Quarry Noise Model

User Guide and Technical Reference

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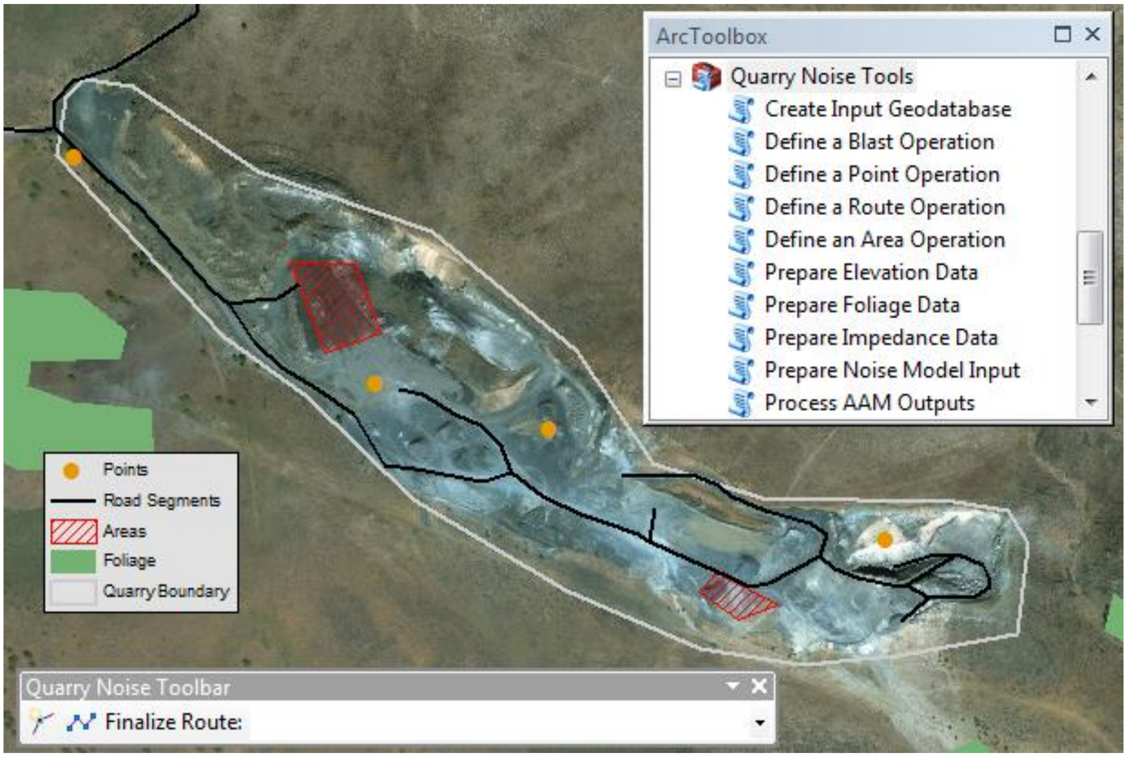

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13. ABSTRACT (Maximum 200 words)

The Oregon Department of Transportation (ODOT) commissioned development of a tool to help predict noise exposure in areas surrounding ODOT quarries by the USDOT's Volpe Center. The QNM has, at its heart, three inter-communicating components. These are the QNM GIS Module, the Noise Database and the Acoustic Engine. This document serves as the user's manual and technical reference for QNM and describes these three components. The GIS Module represents the Graphical User Interface (GUI) for the Quarry Noise Model (QNM) and harnesses both custom and existing built-in tools within ESRI's ArcGIS interface to streamline the process of creating and running quarry noise scenarios. Noise data parameters are required in order to identify and accurately model noise emissions and propagation over distance. Two types of parameters are included in the noise database: classification parameters, which are used to identify the source, and emission parameters, which characterize the physics of the emitted noise. The Acoustic engine leverages the Advanced Acoustic Model (AAM) with the addition of attenuation due to surrounding foliage, the ability to model operations from equipment that is distributed over a quadrilateral area and a simplified blast model for prediction of initial blast overpressure.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
mL	milliliters	0.034	fluid ounces	fl oz
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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List of Abbreviations

Abbreviation	Term
AAM	Advanced Acoustic Model
dB	Decibel
dBA	A-weighted Decibel
DNL	Day-Night Average Sound Level (A-weighted)
EPNL	Effective Perceived Noise Level
FHWA	Federal Highway Administration
Free-Field	Acoustic condition free of reflecting objects including the ground
GIS	Geographical Information System
K	State of Confinement Factor used for Blast Modeling
LEQ	Average Equivalent Sound Level (A-weighted)
LMAX	Maximum Sound Level (unweighted)
LMAXA	A-weighted Maximum Sound Level
Lnn (L1, L10, L50)	The statistical A-weighted sound level that is exceeded nn% of the time, in any consecutive 60 minute period of the day. For example, L1 is exceeded 1% of the time, (36 seconds) in a given hourly period.
LPEAK	Peak Sound Level from Blast Operations (unweighted)
Mic	Microphone
ODOT	Oregon Department of Transportation
PSF	Pounds per Square Foot
QNM	Quarry Noise Model
RCNM	Roadway Construction Noise Model
SEL	Sound Exposure Level (A-weighted)

Executive Summary

The Oregon Department of Transportation (ODOT) has need of a tool to help predict noise exposure to sensitive receivers in areas surrounding ODOT quarries. The Quarry Noise Model (QNM) was developed for ODOT by the Volpe Transportation Systems Center, a division of the U.S. Department of Transportation. The QNM has, at its heart, three inter-communicating components as shown in Figure 1. These are the QNM Noise Database, the Acoustic Engine, and the QNM GIS Module.

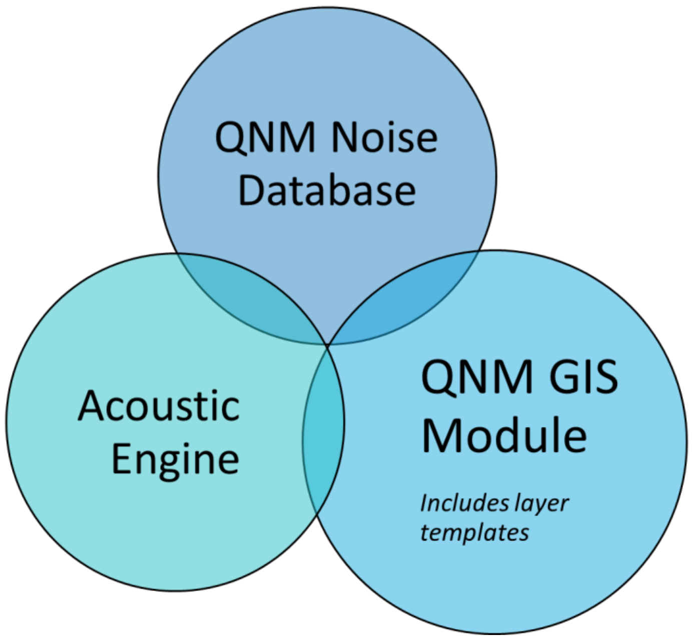


Figure 1. The Three Main Components of the Quarry Noise Model

The QNM GIS Module was developed expressly for the purpose of identifying, in a georeferenced fashion, quarry operations that create noise. The GIS Module streamlines the running of the Acoustic Engine using this data and receives the noise calculations that are then displayed within the GIS environment.

This documentation describes the QNM model, its operation and limitations, and assumptions. Guidance for typical quarry analyses, default modeling parameters and recommendations for sensitivity studies to provide insight as to the uncertainty of the modeled results are provided.

1. Introduction

Large regions of Oregon rely heavily on material from Oregon Department of Transportation (ODOT) quarries for projects such as road maintenance. Recently, the potential listing of sage grouse as endangered species prompted ODOT to consider whether activities from ODOT aggregate source sites would comply with potential Oregon Department of Fish and Wildlife (ODFW) recommended mitigation. Given that noise levels of ODOT quarry operations have yet to be fully investigated, a need was identified to collect, analyze, and model quarry noise data for development of a methodology that can be applied throughout the state for determining noise impacts within habitats of noise sensitive species.

The key objective of this project was to develop a GIS-based noise model of ODOT aggregate source (quarry) operations that can be visually mapped in relation to habitats for noise sensitive species.

Potential benefits from this research and development project include:

- Determination of ODOT compliance with ODF&W habitat quantification tool (HQT) and mitigation recommendations. This research also may have the potential to support ODOT requests for refined ODF&W guidelines.
- Findings can apply to several sensitive species adjacent to quarries.
- Findings can apply to other sensitive receivers (residences) located near ODOT material sources.
- Establishment of methodology for impact analysis that can be used at any aggregate source site.
- Provide streamlining process for future impact determinations at other aggregate source sites.
- Data and tools can be useful to other states, the FHWA and the USDOT.

2. QNM GIS Module

The QNM GIS Module Version 1 represents the Graphical User Interface (GUI) for the Quarry Noise Model (QNM). The GIS Module harnesses both custom and existing built-in tools within ESRI's ArcGIS 10.5.1 interface to streamline the process of creating and running quarry noise scenarios. Below is a brief overview of the QNM GIS Module functionality.

- Create and populate the scenario inputs geodatabase with actual quarry geography data.
- Define routes using the Quarry Noise Toolbar.
- Define Operations (Point, Route, Area, and Blast).
- Prepare Elevation Data.
- Prepare Impedance Data.
- Prepare Foliage Data.
- Prepare Noise Model Input.
- Run AAM (from Noise Model Output file).
- Process AAM Outputs.

This document provides detailed instructions on using the QNM GIS Module. To get started running the noise model using the existing sample data, refer to the QNM GIS Module Quick Start Guide in Appendix A. For details on the parameters that need to be defined by the user when setting up a scenario, refer to the AAM input file format documentation (Section 4.2).

2.1 Installation Instructions

The QNM GIS Module consists of the existing functionality of ArcGIS 10.5.1—which must be installed on the user's computer, along with two Python-based ArcMap add-ins: the Quarry Noise Toolbar and the Quarry Noise Toolbox. The Quarry Noise Toolbar and Toolbox are designed for users with at least some prior experience using ArcMap. Both the Quarry Noise Toolbar and the Quarry Noise Toolbox were designed and tested using ArcGIS 10.5.1 but the Module should also be compatible with subsequent versions of ArcGIS (e.g. 10.6.1).

2.1.1 Quarry Noise Toolbar Installation

1. To install the Quarry Noise Toolbar, with ArcMap closed, double click on the Quarry_Toolbar_Add_In.esriaddin file located within the following directory: …/QNM_v_**XXXXX**/QNM_program/GIS_Module/Toolbar/Quarry_Toolbar_Add_In. An "Esri ArcGIS Add-In Installation Utility" dialog box will open-- click Install Add-In to confirm the Add-In file installation. A message should immediately pop up indicating that the installation succeeded. Click OK. Any previous versions of the Quarry Noise Toolbar will be overwritten when a new version is installed.

2. Open ArcMap. The custom toolbar or menu may already be visible and ready to run. If it is not visible, navigate to the Customize menu and click Add-in Manager. The Add-In Manager dialog box lists the installed add-ins that are targeting the current application. Add-in information, such as name, description, and image, entered as project settings should be displayed.
3. If the Quarry Noise Toolbar add-in is listed in the manager, click the Customize button to open the Customize dialog box. To add a toolbar to the application, click the Toolbars tab and choose the Quarry Noise Toolbar.

2.1.2 Quarry Noise Toolbox Installation

1. With ArcMap open, navigate to Geoprocessing-> ArcToolbox.
2. If applicable, remove any existing version of the Quarry Noise Toolbox from the ArcToolbox menu by right clicking on it and selecting “Remove”.
3. Right click on ArcToolbox and select Add Toolbox. Navigate to the directory where the Quarry Noise Toolbox (Quarry_Toolbox.pyt) was saved, (…/QNM_v_**XXXXX**/QNM_program/GIS_Module/Toolbox) and open it. It should now be added to the list of toolboxes available within the open map document.

2.2 Preparing the Quarry Noise Scenario GIS Data

Before beginning to prepare the quarry geography, identify the quarry’s location. Open ArcMap and add Esri’s built-in basemap to the map document (located under File→ Add Data→ Add Basemap). Having the basemap available will also help with digitizing quarry geography later in the process. Zoom to the quarry of interest. The user can refer to the aggregate quarry layer and milepost layer available at ODOT’s TransGIS site to help with location quarries in Oregon.

Within the Scenarios subfolder of the QNM application (or alternatively, a folder of the user’s choice), create a new working scenario folder for storing all scenario inputs and outputs. The user may wish to make this folder the map document’s home folder for quick access (to change the Home folder, open the Catalog window within the active map document, click the Options button, and select the Home Folder tab). If there is existing elevation data to be used in the scenario, place a copy of the data within the scenario directory. Likewise, any existing impedance data can be placed in the scenario directory as well. If this data needs to be tracked down or created, users can refer to Section 2.4 Prepare Elevation and Section 2.5 Prepare Impedance for additional tips.

Before running the quarry noise module, the user must prepare the input data associated with the quarry. The first step in this process is to run the **Create Input Geodatabase** tool within the Quarry Noise Toolbox. The purpose of this tool is to generate a template scenario input geodatabase that contains empty feature classes that will store the quarry features (points, road segments, routes, and areas), along with other supporting feature classes and tables.

The parameters the user can customize in this tool include:

- The working scenario directory the user wishes to store the geodatabase, which is also where the scenario outputs will be stored.
- The spatial reference system to be designated for all generated scenario inputs. The spatial reference system should be a local coordinate system appropriate for use in the region, with linear units in feet. The current version of QNM only supports scenario data prepared using a foot-based coordinate system.

The output of this tool is a geodatabase called scenario_inputs.gdb which includes the following feature classes and tables:

- **Points, Road_Segments and Areas**—for storing the three categories of geographic data where quarry noise operations can occur.
- **Routes and Routes_Description**—for storing the information related to the series of road segments over which a quarry noise operation might travel.
- **Area of Interest (AOI)**: Utilized by QNM GIS Module to calculate the scenario's analysis extent and clip elevation, impedance and foliage data during preparation.
- **Operations** table: Stores the linkage between a noise source and the geography the noise source will be utilizing in the scenario.
- **Foliage:** Optional polygon feature class for identifying areas where foliage may impact noise propagation.
- **Points of Interest (POI):** Optional feature class for storing points where the user would like to determine specific noise impacts
- **Quarry Boundary**: Optional feature class that can be used to help calculate the 'worst-case scenario' directionality of point noise sources.

The following section (2.2.1) of the documentation provides instructions on populating most of the feature classes and tables with real quarry data. The exceptions are the routes feature class, routes_description table and operations table. See the Quarry Noise Toolbar section (2.2.2) for information on populating the routes feature class and routes_description table. The operations table is populated by the user through the running of various tools in the Quarry Noise Toolbox (2.3).

2.2.1 Digitizing the Quarry Noise Scenario

The most time consuming part of the scenario preparation is the digitization of the quarry geography. While it is possible to use existing GIS and CAD data for the quarry to help populate these datasets, it is important that the data fit into the template input geodatabase generated by the Create Input Geodatabase Tool. This tool creates all the feature classes and tables and relevant attributes that need to be read in order to properly generate the scenario's AAM input file.

The feature classes must be populated with actual quarry data by the user, utilizing built-in ArcGIS tools. It is recommended that the user digitize features using the ArcMap Editor Toolbar. To get started, use the Add Data Button to add the scenario geodatabase's empty feature classes to a map, and zoom in to the quarry's immediate vicinity. Before editing make sure the data frame coordinate system matches the coordinate system of this layer (ODOT GIS milepost layer is in NAD_1983_Oregon_Statewide_Lambert_Feet_Intl). This can be done from the Table of Contents (right click input layer > Properties > scroll to Layers > select appropriate coordinate system).

Next, under Customize→ Toolbars, ensure that the Editor Toolbar is enabled. Within the Editor Toolbar, click the Editor dropdown and select 'Start Editing'. Click on the Editor dropdown again and select Editing Windows→ Create Features. The Create Features window should open. The user can then select the feature class of interest, and then digitize the feature by clicking on the map.

When digitizing point, road segment, area, and POI features, the user should ensure that all these features have a unique name or short descriptor of no more than 12 characters. The user can open the attribute table to populate this information while digitizing each feature (right-click on the feature within the Table of Contents window and select Open Attribute Table). This will streamline the defining of operations later on in the process. It is not necessary for the AOI and Quarry_Boundary feature classes to contain any attribute data, including names. For reference, a sample scenario input geodatabase is included with QNM.

Foliage data must be populated with real data indicating the spatial extent of foliage that is dense enough to impact noise propagation. When digitizing foliage data, the user should edit the "Foliage_Height" field for every distinct section of foliage, inputting the estimated height of the foliage in feet.

In QNM, features within the areas feature class must consist of only four corners (e.g. all areas must be quadrilaterals). Any areas consisting of more or less than four corners will not be processed by QNM. This limitation does not apply to the other polygon feature classes in the scenario (e.g. AOI, Foliage and Quarry Boundary feature classes), though it is worth nothing that regardless of the number of corners, any AOI feature class will always be simplified to the closest-fitting rectangle due to limitations with the ASCI raster format.

Special care should be taken when adding road segments to the scenario. Most importantly, the quarry road network must be split at every intersection. For example, if there is a road traveling from points A-B-C, and another road segment traveling from points B-D, there should be three road segments (A-B, B-C, and B-D). A scenario with two road segments (A-C and B-D), would not allow an operation to flow from A-B and onwards onto B-D. The user should also take care to ensure that there are no gaps in the road segment network. To that end, it is critical that the user enable snapping functionality within ArcGIS when digitizing the road segment network by clicking on the Editor Dropdown→ Snapping, enabling the Snapping Toolbar and ensuring that End Snapping is enabled during the active edit session.

Routes (which are a series of two or more road segments that are traversed by a quarry vehicle in a certain direction) are not to be digitized or edited the same way as the other quarry features described in this section—while in Editing mode, routes instead must be defined using buttons located within the

Quarry Noise Toolbar (see Section 2.2.2 below). The user should completely finalize the road segment network before moving on to defining routes.

While in Editor mode, the user can easily delete any points, POIs, areas, road segments, foliage areas, AOIs, and quarry boundaries digitized in error by opening the attribute table for the feature class of interest, selecting the feature that should be deleted, right clicking the edge of the attribute table and clicking Delete Selected. When complete with feature digitization, use the Editor dropdown menu within the Editor toolbar to save and stop editing.

2.2.2 Quarry Noise Toolbar

The purpose of the Quarry Noise Toolbar is to utilize the ArcMap interface to define routes that will be utilized by quarry noise sources-- and in turn fed into AAM for the purposes of modeling noise. Before running the set of buttons within the toolbar, the user should ensure that the road_segments feature class has been finalized with all the road segments to be utilized in the scenario. Each road segment should be given a name or short descriptor. In order to properly use the Quarry Noise Toolbar, the user will need to add the quarry scenario input geodatabase's road_segments and routes feature classes along with the routes_description table to an ArcMap document. The toolbar will not function properly without these feature classes and tables added to the map document. It may be helpful to also add an ArcMap imagery basemap. Also, the user should open the ArcMap Python window (Geoprocessing→ Python) to view any warning/error messages that are communicated while using the toolbar.

There are three components to the toolbar:

- **Initialize Route**
    - This button clears out any existing temporary route feature classes and generates a new in memory feature class ready to be populated.
- **Prepare Route from Segments**
    - Once this button is clicked, the user can select—in order—the road segments that make up a route. Road segments must be selected in the order they are traversed—and a road segment must neighbor the previously selected road segment. The ArcMap Python window will warn the user if a road segment is selected which is not neighboring the previously selected road segment. If the user makes a mistake or wishes to start over with the route creation process, simply click on Initialize Route again to reset the process.
    - The tool automatically captures the directionality of each road segment based on the order the user selects the road segments.
- **Finalize Route**
    - The user has the opportunity to name the route (by entering text in the text box to the right of the button's icon) and then pressing enter on the keyboard finalizes the route and appends it to the scenario's routes feature class. Limit the route name to 12 characters or less.

Figure 2 shows an example of what the ArcMap display might look like after populating a quarry scenario with actual GIS data.

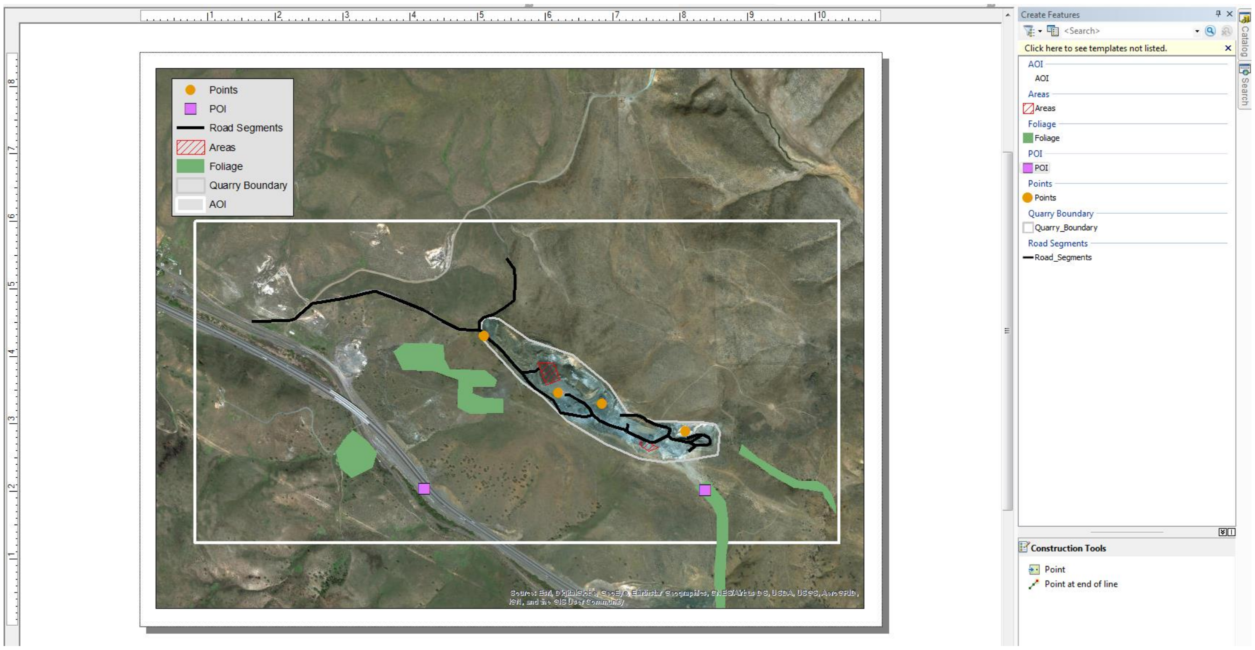


Figure 2. ArcMap display after quarry scenario digitization

2.3 Defining Quarry Operations

Once the Quarry Noise Scenario digitization is finalized, the user is ready to define quarry operations. There are a series of four tools (**Define a Point Operation, Define a Route Operation, Define an Area Operation, and Define a Blast Operation**) in the Quarry Noise Toolbox that streamline the process of defining a quarry operation by allowing the user to link a noise source to the geography that a noise source is utilizing.

Specific inputs required for each of the tools vary for each of the tools, but always include:

- Scenario Geodatabase—Input geodatabase storing the quarry geographies (points, routes, areas).
- Number of Daytime Operations and Number of Nighttime Operations (operation count). If a quarry operation is associated with more than one identical piece of equipment running on the same geographic feature, the user can define the number of operations here. For example, if there are four trucks running along the same quarry route during the day (but not during the night), then the user can define the number of daytime operations as four and the number of nighttime operations as 0.
- The specific geographic feature (from the digitized quarry scenario) associated with the operation. The geography names are populated based on the input geodatabase selected. The

tool will automatically provide a list of options populated with the user-defined name of each geographic feature (from Section 2.2).

For points, routes and areas, the users will also need to define the following:

- Directory containing the quarry noise database (Within the AAM program directory, this should be located in common_data→ acoustic data).
- The specific noise source associated with the operation. These noise sources are populated from the noise database—stationary equipment can only occur at points and passby equipment can be assigned to routes or areas.

For points and areas, the user will also need to define the following:

- Operation time (duration) in hours. The operation time must not exceed the maximum of 15 hours for daytime operations and 9 hours for nighttime operations. If the operation time is different for daytime and nighttime operations, then run the Define Operation tool separately for the daytime and nighttime operations to properly associate the two distinct run times with each operation. Examples 1 and 2 below are valid for daily operation (24 hour) analysis for a single piece of equipment; Examples 3 and 4 are valid for a statistical metric (1 hour) analysis for a single piece of equipment. Example 5 is valid for a statistical metric (1 hour) analysis for 3 pieces of equipment running concurrently. Note that Examples 1 and 2 result in the same noise output.
    - Example 1: if the same operation is running for 15 hours during the day and 9 hours at night – 24 hours overall, enter 15 day hours and 9 night hours as separate entries with 1 operation for daytime and 1 operation for night time. Because the operation time can only be set once for each run of the Define Operation tool, the tool will have to be run twice—once for the daytime portion of the operation and once for the nighttime portion of the operation.
    - Example 2: if the same operation is running for 15 hours during the day and 9 hours at night – 24 hours overall, enter a single operation with 1 hour duration, but specify 15 daytime operation count and 9 for the night time operation count.
    - Example 3: if the hour to be modeled for statistical metrics is during the daytime, enter 1 hour duration and 1 daytime operation count.
    - Example 4: if the hour to be modeled for statistical metrics is during the nighttime, enter 1 hour duration and 1 night time operation count.
    - Example 5: if the hour to be modeled for statistical metrics is during the daytime and there are 3 pieces of equipment running concurrently, enter 1 hour duration and 3 for the daytime operation count.

Once run, the tool will write a new row with all the applicable information within the operations table of the scenario inputs geodatabase (scenario_inputs.gdb, created by the Quarry Noise Toolbox script 'Create Input Geodatabase'). To edit these operations after running these tools, use the Editor toolbar to activate an Editing session, open the attribute table for the Operations table, select operation and select delete. There are additional parameters specific to geography types described in the following sections. For more details on all the parameters that need to be defined using these tools, refer to Section 4.2 below.

2.3.1 Define a Point Operation

Parameters unique to defining a point operation include the optional heading and quarry boundary. The user can either set the quarry boundary or explicitly define the heading—not both. Selecting a quarry boundary feature class will prompt the noise model to automatically calculate the worst case scenario that orients the loudest noise from that operation to the closest quarry boundary. The quarry boundary option requires the ArcGIS Desktop Advanced license and will not function with a Basic or Standard license. Defining a heading simply orients the front of the equipment as specified. Note that in the case of equipment with omnidirectional noise, specifying a heading or quarry boundary will not make a difference.

2.3.2 Define a Route Operation

For operations traversing routes, the user will need to define the speed of the equipment at each node along the route, in miles per hour (mph). The default is 10 mph for each node. All speed values must be comma-separated. The user can edit these values before running the tool.

2.3.3 Define an Area Operation

Parameters unique to area (distributed) operations include the number of model points along the primary (longest) edge and the number of model points along the secondary edge. These numbers allow the user to customize the density of the points across the areas which will be used to distribute operations across the specified area.

2.3.4 Define a Blast Operation

Parameters unique to blast operations include the state of confinement factor and instantaneous charge per hole (lbs). Note that scenarios which contain blast operations should not include any other operation types, as AAM must model blast noise separately.

2.4 Prepare Elevation

The purpose of this tool is to generate elevation data compatible with the Quarry Noise Model. Before running this tool, the user must have available a GIS-based raster dataset of elevation data. The user can use pre-existing elevation data such as the Oregon Statewide 10-meter geodatabase available via ftp://ftp.gis.oregon.gov/elevation/DEM/Statewide_Filegeodatabase/, or generate their own using other more detailed data, such as quarry-based CAD data. For more information on using CAD data in ArcMap, see Appendix B of this documentation. While the elevation data can be stored anywhere on the user's local machine, it may be beneficial to place a copy of the data into the scenario directory for easy access.

The Prepare Elevation tool clips elevation data to the area of interest (AOI), re-projects elevation data to the user-defined spatial reference (if necessary), and converts the data into a format that can be read by AAM. It also allows the user to resample the elevation data to a different cell size than the cell size of the raw data, if desired. Using a larger cell size may help with AAM performance when the scenario is run. The Prepare Elevation tool will not function properly if an AOI has not been populated in the scenario input geodatabase.

The user will need to define the following parameters:

- The directory containing the scenario data and where the generated elevation data should be saved.
- The source elevation data (any GIS-based raster format).
- Output file name.
- The spatial reference to be used in the scenario—this should be identical to the spatial reference used by the scenario input geodatabase.
- The analysis extent—this should be the AOI feature class populated by the user during scenario geodatabase setup.
- Resample elevation data—if checked, the elevation data will be resampled.
- Resampled elevation grid size—the desired resampled grid size (in the same units as the scenario spatial reference system). Defining a larger grid size decreases the level of detail in the elevation data processed by AAM, but can also significantly improve run time.

For more information and context on running the Prepare Elevation tool (along with the Prepare Impedance, Prepare Foliage, Prepare Noise Model Inputs, and Process AAM Outputs tools) see the Quick Start Guide (Appendix A).

2.5 Prepare Impedance

The purpose of this script is to generate impedance data compatible with the Quarry Noise Model. Before running this tool, the user must have available a GIS-based raster dataset of impedance data with values in RAYLs. The user can use pre-existing impedance data such as the dataset provided with the sample scenario. The dataset provided with the sample scenario is Oregon-wide impedance data based on the 2011 National Land Cover Dataset (NLCD). The land cover categories from the NLCD were reclassified using ArcMap's Reclassify tool into RAYL impedance values that followed the guidance in the AAM User Manual. Alternatively, users can generate their own raster-based impedance data based on a newer version of the NLCD or other land cover datasets.

Table 1 shows the reclassification values used to convert the 2011 NLCD into RAYL values using the ArcMap Reclassify tool.

Table 1. Reclassifying the National Land Cover Dataset into Impedance Values

NLCD Value	Remapped Impedance Value (RAYLS)
11	1000000
12	30
21	30000
22	30000
23	30000
24	30000
31	6000
41	50
42	50
43	50
52	225
71	225
81	225
82	225
90	50
95	225

Refer to the AAM Technical Reference and User Manual for further information on impedance data. The Prepare Impedance tool itself operates identically to the Prepare Elevation tool. The Prepare Impedance tool will not function properly if an AOI has not been populated in the scenario input geodatabase.

2.6 Prepare Foliage

The purpose of this script is to generate foliage data compatible with the Quarry Noise Model. Unlike elevation and impedance data, foliage data is not required for running the Quarry Noise Model. However, including it can enhance the accuracy of analyses where foliage may impact noise propagation. Before running this tool, the user must have populated the scenario input geodatabase’s foliage feature class with actual foliage data, including a foliage height attribute (units in feet). The remainder of the tool operates similarly to the Prepare Elevation and Prepare Impedance tools, although there are fewer parameters that need to be defined.

Grid size refers to the spacing between each point in the foliage height grid that is output by this tool. Choosing a smaller grid size increases the level of detail of the mesh of points representing foliage height. When determining a grid size, one needs to consider the desired fidelity of the foliage and the number of mesh points that accurately represent their locations. In general the geometric spacing used for the foliage file should be similar to that used for the elevation and impedance files. The Prepare

Foliage tool will not function properly if an AOI has not been populated in the scenario input geodatabase.

2.7 Prepare Noise Model Input

The purpose of this tool is to prepare the noise model input deck based on all the quarry geography and operation information. It also creates a .bat file which allows the user to run AAM outside of the QNM GIS Module. This tool must be rerun anytime any portion of a scenario's GIS data changes. If a point is added to a scenario, or the name of a geography is changed, this tool should be rerun to ensure that the AAM input file generated is up to date.

Note that the tool will not run if blast operations are mixed with any other type of operation, as blast operations must be modeled separately in AAM.

Parameters that will need to be defined by the user include:

- Scenario Name (the scenario's input file will be given this as the file name; do not start the name with a numerical value or include spaces in the file name).
- Input Geodatabase.
- Elevation Data.
- Impedance Data.
- Noise Database Directory.
- AAM Executable.
- Scenario Directory (where the outputs will be saved—should be the same directory containing the input geodatabase).
- Compute Noise Grid: if checked, the tool will calculate noise impacts across the entire grid represented by the AOI feature class.
- Compute Noise at POIs: if checked, the tool will calculate noise impacts for the points included within the scenario's POI feature class.
- Analysis Grid Size (in the units of the scenario's spatial reference system). The grid size must be small enough to generate at least a 5x5 grid across the Area of Interest. For example, if the scenario's area of interest is only 1,000 meters by 1,000 meters in size, a grid size of 300 meters will be too large – the grid size must be no grated than 200 meters in order to produce a grid of at least 5x5 cells. Take care not to define too low of a grid size as the analysis run time will increase with lower values.
- Temperature, Pressure and Relative Humidity.
- Foliage Data (optional).

2.8 Run AAM

There is currently no functionality to run AAM directly within the QNM GIS Module. In order to run AAM, the user will need to double click on the Run_AAM.bat file created by the Prepare Noise Model Input tool (located in the scenario directory where outputs are saved from running the Prepare Noise Model Input tool). A command prompt window will open and provide messages updating the user on the progress of running the tool. Refer to Section 4.4 of this documentation and the AAM Manual for additional information on any of the status or error messages displayed within the command prompt.

2.9 Process Outputs

This tool processes the .asc files and .csv files generated by AAM and converts them into GIS-formatted files that can be viewed in ArcMap. It also moves all raw AAM outputs into a scenario directory subfolder to keep the scenario directory organized. The new GIS files generated include:

- Point feature classes representing noise at POIs.
- Raster datasets representing noise over the extent of the AOI for each noise measurement.
- Polyline feature classes representing noise contours over extent of the AOI for each noise measurement.

Parameters that will need to be defined by the user include:

- The scenario directory containing the AAM output data.
- The scenario name.
- The spatial reference system. This should be the same spatial reference used for the scenario inputs.

The output feature classes and raster datasets from this tool can be added to a map document in ArcMap for analysis and visualization. See Figure 3 for an example of what that might look like in the ArcMap interface.

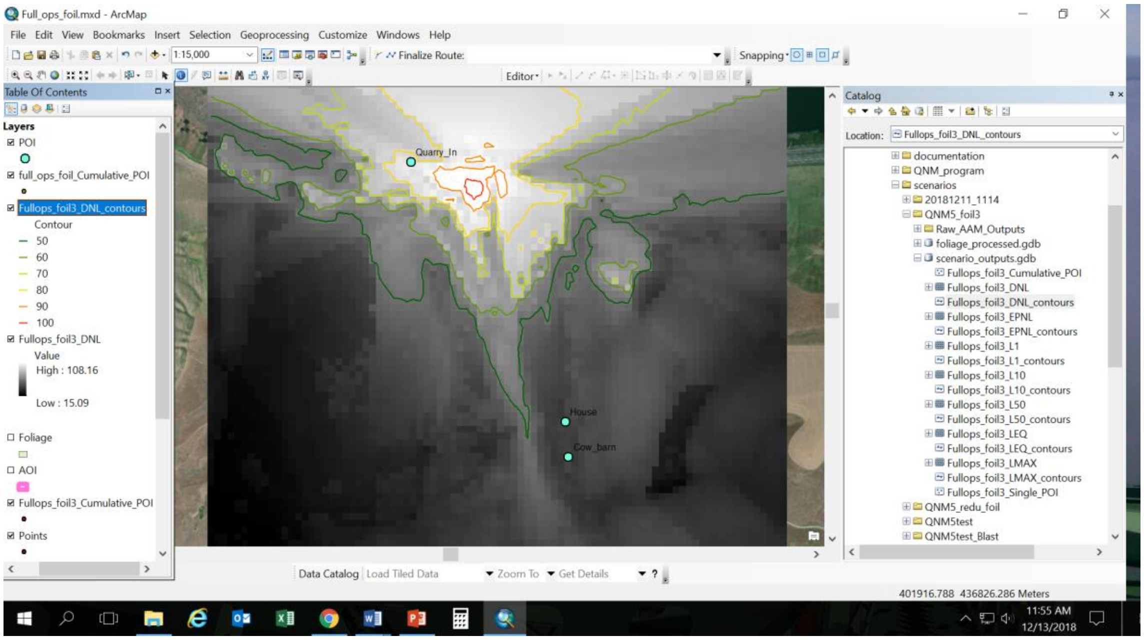
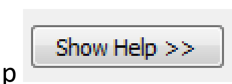
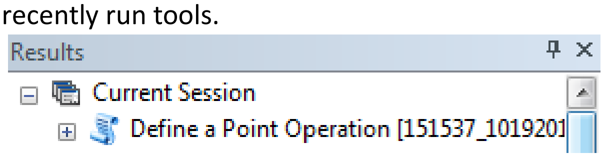


Figure 3. Example Noise Output within the ArcMap environment

2.10 General Tips for Running the GIS Module

- When any GIS Module Toolbox tool is open, click on the Show Help 

button to expose additional tool documentation, including details defining each parameter.
- In the ArcMap tool dialog, click on Geoprocessing→ Results to open up a window showing recently run tools.

  When the user double clicks on a previously run tool that appears in this list, the tool's dialog will appear with all of the parameters populated with what was run previously. This facilitates the process of repeatedly defining new quarry operations for a specific scenario, automatically populating all the parameters and allowing the user to change only what needs to be changed for the definition of a new operation.
- Do not include any special characters (-',.) or spaces in GIS Module file names. Underscores are an acceptable substitute for spaces. Do not start file names with numbers.

3. QNM Noise Database

This section describes the methodology used to develop the QNM Noise Database and includes information about the noise data parameters, origins, standardization, aggregation and organization.

3.1 Noise Data Parameters

Noise data parameters are required in order to identify and accurately model noise emissions and propagation over distance. Two types of parameters are included in the noise database: classification parameters, which are used to identify the source, and emission parameters, which characterize the physics of the emitted noise. The classification parameters are: Source ID, Source Name, Source Mode and Operation and are defined as follows:

- Source ID – a unique, numeric value, e.g. 1024, that is associated with a particular noise source, mode and operation combination.
- Source Name – the type of equipment that the data are associated with, e.g. “Front End Loader”.
- Source Mode – indicates whether the source is moving or stationary.
- Operation – provides a description of the activity being conducted, e.g. “scooping and dumping dirt/rocks or scooping gravel piles”

The emission parameters are: Source Height, Noise Metric, Orientation and the Z-weighted One-third Octave Band Levels from 10 Hz to 10 kHz and are defined as follows:

- Source Height – indicates that height above ground from which the sound will propagate.
- Noise Metric – indicates whether the sound pressure level data are a maximum (LZmax, for moving sources) or an average (LZavg, for stationary sources).
- Orientation – the orientation between the nominal front of the source and the receiver location. Four angles are defined: 0 degrees, the receiver is directly in front of the source, 90 degrees, the receiver is directly to the right of the source, 180 degrees, the receiver is directly behind the source, and 270 degrees the receiver is directly to the left of the source.
- Z-weighted One-third Octave Band Levels – the sound pressure level for each one-third octave band level between 10 Hz and 10 kHz, normalized to reference distance of 100 feet. There is a unique value for each Source ID, orientation, and one-third octave band combination.

Note: Z-weighting is a technical descriptor for data that has not had any spectral filters (such as A, C, D-weighting) applied.

3.2 Noise Data Origins

While the QNM has an expandable database allowing for newly measured sources to be added, the initial database was developed using existing source measurements. There were three main sources that supplied these data. The first was a set of reports, copies of which ODOT provided to the Volpe Center (Table 2 #1 to #6 and #8 to #11). The second was a single report from ODOT that was provided to the Volpe Center (Table 2 #12), which was generated specifically for ODOT and thus represents specific equipment found at ODOT sites. The third was a set of source data that were collected for the National Highway Cooperative Research (NCHRP) Project 25-49 for an update to the Federal Highway Administration's (FHWA) tool, Roadway Construction Noise Model (RCNM) (Table 2 #7). As none of these data sets were developed for the specific purpose of supplying the QNM with emissions data, the degree of suitability varied from one source to the next and Table 2 summarizes the strengths and weaknesses of various data sets.

Table 2. Summary of Data available in Reports and other Sources of Quarry Noise Data

Data Source	Included in Database	IDs	Source Height	Mic Height	Mic Distance	Ground Type	Overall Level	Octave Band	1/3 Octave Band
1) Back River Project - (Rescan, 2013) (Table A1-1)	Yes	2024-2038	Estimated	Estimated	Yes	No	L_w	L_w	Estimated
2) Black Point Quarry - (SLR, 2015) (Table 7-1)	No	No	Estimated	No	No	No	Estimated L_w	No	No
3) Blackwater Gold Project - (Newgold, 2015) (Table 1,2, 4, 5, 6)	No	No	Estimated	No	No	No	L_p Range	L_w	Estimated
4) Brown's Range Project - (LGA,2014) (Table 3-3)	No	No	Estimated	No	No	No	L_w	L_w	Estimated
5) Khongoni Haskraal Coal Project -(Golder, 2015) (Table 3)	No	No	Yes	No	No	No	L_w	No	No
6) Klamath Facilities Removal – EIS (Klamath EIS, 2011) (Table U-3, U1A-D)	No	No	Estimated	No	50ft	No	L_max	No	No
7) NCHRP 25-49 (NCHRP 25-49, initiated 2015)	Yes	1000-1069	Estimated	Yes	Yes	Yes	Yes	Estimated	Yes
8) NOISE DATABASE DEFRA (DEFRA, 2005) (Table 1-8)	Yes	2039-2337	Estimated	Estimated	10m	No	L_p	L_p	Estimated
9) Noise Effects - HARPER CREEK MINING CORP. (Harper, 2015) (Table 10.5-2, 10.5-3)	No	No	Estimated	No	No	No	L_w	No	No
10) Pinedale Sage Grouse (Ambrose, 2013) (Table 7)	No	No	Estimated	No	100m	No	L_50	No	No
11) TNG- NVA Report (GHD, 2015) (Table 7-2 to 7-5)	Yes	2338-2371	Estimated	Estimated	Yes	No	L_w	L_w	Estimated
12) SLR Noise Measurements for ODOT Region 4 and 5 Aggregate Sites (SLR, 2016)	Yes	1070-1077	Estimated	4 ft	Varies	No	L_p	L_p	L_p
Color Key:	Yes		Partial / Need to Estimate			Not Available			

3.3 Standardization of Noise Data

For each noise source, the noise data were standardized to Z-weighted, one-third octave band sound pressure levels at the source's height, 100 feet from the source itself. When sufficient data were available the sources were also converted to the free-field (i.e. the ground effects were removed). The ways in which the original noise data did not fit this format included the following:

- Distance to source was other than 100 feet
- Spectral resolution other than one-third octave bands
- Frequency weighting other than Z
- Noise metrics other than sound pressure level
- Not free-field (ground effects were included)

Corrections to the reference distance of 100 feet were accomplished by subtracting the spherical spreading attenuation at the measured distance and then adding the spherical spreading attenuation at 100 feet. Both of these attenuations were computed using AAM (Note this correction uses the AAM acoustic module, as does QNM, to propagate the sound from the reference distance to receptor locations).

Only one-third octave band and octave band data were considered. Estimation of one-third octave band levels from overall levels was not performed since there is no way to estimate from overall levels how the spectrum will vary from one octave band to the next. (This would be analogous to estimating the elevation at a given point in a hilly area, knowing only the average elevation, but having no knowledge of where peaks and valleys are or even whether there is a general trend of approaching the sea or mountains.) One-third octave band data were estimated from octave band data using a spline interpolation described below. (The spline interpolation was implemented using the "fit" function in Mathworks' Matlab 2018. www.mathworks.com)

Spline interpolation assumes that one-third octave bands change monotonically between octave band center frequencies. This assumption is reasonable for sources that are composed predominantly of broadband noise or dense tonal complex; however, discrete tones may not be well represented by this approach. To guarantee that the overall level is unchanged in the spline interpolation used in the development of the QNM acoustic database, the one-third octave band spectra for each cluster of three one-third octave bands contained within a single octave band were modified as follows:

$$\boldsymbol{O_{\frac{1}{3},j-1} = O_{\frac{1}{3},j} + \Delta_{j-1}} \qquad \text{Equation 1}$$

$$O_{\frac{1}{3},j+1} = O_{\frac{1}{3},j} + \Delta_{j+1} \qquad \text{Equation 2}$$

$$O_{\frac{1}{3},j} = O_i - 10 \times \log_{10}(1 + 10^{\frac{\Delta_{j-1}}{10}} + 10^{\frac{\Delta_{j+1}}{10}}) \qquad \text{Equation 3}$$

where O is the octave band that contains $O_{\frac{1}{3},j-1}$, $O_{\frac{1}{3},j}$ and $O_{\frac{1}{3},j+1}$, and Δ_{j-1} and Δ_{j+1} are differences in the values of the spline fit between *j-1* and *j* and between *j+1* and *j* respectively. *i* and *j* are indices used for tracking which octave band or one-third octave band is being considered, so they do not include any units. $O_{\frac{1}{3}}$ and O are in units of Hertz. In some cases the original octave band data did not have levels for some high and/or low frequencies. These components were set to zero dB. A sample result is shown in Figure 4. In this case, eight low frequency one-third octave bands within the frequency range of interest were set to zero and one high frequency one-third octave band within the frequency range of interest were set to zero. Note also that the one-third octave band data have lower levels than the octave band data. This is required in order to maintain the overall level of the source in question during the interpolation process. (The interpolation process triples the number of elements in the summation. If the levels for each were not lowered in accordance with Equations 1 to 3, the overall level would be overestimated.)

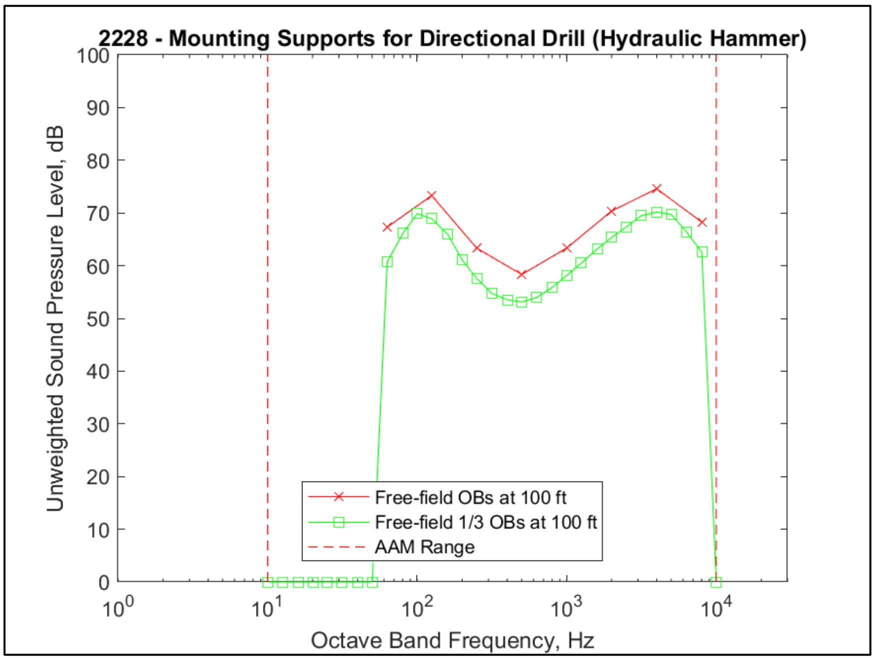


Figure 4. Sample of the interpolation process to estimate one-third octave band levels from octave band data

In some cases the original data were reported using A-weighting. Because AAM utilizes Z-weighting data, these were converted from A- to Z-weighting by removing the standard A-weighting attenuations.

In some cases, the reported levels were for sound power level rather than sound pressure level. Sound power level is a convenient method to report noise data as it is not a function of distance; however, AAM expects sound pressure level at 100 feet. To accommodate for AAM inputs these data were converted to sound pressure level at 100 feet using the following standard equation (Pierce, 1989):

$$L_p = L_w + 10 \cdot \log_{10}\left(\frac{Q}{4\pi r^2}\right) \qquad \text{Equation 4}$$

Where L_p is the sound pressure level, L_w is the sound power level, Q is the directivity factor, which is 2 for a flat surface [Pierce, 1989], and r is the distance in meters. Note that this formula does not account for the complexity of the interference pattern between direct and reflected rays. Given the limited detail in the source data, it was not possible to estimate the interference patterns accurately. So the ground effect described by Q = 2 was maintained.

In cases where there was sufficient data to estimate ground effects, e.g. accurate estimates of source and measurement heights, distance and ground type, the ground effects were computed in AAM for the measured distance, source and receiver heights, ground type and atmospheric conditions. The AAM output values were then subtracted from estimates to remove the ground effect. Correcting for the ground effect was attempted for the values from Table 2 (#1 to #6 and #8 to #12); however, depending on the estimates of the geometry components and ground type, the ground effect interference patterns became overemphasized to a point that they could adversely affect the accuracy of the propagation predictions. See for example the 500 Hz peak in the free-field spectrum in Figure 5. In general, these peaks would not be expected due to variation in the geometry and ground (for moving sources) and spectral density (energy is not all concentrated at a single frequency within the octave band) in a practical application. For the current database, ground effect corrections were only applied to the RCNM data. Eventually, an approach to decrease the coherence between the direct and reflected rays could help to mitigate this overestimation, but this was not feasible for this ODOT research project.

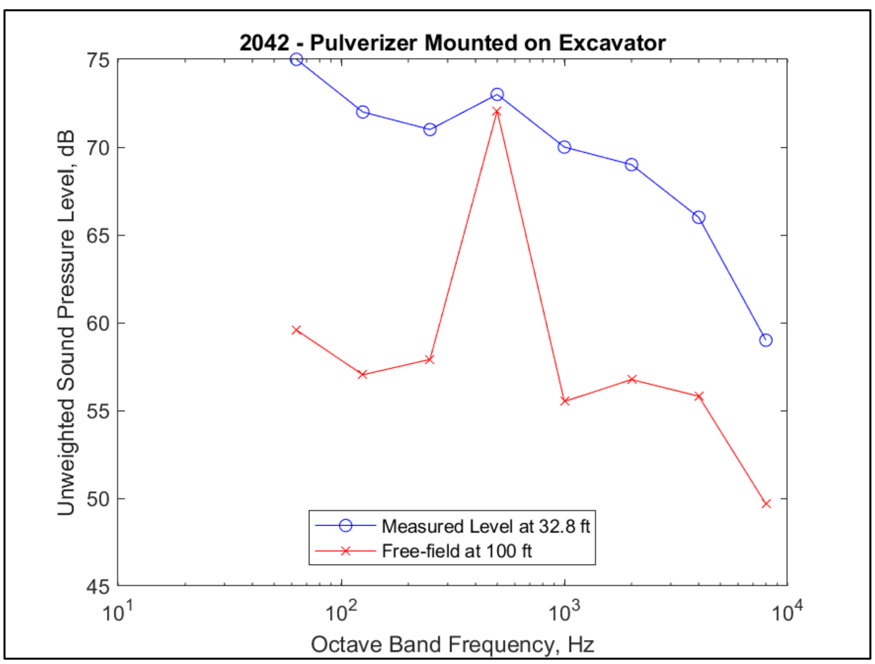


Figure 5. Comparison of Measured and Free-field Corrected Spectra (includes Correction for Ground Effects) for Octave Band Data

In many instances some data necessary for standardization were not provided by the source reference (Table 2). Each type of missing data was handled according to the availability of surrogate data as follows:

- Measurement height – when the measurement height was not included in the original reporting, a height of four feet was assumed. This is a typical height for environmental noise measurements for ground based sources [Fleming, 1995].
- Source Height – when the source height was missing, the height was estimated by averaging the source heights of similar sources found in NCHRP 25-49, initiated 2015.
- Ground Type – The ground was assumed to have an effective flow resistivity of 5000 cgs Rayls. This is a ground that is between acoustically soft ground such as tilled soil and acoustically hard ground such as asphalt pavement.
- Levels for four orthogonal directions – If no orientation data were available, then one-third octave band levels were assumed to be the same for each orientation.
- Missing high or low frequency one-third octave band levels – As mentioned previously, zero dB was assigned to bands when original source data are lacking and could not be interpolated.
- No octave band or one-third octave band data – It is not possible to accurately predict noise propagation without spectral data. In cases where all spectral data were lacking, these data were not included in the database.

A summary of the steps taken to transform each sample in the database is given in Table 3 for one example source from the 1000, 2000 and 3000 series. (See Table 4 for explanation of sources in Source IDs in the 3000s category.) Appendix C contains a full listing of the transformation steps for all of the QNM data sources.

Table 3. Summary of Steps Taken to Transform each Sample (three examples shown)

Source ID	Reference	Source Name	Source Mode	Operation	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
1000	NCHRP 25-49, initiated 2015	Air-Operated Post Driver	Stationary	Driving steel posts	7	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
2024	Rescan, 2013	Haul Truck CAT- 785D (Lw converted to Lp	Stationary	NA	4	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	Yes	No
3000	See Table 4 for Individual Samples	Angle Grinder	Stationary	Miscellaneous -- Grinding Steel	2.5	See Table 4 or Individual Samples											

3.4 Aggregation of Noise Data

Independent from the 2016 ODOT SLR Report and the RCNM project [FHWA, 2013; NCHRP 25-29, initiated 2015], there are 314 individual sources included in the QNM noise database from Table 2. While these individual entries may give the QNM user better precision when modeling, the number of choices could be overwhelming. Therefore, a more user-friendly third dataset was created using aggregated similar sound sources from these 314 individual noise sources as follows:

- Most of the standardized data were included in the aggregation. A few sources such as a barge and a sledge hammer breaking glass were exclude since they were not really applicable and the intent was to simplify selection. To reiterate, RCNM [FHWA, 2013; NCHRP 25-29, initiated 2015] and ODOT's SLR Report [2016] data are not included in the aggregated dataset.
- Aggregated categories include one or more samples. In some cases only a single source reasonably fit into a category. In many cases multiple sources were aggregated. See Table 4 for the samples used in each aggregated category.
- One-third octave band levels were linearly averaged, since the categories represent a distribution of sources and not an average exposure.
- Heights within each category were linearly averaged.
- When multiple samples were combined, their operation descriptions were appended in the file. This makes for some long descriptions and some repetitions (see below), but allows the user to get an idea of how many samples were actually used.
- When meta-data allowed, idle operations were aggregated separately from sources executing their intended purpose.
- Categorization was first based on source type and then sub-categorized based on engine power.

The final number of sources in the aggregated data set is 70.

Table 4. Samples in each Aggregated Category

Category Name	IDs																														
Angle Grinder	2229																														
Articulated Truck (Hauler) > 180 kW	2049	2091	2140	2141	2248	2249	2287	2288	2289	2297	2298	2326	2327	2328	2329																
Asphalt Paver (+ Tipper Lorry)	2262	2263	2264	2265																											
Breaking up concrete/rock - Hand Held - Powered	2044	2045	2238	2235	2236																										
Breaking up concrete/rock - Large Machine	2042	2043	2041	2039	2040	2233																									
Cable Percussion Drilling Rig	2101																														
Circular Bench Saw (Petrol)	2208																														
Compressor	2237	2307	2123																												
Concrete - Poker Vibrator	2172	2173	2174	2175																											
Concrete Mixer - Truck	2157	2158	2159	2160	2161																										
Concrete Mixer -Portable	2162																														
Core Drill (Electric)	2206																														
Crushing Plant	2033																														
Diesel Bowser	2307	2155																													
Drill Rig	2030	2031	2306																												
Dump Truck > 350 kW	2284	2285	2286	2295	2296	2024	2025																								
Dump Truck <= 350 kW	2088	2089	2090																												
Dumper < 100 kW	2145	2146	2148	2142	2143																										
Dumper < 100 kW - Idle	2144	2147																													
Dust Suppression Unit Trailer	2227																														
Excavator < 70 kW	2065	2151	2156	2195	2266	2267	2083	2204																							
Excavator < 70 kW - Idle	2064																														
Excavator > 180 kW	2048	2050	2051	2054	2060	2072	2201	2272	2273	2274	2275	2276	2324																		
Excavator >=70 < 180 kW	2047	2055	2061	2063	2073	2074	2075	2076	2079	2080	2081	2082	2087	2149	2150	2202	2203	2243	2250	2277	2278	2279	2280	2281	2282	2283	2312	2323	2325	2077
Excavator >=70 < 180 kW - Idle	2062	2078																													
Front end loader <= 100 kW - Idle	2067																														
Front end loader > 100 kW	2084	2085	2086	2303	2304	2305	2026																								
Front end loader <= 100 kW	2152	2153	2066																												
Gas Cutter	2056	2138	2139																												
Generator < 20 kW	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2337	2230	2136																	
Generator >= 100 kW	2114	2232																													
Generator >= 20 kW < 100 kW	2310	2102	2109	2137																											
Grader	2029	2302																													
Hammer Rig	2105	2106	2107	2108																											
Hand-held Circular Saw	2210																														
Hand-held Circular Saw (Petrol)	2209	2268																													
Handheld Cordless Nail Gun	2231																														
Jaw Crusher	2035	2036	2034																												
Man Lift	2196	2197	2198	2199	2200																										
Material Handler / Boom	2192	2193	2194	2176	2093																										
Mini Planer	2241																														
Mini Planer - Idle	2242																														
Mini-Excavator - Breaking rock/concrete	2234																														
Mini-Excavator - Trenching	2205																														
Mobile Cranes	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2189	2190	2191	2269	2270	2132	2133	2134													
Petrol Hand-held Circular Saw	2207																														
Piling	2110	2112	2113	2115	2118	2119	2120	2121	2122	2124	2125	2126																			
Processing Plant	2032																														

Category Name	IDs											
Pump (Concrete)	2129	2130	2166	2167	2168	2169	2170	2171	2163	2164	2165	
Pump (Water)	2224	2225	2103	2104	2117	2335	2311	2271				
Refuse Wagon / Lorry	2331	2332	2333	2334								
Road Lorry	2290	2291	2292	2293	2092	2154						
Road Planer	2239											
Road Planer - Idle	2240											
Road Sweeper	2226											
Roller Compactor < 100 kW	2097	2098	2251	2252	2253	2254	2256	2257	2258	2259	2260	
Roller Compactor >= 100 kW	2095	2096	2100									
Tower Crane	2187	2188										
Track Dozer < 150 kW	2319	2320	2321	2322	2330	2059	2070	2071	2094	2244	2245	2247
Track Dozer >= 150 < 230 kW	2069											
Track Dozer >= 230 kW	2068	2246	2299	2300	2301	2028						
Tracked Crusher	2052	2053										
Tractor	2211	2212	2309									
Vibratory Plate	2100	2261										
Vibrodisplacement and Compaction of Stone Columns	2131											
Waste Compactor	2314	2315	2316	2317	2318							
Water Bowsers	2308											
Welder	2135											
Wheel Dozer > 200 kW	2027											
Winder, cage, motor and gearbox	2038											

3.5 Organization of Noise Data

Noise data are organized in the database as follows:

The RCNM Noise data [FHWA, 2013; NCHRP 25-49, initiated 2015] have Source IDs in the 1000s range, specifically between 1000 and 1069. These data include some measurements that are for a single piece of equipment and some data that are for several pieces of equipment averaged together. ODOT's SLR Report [2016] also have Source IDs in the 1000s range, specifically between 1070 and 1077, with equipment names appended with PV (Pleasant Valley, the quarry data source within the SLR 2016 report) for ease of identification. Because the 1000s data required the fewest assumptions to convert them to a form suitable for use in the QNM, when a source matches the equipment type and activity, these data should be used in preference to the next two categories and are therefore expected to produce the most accurate results.

Excluding the RCNM Noise data [FHWA, 2013; NCHRP25-49, initiated 2015] and ODOT's SLR Report [2016], noise data from Table 2 have Source IDs in the 2000s range. Each entry in the 2000s represents a single piece of equipment and activity. If there is a source that matches the equipment type and activity in these data, these data should be used in preference to the aggregated category (described below, in the 3000 ID range) since these data reflect a specific piece of equipment and a specific activity.

Noise data that have been aggregated from Table 2 #1 to #6 and #8 to #11 sources have Source IDs in the 3000 range. These data are aggregated as described in the previous section and are the best choice, when there is not a close match to the specific piece of equipment or activity.

A summary of the database is provide in the "codex.csv" file. For the reader's convenience, the first few rows of the codex are shown in Table 5. Due to the number of sources and widths of the data columns needed to document all source IDs, source names, source modes, operations and source heights, the full codex is too large to be documented within a standard report format and therefore is not repeated here. The full codex can be found in the codex.csv file, which serves as the method to document this information.

Table 5. Selection of Data Sources Identified in CODEX.CSV

Source ID	Source Name	Source Mode	Operation	Source Height, ft
1000	Air-Operated Post Driver	Stationary	Driving steel posts	7
1001	Asphalt Distributor Truck (Asphalt Sprayer)	Passby	Spraying / Spraying Adhesive	5
1002	Auger Drill	Stationary	Deep Foundation Drilling / Drilling	6.4
1003	Backhoe	Stationary	Breaking asphalt / Digging in dirt / Moving concrete blocks	4.5
1004	Bar Bender	Stationary	Bending rebar	2
1005	Blasting (Abrasive)	Stationary	Collecting dust / Recycling material / Removing paint	12.3
1006	Blasting (Explosive)	Stationary	Exploding granite	1
1007	Chip Spreader	Passby	Spreading chips	6
1008	Compactor (Plate)	Passby	Compacting gravel	1

The codex.csv file can be found in the acoustic_data folder, which is a subfolder of the common_data folder as shown in Figure 6. Comma separated variable files for each noise source can be found in the 1000s, 2000s and 3000s folder; however, QNM does not use these files, but rather a netCDF file derived from these.

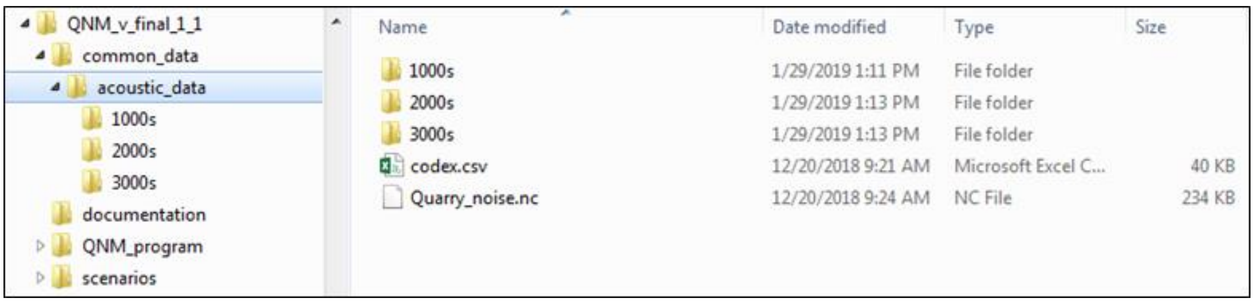


Figure 6. Illustration of Noise Database File Structure

3.6 NetCDF Format

The AAM requires the noise source data to be in netCDF format. The QNM_NoiseDatabase_Builder Python script uses the codex.csv file and the data in the folders 1000s, 2000s, and 3000s to create the required netCDF format file. The script is run using a standard windows command prompt and by specifying the full path to the noise database. Figure 7 shows an example of the text in the command line for execution.

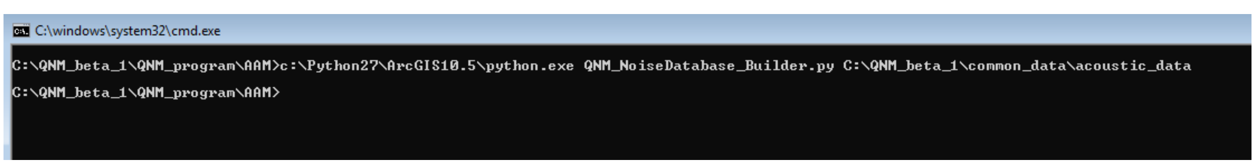


Figure 7. Sample Execution of the QNM Noise Database Builder

Once the QNM Noise Database Builder program is run the user should see that a file named Quarry_noise.nc now exists in the noise database. Note that the QNM_NoiseDatabase_Builder Python script must be rerun anytime modifications are made to the input noise database files (e.g. csv files in the 1000s, 2000s, or 3000s folders or the codex file). The NetCDF output based on the latest noise database input is included with the QNM Program, so the Noise Database Builder does not need to be run unless new input noise data is added.

Note: QNM_NoiseDatabase_Builder Python script leverages the non-standard netCDF4 python module. This can be installed using the python package manager PIP, however it may require administrative privileges. The following provides the typical syntax required at the command line to accomplish this:

```
>python.exe -m  pip install netCDF4
```

4. QNM Acoustic Engine

This section describes the Quarry Mode functionality incorporated into the Advanced Acoustic Model (AAM) Version 2.3 and the associated Quarry Noise Database Structure. The Quarry Noise Model (QNM) Graphical Information System (GIS) module creates the file type (.INQ) described here. This information is provided in case a power-user wants to make input file modifications manually. This document is intended to supplement the AAM Technical Manual [Page *et al.,* 2009] with QNM specific information. Recent modifications to AAM include the addition of attenuation due to surrounding foliage and the ability to model operations from equipment that is distributed across a quadrilateral area.

Some AAM analysis requirements for use of the Quarry features include:

- Quarry mode requires use of the TERRAIN keyword
- Minimum quarry equipment source height in the Quarry Noise Database is 1.0 Ft AGL
- Even if there is only one operation, multiple ops Quarry formatted input must be used
- Input rows with mixed character and numbers are FIXED FORMAT and must conform to the length/spacing as indicated in the tables.
- Inside AAM simulation, quarry operations are mapped to trajectories with point-to-point modeling. Operational modes (speeds, etc.) are defined at points, not along segments. Parameters are varied linearly between points to create the equipment path (referred to in this documentation as a trajectory).
- In the keyword tables A refers to alphanumeric characters followed by the maximum number (i.e. A12 means 12 alphanumeric characters).
- In the keyword tables F refers to Fixed Field Numerical input (i.e. F10 means it must have 10 digits maximum, including sign and decimal points: 123.567890 or -2.4567890 or 123456789).
- In the keyword tables I refers to an integer value input (i.e. I5 means it must have 5 digits with no decimal point: 00010 or 12345).

4.1 AAM Configuration File

The AAM **Configuration File** may be used to avoid including the SET option in the execution batch file. The file must be called AAM.config and contain the path information as shown in Table 6. The AAM.config file should be located in the same directory with the AAM executable. Any or all of the configuration parameters (ROTOR_NOISE, FWING_NOISE or QUARRY_NOISE) may be entered into the file in any sequence.

Table 6. AAM.config File Format

Line	Position	Max Length	Description
1	1	A12	RWING_NOISE keyword for setup parameters
2	1	A256	Path to Helicopter Noise Spheres. C:\AAM\NCFiles\ or as needed
1	1	A12	FWING_NOISE keyword for setup parameters
2	1	A256	Path to Fixed Wing Noise Spheres. C:\AAM\NCFiles\ or as needed
1	1	A12	QUARRY_NOISE keyword for setup parameters
2	1	A256	Path to Quarry Acoustic Database. i.e. C:\AAM\NCFiles\Quarry\ or as needed

Note: The directory path needs to end with a backwards slash character \

4.2 AAM input file format

The AAM input file is ASCII and should only be edited with an editor such as Notepad or Notepad++ which does not enter formatting or line control features. The following sections describe the input file format.

4.2.1 *Keyword* ATMOS

ATMOS specifies the atmospheric profile. It may be used only for straight ray propagation analysis, and is incompatible with the WEATHER keyword. If this keyword is not included in the input file, the acoustic module will use as default the United States Standard Atmosphere, 1976, with 70% relative humidity. The user may enter a maximum of 32 points to describe the atmosphere. The altitude for each point corresponds to the geometric altitude above the mean sea level. The altitude profile must extend above the highest point on the flight track; otherwise extrapolation will occur, using the highest altitude data entered. The altitude profile must be entered in monotonically increasing order beginning with the lowest altitude. The user may choose the units for altitude, temperature, and pressure by using the system of keywords shown in Table 7.

The defaults for the Quarry GIS Module should use an isothermal atmosphere with user defined temperature, humidity and pressure. The default altitude range should cover -1,000 ft MSL to +20,000 ft MSL. This will cover a range of CONUS quarry sites and the needed atmospheric definitions from the bottom of Death Valley to the tops of mountain ranges. Users can edit the ATMOS keyword manually in the .INQ file if so desired.

Table 7. ATMOS Keyword Format

Line	Position	Max Length	Description
1	1	A5	ATMOS Keyword for atmospheric profile.
2	1	I	Number of points describing atmosphere (32 max).
3	1 2 3	A5 A1 A3	Units for atmospheric altitude (FEET or METER). Units for temperature Fahrenheit or Centigrade (F or C). Units for pressure pounds per square inch, kilo Pascal, or milli Bar (PSI, KPA, or MB).
4	1 2 3 4	I I I I	Altitude in specified units above mean sea level. Temperature in specified units. Pressure in specified units. Relative humidity in percent.

Note: Line 2 should be at least 2 points that span the range of heights to be analyzed
Line 4 should be repeated to satisfy the number of points describing the atmospheric profile.

4.2.2 *Keyword* QUARRY

QUARRY triggers AAM2 to utilize a multiple operations input quarry (.INQ) format and expects the quarry acoustic source data to be contained in a NetCDF quarry format database. QUARRY should be input as the first keyword in the input quarry (.INQ) file. Where possible the keyword formats used for quarry modeling are the same as single and multiple operation input modes for AAM flight vehicles.

4.2.3 *Keyword* SETUP QUARRY

SETUP QUARRY specifies the grid dimensions, the sound source, and several other general input parameters that are required. It can be freely inserted into the input file but is generally inserted at the beginning of the file. Table 8 shows the keyword format. This keyword is used in place of SETUP PARA when QUARRY keyword is in use. The keywords within the SETUP QUARRY section must appear in the order presented below in Table 8.

The X and Y values used to specify the grid spacing and the two grid corners are Cartesian coordinates in units of feet. UTM units (feet) can also be used as inputs. Positive and negative values may be used to define the grid domain provided the lower left and upper right corners are appropriately defined. The location of the operations and the specific points are specified in this coordinate system.

If modeling flat earth, with no TERRAIN keyword: the ground elevation (line 2) specifies the altitude of the ground relative to the mean sea level. The Z-coordinate altitude for the computational grid (line 3) is the elevation of the grid above the local ground level. If using the TERRAIN keyword, the elevation contained in the .ELV file will be used. All points on the grid must be at this elevation above local ground height. Normally the grid elevation is set for 5 feet.

The following default settings are recommended for QUARRY mode (line 5):

- Spherical loss factor: 1000
- Cutoff distance (ft): 500000.
- Flow resistance parameter (CGS Rayls): 200.
- Turbulent decoherence parameter: 0.0004

Table 8. SETUP QUARRY Keyword Format

Line	Position	Max Length	Description
1	1	A12	SETUP QUARRY keyword for setup parameters
2	1 2 3	I15 I15 I15	Grid point spacing in x direction (ft), minimum 100 ft Grid point spacing in y direction (ft) , minimum 100 ft Ground elevation measured relative to the mean sea level (ft)
3	1 2 3	I15 I15 I15	X-coordinate for lower left corner of calculating grid (ft) Y-coordinate for lower left corner of calculating grid (ft) Z-height altitude for the calculating grid above ground level (ft)
4	1 2	I15 I15	X-coordinate for upper right corner of calculating grid (ft) Y-coordinate for upper right corner of calculating grid (ft)
5	1 2 3 4	I10 I10 I10 F10	Spherical loss factor ($\Delta\beta$) Cutoff distance (ft), maximum distance of interest between source and receiver for calculations Flow resistance parameter (CGS Rayls) Turbulent decoherence Parameter $(\mathrm{rad} \cdot \mathrm{sec} \cdot \sqrt{\mathrm{ft}})$
			POINTS
			ROADS
			ROUTES
			AREAS
			QOPERATIONS
			STATICQOPS
			DISTROQOPS
			QBLAST
Last	1	A10	END QUARRY - signals end of SETUP QUARRY keyword section

Notes: (1) Line 2 (21-30) ground elevation is ignored when in TERRAIN mode.
(2) Line 3 Z-grid height will be added to the ground elevation when in TERRAIN mode.
(3) Recommended value of turbulent decoherence Parameter (Line 5) is 0.0004.
(4) Mandatory sub-keyword sequence: POINTS, ROADS, ROUTES, OPERATIONS, STATICQOPS, DISTROQOPS, QBLAST, END QUARRY

4.2.4 *Keyword* POINTS

POINTS is used to define specific equipment locations. The POINTS keyword is within the SETUP QUARRY keyword section. The (x,y,z) and (latitude, longitude) coordinates of each POI as well as a 42-character description are included. X and Y values are defined in the grid coordinate specified under the SETUP QUARRY keyword. The Z location that will be used is the grid height as defined in the SETUP QUARRY keyword section and is input relative to the reference local ground level. The local ground altitude will be that defined in the ground elevation (.ELV) file. Note that the Z value in SETUP QUARRY is in terms of feet Above Ground Level (AGL) and not MSL. Table 9 describes the POINTS format. POINTS has the same structure as the POI keyword. (The AAM POI keyword is used for prescribing specific points of interest for the noise calculations).

Table 9. POINTS Keyword Format

Line	Position	Max Length	Description
1	1	A5	POINTS keyword for points of interest
2	1	I3	Number of points (100 max)
3	1 2 3	A10 F15 F15	Point Identifier (10 chars max) X-coordinate (ft.) Y-coordinate (ft.)

Notes: Line 3 should be repeated to satisfy the number of points defined in Line 2.
The Z-coordinate (ft.) comes from SETUP QUARRY and will be added to the local ground height as defined in the ELV file.

4.2.5 *Keyword* ROADS

ROADS defines the roadways at the quarry within the SETUP QUARRY keyword section. They are defined sequentially from point 1 to point 2 to point 3 etc. When being used the default travel direction is from point 1 to point 2 etc. When placing operations on ROADS or utilizing ROADS to build ROUTES, the direction switch (-1) may be used to indicate travel direction is from point 3 to point 2 to point 1. See keyword QOPERATIONS for more information. The vehicle's orientation is assumed to be tangent to the vector of the road in the direction of travel. The maximum number of roads is 500 and the maximum number of points per road is 50. Roadway elevations will be matched to the local ground height as provided in the terrain file. The format of the ROADS input is defined in Table 10.

Table 10. ROADS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-5	A7	ROADS keyword
2	1-3	I3	Number of roads (max=500)
3	1-3 5-16	I3 A12	Road ID (3 digit value: 1-500, each must be unique) Road Label (12 char max)
4	1-2	I5	Number of road points (min=2, max=50)
5	1-10 12-21	F15 F15	Road X coordinate Road Y coordinate

Notes: Lines 3-5 should be repeated to satisfy the number of roads as provided in Line 2.
Line 5 should be repeated for the number of points defining the road as provided in Line 3.
Road label is not used, it is to allow input file human readability.

4.2.6 *Keyword* ROUTES

ROUTES are used to string together a sequence of road points at a Quarry. The ROUTES keyword section must appear within the SETUP QUARRY keyword section. The Route ID is a 3-digit integer of value 1 to 100 which is used to identify the particular route. The direction of travel for each segment is indicated. Direction of travel +1 indicates the direction in which the route was initially defined. Direction of travel -1 indicates the order is reversed. The ROUTES format is denied in Table 11. The maximum number of routes is 100 and the maximum number of ROADS per ROUTE is 50. As the points are strung together the (X,Y) values are checked and if they are co-located at the end of one ROAD and the beginning of the next ROAD the point will be dropped when creating the operational track for the equipment. If the specified ROADS are not connected, a single straight-line segment will automatically be added connecting them. So be careful defining ROUTES to prevent operations traversing through unrealistic locations.

Table 11. ROUTES Keyword Format

Line	Column Numbers	Max Length	Description
1	1-6	A7	ROUTES keyword
2	1-3	I3	Number of routes (max = 100)
3	1-3 5-16	I3 A12	Route ID (3 digit value, Valid: 0-100, each must be unique) Route Label (12 char max)
4	1-2	I5	Number of roads sequenced to form the route (max=50)
5	1-3 5-16 18-19	I3 A12 I1	Road ID (must match one in keyword ROADS) Road Label (12 char max) Direction (+1=as defined in ROADS keyword, -1=reverse direction)

Notes: Lines 3-5 should be repeated for the number of Routes as defined in Line 2.
Line 5 should be repeated for the number of roads as provided in Line 4.
Route Label and Road Label is not used, it is to allow input file human readability.

4.2.7 *Keyword* AREAS

AREAS is used to define a two-dimensional quadrilateral area in the quarry vicinity over which distributed equipment operations may occur. The AREAS keyword format is provided in Table 12. The 4 vertices are defined in a clockwise manner starting from the lower left corner as defined in lines 5-8. The primary directions do not need to be orthogonal. The Y direction is from the lower left to upper left corner, and the Y direction is defined as the Lower Left to Lower Right corner of the area boundary. The more subdivisions and subheadings specified, the longer the run time but the higher the resultant acoustic resolution. Operations are split up based on total time duration and assigned to the AREAS using the DISTROQOPS keyword.

Table 12. AREAS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-6	A7	AREAS keyword
2	1-3	I3	Number of AREAS (max = 100)
3	1-3 5-16	I3 A12	Area numerical ID (3 digit value, 001-100, each must be unique) Area Label (12 char max)
4	1-15 17-31	F15 F15	Lower-Left X Coordinate Lower-Left Y Coordinate
5	1-15 17-31	F15 F15	Upper-Left X Coordinate Upper-Left Y Coordinate
6	1-15 17-31	F15 F15	Upper-Right X Coordinate Upper-Right Y Coordinate
7	1-15 17-31	F15 F15	Lower-Right X Coordinate Lower-Right Y Coordinate

Notes: Lines 3-7 should be repeated for the number of AREAS as specified in Line 2.
Line 3: Area numerical ID is used for area lookup. Area Label is for reporting i/o purposes only.

4.2.8 *Keyword* QOPERATIONS

QOPERATIONS is used to define the moving operations at the quarry within the SETUP QUARRY keyword section. Operations are assigned to ROADS or to ROUTES (specifically the connected point-to-point geometry defined by ROADS and ROUTES) and the operational state of the equipment is defined for each point along the path. If the operational conditions (i.e. speed) are constant and to be used for the entire path, the number of operational points defined should be 1 and AAM will automatically assign it to all points. For stationary portions of the operations use the STATICOPS keyword. The ROAD/ROUTE label in line 3 is not used but allowed for to provide human readability of the input file.

When using ROUTES the operational state will be applied to all points in the ROAD except for the last point, which is defined explicitly, hence the plus 1 in Table 13, line 3. Consider a ROUTE that is the combination of Road 1 and Road 2. Roads 1 and 2 are each defined by 3 road points. The ROUTE consists of 2 roads, which has 5 points total. The last point of Road 1, is the same geometric location as the first point of Road 2. AAM will apply the first operational state to points 1 and 2, the second operational state to point 3 and 4 and the third operational state to point 5.

The QOPERATIONS keyword format is defined in Table 13.

Table 13. QOPERATIONS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-11	A11	QOPERATIONS keyword
2	1-3	I3	Number of Unique Operations defined below (max=500)
3	1-4	I4	Equipment ID (4-digit integer code, must match noise database)
	6	I1	RR FLAG (ROAD =1, ROUTE = 2)
	8-22	A15	ROAD/ROUTE label for the operation (15 chars)
	24-26	I3	ROAD/ROUTE ID (must match ROADS or ROUTES line 3)
	28-30	I3	Operational State Points defined. Must equal 1 <or> The number of points in the ROADS keyword (line 4) <or> The number of points in the ROUTES keyword (line sections) plus 1
	32-41	F10	Number of times during the day this Operation occurs
	43-52	F10	Number of times during the night this Operation occurs
	54-113	A60	Equipment Name (60 chars max, no spaces)
4	1-5	F5	Speed of the equipment (mph)
	7-11	F5	Equipment heading re: Velocity Vector (0 straight ahead, + is right)

Notes: Lines 3-4 should be repeated to satisfy the number of Operations as provided in Line 2.
Line 3: The Equipment Name makes the file more readable. It is not used. The equipment ID is used for the QNM lookup.
Line 3: Since the routes consist of a series of road segments, the number of end points is the number of road segments + 1.

4.2.9 *Keyword* STATICQOPS

STATICQOPS is used to define the operations of stationary equipment within the SETUP QUARRY keyword section. Static Operations are assigned to point locations as described in the POINTS keyword section. A maximum of 500 Static Quarry Ops may be provided in the input file. When placing the equipment for static operations, the user may select to rotate it to a known orientation/installation, or the tool can use the default orientation, which is to rotate the equipment so that the loudest direction is facing towards the closest quarry boundary. The loudest direction is defined as that direction which has the maximum noise level in the 1000 Hz one-third octave band (band #30). For cases where multiple directions have the same level in band 30, bands 31 and 32 are checked. If there is still no discriminating noise level in these bands, then the lowest angle is oriented towards the closest boundary. In Table 14, the orientation flag is 0 when default orientation is to be used, or 1 when a user defined heading is to be used. If the installation angle of a static piece of equipment is known it should be used, however if its orientation is unknown or if it is possible it will change over time, the conservative approach is to use the default orientation setting. The STATICQOPS keyword input file format is defined in Table 14.

Table 14. STATICQOPS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-10	A10	STATICQOPS keyword
2	1-3	I3	Number of Unique Operations defined below (max=500)
3	1-4	I4	Equipment ID (4-digit integer code, must match noise database)
	6-15	A10	Points Identifier (10 chars max, must match POINTS line 3)
	17	I1	Orientation Flag 0=Default (Worst Case), 1=User Defined Heading
	19-23	F5	Equipment Heading (0=north, 90=east etc…) Valid >=0 to <360.
	25-31	F7	Operation Time (decimal hours)
	33-40	F8	Number of times this Operation is to be modeled in the Daytime
	42-49	F8	Number of times this Operation is to be modeled in the Nighttime
	51-110	A60	Equipment Name (60 chars max, no spaces)

Notes: Lines 3 should be repeated to satisfy the number of Static Quarry Operations as provided in Line 2.
Line 3: The Equipment Name makes the file more readable. It is not used. The equipment ID (cols 26-29) is used for the QNM lookup.
Line 3: The Points Identifier (cols 31-42) must exactly match as it is used to identify the location of the equipment.

4.2.10 *Keyword* DISTROQOPS

DISTROQOPS is used to define distributed operations over quadrilateral areas in the quarry with inputs as illustrated in Figure 8. The user defines the number of operational/fractional hours (with user defined split between daytime and night time) and the total number of a pieces of equipment that are operating. The areas over which these operations occur is defined using the AREAS keyword and DISTROQOPS assigns the operations to these areas. Internally the area is divided evenly into a distributed mesh of points (they can be different numbers in both dimensions).

Note that both static and moving equipment can be selected using the DISTROQOPS section. The noise exposure is accumulated using the user defined total time. The user should take care to select the appropriate equipment ID that corresponds to the desired operational state of the equipment.

The area is divided up into points which will be used to model the equipment over the area. The user can specify how many points are used for the noise calculations. An example with 2 distributed quarry operations (DIRTMOVE01 and LOADSTUFF03) is illustrated in Figure 8. In the case of DIRTMOVE01 the area is divided into a mesh of 8 x 5 points (black rimmed blue dots). These 40 points will be used acoustically to model the noise from the equipment. Note that the run time for AAM is heavily dependent on the number of points used to model the operations and for a case with only a single distributed operation, a 3x3 grid (9 points) will take a little more than twice as long to run as a 2x2 grid (4 points).

When defining the quadrilateral areas within the QNM GUI, one should sequentially select the four corners in a clockwise direction, starting at the lower left. For the example in Figure 8, start with point 1 for the DIRTMOVE01 area and then move to points 2, 3 and 3. For the LOADSTUFF03 area, start with point A, and then click on points B, C and D. When defining the number of subdivisions across the primary and secondary edges, the primary edge is from point 1 to 2 (or A to B) and the secondary edge is from point 2 to 3 (or B to C). The opposite edges will have the same number of subdivisions. In the example in Figure 8, LOADSTUFF03 has been subdivided to a 3x2 area (green squares), or a 3x3 area (red dots) or a 9x9 area (orange Xs). The Primary edge is always between the first and second points and the secondary edge is between the second and third corner points identified in the POINTS keyword section.

The orientation of the equipment is also distributed across 4 distinct heading angles. The primary heading orientation will be from point 1 to point 2 as defined in the AREA keyword section, with the other headings incremented by 90 degrees. If further granularity or control over the equipment distribution and orientation is needed, use the POINTS and STATICQOPS keyword and explicitly define the points, equipment heading angles and operating times.

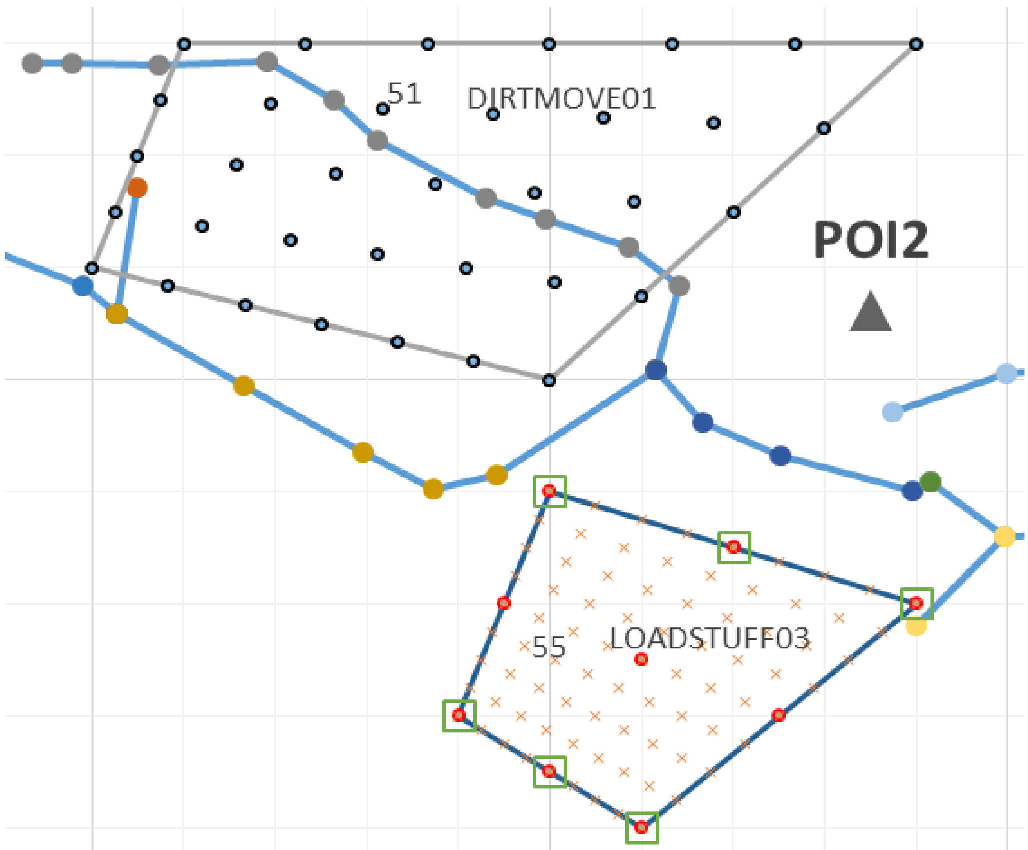


Figure 8. Example of distributed operations with acoustic modeling nodes shown.

Table 15. DISTROQOPS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-10	A10	DISTROQOPS keyword
2	1-3	I3	Number of Unique Distributed Operations defined below (max=50)
3	1-4	I4	Equipment ID (4-digit integer code, must match noise database)
	6-8	I3	Area numerical ID (3 digits, must match AREAS line 3, valid 1-100)
	10-14	F5	Number of Hours of Operation (decimal hours)
	16-20	F5	Number of times this Op is modeled in the day
	22-26	F5	Number of times this Op is modeled at night
	28-30	I2	Number of noise modeling points - primary edge (valid range: 2-11)
	32-34	I2	Number of noise modeling pts. – secondary edge (valid range: 2-11)
	36-95	A60	Equipment Name (60 chars max, no spaces)

Notes: Line 3 should be repeated to satisfy the number of Static Quarry Operations as provided in Line 2.
Line 3: The Equipment Name makes the file readable. It is not used. The equipment ID (cols 1-4) is used for the acoustic data lookup.
Line 3: The AREAS ID (cols 6-8) is case sensitive and must exactly match that provided in the AREAS keyword line 3.
Line 3: The total time used to compute the acoustic result is the sum of day and night hours times the number of pieces of equipment.

4.2.11 *Keyword* QBLASTOPS

QBLASTOPS is for Quarry Blast Operations – Simple mode for airblast modeling as defined in Table 16. The airblast is an airborne shock wave that results from explosive detonation and is dependent on the explosive charge weight per hole and the confinement factor (an indication of the degree of explosive confinement). This may be used to estimate the overpressure from airblast operations in an aggregate manner and does not take into account specific blasting sequences, depths or orientation or the phasing that may result.

When modeling blasting operations in QNM, it is strongly recommended that blast operations be modeled separately from non-blast operations and only the peak metrics, including Lpeak (peak overpressure, unweighted dB, same units as Lmax_dB), PSF (overpressure in pounds per square foot), PSI (overpressure in pounds per square inch) be utilized. While QNM predicts cumulative metrics (SEL, DNL) and other spectral weighted metrics (such as Lmax_dBA, Lmax_dBC) there is sufficient uncertainty over duration and spectral propagation that they should not be combined with non-blast operations metrics. A WARNING note will be generated if mixed blast and non-blast operations are modeled in a single run.

The simple blast model adopted for QNM encompasses four parts:

- Airblast overpressure calculation from the user defined maximum blast charge, based on the Minnesota recommended model [Minn., 2015], a derivative of the Linehan and Wiss methodology [1982] with the propagation exponent modified to remove the ground effect,
- Ground effect computed based on local terrain using the AAM methodology,
- Blast event duration as specified by the user,
- Normalized spectrum application based on published Tunisia [Aloui, 2016] empirical data.

Within AAM, the airblast overpressure is computed using $\mathrm{P} = \mathrm{K}\left[\frac{\mathrm{R}}{\mathrm{Q}^{0.33}}\right]^{\mathrm{Bexp}}$ Equation 5 based on the user provided maximum blast charge, state of confinement factor (K) and the slant range distance between the blast location and the receiver. The normalized spectrum is adjusted to the spectrum at the receiver so that the unweighted energy across all frequency bands from 10 Hz – 10 kHz matches the overpressure calculation. The ground effect is computed between source and receiver by AAM and applied to the spectrum for determination of spectrally dependent metrics such as A- and C-weighted metrics. The duration of the positive pressure portions of the event for the purposes of integrated metric calculations may be specified by a power user. The default in the QNM GUI is 1.0 second duration. The duration can be obtained from a detailed blast planning report if available, or determined using the nominal blast duration times the number of blast holes or from empirical measurements. $\mathrm{P} = \mathrm{K}\left[\frac{\mathrm{R}}{\mathrm{Q}^{0.33}}\right]^{\mathrm{Bexp}}$ Equation 5 presents the method for calculating the blast overpressure, where P is the overpressure (kPa), K is the state of confinement factor (where 3.3 indicates fully confined and 185 indicates unconfined explosions), Bexp is the Blast Propagation Exponent, Q is the maximum instantaneous charge (lb) and R is the distance from the charge (m). (The metric relation is presented here for consistency with literature; units of Ft are used in AAM with appropriate conversions applied). The propagation coefficient in the Minnesota model has Bexp = -1.2, however this has been updated to Bexp = -0.8552 in QNM to remove the ground effect so that it can be replaced with the AAM calculations so that terrain effects can be taken into account.

$$\mathrm{P} = \mathrm{K}\left[\frac{\mathrm{R}}{\mathrm{Q}^{0.33}}\right]^{\mathrm{Bexp}} \qquad \text{Equation 5}$$

Evaluation of the state of confinement factor (K) can be empirically derived for a particular quarry if blast data is available. Analysis of Tunisia quarry noise measurement data [Aloui et al, 2016] suggests a suitable empirical value of K=6.5 for the state of confinement factor for the conditions experienced during these blasting events and a Bexp of -0.8552. (Confinement is a controllable variable in the blast design which can be optimized to maximize yield while minimizing noise, vibration and fly rock. It is often the result of the amount of stemming material in the drill hole surrounding the explosive, the burden and spacing of the drill holes and the type and amount of spacing but can also depend on the local geology, rock type and placement of the drill holes relative to an open face.)

While this simplified blast noise model implemented in QNM is omnidirectional, the propagation will take into account the surrounding terrain and shielding and the effects of nearby foliage (see the Foliage keyword section) and apply them spectrally to the blast noise at the receiver location. A side by side example of blast noise predictions considering propagation over flat and natural varying terrain is provided in Figure 9. One can see the impact terrain shielding has on the signal, but also the places where terrain actually amplifies the sound. Generally, noise reductions are in areas where line of sight between source and receiver is broken by the intervening terrain, and areas that increase in noise are often the side of a hill that is facing the blast.

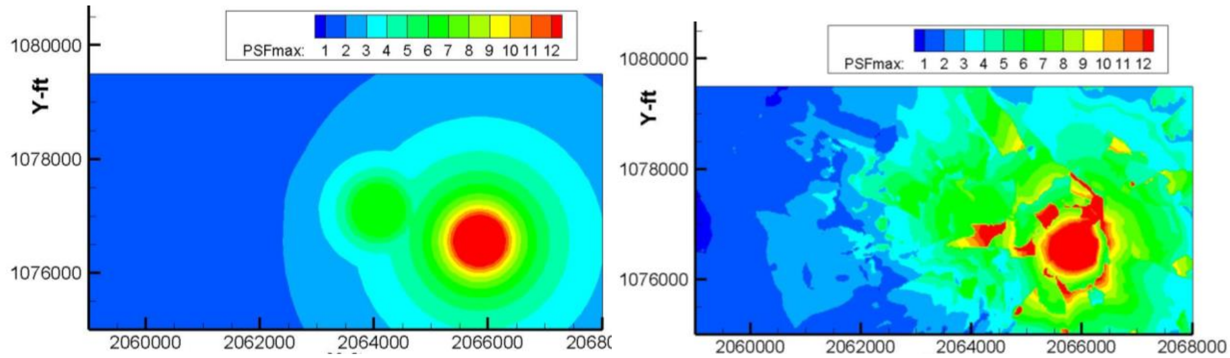


Figure 9. Comparison of Two Blast Noise Events Propagated over Flat (left) and Natural (right) Terrain.

Using the Tunisia data, the blast propagation exponent was determined by matching the slope of the curve of overpressure levels with distance to the empirical data (Figure 10). The curve was then adjusted up and down by varying the confinement factor to match the overpressure amplitudes. This resulted in a propagation exponent of -0.8552 and a state of confinement factor of 6.5 and the results are shown in Figure 10 with the scaled distance (consistent with the literature) and in Figure 11 with physical distance (for ease of physical interpretation). The scatter in the predictions is commensurate with the scatter in the empirical data. One could use the same procedures with QNM analysis for any quarry to obtain empirical based values for Bexp and K. It is suggested that a range of propagation distances and locations be used to make an empirical determination.

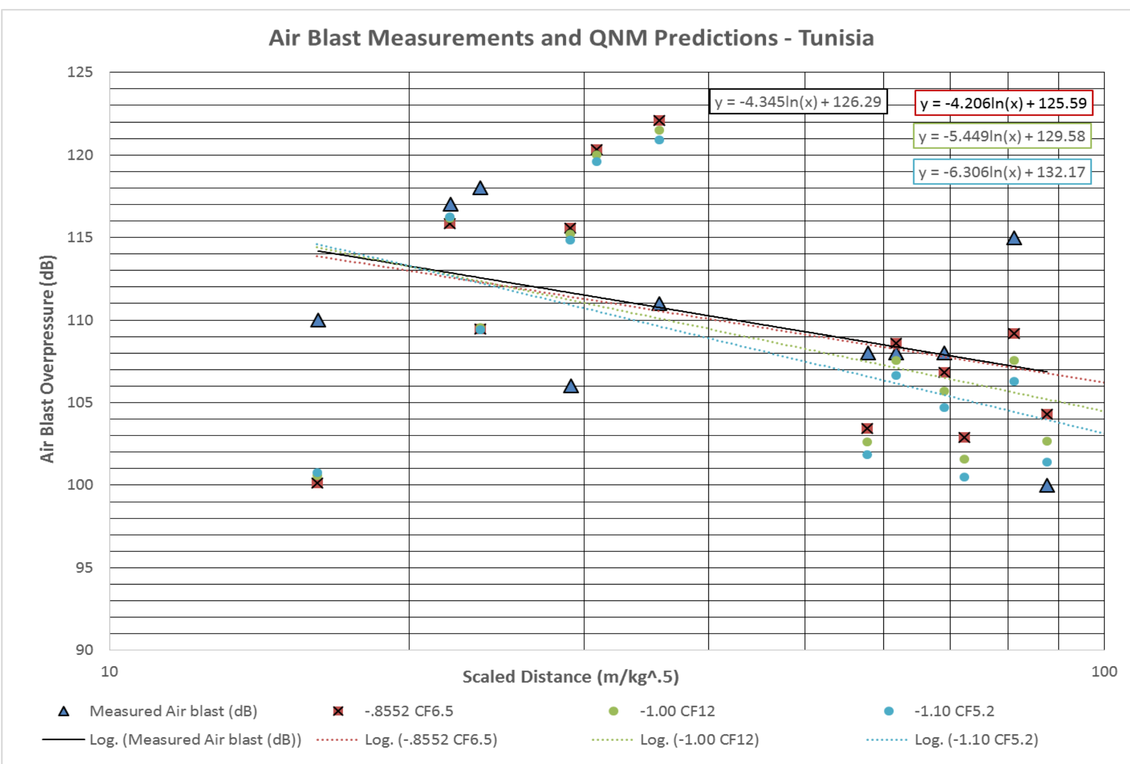


Figure 10. Comparison of Tunisia Data (Scaled Data) and QNM Calculations Yielding Bexp=-0.8552, K(CF)=6.5

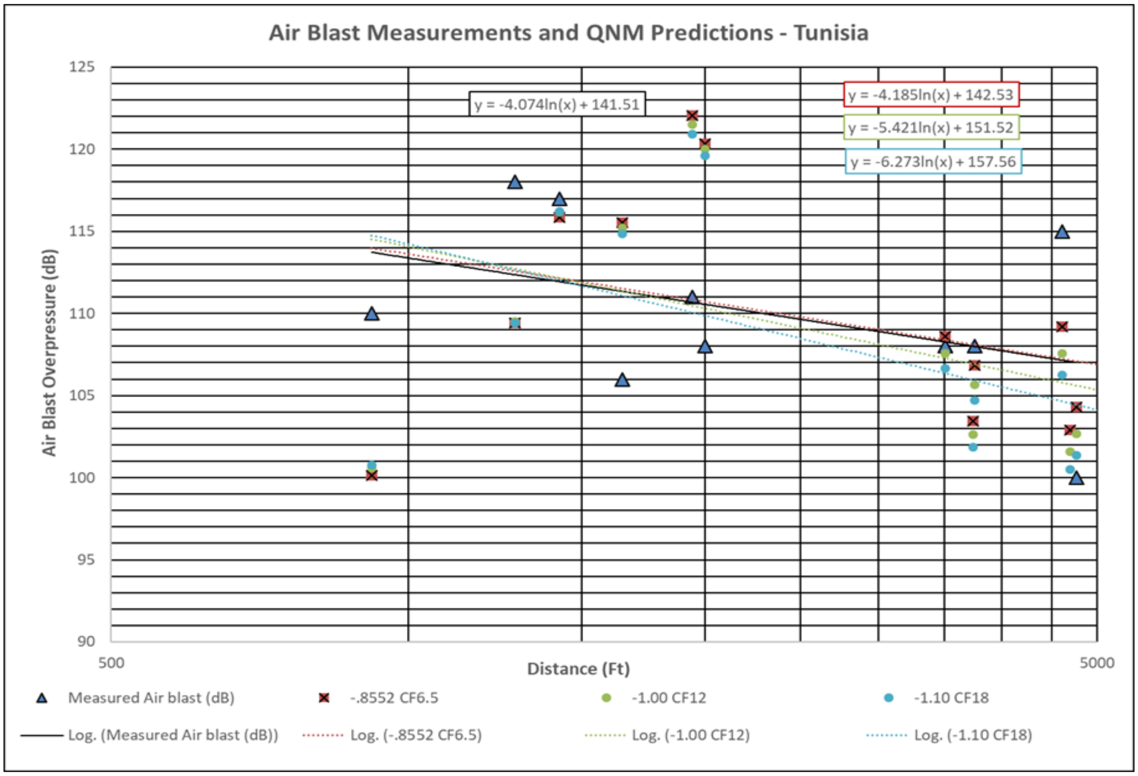


Figure 11. Comparison of Tunisia Data (Physical Dist) and QNM Calculations Yielding Bexp=-.8552, K(CF)=6.5

Within the model, the overpressure is capped at a minimum distance of 250 ft from the blast location. Due to the exponential formulation of the simple blast model excessive and unrealistic overpressure values would otherwise result for shorter distances. This 250 ft distance was selected to prevent unrealistic overpressure levels while permitting contouring of blast noise throughout the quarry study area. To evaluate noise at distances closer than 250 ft to the blast location a different blast noise model should be used which has the ability to take into account phasing due to blasting hole patterns and timing delays. That capability is not available within QNM.

Based on measured published Tunisia blast data [Aloui *et al.*, 2016], a reference blast spectrum was also obtained for QNM (Figure 12). Because the primary energy of the blast is below 10 Hz and AAM only includes 10 Hz – 10 kHz additional energy from the 6.3 and 8 Hz bins was lumped into the 10 Hz band so that it could be accounted for in the cumulative metrics. Figure 12 is the representative spectra included in the QNM/AAM model. Note that this is the weakest part of the model and the author recommends updating with empirical data from Oregon quarries when available. When obtaining such empirical data, care should be taken to ensure that the spectrum is obtained using instrumentation suitable to obtain 5 Hz to 10 kHz high resolution instantaneous pressure time waveforms from which the spectra can be derived. A minimum of three monitors should be used along a radial extending from the blast site. Ideally multiple radials should be instrumented in the directions of interest. Distances should be commensurate with noise modeling coverage intents, and could follow the range illustrated in Figure 11 (i.e. 1000 ft to 5000 ft) so that the empirical method presented above can be utilized.

This simplified methodology in QNM does not account for the actual non-linear signature evolution of the blast pressure-time history as it propagates to the receiver. A limitation of this method is that the nominal blast spectrum, derived from a distance of 1000 Ft. is assumed to apply to the full area of interest being calculated using QNM. In reality non-linear propagation effects will transform the pressure time history with distance and change the spectral content moving energy from one band to another. Accounting for this kind of non-linear propagation is beyond the capabilities of the current QNM model. It is recommended that for critical points of interest, empirical data be used to check that the assumed spectrum is applicable at that distance and the predicted results are valid. By using the DIAGNOSTICS keyword, AAM will output the analytical spectra employed in the model for checking against empirical data.

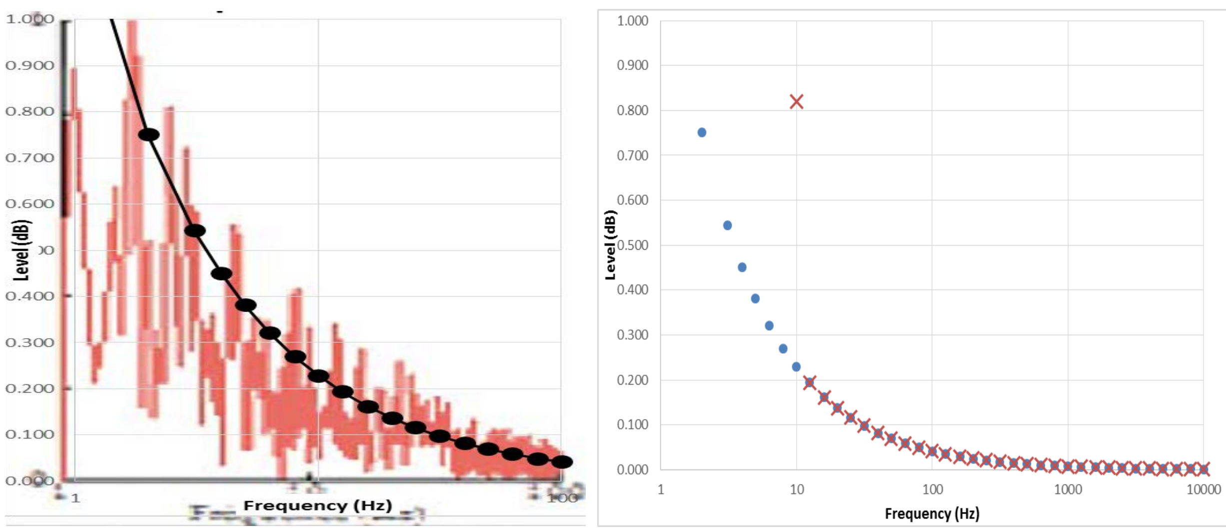


Figure 12. Left: Nominal Blast Spectrum Based on Measured Data and AAM Ground Effects Calculations Right: Reference Blast Spectrum in AAM with supplemental low-frequency energy added to the 10 Hz band.

This QNM simple blast method is capable of predicting the peak and maximum style metrics including LAmax, LZmax, LCmax, Lpeak and PSF. In order to compute integrated metrics in QNM, the total duration of the blasting event across all holes must be specified by the user. A conservative approximation can be made by multiplying the number of holes times the maximum charge time delay. Integrated metrics such as SEL, DNL and Leq require prediction of the duration of the event, which dependent on the number of individual blasts and the timing/delay. While QNM does not have the capability to predict the time accurate pressure waveform, the user supplied blast duration is used to determine energy and approximate the integrated metrics.

Figure 13 shows an empirical pressure time history from a 3x6 firing pattern with a 58 ms delay time which corresponds to 1.044 seconds from Linehan and Wiss [1982]. The total duration of the event as shown in Figure 13 was measured to be approximately 1.05 seconds. The individual blast peaks and troughs for the 3 blasts from each of 6 rows are highlighted with the colored dots. If the user has empirical data and finds that the predicted Leq or integrated metric levels are too high even though the peak values match empirical data, the duration of the blasting event may be reduced. The default duration in QNM when using the GUI is 1.0 sec however a power user can modify the .inq file directly to change this value. See Table 16 for explanation of the QBLASTOPS keyword format. Within QNM the time history is modeled as the peak pressure (expressed in dB) for the user specified duration of the event. The individual blasts are not modeled. A conservative stance has been made in the QNM blast model for future planning evaluation of environmental impacts of blast noise around quarries. Modeling of the actual time history including the shock rise times and pressure phasing (which are dependent on non-linear propagation, timing and orientation of the blasting sequence and geometric firing patterns and complex interactions of ground-to-ground propagation over complex terrain), is beyond the capability of the simple blast model employed in QNM.

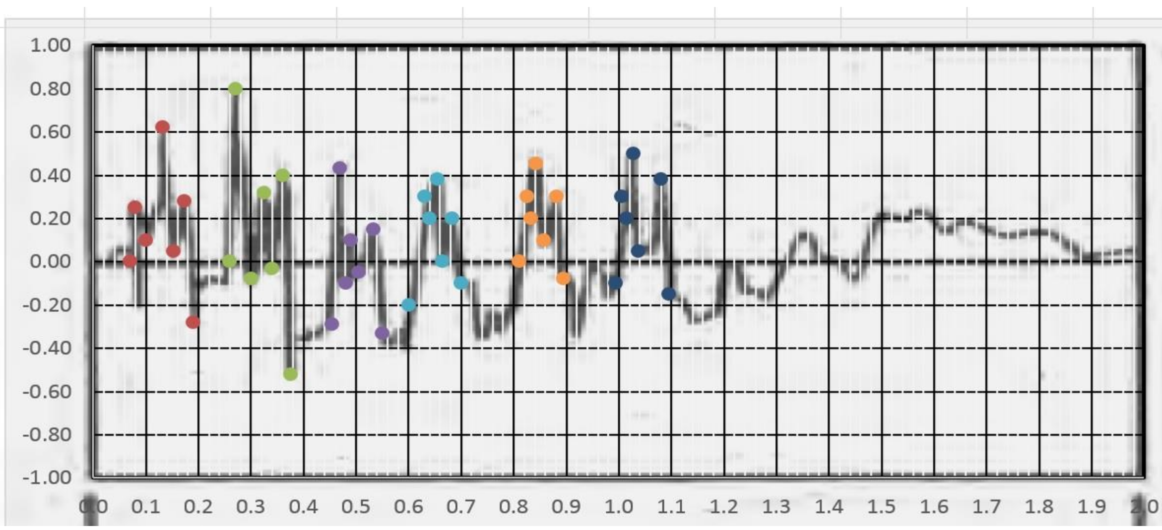


Figure 13. Empirical evaluation of blast duration for calculation of integrated metrics in QNM. Ordinate: time (sec), abscissa: overpressure (units undefined). Source: Linehan and Wiss [1982].

The structure of the QBLASTOPS keyword is itemized in Table 16. The blast operations occur at locations defined in the POINTS keyword section. One should identify the blast centroid. The basic parameters the user must define to model the blast include the instantaneous charge for a single bore hole (in lbs.), the state of confinement factor K, the blast propagation exponent Bexp, the total blast duration across all charges (seconds). To be conservative model the maximum instantaneous charge. The average instantaneous charge can also be used if empirical data is available and QNM is over predicting the results. Typical values of confinement factor are 3.3 for fully confined blasting, and 185 for unconfined blasting. If quarry-specific shot reports with measurement data are available, they can be used to empirically determine the state of confinement factor (K) for that specific quarry by running QNM for the blast event and adjusting the confinement factor to match the measurement data. A reasonable confinement factor based on empirical measurements in Tunisia is 6.5. It is recommended that only peak metrics be used to determine the confinement factor empirically. Presently, calculation of Leq metrics are suppressed in QNM for blast operations as they were found to not correlate well with empirical data.

Table 16. QBLASTOPS Keyword Format

Line	Column Numbers	Max Length	Description
1	1-6	A7	QBLASTOPS keyword
2	1-3	I3	Number of blast operations (max = 100)
3	1-10 11-15 17-28 30-34 36-40 42-46 48-55	I10 F5 F12 I5 I5 I5 F8	Points Identifier (10 chars max, must match POINTS line 3) Confinement Factor (Between 3.3=fully confined, 185=unconfined) Instantaneous charge per hole (lbs.) Number of Daytime blasting events at this location Number of Nighttime blasting events at this location Blast Duration (seconds) (default = 1.) Blast Propagation Exponent (default = -0.8552)

Notes: Line 2. The maximum number of blast operation locations that may be defined is 100.
Line 3 should be repeated for each of the number of blast operations defined in Line 2.
Line 3. Empirical analysis of Tunisia blast data suggests a confinement factor of 6.5 is a reasonable fit.
Line 3. Recommended value Blast Propagation Exponent is -0.8552.

4.2.12 Keyword TERRAIN

TERRAIN signals analysis considering terrain effects on sound propagation (Table 17).

Table 17. TERRAIN Keyword Format

Line	Column Numbers	Max Length	Description
1	1	A7	TERRAIN keyword for non-uniform ground input
2	1-3	A256	Elevation filename (.ELV format) and path
3	1	A256	Impedance filename (.IMP format) and path

Notes: Line 2: Filename and path may NOT contain spaces.

4.2.13 *Keyword* FOLIAGE

FOLIAGE signals AAM to compute and apply foliage effects on sound propagation (Table 18). The Foliage model in AAM utilizes the method described in ISO 9613-2 [1996]. The method applies only in instances where the foliage of trees and shrubs are sufficiently dense to completely block the view along the propagation path and when it is impossible to see a short distance through the foliage. The .FOL binary file is structured similarly to the .ELV and .IMP files and contains the height of the foliage trees or shrubs for only those regions meeting the foliage density criteria. In this instance the variable label in the .FOL file that indicates it is a foliage grid is “FOLI”.

The effective propagation distance d_f used to compute the attenuation through dense foliage is the summation of the line of sight blockage near the source d_1 and receiver d_2 based along a ray propagating at an angle of 15 degrees (Figure 14). Within AAM, for the purposes of computing foliage attenuation, the ground is treated as a horizontal line between the source and receiver locations (local terrain effects are ignored in computing d_1 and d_2). The 15 degree ray path is modeled as an arc and computed independently at the source and receiver sides. The rays may not connect in the middle if the source and receiver heights are different. The curved ray path radius is assumed to be 5 km as noted in the standard. A height comparison is made at incremental distances until the ray exits the foliage when the ray path propagation distances through the foliage (d_1 and d_2) are calculated and summed. Subsequent secondary ray reentry into foliage due to the presence of taller dense foliage is not considered.

The ISO standard defines attenuation for octave bands. Within AAM these attenuations are applied to each of the one-third octave bands within the associated octave band. Attenuation of noise due to a propagation distance d_f through dense foliage is given in Table 19. AAM internal units and input/output are in units of feet so the distances cited in Table 19 are feet. Within the AAM foliage model the attenuation applied is based on the standard, and dB/meter is quoted in Table 19 for consistency with the model.

When the ALL MESSAGES diagnostic keyword is in use, AAM creates an .FLD file which contains additional information about the slices between source and receiver through the terrain and the calculated attenuation due to propagation through foliage. This should only be used with the COMPUTEPOI keyword and one or two points of interest as it will create huge files if used with the COMPUTEGRD keyword.

Within AAM the Foliage is defined on a 2D grid as a set of foliage tree heights at every grid point. The acoustic module uses this data to determine the ray paths as shown in Figure 14. The handling of the foliage data is directly analogous to the handling of the ground elevation and surface impedance. When selecting a grid size and spacing, one needs to consider the fidelity of the foliage and the number of mesh points to accurately represent their locations. In general the geometric spacing used for the foliage file should be similar to that used for the elevation and impedance files.

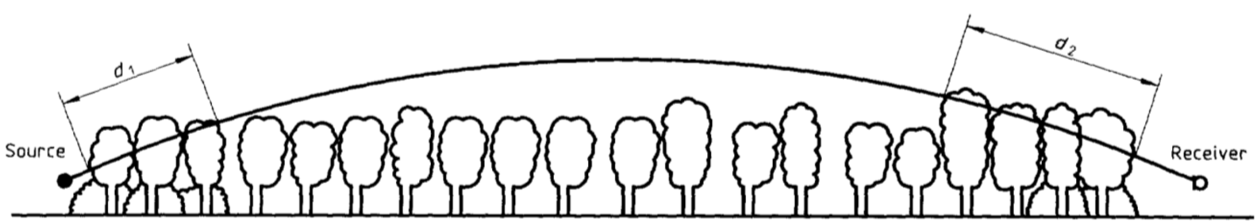


Figure 14. Geometry for computing foliage $d_f = d_1 + d_2$ parameter. *(Source: ISO 9613-2)*

Table 18. FOLIAGE Keyword Format

Line	Position	Max Length	Description
1	1	A7	FOLIAGE keyword for dense tree coverage input
2	1	A256	Foliage filename (.FOL format) and path

Notes: Line 2: Filename and path may NOT contain spaces.

Table 19. Attenuation of octave band noise due to propagation a distance d_f through dense foliage

Foliage Propagation Distance d_f (feet)	Octave Band Nominal Mid-band Frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
d_f<32.8 ft Total attenuation (dB)	0	0	0	0	0	0	0	0
32.8≤d_f<65.6 ft Total attenuation (dB)	0	0	1	1	1	1	2	3
65.6 ≤d_f< 656.1 ft Attenuation (dB/m)	.02	.03	.04	.05	.06	.08	.09	.12
d_f≥656.1 ft Total attenuation (dB)	4	6	8	10	12	16	18	24

4.3 Power-User Features not implemented in the QNM GUI

There are numerous capabilities that are included as part of the AAM modeling tool that might be of interest to an advanced user. These are not implemented as part of the QNM GUI, but are included here as some might be useful for understanding the acoustic results more fully. These keywords and features must be manually edited in the .INQ file using a text editor like Notepad. Do not use Word or a document editor as the resulting .INQ file will input extraneous information to the file. Additional information on these keywords may be found in the AAM manual.

4.3.1 *Keyword* ALL MESSAGES

ALL MESSAGES triggers AAM to output terrain (.TER) and a foliage (.FLD) files that contain the terrain and impedance profile data for a "slice" between each source and receiver point. This data can be imported to a graphics program and plotted to gain insight into the physical situation and acoustic results (Figure 15). Only use this with COMPUTEPOI. The slices will be output for each source-receiver combination. This information is useful to understand why certain acoustic results are being predicted. For example, is the line of sight between the source and receiver broken by the intervening terrain? Does the ray penetrate the foliage tree line or pass above the trees providing no acoustic benefit? What is the value of the foliage attenuation per one-third octave band for a particular source-receiver combination?

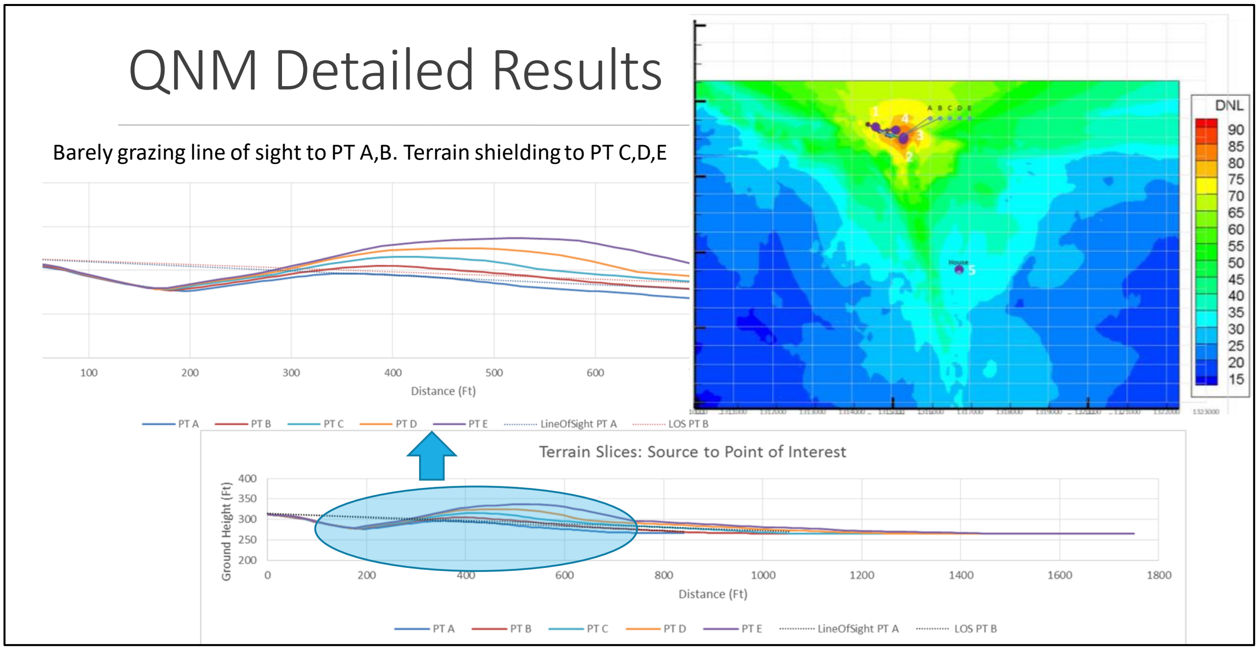


Figure 15. Example quarry results & diagnostic POIs A-E (top) and QNM Terrain slice data (bottom) from .TER file

4.3.2 *Keyword* DIAGNOSTICS

DIAGNOSTICS triggers the writing of supplemental information to the primary ASCII output .TXT file. This file will have the same root name as you scenario case name. It contains a wealth of information about the QNM run including detailed operational information including trajectory details for moving operations along roads and routes, points and orientations/hold times for static and distributed operations and blasting parameters including spectral information. Much of this information can be plotted and examined outside of the QNM ArcGIS GUI. The TXT file also contains an echo of the acoustic database. Near the bottom of the file are summary results and time history diagrams for each source-receiver combination for POI analyses.

4.4 Error and Warning Messages

When AAM is executed it performs input file checking and may also create error and warning messages during execution. These are output to the command prompt screen and also into an ASCII file with extension .txt. This file will be located in the same directory as the input .INQ file and can be examined using a text editor such as Notepad.

Error messages fall into three categories: Error, Warning and general information. Error messages are created when fatal situations are encountered that require cessation of program execution. These are preceded by ERROR: in the output. Warning messages are preceded by WARNING: and give critical information about analysis. Under warning conditions, execution is continued, however the user should be aware that non-standard program operation has occurred. All other messages and output fall into the informational category.

The ERROR and WARNING messages are itemized here in **BOLD** type along with an explanation and where appropriate, recommended changes to the input file. In some instances, values of particular variables are provided to the user. These are indicated in *italics* and explained with each error message. At the end of every message is the name of the subroutine that generated the message. While this is not likely to be of significant value to the user it should be reported when inquiring about AAM to Volpe.

Error messages are generated based on problems in two different areas: Input file errors and run time errors. Input file error message are generated after screening of the inputs and are standardized and conform to the general output listed in Table 20, with details as explained in Table 21. Run time errors are generated later in program execution and may include a variety of output messages, all of which appear in alphabetical order in this section of the manual.

Table 20. Input File Error Message Standardized Output

Input File Error Message Standardized Output
ERROR: Read Error in the Advanced Acoustic Model. Problem in the following file: Filename *Detailed Message* Problem detected at line number *line*# Error located at or above this line: *Input file content*

This is a generalized error reporting message, which is generated when problems are encountered in the input file, filename. The line number at which the error occurs is identified (line #), as well as a repeat of the Input file content. A Detailed Message is provided for the user’s benefit and a summary of possible error messages are given below. The last word on the detailed message line contains the name of the subroutine, which reported the error. This additional diagnostic information is useful when contacting Volpe with questions.

Table 21. Input File Error Message Detailed Output

Detailed Error Message Output
Unable to locate POINT specified in STATICQOPS. RRreader The user specified POINT, identified by the POINT label in the POINTS section of the SETUP QUARRY keyword, could not be found in the input file. Make sure the column numbers are lined up according to the input specifications and that spaces and no tabs are used in the input file.
ROAD/ROUTE ID not specified in STATICQOPS. RRreader The user specified ROAD/ROUTE ID identified in the STATICOPS keyword section was not found in the input file. Check the ROADS and ROUTES section and be sure the column alignment matches the keyword descriptions. If there is a leading space on the ID in one place, but not the other they will not match and will create this error.
RR FLAG error. RRreader The RR Flag in the QOPERATIONS keyword section was not set to 1 (road) or 2 (routes).
ROAD ID not found in input. MapQData *RoadID* In the QOPERATIONS keyword section, the road specified (*RoadID* in keyword ROADS, line 3) was not found in the ROADS keyword section so the trajectory of the equipment operation could not be determined. Make sure ROADS keyword section appears before QOPERATIONS keyword section. *RoadIDs* are treated as 3-digit integer values and must match.
Road ID not found in input ROUTE. MAPQDATA *RoadID* In the QOPERATIONS keyword section, the road specified (*RoadID* in the ROUTES definition that is being identified for use) could not be found. Check that in the identified ROUTE (ROUTES keyword section) all the ROADS exist in the input file before the QOPERATIONS keyword section.
Number of Speeds/Headings in QOPERATION doesn't match ROUTE. RRreader There were insufficient entries of line type 4 in the QOPERATION. For a route one must define the speed and heading for each point along the route plus 1. The operating conditions will be defined at each end point along the route. Since the routes are segments, the number of end points is the number of routes + 1.
Unable to locate QUARRY_NOISE. ReadQNCdata The directory specified either using SET QUARRY_NOISE in the batch file or the QUARRY_NOISE pointer in the AAM.config file did not contain the Quarry_Noise.NC file.
Blast Propagation Exponent is not negative in QBLASTOPS. RRreader A positive value for the blast propagation exponent was found in the QBLASTOPS keyword section in the input file. The default value when propagating over terrain is -0.8552.
AREA ID specified in DISTROQOPS not found in input. MAPQDATA *AreaID* The *AreaID* that is in the DISTROQOPS was not found in the AREA keyword section.
WARNING: Mixed Blast and non-Blast Ops. RRreader It is recommended that blast operations be modeled separately from non-blast operations and the acoustic results not combined due to uncertainty in the simplified blast propagation model in AAM. Create two separate .INQ files, one with only QBLASTOPS and one with everything else.

4.5 Quarry Noise Database Structure

The Quarry Noise Database consists of 1000 series (RCNM and SLR 2016 Report), 2000 series (literature sources provided by ODOT) equipment and 3000 series (aggregated sources from literature provided by ODOT). Each piece of equipment and operating state has a unique 4-digit ID. Each item in the database is defined in a codex CSV information file as defined in Table 22. The acoustic data is one-third octave band data (Broadband, BB) at four ordinal directions defined from the front, clockwise at 0, 90, 180 and 270 degrees. There are one or two sets of acoustic entries for each piece of equipment: Stationary (LZavg (and LZmax for the 1000 series)) or Passby (LZmax), which reflect the average or maximum unweighted spectral levels. The “raw” data are stored as .csv files with the descriptor information in a codex.csv file (Table 22) and individual acoustic CSV files for each ID (Figure 16). The Quarry noise model automatically uses the LZmax data (for those pieces of equipment for which it is available) because it is deemed more conservative for environmental planning purposes. The acoustic database NetCDF file that the acoustic module reads, contains only one set of data per equipment. The acoustic NetCDF database is provided with QNM and information describing the QNM Noise database builder is described in Section 3.6.

Table 22. Quarry Noise Database codex information structure

Line	Position	Max Length	Description
1			Column Headers (for readability, not used)
2	1 2	I4 I4	Number of Entries Reference Radius for Acoustic Data (Ft) normally 100 Ft.
3			Column Headers (for readability, not used)
4	1 2 3 4 5	I4 A6 A24 F3 A256	Equipment ID Mode of Operation (Stationary or Passby) Operational Description (24 characters read & used, rest ignored) Source Height (ft) Equipment Name (256 characters read & used, rest ignored)

Notes: Repeat Line 4 as needed to meet the Number of Entries identified in Line 2.

```
ID,Name,Mode,Operation,Height_ft,Metric_dB,Orientation_deg,Hz_10,Hz_12p5,Hz_16,Hz_20,Hz_25,Hz_31p5,Hz_40,Hz
_50,Hz_63,Hz_80,Hz_100,Hz_125,Hz_160,Hz_200,Hz_250,Hz_315,Hz_400,Hz_500,Hz_630,Hz_800,Hz_1000,Hz_1250,Hz_16
00,Hz_2000,Hz_2500,Hz_3150,Hz_4000,Hz_5000,Hz_6300,Hz_8000,Hz_10000
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZmax,0,48.02,44.88,40.49,42.2,43.01,55.13,50.86,52.11,64.48,60.4,53.89,59.88,62.59,68.26,75.45,72.
34,67.97,66.65,56.62,56.95,51.89,61.62,69.5,62.54,64.88,67.09,66.58,69.05,66.28,66.63,64.92
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZmax,90,48.02,44.88,40.49,42.2,43.01,55.13,50.86,52.11,64.48,60.4,53.89,59.88,62.59,68.26,75.45,72
.34,67.97,66.65,56.62,56.95,51.89,61.62,69.5,62.54,64.88,67.09,66.58,69.05,66.28,66.63,64.92
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZmax,180,48.02,44.88,40.49,42.2,43.01,55.13,50.86,52.11,64.48,60.4,53.89,59.88,62.59,68.26,75.45,7
2.34,67.97,66.65,56.62,56.95,51.89,61.62,69.5,62.54,64.88,67.09,66.58,69.05,66.28,66.63,64.92
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZmax,270,48.02,44.88,40.49,42.2,43.01,55.13,50.86,52.11,64.48,60.4,53.89,59.88,62.59,68.26,75.45,7
2.34,67.97,66.65,56.62,56.95,51.89,61.62,69.5,62.54,64.88,67.09,66.58,69.05,66.28,66.63,64.92
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZavg,0,43.60,42.18,40.19,41.2,44.11,56.73,50.56,55.81,63.98,58.9,53.69,59.38,61.79,68.56,75.25,71.
94,65.77,65.95,55.82,56.45,52.89,61.12,68.6,60.94,64.08,64.19,64.38,65.75,63.58,63.03,61.72
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZavg,90,43.60,42.18,40.19,41.2,44.11,56.73,50.56,55.81,63.98,58.9,53.69,59.38,61.79,68.56,75.25,71
.94,65.77,65.95,55.82,56.45,52.89,61.12,68.6,60.94,64.08,64.19,64.38,65.75,63.58,63.03,61.72
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZavg,180,43.60,42.18,40.19,41.2,44.11,56.73,50.56,55.81,63.98,58.9,53.69,59.38,61.79,68.56,75.25,7
1.94,65.77,65.95,55.82,56.45,52.89,61.12,68.6,60.94,64.08,64.19,64.38,65.75,63.58,63.03,61.72
1000,Air-Operated Post Driver,Stationary, Driving steel
posts,7,LZavg,270,43.60,42.18,40.19,41.2,44.11,56.73,50.56,55.81,63.98,58.9,53.69,59.38,61.79,68.56,75.25,7
1.94,65.77,65.95,55.82,56.45,52.89,61.12,68.6,60.94,64.08,64.19,64.38,65.75,63.58,63.03,61.72
```

Notes: Data in lines are wrapped to fit. There are a total of 9 lines of data in the CSV file.

Figure 16. Example single CSV acoustic file for ID 1000 (Air-Operated Post Driver)

The codex and acoustic data is transformed using the NCGen utility into a NetCDF database with the structure (ASCII rendition). An example with 8 acoustic entries is shown in Figure 17.

Note that the sequence in the NetCDF file must match the sequence shown in Figure 17 or the file will not be read properly. A supplemental tool, QNM_NoiseDatabase_Builder that automatically builds the NetCDF database from the codex and individual csv files is provided with the QNM software suite and is described in more detail in Section 3.6.

```
netcdf Quarry_Noise {
dimensions:
        RADIUS = 1 ;
        QID = 8 ;
        HEIGHT = 8 ;
        DIRECTION = 4 ;
        FREQUENCY = 31 ;
variables:
    float RADIUS ;
            RADIUS:unit = "FEET                " ;
        float QID(QID) ;
                QID:unit = ".                   " ;
    float HEIGHT(HEIGHT) ;
            HEIGHT:unit = "FEET                " ;
        float DIRECTION(DIRECTION) ;
            DIRECTION:unit = "DEGREE              ";
        float FREQUENCY(FREQUENCY) ;
            FREQUENCY:unit = "HERTZ               " ;
        float AMPLITUDE(QID, DIRECTION, FREQUENCY) ;
                AMPLITUDE:unit = "DECIBEL" ;
// global attributes:
        :title = "Quarry Noise Acoustic Database  VERSION 1.0  24 Mar 2018  Volpe, USDOT       " ;
data:
RADIUS = 100 ;
QID = 1000, 1010, 1013, 1015, 1020, 1021, 1024, 1025;
HEIGHT = 7 , 4.3, 5., 2.2, 4.8, 5.1, 6., 5.4 ;
DIRECTION =  0.0 ,     90.0 ,    180.0 ,   270.0 ;
FREQUENCY =
   10.0 ,    12.5 ,    16.0 ,    20.0 ,    25.0 ,    31.5 ,    40.0 ,    50.0 ,    63.0 ,    80.0 ,
  100.0 ,   125.0 ,   160.0 ,   200.0 ,   250.0 ,   315.0 ,   400.0 ,   500.0 ,   630.0 ,   800.0 ,
 1000.0 ,  1250.0 ,  1600.0 ,  2000.0 ,  2500.0 ,  3150.0 ,  4000.0 ,  5000.0 ,  6300.0 ,  8000.0 ,
10000.0 ;
AMPLITUDE =
8.02,    44.88,   40.49,   42.2,    43.01,   55.13,   50.86,   52.11,   64.48,   60.4,
53.89,   59.88,   62.59,   68.26,   75.45,   72.34,   67.97,   66.65,   56.62,   56.95,
51.89,   61.62,   69.5,    62.54,   64.88,   67.09,   66.58,   69.05,   66.28,   66.63,   64.92,
48.02,   44.88,   40.49,   42.2,    43.01,   55.13,   50.86,   52.11,   64.48,   60.4,
53.89,   59.88,   62.59,   68.26,   75.45,   72.34,   67.97,   66.65,   56.62,   56.95,
51.89,   61.62,   69.5,    62.54,   64.88,   67.09,   66.58,   69.05,   66.28,   66.63,   64.92,
Etc...
```

Figure 17. Quarry Acoustic NetCDF Database (ASCII version)

5. Acoustic Analysis Modeling Tips

This section includes a description of the acoustic metrics and provides guidance on analysis techniques for modeling noise from quarry operations using the Quarry Noise Model and the Advanced Acoustic Model. Some recommendations for time-based and geometric based sensitivity analyses which can provide some insight as to modeling uncertainty are provided in Section 5.1.

5.1 Acoustic Metrics

Some of the metrics needed for assessment of quarry impacts and what that means in terms of the QNM analysis are described in this section. Using QNM is a means of modeling a representation of the noise expected from a given scenario and does not necessarily capture all of the temporal variation that occurs in actual operations at a quarry. Some assumptions are made by the modeler and within QNM to facilitate analysis. The influence of these decisions can impact the predicted results.

It is suggested that the user of QNM also conduct a sensitivity analysis of the key noise drivers to determine precision with which they should be modeled in any scenario. An example of a time-based sensitivity analysis is varying the time duration or number of pieces of equipment by 25 or 50% to ascertain the influence on the results. Extra care should be given in selection of the modeling parameters if the results are very sensitive to the inputs.

Another example of a geometric sensitivity analysis is to vary the location of the equipment and points of interest slightly especially if they are located close to distinct terrain features such as steep vertical cliffs or the ray path between the source and receiver is on the cusp of being blocked. The ground effect propagation modeling near grazing angles is very sensitive to the fidelity of the intervening terrain. This kind of sensitivity analysis can provide some insight as to the uncertainty in the AAM predictions.

- Maximum Value Metrics (AmaxL, CmaxL, MaxL) – these metrics (found in the single event.CSV file) indicate the maximum level of the noise event. For moving operations the peak level is usually obtained when the equipment is closest to the point of interest. For static operations the level is constant so the peak is also the average and the peak or maximum level is not a function of the amount of time the equipment is operating. Peak and maximum level metrics do not include any penalties that account for the time of day of the event. When running multiple operations/events in a QNM analysis, the peak or maximum value metrics reported will be across all operations/events. A single grid file could have peak values in different areas of the grid from different operations.
- Peak Metrics (Lpeak, PSFmax) – these metrics are blast noise specific. They will only be generated when conducting a blast analysis. They are not combined with any of the A, C or unweighted metrics from the other kinds of quarry operations.

- Time Based Single Event Metrics (SEL, SELA, SELC, EPNL) – these metrics account for the time variation and duration of a single event and are essentially the area under the acoustic time history plot. The amount of time the equipment is operating affects the integrated metric level. A constant level event operating for twice the amount of time amounts to a 3 dB increase in the metric level. These metrics are output when a single event is analyzed in QNM.
- Day/Night Metrics – these are metrics such as DNL which include a 10 dB night time penalty for events occurring after 10 pm and before 7 am. To compute DNL for a quarry, the QNM analysis needs to include all operations over the 24 hour time period and identify which occur during the day and which occur at night.
- Statistical Noise Levels – These metrics represent a statistical exceedance threshold for an hourly interval. Per the State of Oregon: Department of Environmental Quality (ODEQ) standard [Oregon, 1983], an L10=65 dBA means that in any consecutive 60 minute period of the day, 65 dBA is equaled or exceeded only 10% of the time, or for a total of 6 minutes. The standard process involves examining the time history every few seconds at a receiver point and counting the number of times the sound level exceeds a particular level. One must consider the ebb and flow of activities and select representative time intervals and the associated operations during those intervals. Statistical noise levels are based on A-weighted sound levels. When modeling the quarry in QNM one should model each representative time interval separately and then examine the results. Additional modeling suggestions for statistical noise levels is presented below.
- A, C and Unweighted Metrics – Metric weighting is a method for taking into account the spectrum of the sound. The A weighted metric mimics the human ear, while C weighted metrics are useful for determining structural impacts. Within QNM the equipment database include both level and spectral information for modeling. However the simplified blast noise model assumes a single blast spectrum at the receiver.

5.2 Selection of Equipment

The noise database is organized into three primary sections:

- 1000 series – high fidelity / high resolution equipment source noise database from RCNM and ODOT’s 2016 SLR Report (Pleasant Valley (PV) quarry was studied in this 2016 report).
- 2000 series – data from multiple literature sources including specific quarry measurement reports (refer to Section 3).
- 3000 series – aggregated generalized data from multiple literature sources (refer to Section 3).

To maximize acoustic fidelity and minimize uncertainty, the lowest series data should be chosen when possible.

5.3 Physical Modeling

Within QNM there are three primary physical modeling phenomena that may be included in the acoustic analysis: terrain, foliage and meteorological effects. General information about each are described below.

- Terrain Effects – the sound propagation is affected by the terrain over which it propagates as it travels from the source to a receiver. The terrain is characterized by two key parameters: elevation and surface property. The terrain elevation, particularly in situations where line of sight is blocked, strongly influences the sound propagation. The characteristics of the terrain (be it gravel, grass, trees) are also an influence.
- Foliage Effects – sound can be attenuated by dense foliage along the propagation path. This model requires the user to outline the areas which include dense foliage and prescribe the nominal height of the foliage trees or shrubs above the local ground. The foliage should be sufficiently dense to completely block the line of sight.
- Meteorological Effects – the temperature and humidity near the quarry have an effect on propagation and the sound levels arriving at the receiver. The model is setup to consider only a single atmospheric instance, so separate AAM runs must be conducted if different atmospheric conditions are required. For example when conducting seasonal analyses, winter, spring, summer and fall conditions must be analyzed separately.

5.4 Blast Event Analysis

When modeling blast noise the charge weight per single charge should be modeled. The confinement factor is typically low in the range of 3.3-10 but can increase with poor stemming. If blast data is available for a particular quarry location, the confinement factor can be derived empirically using AAM by modeling the single blast operation and comparing the predicted results at the microphone location (POI analysis) and adjusting the confinement factor until the predicted results are matched. If the actual measured spectrum is considerably different from the modeled spectrum used in AAM, it is possible that some metrics will match better than others. This is a limitation of the simplified empirical blast prediction methodology employed in QNM. Based on examination of Tunisia data a confinement factor of 6.6 is suggested. Additional information about empirically validating the blast propagation exponent is contained in Section 4.2.11.

5.5 Impact of Topography Refinement on Blast Noise

It is important to accurately capture the local topography near the quarry in order to predict the ground effect. This can be accomplished by updating the topography using CAD data. The process for incorporating CAD data and creating an elevation file for AAM is described in detail in Appendix B. An example of the acoustic Blast results are presented here. Figure 18 shows in 3D the planned excavation and buildup of an earthen berm which are defined in a CAD file which is applied to the local topography. A layout of this scenario is provided in Figure 19 where the white star indicates the blast point and the black dots indicate five receiver locations in a line to the west, ranging from 500 Ft to 5000 Ft distance from the blast location. In the AAM acoustic analysis, a "slice" is taken between the source and receiver to determine the intervening terrain profile and evaluate the ground effect. These terrain profiles are shown in Figure 20 for receiver points 500 ft, 1000 ft and 5000 ft west of the blast location and one can see the excavation and the berm buildup between the two scenarios. The excavation and buildup creates additional shielding (resulting in an additional ground effect) and hence a significant noise reduction (3 – 17 dB and 4 PSF depending on the location) across multiple metrics (Table 23).

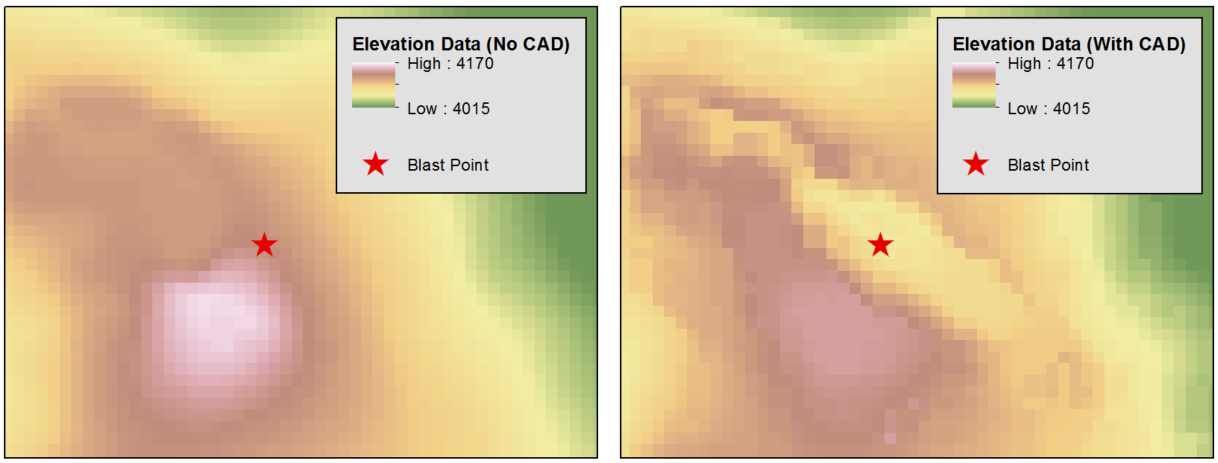


Figure 18. Terrain before and after CAD updates.

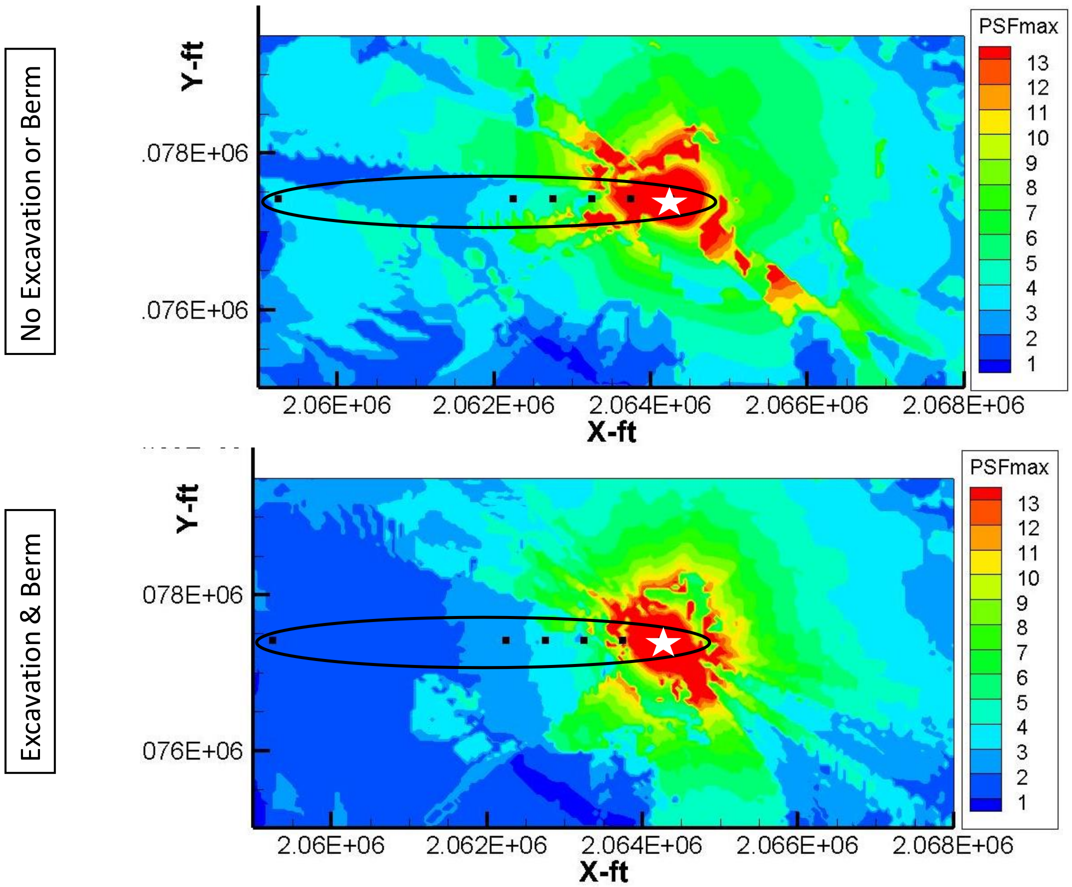


Figure 19. Blast Scenario to Evaluate Overpressure (PSF) Impact of Excavation and Berm

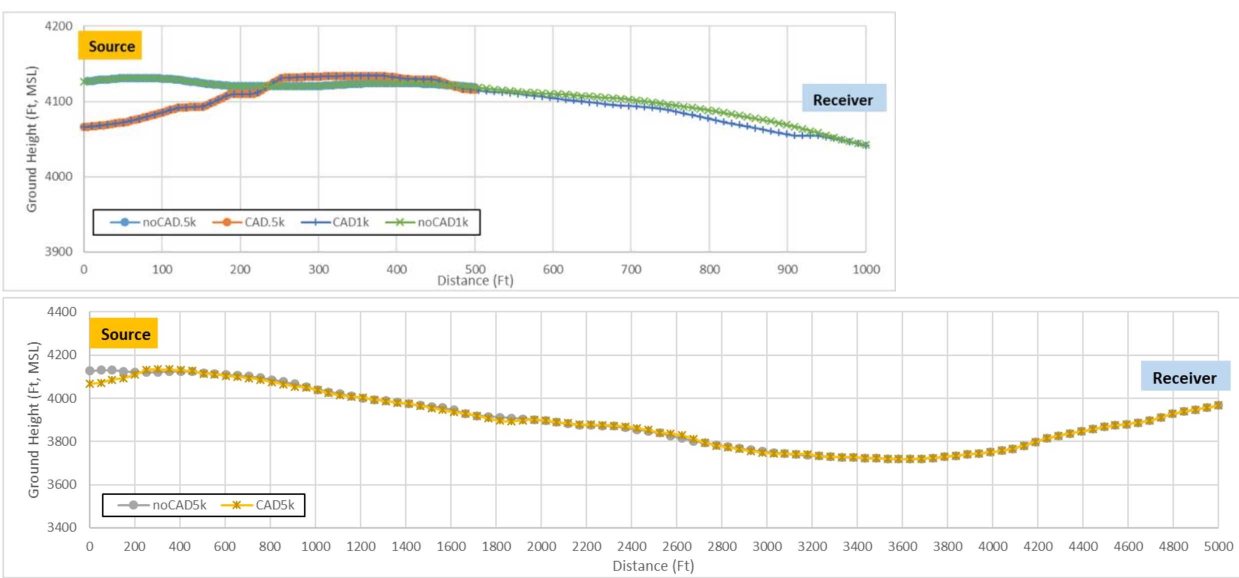


Figure 20. Natural and Excavated Terrain between Blast and Receivers (500ft, 1000 Ft and 5000 Ft West)

Table 23. Propagation Results at Receivers with and without Excavation Terrain Modeling

Scenario	POIname	X	Y	Lmax_dBA	Lpeak_dB	PSF
No Excavation or Berm	W500	2063749	1077409	122.28	153.21	14.15
	W1k	2063249	1077409	107.16	139.79	4.08
	W1.5k	2062749	1077409	102.95	141.29	4.85
	W2k	2062249	1077409	99.71	139.07	3.75
	W5k	2059249	1077409	112.15	138.53	3.52
Excavation & Berm	W500	2063749	1077409	113.35	147.59	10
	W1k	2063249	1077409	104.26	141.79	5.13
	W1.5k	2062749	1077409	98.03	138.14	3.37
	W2k	2062249	1077409	95.3	135.85	2.59
	W5k	2059249	1077409	95.21	128.83	1.15

5.6 Hourly Statistical Noise Levels

The State of Oregon Department of Environmental Quality (ODEQ) guidelines [Oregon, 1983] defines "Allowable Statistical Noise Levels in Any One Hour" applicable to existing industrial and commercial noise sources. The statistical noise levels are A-weighted and can be calculated using QNM/AAM. They are generated using the A-weighted time history data following the identified statistical procedures. Within AAM this procedure encompasses binning the predicted dBA values for a representative hourly period and interpolating to other L_{nn} levels based on a Gaussian probability distribution. Per the ODEQ guidelines, an L_{10} = 65 dBA means that in any consecutive 60 minute period of the day, 65 dBA is equaled or exceeded only 10% of the time, or for a total of 6 minutes. The L_1 level represents the sound level that would only be exceeded 1% of the time, or for 36 seconds in a given hourly period.

To compute the hourly statistical noise levels it is the user's responsibility to identify representative hourly periods during the day. Each representative hour of operation is modeled using a separate analysis in QNM. The loudest results are used to compare against the ODEQ guidelines. QNM will combine the operations within the representative hourly period in a conservative manner by assuming they are all coincident in time and combining the sound energy. It is up to the modeler to select and assign the operations across the representative hourly interval. An example of a fictitious operational scenario for a typical day and the representative hours is provided in Table 24 with equipment IDs indicated.

An example table to facilitate evaluation against ODEQ statistical noise level limits (dBA) for the seven representative hours is provided in Table 25. Each of these Representative 1 hour periods would be modeled separately using QNM.

Table 24. Fictitious Quarry Operational Scenario and Representative Hours

Rep Hour	Applicable Timeframe	Representative Hourly Activities
1	7pm – 5am	1 Diesel Generator (1026)
2	5am – 7am	2 Front End Loaders (1024) – 40 mins / hour 3 dump truck (1021) passby on roads 1 water spray truck (1068)
3	7am - 9am	2 CAT Generators 1 Directional Drill Rig (1017) - 10 mins/hour
4	9am - 10am	2 CAT Generators 1 blast operation (700 lb charge weight, K=3.3) 2 dump trucks (1021) passby on roads (ingress) 2 wheeled backhoe loaders (2153) – 45 mins/hour operational time 3 dumpers (2147) – stationary 20 mins 3 dumpers (2146) – driving 1 pass each
5	10am – 4pm	1 PV CAT 926G Dozer – 60 mins/hour operational time 3 dumpers (2147) – stationary 20 mins 3 dumpers (2146) – driving 1 pass on roads (ingress/egress) 1 Track Dozer Excavation (3071) - 40 mins/hour 1 Jaw Crusher (2002) – 60 mins/hour operational time 1 PV Crusher Full Operation (2340) – 60 mins/hour operational time PV crusher conveyor (2342) loading hauler – 60 mins/hour operational time 2 dump trucks (1021) passby on roads (ingress/egress - 4 per hour)
6	4pm - 5pm	PV crusher conveyor (2342) loading hauler – 60 mins/hour operational time 2 dump trucks (1021) passby on roads (ingress/egress - 4 per hour)
7	5pm -7pm	1 Diesel Generator (1026) 1 Street Sweeper near quarry entrance (1061)

Table 25. Statistical Noise levels for Representative Hours

	Daytime 7am – 10 pm			Night time 10pm – 7am		
Statistical Noise Levels (dBA)	**L50**	**L10**	**L1**	**L50**	**L10**	**L1**
ODEQ Limit (dBA)	55	60	75	50	55	60
QNM #1	n/a	n/a	n/a			
QNM #2	n/a	n/a	n/a			
QNM #3				n/a	n/a	n/a
QNM #4				n/a	n/a	n/a
QNM #5				n/a	n/a	n/a
QNM #6				n/a	n/a	n/a
QNM #7				n/a	n/a	n/a

When modeling operations in QNM for the purpose of computing statistical metrics, it is important to understand that stationary equipment emits a continuous sound. It is possible that statistical metrics for different times (i.e. L10 and L50) can have the same dBA values. Consider an example with a crusher (1072) and a Generator (1070) operating continually, and a single dump truck (1021) moving operation along a quarry road. At a point near the quarry entrance, the A-weighted time history for each of these three pieces of equipment is reflected in Figure 21. For power users, this data is tabulated and may be found in the .POI or .TXT output files. An excerpt is provided in Figure 22 with the dBA time history for each piece of equipment highlighted in yellow.

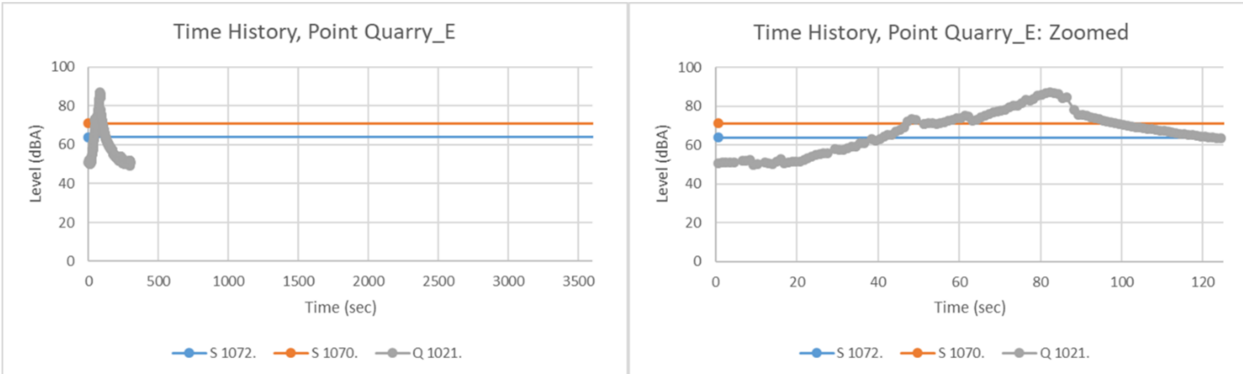


Figure 21. Time Histories from a Stationary Crusher (1072), Generator (1070) and Moving Dump Truck (1021)

```
TITLE = "Points of Interest Time History"
VARIABLES = "Time"  "SPL" "dBC"   "dBA"    "PNL"    "PNLT"  "f   10.0Hz" "f   12.5Hz" "f   16.0Hz" "f   20.0Hz" "f   25.0Hz"
ZONE T="Track S 1072.    Profile  1.        Point Quarry_E  " I=   2  F=POINT
      0.63     78.03     76.56     63.94     77.21     78.90      47.0      69.8      56.7      59.4      65.7
   3600.63     78.03     76.56     63.94     77.21     78.90      47.0      69.8      56.7      59.4      65.7
ZONE T="Track S 1070.    Profile  2.        Point Quarry_E  " I=   2  F=POINT
      0.69     83.94     83.13     71.12     84.39     89.62      52.4      74.1      60.8      56.9      60.9
   3600.69     83.94     83.13     71.12     84.39     89.62      52.4      74.1      60.8      56.9      60.9
ZONE T="Track Q 1021.    Profile  1.        Point Quarry_E  " I=  94  F=POINT
      0.68     57.51     56.46     50.85     59.60     63.76      40.0      40.8      42.0      41.8      40.3
      1.66     57.68     56.63     51.05     59.76     64.10      40.1      41.0      42.1      42.0      40.5
      2.64     57.67     56.58     51.11     60.16     64.81      40.2      41.0      42.2      42.0      40.5
      3.62     57.81     56.71     51.09     59.96     65.46      40.4      41.2      42.3      42.2      40.7
      4.60     57.98     56.87     51.17     60.02     66.47      40.5      41.3      42.5      42.3      40.9
      6.55     59.22     58.17     52.11     60.94     67.60      41.3      42.0      43.1      42.9      41.6
      7.48     58.70     57.63     52.03     61.12     64.54      41.2      42.0      43.3      43.2      41.6
      8.41     59.00     57.95     52.42     61.12     67.79      41.4      42.2      43.5      43.4      41.8
      9.35     59.14     58.15     49.94     61.41     64.75      41.3      42.2      43.4      43.3      41.7
     10.28     59.39     58.42     50.23     61.77     65.11      41.5      42.4      43.6      43.5      41.9
     12.14     60.46     59.44     50.91     62.07     66.07      42.4      43.1      44.2      44.0      42.7
     13.10     59.59     58.54     50.46     61.51     65.02      42.2      43.0      44.3      44.3      42.6
     14.06     59.53     58.51     50.37     61.87     66.13      42.1      43.0      44.2      44.1      42.4
     15.03     59.90     58.82     51.52     61.86     64.84      42.6      43.5      44.7      44.7      43.0
     15.99     60.23     59.16     52.62     62.46     68.59      42.8      43.7      45.0      44.9      43.2
     16.96     60.15     59.11     50.84     62.53     65.80      42.8      43.7      44.9      44.8      43.1
     17.92     60.44     59.40     51.12     62.81     66.05      43.1      43.9      45.2      45.1      43.4
```

Figure 22. Excerpt from .POI file with highlighted dBA Time Histories for Individual Pieces of Equipment

The module that computes statistical metrics follows the procedures [Oregon, 1983] sums the noise (on an energy basis) from each operation and counts (bins) the number of seconds (for all operations combined) that each dBA value (in .1 dBA increments) is exceeded. This tabulation (sections of the output is abbreviated with "…") for this example case is provided in Figure 23. Per the procedure, the L1 is the dBA value that is exceeded for 36 seconds (reported as 75.7 dBA); the L10 is the dBA value exceeded for 360 seconds and L50 for 1800 seconds. In this example L10 and L50 are both reported as 71.9 dBA because that is the value of the sound level (all equipment) at POI #1 that is exceeded for the specified time duration during the 1 hour modeled interval.

```
Statistical Metrics Addl Output, POI#           1
dBA max,min=   87.24886       71.80732
dBAlevel, #Exceedances.
  87.20000              0
  87.10000              2
  87.00000              2
  86.90000              3
  86.80000              4
...
  76.30016             30
  76.20016             31
  76.10017             32
  76.00017             33
  75.90017             35
  75.80017             35
  75.70017             37
  75.60017             38
...
  72.50022             83
  72.40022             90
  72.30022             95
  72.20023            106
  72.10023            120
  72.00023            146
  71.90023           3600
SML1(36s)     SML10(360s)     SML50(1800s)
  75.70017       71.90023       71.90023
```

Figure 23. Excerpt of the Statistical Metric Tabulation contained in the .txt (power user) file.

6. Limitations and Recommendations

The Quarry Noise Model includes a GIS-based front end and a linear acoustics simulation Advanced Acoustic Model tool for the noise calculations. The limitations of the model are outlined below with some recommendations for future enhancement activities.

The GIS interface requires a user familiar with typical ArcGIS functionality. The interface was tailored based on the requirements of the AAM model and thereby impart some restrictions on the user namely:

- Input scenario data must be prepared in a foot-based coordinate system, and
- Operational noise sources and blast noise sources should be modeled separately.

The AAM model was initially developed for helicopter and aircraft noise analysis for NEPA purposes and covers the spectral range of 10 Hz to 10 kHz. It has been successfully applied for ground based vehicles including aircraft and stationary noise sources such as power station warning sirens. Ground-to-ground propagation is a very difficult phenomena to model since it is heavily influenced by local topology including terrain elevation and ground impedance. This is the predominant effect for modeling noise at quarries. While some verification of QNM results have been conducted with limited measurement data (along with some necessary assumptions), the developers of QNM recommend that a more thorough verification study be conducted with empirical quarry noise data, including identification of meteorological conditions, topography and equipment in use and their operating states.

Refraction of sound waves due to atmospheric effects such as temperature gradients and winds can also have a significant effect on the sound propagation and noise levels at a particular receiver. The current implementation of QNM/AAM utilizes a quiescent uniform atmosphere. Removing this meteorological limitation is something that should be considered in the future. There are some companion modules for AAM that incorporate mixed terrain and layered atmospheric effects, which could be implemented into the GUI, but were not due to budget and scope limitations and also run time considerations.

The blast noise model is the weakest element of the QNM tool. The simplified blast noise model implemented in AAM models only the Initial Overpressure (IOP) airborne sound propagation and refines the result by applying the ground-to-ground spectral propagation effects. Seismic noise and air-ground coupling are not considered. The simplified model relies on a user defined Confinement Factor and a propagation exponent. Section 4.2.11 describes how the user can tailor the state of confinement factor (K) and propagation exponent based on empirical data for a specific quarry site. A single assumed blast spectra is applied, and only peak metrics are deemed reliable, though in *power user mode* one can access additional metrics from blast operations. The model developers strongly recommend that supplemental blast measurements be conducted in Oregon to develop improved blast spectra (perhaps as a function of distance). Limited verification of the results with empirical data has been provided in Section 4.2.11 however we recommend that a confinement factor be empirically derived and utilized for Oregon quarries.

The acoustic database included with QNM was developed from a blend of empirical data sources as is described in Section 3. These data were harmonized into a common reference format. Only some of the data sources were gathered for the purpose of source characterization, so some engineering approximations were applied. The following summarizes these approximations, which should be considered when conducting QNM analyses:

- Effective source height provided in the database are not deterministically derived.
- Most available spectral data were in the form of octave bands, which are of a lower resolution than the one-third octave bands required by AAM. One-third octave bands were derived from the octave band data; however, this process has the potential to "smooth out" some tonal sounds in the sources.
- Most sources were not measured for all four orthogonal orientations. When this was the case, the levels for other orientations were interpolated using existing data from the source. For the common case where only one orientation was measured, this results in an omnidirectional source directivity.

When adding new sources to the database, e.g. for site specific sources, it is recommended that care be taken to accurately determine source heights, measure one-third octave band levels and to do so from four orthogonal orientations. Measurement of the vehicle source from the front, right, back and left sides will provide the highest fidelity data. In order to correct the measured data to reference conditions using the procedures described in Section 3.3, one must obtain meteorological conditions (temperature and humidity). Ideally the measurements should be conducted in a flat area with uniform ground and no reflecting surfaces under quiescent atmospheric conditions and with at least 10 dB signal to ambient noise levels in the 10Hz to 10 kHz one-third octave bands. The measurement distance for adding compact source data for AAM should be taken in the acoustic far field. This distance can vary based on the piece of equipment, but is generally at 100 to 500 feet away. Measurements should be conducted over a period of time (i.e. 30 seconds if possible) for each operating state condition to better represent nominal noise emission.

In the case of the majority of the limitations and recommendations described in this section, the user can evaluate the uncertainty of the approximations by conducting a sensitivity study and quantifying the variation in the noise results. For example if the topography is uncertain, the elevation and impedance and foliage can be modified systematically to evaluate the effect the changes have on the results. If blasting confinement factors are uncertain, one can vary the state of confinement factor (K) to evaluate the impact. A similar approach can be used to determine the effect of equipment location, orientation and number of operations on the results. Additional sensitivity study recommendations are provided in Section 5.1.

With an understanding of the effect the modeling inputs have on the results, one can then suitably tailor the level of effort for quantifying model inputs and if needed conduct a more in-depth analysis for particular scenarios.

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Appendix A: QNM GIS Module Sample Scenario Quick Start Guide

The following guide provides instructions for quickly running the Quarry Noise Model with the accompanying sample data. It assumes use of the sample scenario data provided within the …/QNM_v_**XXXXX**/scenarios/sample_scenario directory. This data provides basic quarry noise scenario for the Pleasant Valley Quarry in Oregon and includes pre-defined quarry geography, quarry operations, elevation, and impedance data. Operations modeled in the sample scenario include a handful of blast, point and route operations. For full instructions on running the QNM GIS Module, including preparing a custom scenario from scratch, refer to the full QNM GIS Module documentation (Section 2).

1. Follow “**Installation Instructions”** (Section 2.1) in the QNM GIS Module Documentation.
2. Because the scenario geodatabase has already been prepared with sample quarry geographic data and operations, running the sample scenario does not require using the Create Input Geodatabase, the Define Operation tools, nor the Quarry Noise Toolbar. Open and run the **Prepare Elevation Data** tool within the Quarry Noise Toolbox. The user must define the working scenario directory (where the input data is already stored and where the processed elevation data will also be stored), the elevation data to be processed, the output file name, the scenario’s spatial reference, and the analysis extent. The user must also indicate whether or not to resample the elevation data to a different grid size than what is provided in the raw data-- and if so, provide a grid size in the units of the scenario’s spatial reference. Sample parameters are shown in Figure 24. In the below case, the user wishes to use the native resolution of the elevation data and therefore does not check the box to resample the elevation data.

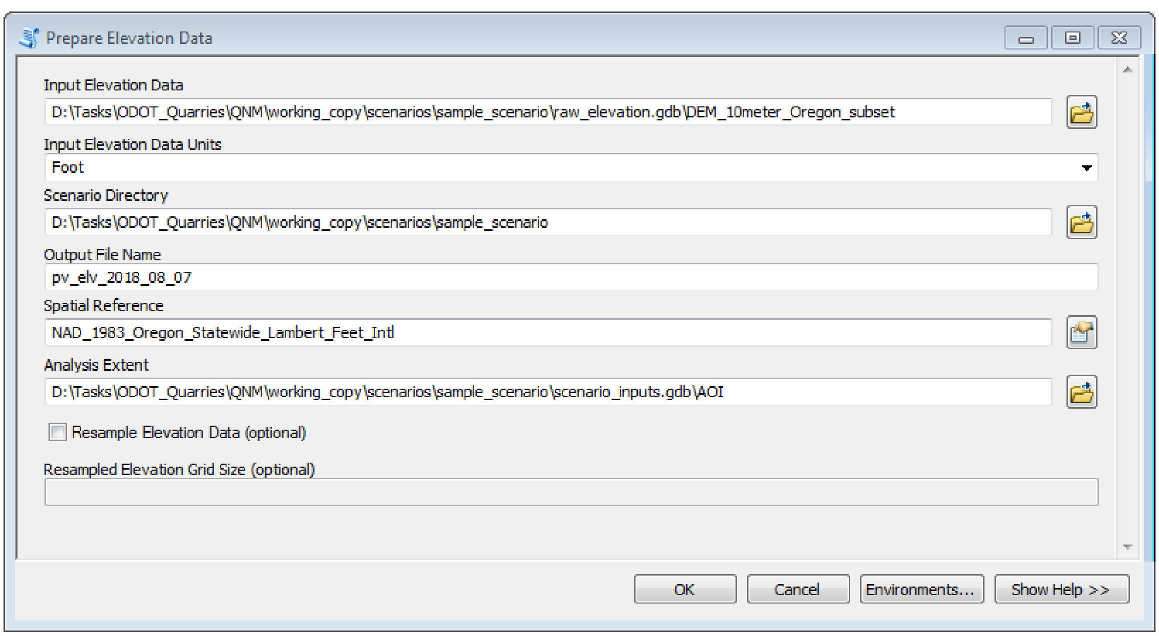

Figure 24. Prepare Elevation Data

3. Open and Run the **Prepare Impedance Data** tool. This tool is identical to the Prepare Elevation Data except it processes impedance data rather than elevation data. Sample parameters are shown in 25.

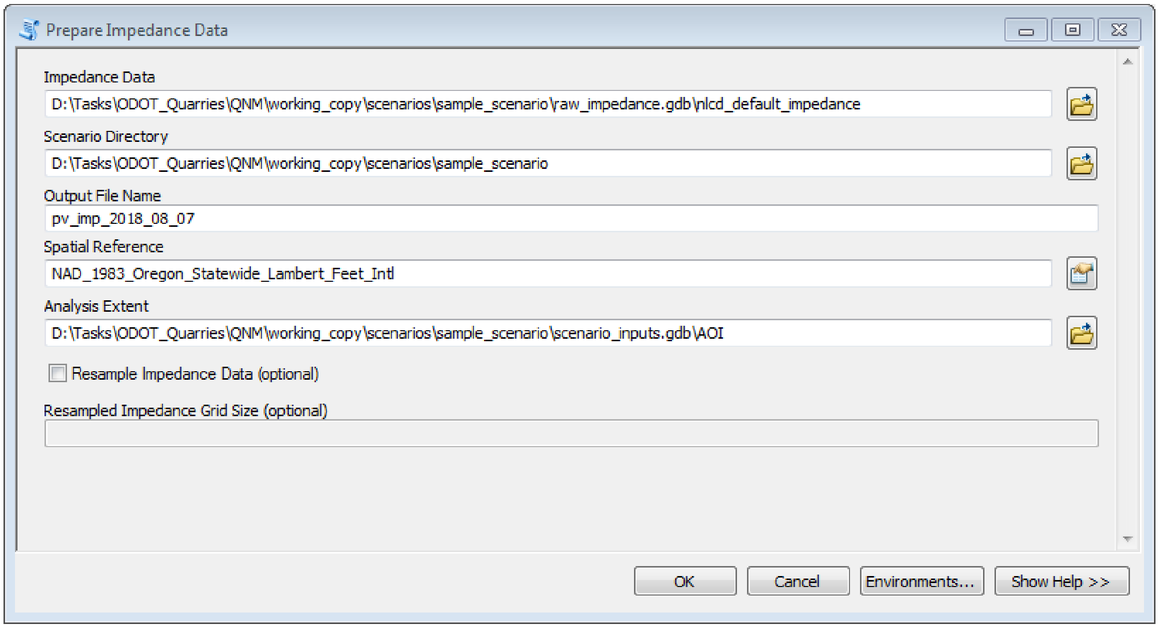

Figure 25. Prepare Impedance Data

4. Open and run the **Prepare Foliage Data** tool. The tool is similar to the Prepare Elevation and Prepare Impedance tools except that it bases itself on a feature class located within the scenario inputs geodatabase, rather than a standalone raster dataset. Sample parameters are shown in Figure 26.

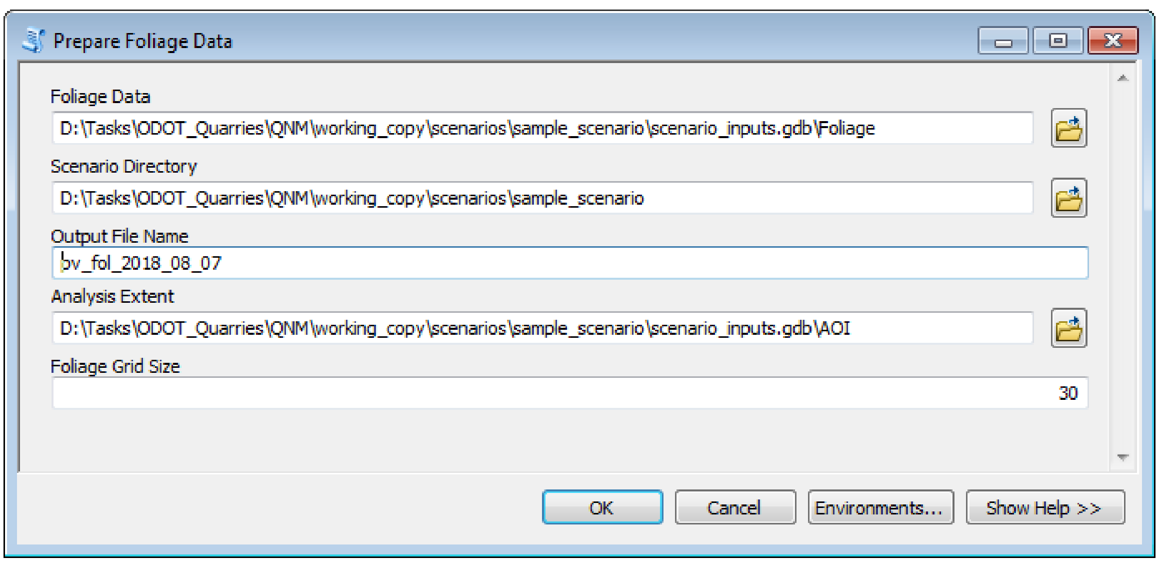

Figure 26. Prepare Foliage Data

5. Open and run the **Prepare Noise Model Input** tool. The user must define a scenario name, the scenario input geodatabase, the elevation and impedance data, the directory containing the noise database, the full path the AAM executable, and the working scenario directory. The user must also indicate whether or not to compute a noise grid and whether or not to compute noise at particular points of interest. The user should also define an analysis grid size (in the units of the scenario spatial reference system), a scenario temperature, pressure and relative humidity. Figure 27 provides potential parameters for a basic noise model scenario.

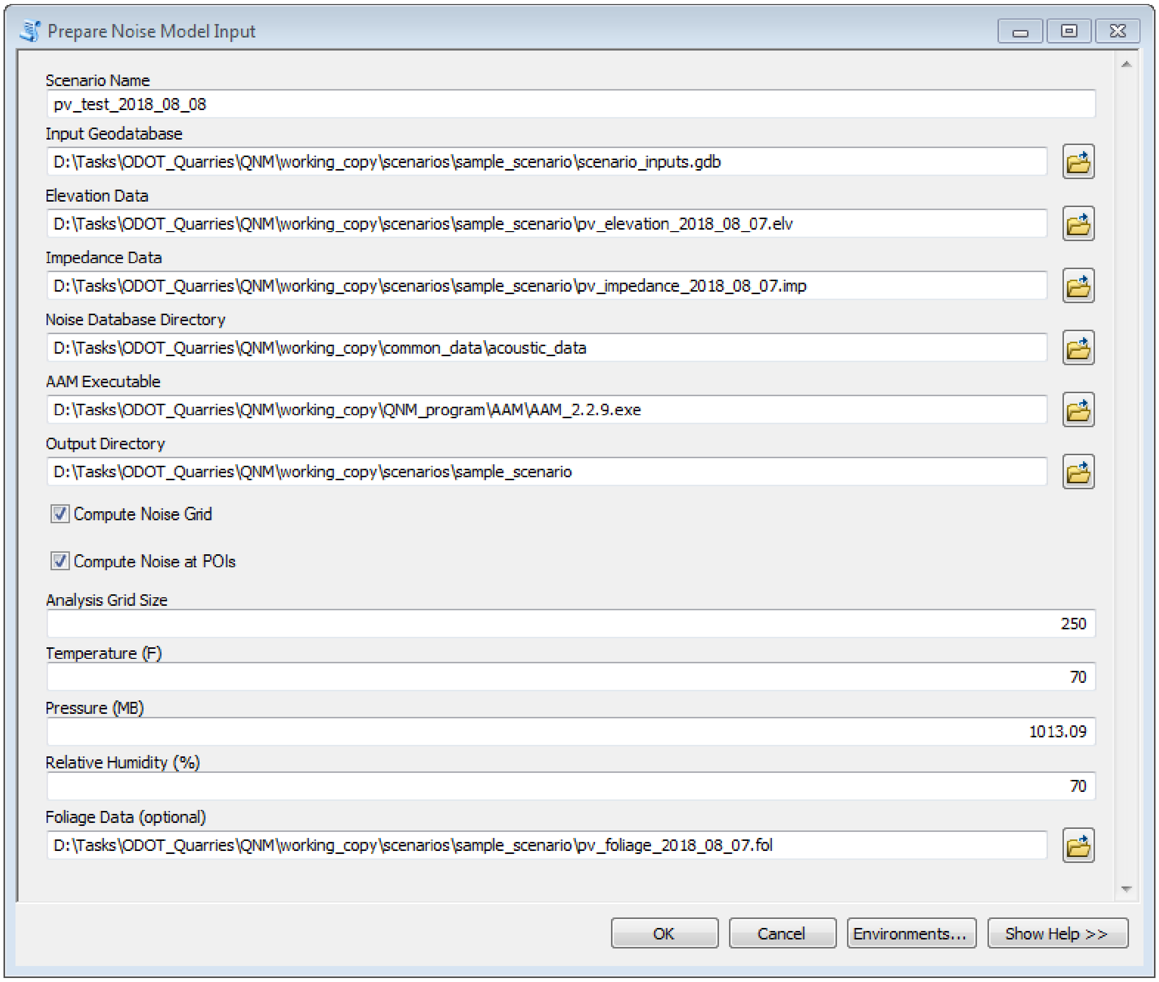

Figure 27. Prepare Noise Model Input

6. In the scenario output file, double click on RunAAM.bat. A command window should open and provide updates on the progress of running AAM.

7. Once complete, close the command window and open and run the **Process AAM Outputs** tool. The user must define the working scenario directory and the scenario spatial reference. All scenario outputs will be converted into GIS-formatted data which will be stored in the

scenario_outputs geodatabase within the scenario directory. See Figure 28 for an example of a typical set of tool parameters.

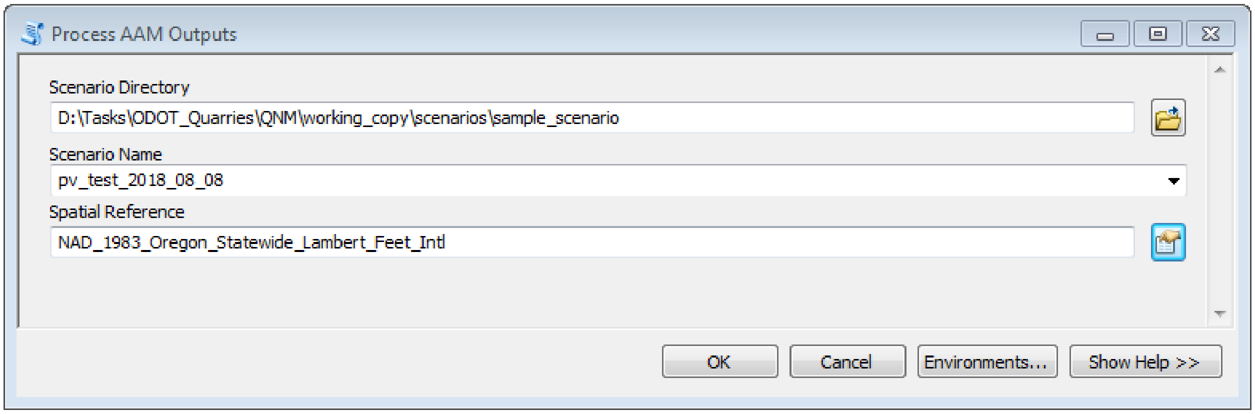

Figure 28. Process AAM Outputs

8. Add the output data to an ArcMap document for visualization and analysis (Figure 29 maps the DNL output)

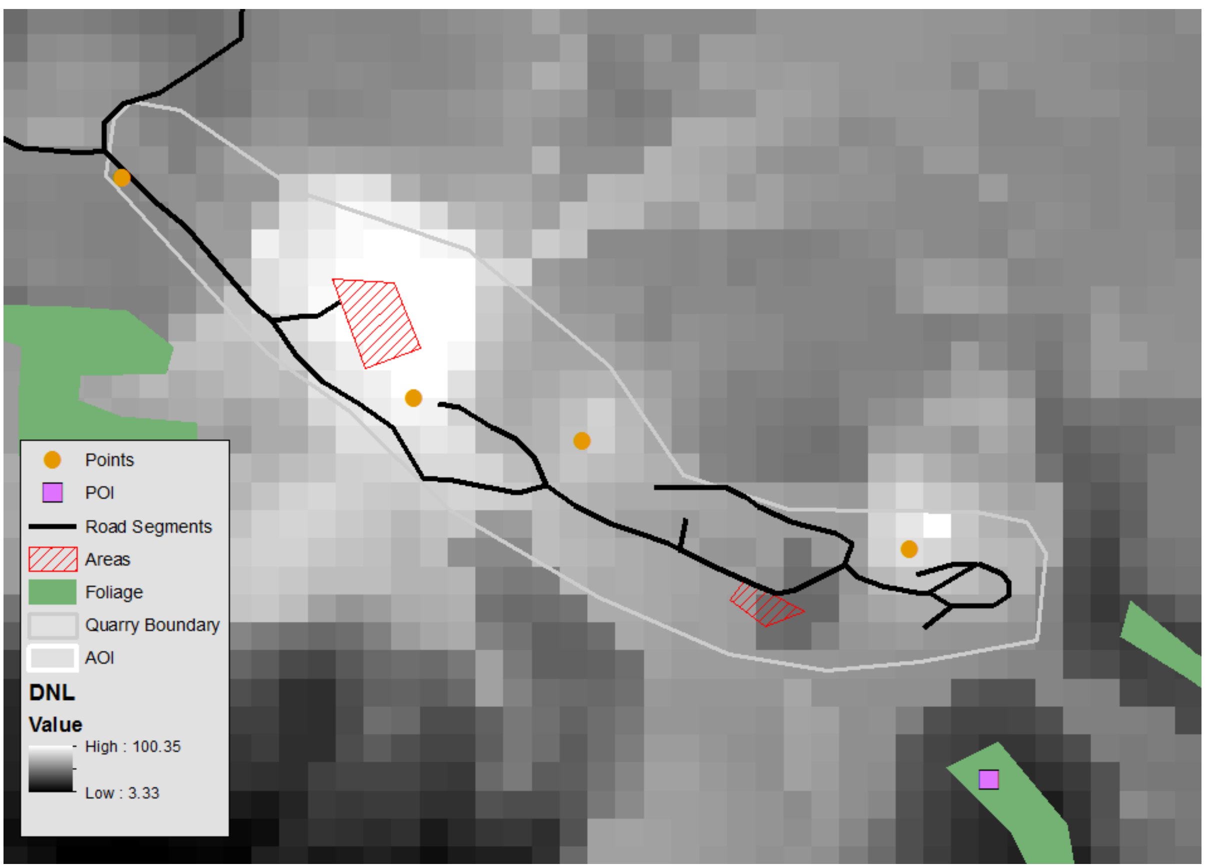

Figure 29. Example QNM output data visualization

Appendix B: Requirements for Utilizing CAD Data in ArcGIS and QNM

Computer-aided design (CAD) data is digital data used to represent real-world objects. Common CAD data formats include Drawing (DWG), Drawing Exchange Format (DXF), and Design (DGN). While ArcGIS supports CAD data, its full functionality only emerges if the spatial reference information used to make the CAD data is known and fully defined by the user in ArcGIS. The requirements for CAD data to be used within ArcGIS and the ODOT Quarry Noise Model are listed in Table 26.

Table 26. CAD data requirements

Item	Description
CAD data common format	DWG, DXF, or DGN
Spatial Reference	Information on the spatial reference system (also known as a coordinate system) utilized to draw the CAD data. Typical spatial reference systems include: • UTM Grid Zones • State Plane Coordinate Systems • Oregon Coordinate Reference System Zones such as OCRS_Baker_NAD_1983_CORS96_TM_Feet_Intl

The specific steps needed to view CAD data in ArcGIS and the ODOT Quarry Noise Model are summarized below.

- Open a new ArcMap document. Add an imagery basemap and/or any other GIS data related to the quarry that is referenced by the CAD data. In any case, it is important that data with a known spatial reference system is added to the ArcMap document before CAD data is added to the document.
- Add the CAD dataset to the ArcMap document. Ensure that the top level file is selected and added (e.g. the DWG or DGN file)—not the individual elements located within the DWG or DGN (Figure 30).

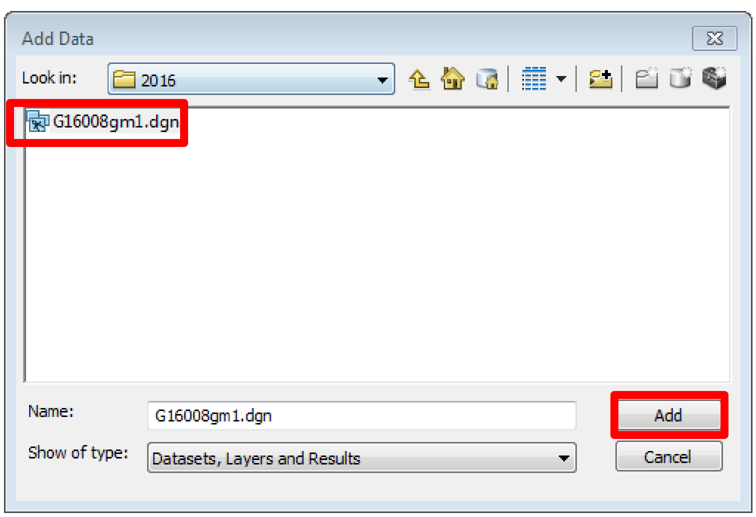

Figure 30. Adding CAD Data to a Map Document

- After clicking Add, the user will likely receive a warning that the data is missing spatial reference information. Click OK. Because CAD data typically comes with no GIS-defined spatial reference system (also known as a coordinate system), this must be manually defined. Sometimes the spatial reference system is identified in the lower-left corner of the CAD file, within the drawing's annotation. Alternatively, it may be listed in documentation from the surveyor that came with the CAD file.
- Open the Define Projection tool in ArcGIS, select the CAD (DWG, DXF, or DGN) dataset as the Input, and select the appropriate coordinate system. If the coordinate system is not one of those listed as an option in the ArcGIS interface, the user may need to define a new coordinate system. In the example case in Figure 31, the coordinate system is one of the options provided by ArcGIS: OCRS_Baker_NAD_1983_CORS96_TM_Feet_Intl
- Once the projection is defined, the user can right click on the CAD group layer in the ArcMap Table of Contents, and select Zoom to Layer. The CAD data should be lining up appropriately with the basemap and any other GIS data loaded into the document (Figure 32).

For more information on using CAD data in ArcGIS, refer to the following ArcGIS Resource: http://desktop.arcgis.com/en/arcmap/10.3/manage-data/cad/

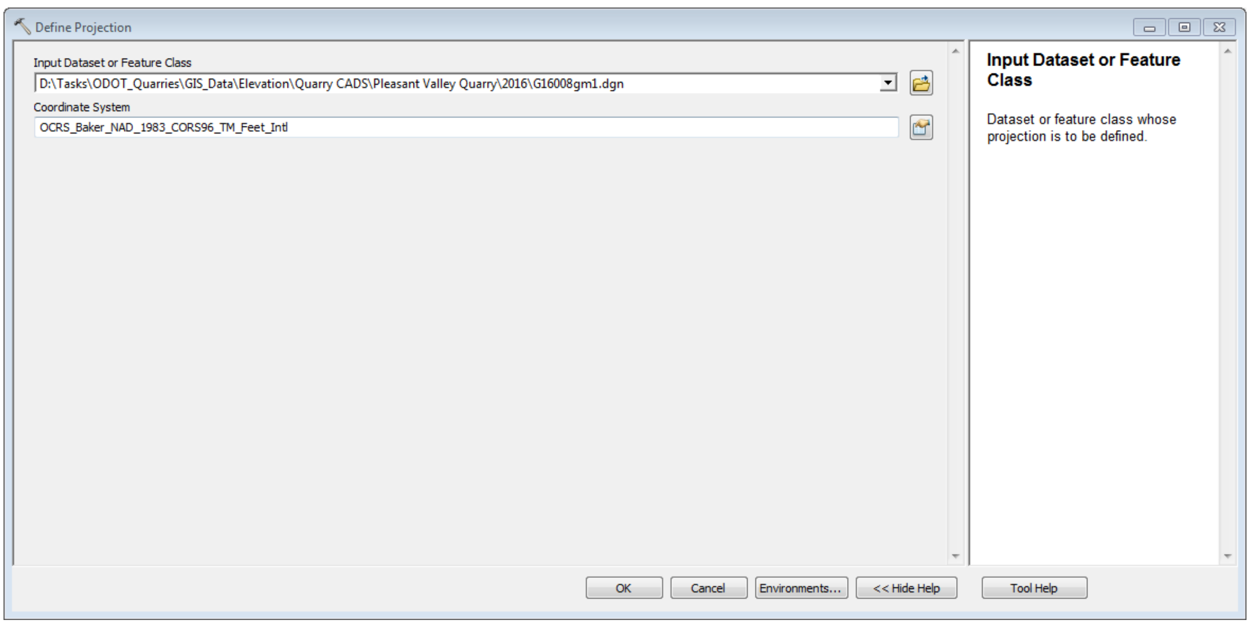

Figure 31. Defining the Projection

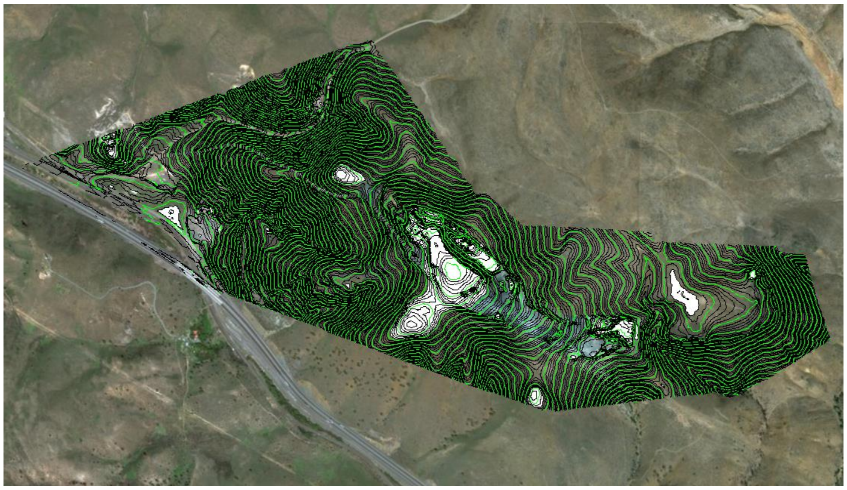

Figure 32. CAD Data Lining up with other GIS Data

This section discusses approaches to converting CAD into a digital elevation model that can be used as the elevation data by the Quarry Noise Tool. Note that the specifics of the process will vary depending on how the individual CAD dataset is set up. This example follows the pattern of the 2016 Pleasant Valley CAD dataset.

- Closely examine the CAD's polyline layer, which should include all of the contour data associated with the CAD file. Create a new geodatabase in a working folder (ex. output.gdb). Use the Feature Class to Feature Class tool (Figure 33) to export the polyline CAD data to a geodatabase feature class. (Hint: under the Windows tab, click Search to open the search window, and type "Feature Class to Feature class"). The user can also export the polygon CAD layer to a new feature class if that layer also contains elevation data. This tool converts the CAD data into a GIS format which allows it to be further processed.

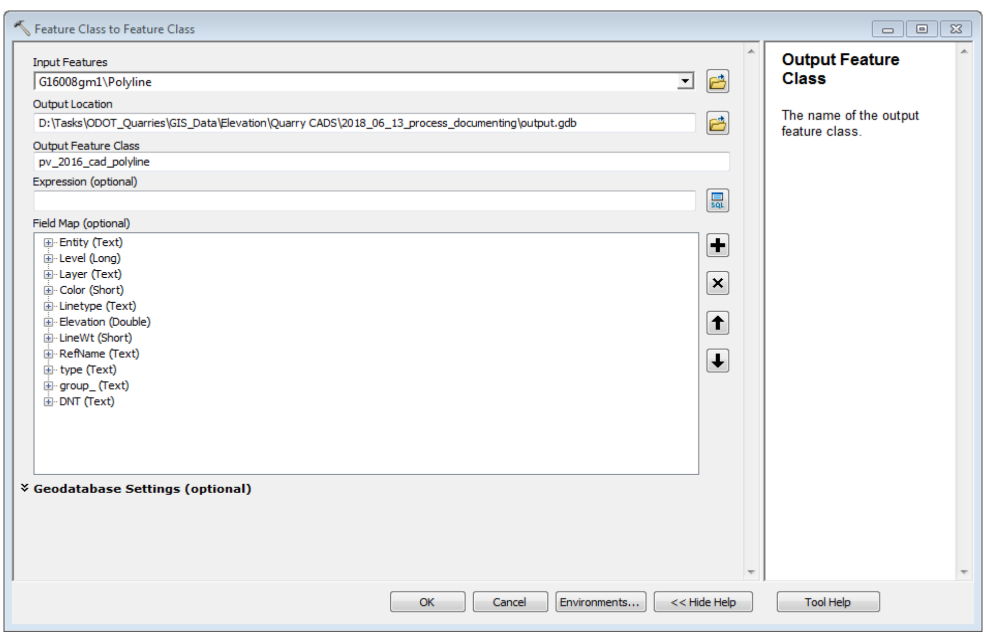

Figure 33. Feature Class to Feature Class

- Use the Create TIN tool (Figure 34) to make a TIN based on the exported CAD layers that contain elevation data. Be sure to define the height field as the attribute that contains the elevation values. The Input Feature Class for this tool is the new polyline created by the Feature Class to Feature Class step above. The user can also include the polygon data if it also includes useful elevation data, but for many CAD datasets all of the elevation data is located in the polyline layer.

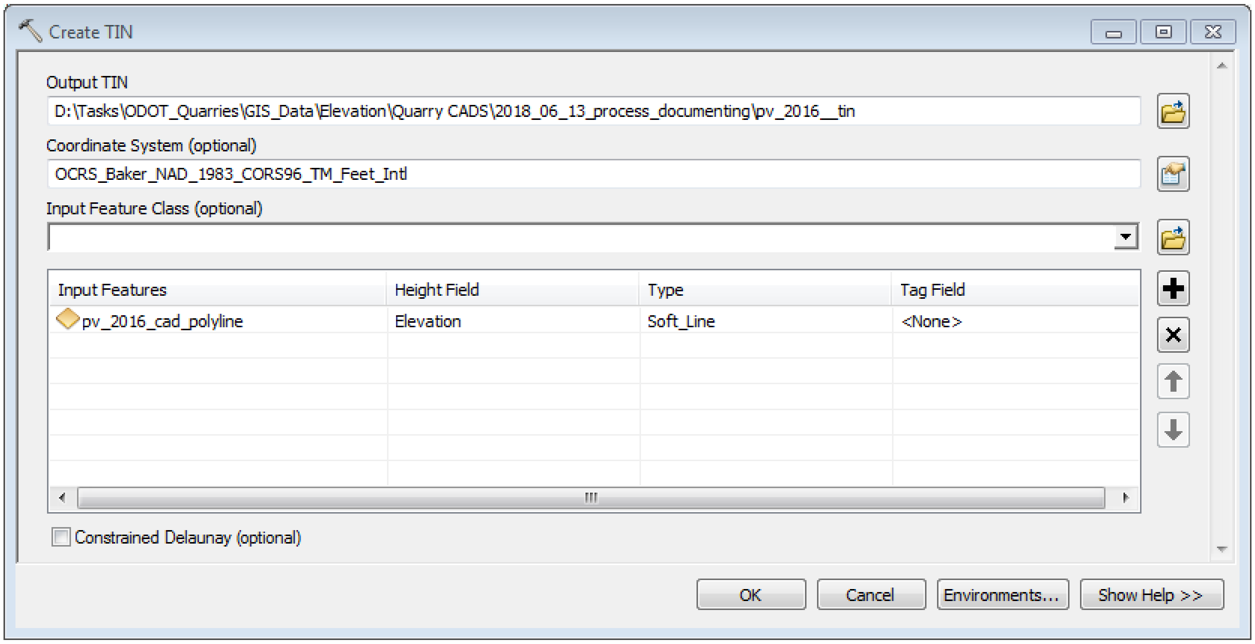

Figure 34. Create TIN

- Use the Delineate Tin Data Area tool (Figure 35) to clean up the edges of the TIN where inaccurate elevation values may have been calculated. The Maximum Edge Length will vary depending on the CAD data, but should be larger than the average spacing between CAD contours. For ODOT CAD data, minimum spacing is 5 ft.

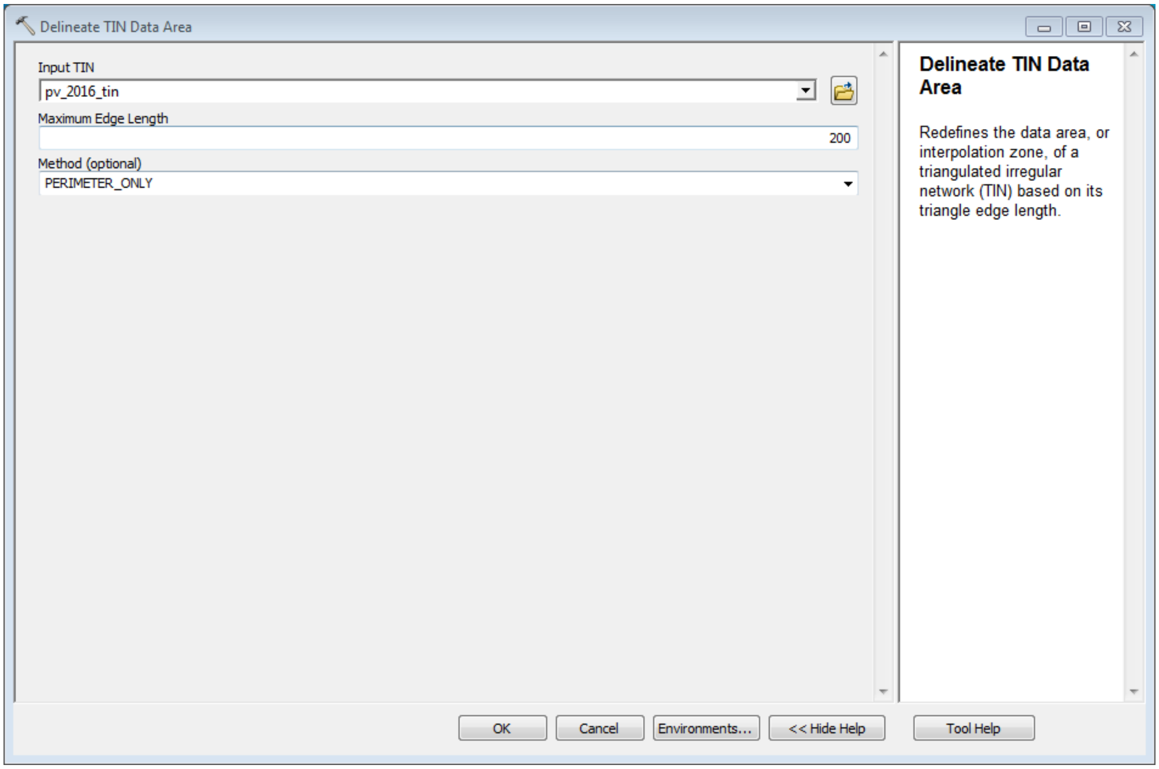

Figure 35. Delineate TIN Data Area

- The output, with the soft edges portion of the output not symbolized, should look like Figure 36 when displayed in ArcMap.

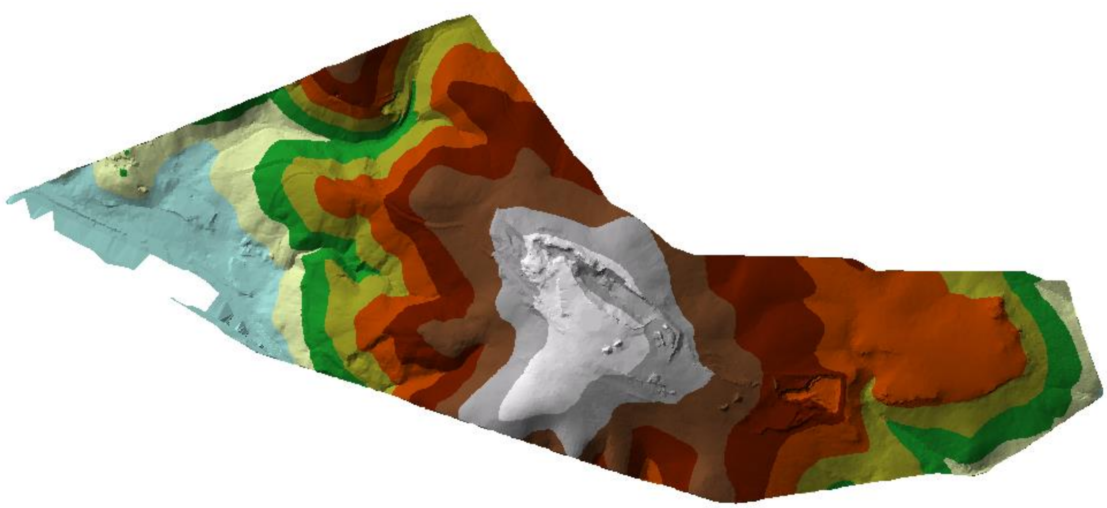

Figure 36. CAD TIN Output

- Use the TIN to Raster tool to convert the TIN into a digital elevation model.

- Typically the CAD dataset will only contain elevation data covering the quarry and limited coverage of the surrounding area. Therefore, the data must be merged with an existing DEM that covers a larger area. In order to merge this with an elevation dataset that covers a larger area, use the Mosaic to New Raster tool (Figure 37). Ensure that the two elevation datasets have the same elevation units. For the mosaic operator, ensure that the CAD-based DEM is designated as LAST so that its values override the values of the broader DEM. This tool is also a good opportunity to change the coordinate system of the raster to one which is consistent with the rest of the scenario's input datasets. The user will also have the opportunity to set the cell size of the new raster.

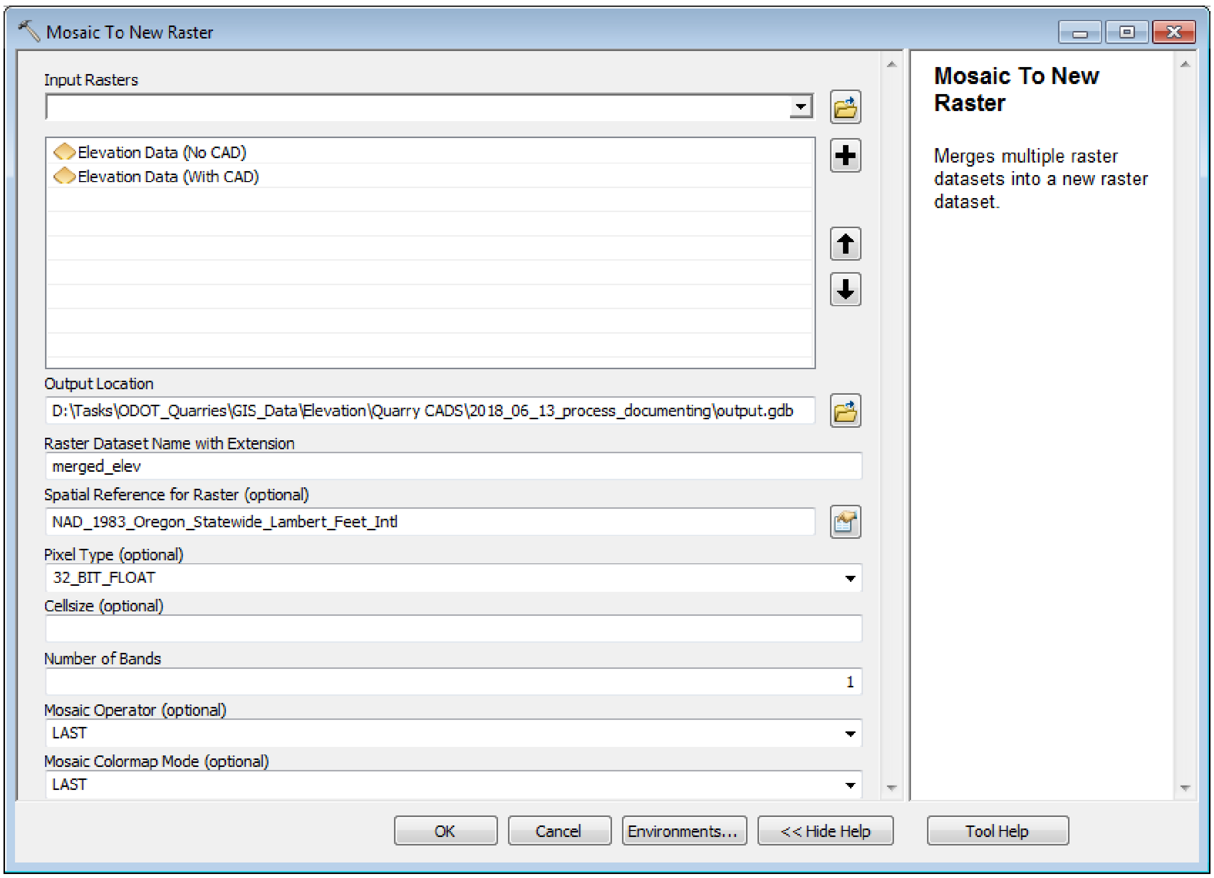

Figure 37. Mosaic to New Raster

- The output generated by the Mosaic to New Raster tool finalizes a more detailed version of the DEM, representing the quarry at the time the CAD data was collected. This output can then be brought into QNM as an input to the **Prepare Elevation** tool.

Appendix C: QNM Noise Database Transformation List

Table 27. QNM Noise Database Transformation List

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
1000	NCHRP 25-49, initiated 2015	7	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1001	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1002	NCHRP 25-49, initiated 2015	6.4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1003	NCHRP 25-49, initiated 2015	4.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1004	NCHRP 25-49, initiated 2015	2	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1005	NCHRP 25-49, initiated 2015	12.3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1006	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1007	NCHRP 25-49, initiated 2015	6	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1008	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1009	NCHRP 25-49, initiated 2015	4.4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1010	NCHRP 25-49, initiated 2015	4.3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1011	NCHRP 25-49, initiated 2015	25	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1012	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1013	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1014	NCHRP 25-49, initiated 2015	5.7	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1015	NCHRP 25-49, initiated 2015	2.2	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1016	NCHRP 25-49, initiated 2015	7.7	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1017	NCHRP 25-49, initiated 2015	4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1018	NCHRP 25-49, initiated 2015	5.3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1019	NCHRP 25-49, initiated 2015	3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1020	NCHRP 25-49, initiated 2015	4.8	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1021	NCHRP 25-49, initiated 2015	5.1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
1022	NCHRP 25-49, initiated 2015	6.2	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1023	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1024	NCHRP 25-49, initiated 2015	6	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1025	NCHRP 25-49, initiated 2015	5.4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1026	NCHRP 25-49, initiated 2015	4.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1027	NCHRP 25-49, initiated 2015	6	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1028	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1029	NCHRP 25-49, initiated 2015	9	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1030	NCHRP 25-49, initiated 2015	5.3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1031	NCHRP 25-49, initiated 2015	3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1032	NCHRP 25-49, initiated 2015	3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1033	NCHRP 25-49, initiated 2015	5.8	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1034	NCHRP 25-49, initiated 2015	5.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1035	NCHRP 25-49, initiated 2015	4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1036	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1037	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1038	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1039	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1040	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1041	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1042	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1043	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1044	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1045	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1046	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
1047	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1048	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1049	NCHRP 25-49, initiated 2015	6.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1050	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1051	NCHRP 25-49, initiated 2015	5.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1052	NCHRP 25-49, initiated 2015	9	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1053	NCHRP 25-49, initiated 2015	8	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1054	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1055	NCHRP 25-49, initiated 2015	4.3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1056	NCHRP 25-49, initiated 2015	3.8	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1057	NCHRP 25-49, initiated 2015	3.7	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1058	NCHRP 25-49, initiated 2015	6	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1059	NCHRP 25-49, initiated 2015	8	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1060	NCHRP 25-49, initiated 2015	4	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1061	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1062	NCHRP 25-49, initiated 2015	3	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1063	NCHRP 25-49, initiated 2015	5.6	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1064	NCHRP 25-49, initiated 2015	1.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1065	NCHRP 25-49, initiated 2015	2	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1066	NCHRP 25-49, initiated 2015	1	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1067	NCHRP 25-49, initiated 2015	5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1068	NCHRP 25-49, initiated 2015	5.2	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1069	NCHRP 25-49, initiated 2015	2.5	Yes	No	Yes	Yes	No	No	No	Yes	Given	No	Yes	No
1070	SLR, 2016	2.5	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1071	SLR, 2016	2.5	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No

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1072	SLR, 2016	2.5	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1073	SLR, 2016	2.5	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1074	SLR, 2016	6	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1075	SLR, 2016	4	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1076	SLR, 2016	4	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
1077	SLR, 2016	4	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	No	No
2024	Rescan, 2013	4	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	Yes	No
2025	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2026	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2027	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2028	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2029	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2030	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2031	Rescan, 2013	4	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2032	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2033	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2034	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2035	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2036	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2037	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2038	Rescan, 2013	2.5	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2039	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2040	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2041	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2042	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2043	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2044	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2045	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2046	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2047	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2048	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2049	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2050	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2051	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2052	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2053	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2054	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2055	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2056	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2057	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2058	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2059	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2060	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2061	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2062	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2063	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2064	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2065	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2066	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2067	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2068	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2069	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2070	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2071	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2072	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2073	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2074	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2075	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2076	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2077	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2078	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2079	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2080	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2081	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2082	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2083	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2084	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2085	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2086	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2087	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2088	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2089	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2090	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2091	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2092	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

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2093	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2094	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2095	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2096	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2097	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2098	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2099	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2100	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2101	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2102	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2103	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2104	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2105	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2106	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2107	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2108	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2109	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2110	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2111	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2112	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2113	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2114	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2115	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2116	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2117	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2118	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2119	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2120	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2121	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2122	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2123	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2124	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2125	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2126	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2127	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2128	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2129	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2130	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2131	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2132	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2133	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2134	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2135	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2136	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2137	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2138	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2139	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2140	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2141	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2142	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

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2143	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2144	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2145	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2146	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2147	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2148	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2149	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2150	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2151	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2152	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2153	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2154	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2155	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2156	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2157	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2158	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2159	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2160	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2161	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2162	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2163	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2164	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2165	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2166	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2167	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2168	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2169	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2170	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2171	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2172	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2173	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2174	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2175	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2176	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2177	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2178	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2179	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2180	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2181	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2182	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2183	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2184	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2185	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2186	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2187	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2188	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2189	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2190	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2191	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2192	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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2193	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2194	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2195	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2196	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2197	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2198	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2199	DEFRA, 2005	10	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2200	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2201	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2202	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2203	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2204	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2205	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2206	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2207	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2208	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2209	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2210	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2211	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2212	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2213	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2214	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2215	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2216	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2217	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2218	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2219	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2220	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2221	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2222	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2223	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2224	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2225	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2226	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2227	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2228	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2229	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2230	DEFRA, 2005	3.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2231	DEFRA, 2005	5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2232	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2233	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2234	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2235	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2236	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2237	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2238	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2239	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2240	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2241	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2242	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2243	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2244	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2245	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2246	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2247	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2248	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2249	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2250	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2251	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2252	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2253	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2254	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2255	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2256	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2257	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2258	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2259	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2260	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2261	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2262	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2263	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2264	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2265	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2266	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2267	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2268	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2269	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2270	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2271	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2272	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2273	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2274	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2275	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2276	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2277	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2278	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2279	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2280	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2281	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2282	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2283	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2284	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2285	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2286	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2287	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2288	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2289	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2290	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2291	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2292	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2293	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2294	DEFRA, 2005	4	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2295	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2296	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2297	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2298	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2299	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2300	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2301	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2302	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2303	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2304	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2305	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2306	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2307	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2308	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2309	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2310	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2311	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2312	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2313	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2314	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2315	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2316	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2317	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2318	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2319	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2320	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2321	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2322	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2323	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2324	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2325	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2326	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2327	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2328	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2329	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2330	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2331	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2332	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2333	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2334	DEFRA, 2005	4	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2335	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2336	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2337	DEFRA, 2005	2.5	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2338	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2339	GHD, 2015	3.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2340	GHD, 2015	3.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2341	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2342	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2343	GHD, 2015	3.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2344	GHD, 2015	3.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2345	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2346	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2347	GHD, 2015	3.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2348	GHD, 2015	3.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2349	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2350	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2351	GHD, 2015	2.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2352	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2353	GHD, 2015	3.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2354	GHD, 2015	2.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2355	GHD, 2015	2.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2356	GHD, 2015	2.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2357	GHD, 2015	1.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2358	GHD, 2015	1.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2359	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2360	GHD, 2015	4.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2361	GHD, 2015	1.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2362	GHD, 2015	1.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2363	GHD, 2015	2.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2364	GHD, 2015	3.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2365	GHD, 2015	5.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2366	GHD, 2015	2.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2367	GHD, 2015	10.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
2368	GHD, 2015	2.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2369	GHD, 2015	2.5	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2370	GHD, 2015	2.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
2371	GHD, 2015	10.0	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
3000	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3001	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3002	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3003	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3004	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3005	See Table 4 for Individual Samples	3.1	See Table 4 for Individual Samples											
3006	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3007	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3008	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3009	See Table 4 for Individual Samples	3.5	See Table 4 for Individual Samples											
3010	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3011	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3012	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3013	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3014	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3015	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3016	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3018	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3017	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3019	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3020	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
3021	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3022	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3023	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3024	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3025	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3026	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3027	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3028	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3029	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3030	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3031	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3033	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3032	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3034	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3035	See Table 4 for Individual Samples	2.6	See Table 4 for Individual Samples											
3036	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3037	See Table 4 for Individual Samples	2.9	See Table 4 for Individual Samples											
3038	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3039	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3040	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3041	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3042	See Table 4 for Individual Samples	5	See Table 4 for Individual Samples											
3043	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3044	See Table 4 for Individual Samples	5.2	See Table 4 for Individual Samples											
3045	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
3046	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3047	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3048	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3049	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3050	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3051	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3052	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3053	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3054	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											
3055	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3056	See Table 4 for Individual Samples	2.9	See Table 4 for Individual Samples											
3057	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3058	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3059	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3060	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3061	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3063	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3062	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3065	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3064	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3066	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3067	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3068	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3069	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3070	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											

Source ID	Reference	Source Height	Convert to Z-weighting	Convert from Sound Power	Convert to 100 ft Distance	Can Correct for Ground Effect	Convert to 1/3 Octave Bands	Estimate Maximum Level from Average	Estimate Measurement Height	Estimate Source Height	Estimate Ground Type	Assume Uniform Directivity	Extrapolate to 10 Hz	Extrapolate 10 kHz
3071	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3072	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3074	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3073	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3075	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3076	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3077	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3078	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3079	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3080	See Table 4 for Individual Samples	4	See Table 4 for Individual Samples											
3081	See Table 4 for Individual Samples	2.5	See Table 4 for Individual Samples											

U.S. Department of Transportation

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