up windows to easily view these tables can be tricky. It helps to first check the “Barrier Design” lines to ensure the tables link to the intended design case, then “Hide” header rows of the tables.

The following issues need to be fixed in TNM 2.5 for the new Barrier Design Table:

1. The table takes up the full screen width with “Receiver” name and “Partial $L_{Aeq}1h$ ” on opposite sides; and “Calculated $L_{Aeq}1h$ ” and “Noise Reduction” in middle.
2. The full width of the table is not visible when the vertical scroll bar is on.
3. It is cumbersome to switch versions of the table back and forth to show/hide the “Important Segments” during barrier design.

10.3 Hide Rows

Tip: The “Tables,” “Hide Rows” command works in TNM 2.5. However, all rows become unhidden when a table is printed.

10.4 Print Tables

Tip: In TNM 2.5, when using the “Tables,” “Print Tables” dialog box, the results tables are only printed for the “INPUT HEIGHTS” case, not the currently active barrier design. Open the table you want to print, select the window containing the table, click on “File,” then “Print.”