

# **SPreAD-GIS: an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting**

*Version 1.2*  
June 26, 2009

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***Noise model based on:***

Harrison, R.T., R.N. Clark, and G.H. Stankey. 1980. Predicting impact of noise on recreationists. ED&T Project No. 2688: Noise Pollution Prediction Method. USDA Forest Service, Equipment Development Center, San Dimas, CA.

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## ***Abstract***

The nationwide Travel Management Planning process provides an unprecedented opportunity to plan for and manage the soundscapes of U.S. National Forests. Since the first Executive Order governing motorized recreation, issued by the Nixon administration in 1972, federal agencies have been required to consider noise propagation when analyzing the potential impacts of motor vehicle activity on public lands. The Travel Management Rule, published by the Forest Service in 2005, also requires that decisions to designate roads, trails, and other areas for motorized use take engine noise into account. However, accurate and affordable methods for modeling potential noise impacts are critical gaps in the information needed to complete this process. The goal of our project was to identify the best methods for forecasting potential noise propagation from off-road vehicle activity in forested or other natural ecosystems. In this document, we describe the different factors that affect environmental noise propagation, discuss our review of existing spatial models and software packages, and explain how to install and use the new tool that we developed: SPreAD-GIS. Although we developed this tool for use in the Forest Service Travel Management Planning process, we hope it will be useful for a wide range of transportation and recreation planning and research applications.

## ***Background and Purpose***

Sound propagation is the transmission of acoustic energy through space. Sound waves are introduced into a medium, such as air, by a vibrating object. The vibrating object creating the disturbance could be the vocal chord of a person, the string of a musical instrument, or the rumbling of an engine. In fluids such as air and water, sound waves propagate as disturbances to the ambient pressure level. A sound is defined as any variation in pressure that is detectable by a human's (or another species') ear, whereas the concept of noise is more subjective. Noise is generally defined as sound that is unwanted, causes a disturbance, or disrupts a communication system.

Environmental noise refers the propagation of unwanted or disturbing sounds outdoors. Also known as noise pollution, the most common sources of environmental noise are human transportation systems, especially motor vehicles and aircraft. Increasing levels of environmental noise have been linked to a wide array of human health and environmental effects. Prolonged exposure to environmental noise can have physiological and psychological effects on humans, including hearing impairment and loss, interference with communication, sleep disturbance, stress, and declines in job productivity, learning, and social behavior (Berglund & Lindvall 1995). Similarly, environmental noise can affect the physiology and behavior of wildlife species. While the particular impacts vary by species and habitat, studies have shown that transportation noise can lead to increased stress levels, decreased reproductive

success, disruption of communication systems, displacement, flight, and changes in habitat use and foraging behavior (Havlick 2002, Ouren et al. 2007).

In contrast to many other countries, particularly those in the European Union, the U.S. currently has no comprehensive noise control policy, and no single agency is authorized to coordinate noise monitoring or enforce federal regulations. Federal regulation of environmental noise began in 1972, when Congress passed the Noise Control Act, noting that “inadequately controlled noise presents a growing danger to the health and welfare of the Nation’s population.” The Noise Control Act was amended by the Quiet Communities Act of 1978, which established a federal agenda for research and education on noise impacts and promoted the development of State and local programs to monitor and control environmental noise. During this time, the Office of Noise Abatement and Control (ONAC) of the Environmental Protection Agency (EPA) coordinated all federal activities related to environmental noise control. In 1981, however, the Reagan Administration determined that environmental noise issues were best managed at the state or local level, and the ONAC lost its funding. Subsequently, regulation of environmental noise within the federal domain devolved to several different agencies, including the Department of Transportation, Department of Labor, and Federal Aviation Administration, each of which created noise control programs of its own. Many states and cities have also adopted noise ordinances, which vary in scope and degree of enforcement.

Most of the early policies addressing environmental noise on federal lands focused on U.S. National Parks. Concern over the adverse effects of increasing numbers of recreational airplane and helicopter flights over Grand Canyon National Park led to passage of the National Parks Overflights Act in 1987. This legislation required the National Park Service (NPS) to study the impacts of aircraft noise on visitors and natural resources. The research studies mandated by the Act, and the subsequent Director’s Order on Soundscape Preservation and Noise Management in 2000, led to the creation of the NPS Natural Sounds Program, whose mission is to “protect, maintain, or restore acoustical environments throughout the National Park System.” The National Parks Overflights Act also required that the Forest Service assess the impacts of aircraft overflights on National Forest System wilderness areas. The resulting study was limited in scope, but reported few adverse effects of overflights on National Forest wilderness users (Harrison et al. 1992).

More recently, federal land managers have begun to focus their attention on the acoustic footprint of other types of engine noise on public lands – specifically, noise from automobiles and motorized recreational vehicles. For example, Zion National Park has restricted motor vehicle access to Zion Canyon to reduce traffic congestion, improve visitor experiences, and preserve the natural soundscape (Miller 2008). Controversy continues over air and noise emissions from the use of snowmobiles in Yellowstone and Grand Teton National Parks. A National Parks Conservation Association study demonstrated that, on a busy winter weekend, snowmobiles were audible at least 90

percent of the time at eight popular recreation sites located more than 0.5 miles from a road (NPCA 2000). Despite these recent advances, little is known about the acoustic impacts of recreational roads and trails on public lands, particularly on National Forest and BLM lands in the western U.S., where motorized activity is concentrated.

The nationwide Travel Management Planning process offers an unprecedented opportunity to inventory and plan for the soundscapes of U.S. National Forests. Beginning with the earliest Executive Order issued by the Nixon Administration in 1972, the Forest Service has been required to consider the impacts of noise in its management of motorized recreation. The Order states that off-road vehicle areas and trails should be located to minimize damage to natural resources, harassment of wildlife species, and conflicts with other recreational users, “taking into account noise and other factors” (E.O. 11644). The Travel Management Rule issued in 2005 also requires that decisions to designate roads, trails, and other areas for motorized use take sound into account (36 CFR 212.55(b)). To date, however, we are not aware of any forest travel analysis that has included spatially-explicit maps or models of potential noise impacts from motorized activity.

We recognize that monitoring and modeling noise is a critical gap in the information needed for transportation and recreation planning, and the goal of our project is to provide a straightforward, accurate, and affordable approach for modeling noise impacts. To identify the best methods for forecasting potential noise propagation from off-road vehicle activity in forested or other natural ecosystems, we reviewed existing models and software packages available for modeling sound propagation. Based on the results of our review, we decided to adapt the System for the Prediction of Acoustic Detectability (SPreAD; Harrison et al. 1980) to an ArcGIS environment. In this document, we describe the different factors that affect environmental noise propagation, discuss our review of existing spatial models and software packages, and explain how to install and use the new tool that we developed: SPreAD-GIS.

### *Factors Affecting Environmental Noise Propagation*

In the absence of interference, sound waves propagate geometrically; sound levels decline as the square of the distance from the sound’s source. Several additional factors influence the propagation of environmental noise in forested or wildland settings. Acoustic energy is absorbed by the atmosphere, as a function of elevation, air temperature, and humidity (Harris 1966). Additionally, temperature and wind gradients can cause sound waves to retract, or bend, changing the spatial pattern of sound propagation (Ingard 1953, Wiener & Keast 1959).

Sound is also absorbed by the ground. The magnitude of attenuation depends on the surface’s porosity or permeability to air (Aylor 1971). Hard, smooth surfaces such as pavement absorb little sound, whereas soft, porous surfaces such as grasses or bare soil can cause sound levels to attenuate substantially. Sound waves can also be

scattered by vegetation above ground. While empirical data on vegetation loss is limited, the magnitude of attenuation is likely to be a function of the structure, extent, and density of vegetation (Kragh 1981, Fang & Ling 2003).

Terrain features determine the relative importance of ground versus atmospheric effects. Attenuation of noise propagated from hilltops or across valleys primarily depends on geometric spreading and atmospheric absorption (Piercy et al. 1977). On the other hand, a steep hill or ridgeline can act as a sound barrier, creating a 'shadow zone' away from the source where sound waves are not directly transmitted (Embleton 1996).

Lastly, the intensity and frequency of environmental noise disturbances vary according to the characteristics of the sound's source. For example, noise propagated around recreational routes depends on the number and types of vehicles passing by, their engine types (i.e., 2- or 4-stroke), and travel speed (Martin et al. 2005). While the sound propagated from two or more vehicles traveling together is not strictly additive, traffic volume along a route does influence overall noise levels (Dooling & Popper 2007).

The degree to which environmental noises impact humans or wildlife species depends on the ambient sound conditions, as well as individuals' auditory sensitivity. Ambient sound conditions can vary substantially by time of day, day of the week, and season. For instance, cooling air temperatures between day and night can change the direction of sound waves' refraction and increase sound levels near the ground; this is one reason that distant sounds, such as trains, are more audible at night. Similarly, ambient conditions are often much quieter in the winter because snow-covered ground absorbs much more sound than do other ground surfaces.

Determining the 'effect' of environmental noise depends on the physiological characteristics of the listener as well as defining a threshold for what constitutes a disturbance. In some environments, simply having a mechanical noise be audible may constitute a sufficient disturbance for humans. In other environments, sounds may only become disturbing if they exceed typical sound levels or occur at unusual times of day. For wildlife species, noise disturbances are typically described in terms of effects that are likely to be biologically detrimental. For example, noise disturbances can cause increased stress levels or other physiological effects in individual animals, mask detection and discrimination of communication signals between individuals, or reduce habitat quality for wildlife populations.

### *Review of existing software packages and spatial models*

In January and February 2008, we reviewed eight existing software tools available for developing spatial models of sound propagation. We evaluated the models on the basis of their cost, ease of use, and capacity to incorporate various factors that are likely to affect sound propagation in a forest landscape (Appendix A). Based on the results of our review, we decided to develop our model by adapting the System for the

Prediction of Acoustic Detectability (SPreAD; Harrison et al. 1980) to an ArcGIS environment.

SPreAD is a tool that was developed nearly 30 years ago by the U.S. Forest Service (USFS) and Environmental Protection Agency (EPA) to predict the acoustic impacts of recreational activity in wildland settings. SPreAD was explicitly designed to model how noise propagates in forested and other natural ecosystems. Accordingly, the SPreAD calculation process incorporates the majority of the factors that we hoped to include in our model, including wind and atmospheric effects, ground and vegetation effects, and sound source characteristics. Unlike many of the commercial applications, which summarize the frequency spectrum into a single summary sound level tuned to the human ear (i.e., an A-weighted sound level), SPreAD's calculation process tracks the propagation of different frequencies through space. This is especially important for predicting the impacts of noise on wildlife, because different species respond to noise disturbances at different frequencies.

We found that many of the existing programs were either developed in proprietary software at high cost to the user, or had limited functionality or user support available. Further, most of the programs were unable to incorporate other information relevant to recreation planning or land management decisions. Developing SPreAD in ArcGIS allowed us to create a tool that could be extended to researchers and land managers at universities and public agencies and implemented using their existing GIS software at no additional cost.

#### *Current status of the SPreAD-GIS model*

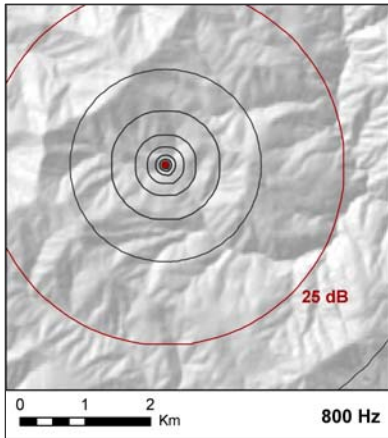
We used ArcGIS ModelBuilder and Python scripts to adapt SPreAD to an ArcGIS environment. In December 2008, we released version 1.1 of the SPreAD-GIS model for testing by interested colleagues. We revised the model based on the feedback we received, and we plan to release the public version of the model (version 1.2) at the end of June 2009.

### **Model Structure**

The System for the Prediction of Acoustic Detectability (SPreAD) was originally developed as a system of worksheets and tables, where the user could enter information about the sound source and environment and manually calculate noise propagation from a single point source to a single point receiver (Harrison et al. 1980). We have adapted the SPreAD model to ArcGIS, automating the hand calculation method to predict the propagation of noise in all directions throughout the area of interest.

The model can be run for a point, line, or polygon sound source. The SPreAD calculation process includes six discrete stages (called 'blocks' in the paper model, and 'modules' in the GIS model), each of which introduces an additional factor that influences how sound propagates through space. The six modules must be run in order,

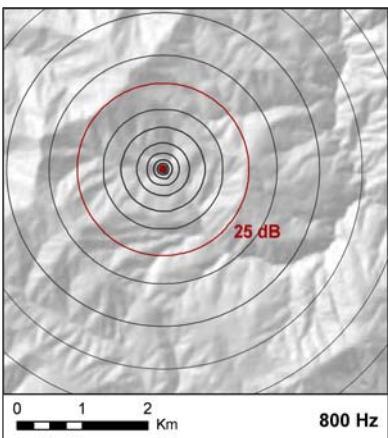
since each module depends on outputs from the previous steps for input data. SPreAD-GIS tracks the resulting noise propagation patterns for eight one-third octave frequency bands (400, 500, 630, 800, 1000, 1250, 1600, and 2000 Hz):



### 1) *Spherical Spreading Loss*<sup>1</sup>

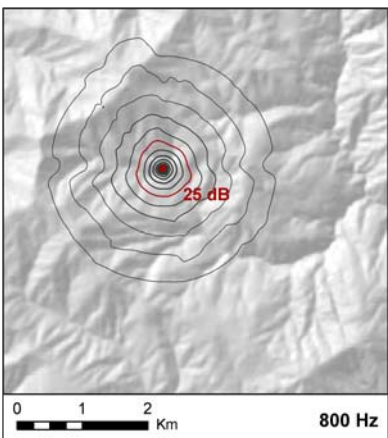
Calculates the decline in sound level as a function of distance from the sound's source.

**WARNING:** Running the *Spherical Spreading Loss* module results in automatic deletion of intermediate data and results from all prior runs of SPreAD-GIS.



### 2) *Atmospheric Absorption Loss*

Calculates the decline in sound level due to absorption by the atmosphere. Atmospheric absorption is a function of air temperature, humidity, and elevation.

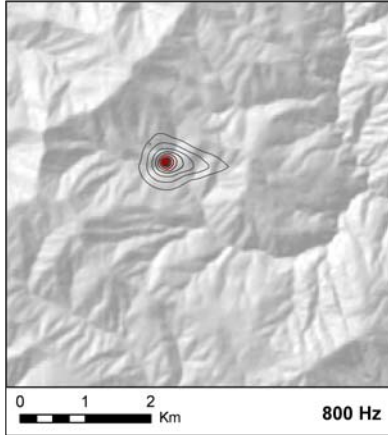


### 3) *Foliage and Ground Cover Loss*

Calculates the decline in sound level due to absorption by the ground and scattering by vegetation. The rate of foliage and ground cover loss is a function of the predominant land cover type (conifer, hardwood, shrub, grass, barren, water, or urban) and distance from the sound source.

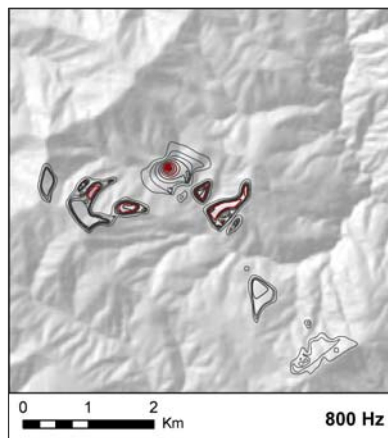
<sup>1</sup>The example shown here illustrates noise propagation at 800 Hz from a single motorcycle engine operating in a mid-elevation mixed forest on a summer day with a westerly wind.





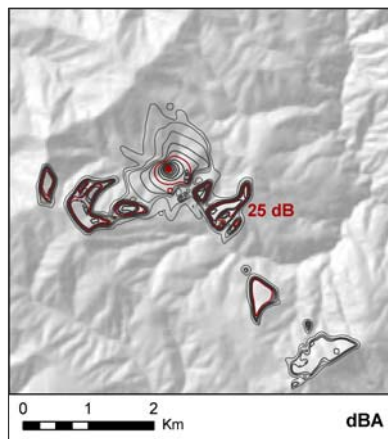
#### 4) *Downwind and Upwind Loss*

Calculates the directional changes in sound level due to blowing wind. Sound levels decline much less rapidly (and may even increase) in downwind areas compared to upwind and crosswind areas. Downwind and upwind areas are defined according to the prevailing wind direction, wind speed, and seasonal conditions.



#### 5) *Terrain Effects*

Calculates the decline in sound levels due to barrier effects from hills or ridgelines, and determines the areas of the landscape that are primarily influenced by ground effects, barrier effects, or atmospheric effects.



#### 6) *Predicted Noise Propagation*

Tracks noise propagation patterns for eight frequency bands, summarizes propagation results for A-weighted sound levels (dBA), and calculates the difference between the introduced noise and background sound levels. The excess noise calculation can be used to identify areas where introduced noise is likely to be audible and/or impact species of concern.

It is important to note that SPreAD-GIS is a static model. The results represent the spatial pattern of potential noise disturbances around the source for a single snapshot in time. Ultimately, the model could be integrated with traffic, recreational visitation, or other dynamic models to forecast the frequency and duration of noise disturbances under different scenarios; however, these improvements are beyond the scope of our current project.

## ***Installing SPreAD-GIS***

Using the SPreAD-GIS model requires that you have an ArcInfo-level licensed copy of ArcGIS 9.3 (ESRI, Redlands, CA) with the Spatial Analyst extension and Python installed on your computer. The latest version of Python is typically included with ArcGIS and installed in the C: directory. If you need to install a copy of Python, go to: <http://www.python.org/download/>. Be sure to select a version of Python that is compatible with the current version of ArcGIS and the scripts you will be using.<sup>2</sup>

Copy the 'SPreAD-GISv1.2.zip' file to your computer. Unzip the folder, and place the 'SPreAD\_model' folder directly into your C: drive. Do not change the name of the folder or any of its sub-folders, and do not move them. They must remain in the C: drive for the model to run correctly. After each model run is complete, you may move the results to another location.

Open a blank project in ArcMap. Open ArcToolbox, right-click in the ArcToolbox window, and select 'Add toolbox.' Navigate to 'C:\SPreAD\_model\toolbox' and add the 'SPreAD-GISv1.2.tbx' file. When you open the toolbox, you will see that it is divided into a series of six Python scripts, each of which includes help documentation:

1. *Spherical Spreading Loss*
2. *Atmospheric Absorption*
3. *Foliage & Ground Cover Loss*
4. *Upwind & Downwind Loss*
5. *Terrain Effects*
6. *Noise Propagation Results*

Before starting a new SPreAD-GIS project, be sure to define a scratch workspace (Environment Settings > General Setting > Scratch Workspace) with sufficient space to store the intermediate data for the model calculations. Also, keep a clean copy of the entire 'SPreAD\_model' folder somewhere easily accessible. Many errors in SPreAD-GIS calculations can be addressed by re-installing the entire 'SPreAD\_model' folder and re-running your model from the beginning.

## ***Model Inputs***

Before running SPreAD-GIS, you will need to collect and prepare several datasets and parameters that are required inputs for the model. Make sure that all of the GIS datasets are in the same projection.

### ***1) Sound Source Location***

The sound source file is a dataset representing the location(s) from which noise propagates through the environment. It can be a point, polyline, or polygon

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<sup>2</sup>SPreAD-GIS v. 1.1 was developed using Python 2.5.1.

feature class representing one or more point sound source(s) (e.g., a single vehicle), a linear source (e.g., a road), or source area (e.g., parking lot).

The sound source file should contain only features that you wish to model as *identical* and *simultaneous* sound sources. In other words, if your file contains sound sources that you wish to model separately, or some features that are one kind of source and some that are another kind of source, then you should divide up your data file and run SPreAD-GIS separately for each source.

The attribute table for the sound source data file must contain a single field labeled 'ID.' If it is a multi-part file (e.g., multiple point sources), then the value in this field must be the same for all features, preferably '1,' because this is the field that will be used to convert the sound source to a raster dataset. Place the sound source location file in the 'source\_data' folder.

## 2) *Sound Source Characteristics*

You will need to provide several characteristics of the sound source you wish to model. You have the option of entering custom sound level measurements for your sound source, or you may choose from a list of nine different types of engines for which source sound level data is provided in the model. Detailed noise emissions data are available for a wide range of engines from vehicle manufacturers or public agencies (e.g., Martin et al. 2005). If you choose the custom source sound level data option, then you must have measurement data for each of the eight one-third octave frequency bands (400, 500, 630, 800, 1000, 1250, 1600, and 2000 Hz).

The nine engine options included with the model are: motorcycle, all-terrain vehicle, snowmobile, chain saw, heavy equipment, automobile, helicopter, power line transformer, and other 2-stroke engine. If you choose one of the built-in engines, then you must also enter an estimated A-weighted sound level (dBA) for the source engine. If you don't have an estimated sound level for the source you wish to model, then you may refer to the suggested values in the table below:

<b>Engine type</b>	<b>Sound level (dBA)</b>
Motorcycle	83
All-terrain vehicle	78
Snowmobile	75
Chain saw	86
Heavy equipment	86
Automobile	75
Helicopter	102
Power line transformer	60
Other 2-stroke engine	90

Lastly, you must enter the distance at which the sound level of the source engine was measured. If you choose to enter custom source sound level data, you will want to verify the measurement distance, because it varies according to the specific noise emission test methods used (Martin et al. 2005). The default measurement distance is 50 feet for the noise sources included in the SPreAD-GIS model.

### 3) *Model Extent:*

The model extent is a dataset – usually, a polygon – that represents the desired spatial extent for your model analysis. The model extent can be any size or shape, but remember that processing time will increase for larger areas. Place the model extent file in the ‘source\_data’ folder.

### 4) *Digital Elevation Model (DEM):*

You will need to prepare a digital elevation model (DEM) for your study area. At a minimum, the extent of the elevation dataset must encompass the model extent selected in the previous step. The elevation values in the ‘VALUE’ field should be converted to feet, and the cell size of the DEM must be 100 ft (30.49 m). Name this file ‘dem\_ft’ and place it in the ‘source\_data’ folder.

### 5) *Land Cover Dataset:*

You will also need to prepare a land cover dataset for your study area. Convert the file to a raster dataset, with a cell size of 100 ft (30.49 m). Create a new field and label it ‘SPREADTYPE.’ Re-classify each land cover type into one of the

seven SPreAD-GIS model land cover type categories, and list the appropriate code in the 'SPREADTYPE' field:

Land cover type	SPREADTYPE
Coniferous forest	CON
Hardwood forest	HWD
Grassland/herbaceous	HEB
Shrubland	SHB
Barren	BAR
Water	WAT
Urban	URB

Clip the land cover dataset to the model extent that you previously selected, and place the file in the 'source\_data' folder.

#### 6) *Weather Conditions:*

Collect representative weather conditions for the time of day and season for which you will be running the model scenarios, including: temperature (°F), relative humidity (%), prevailing wind direction (°), and wind speed (mph). You could calculate median or average values for each parameter, or you could run the model repeatedly for a reasonable range of values.

In the fourth module (*Upwind & Downwind Loss*), you will also be asked to provide a general description of the seasonal conditions for which you will be running the model (e.g., clear, calm summer day); your response determines the shape of the upwind and downwind areas around the sound source.

#### 7) *Ambient Sound Conditions:*

Lastly, you will be asked to characterize the ambient sound conditions for your study area, so that the model may predict where excess noise from the sound source would be audible at different frequencies. Just as for the sound source, you have the option of entering custom ambient sound measurements for your study area, or you may choose from a series of background sound spectra. If you choose the custom ambient sound level data option, then you must have measurement data for each of the eight one-third octave frequency bands (400, 500, 630, 800, 1000, 1250, 1600, and 2000 Hz).

The ambient sound spectra included with the model are calculated as a function of the broad ecosystem type and location (coniferous forest, hardwood forest,

grassland, shrubland, desert or running water) and estimated A-weighted sound level (dBA). If you do not have an estimate for the ambient sound levels for your study area, then we suggest using a conservative estimate of 25 dBA for most areas and 45 dBA for areas adjacent to running water.

As you begin to prepare data for your first model run, here are a few more things to think about:

1) *Start Small:*

Each module of the SPreAD-GIS model has many geoprocessing steps, and depending on the size of your study area and your computer's processing speed, a single run of the model could take anywhere from several minutes to an hour. To begin, we suggest making your model extent as small as possible. Early tests of the model have indicated that a meaningful distance for noise propagation around a single sound source ranges from approximately 2 to 5 km.

2) *Simplify Complex Lines:*

The SPreAD-GIS model makes calculations along straight line pathways radiating away from the sound source(s). When working with polyline source files, particularly files that have many messy or complex line segments, these overlapping pathways can produce errors in the calculations. Consider using the Simplify Line or Smooth Line tools in the Data Management toolbox to simplify the input line segments and reduce the possibility of error in these calculations.

3) *Separate Overlapping Areas:*

For the moment, the SPreAD-GIS model only has the capacity to model noise propagation *unidirectionally* away from the *nearest* sound source. Consider what this means for two sound sources that are located close together, one downwind of the other. Halfway (in Euclidean surface distance) between these two sources, the calculation will shift from representing areas as being downwind of the first source to being upwind of the second source. This may not be desirable, as noise will propagate greater distances downwind than upwind, and areas closer to the second source would experience greater noise propagation from the first source.<sup>3</sup> Instead, we suggest running the model for the two sources separately and then overlaying the results, selecting the maximum noise propagation value from the two model runs.

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<sup>3</sup>A similar issue will apply to areas that are upslope versus downslope of a source.

#### 4) *Try a Range of Input Values:*

The model results will be sensitive to your choices of input values for source characteristics, weather conditions, and ambient sound conditions. We suggest that you run the model multiple times for a range of plausible values for these parameters.

#### 5) *Other Troubleshooting:*

The model, and ArcGIS in general, is sensitive to having input or output data files open in either ArcMap or Windows. Before running the model, be sure to close all open data files and windows, including Windows Explorer, and remove any data layers used in the model from active ArcMap data frames.

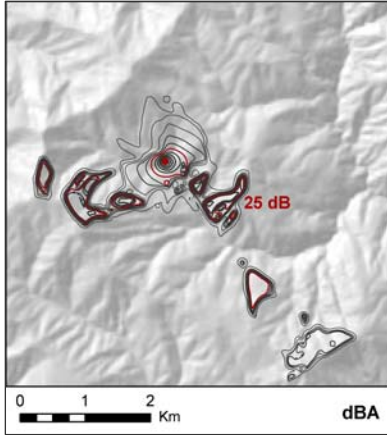
When you encounter an error in a module calculation, try running that module again. First, take a close look at your input data. Have you named all of the data files as instructed (e.g., is your elevation dataset named 'dem\_ft')? Have you entered information into all of the required fields (e.g., if you chose not to enter custom sound level data for your source, did you enter an estimated dBA value)? Once you are confident that your input data is correct, try running the module in which you encountered the error a second time – sometimes, minor errors intermediate data calculations are overwritten and the module will work fine.

If this doesn't work (or anytime you are in doubt about how to proceed), re-install a clean copy of the entire 'SPreAD\_model' folder and re-run your model from the beginning. There is a good chance that any errors you encounter are a function of a missing data file or folder, or a data file that cannot be overwritten for some reason. Do not attempt to move or delete any intermediate data files manually; the directory structure is very sensitive to additions and deletions. Instead, re-install the entire 'SPreAD\_model' folder in your C: drive.

Lastly, many of the problems we encountered during testing of SPreAD-GIS were associated with the relative locations of sound source features and extents of raster datasets. If you encounter repeated errors in the calculation processes for the *Atmospheric Absorption* or *Foliage & Ground Cover Loss* modules, try moving the sound source feature slightly (< 50 ft) or buffering your source location (e.g., using a polygon that is a 100-ft buffer around your point source as the sound source location).

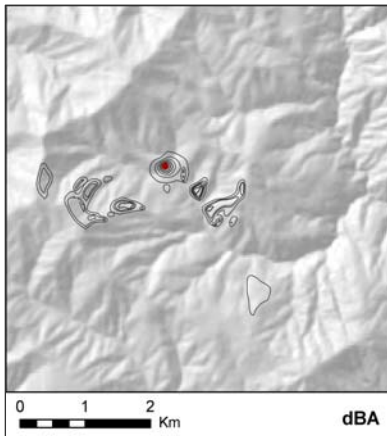
## Model Outputs

The SPreAD-GIS model tracks noise propagation patterns for eight frequency bands (400, 500, 630, 800, 1000, 1250, 1600, 2000 Hz) and also summarizes the noise propagation results for A-weighted sound levels (dBA). Running the final module will yield two types of results:



### 1) *Baseline Noise Propagation*

The predicted pattern of noise propagation around the source, accounting for attenuation due to spherical spreading loss, atmospheric absorption, foliage and ground cover loss, upwind and downwind loss, and terrain effects.



### 2) *Excess Noise Propagation*

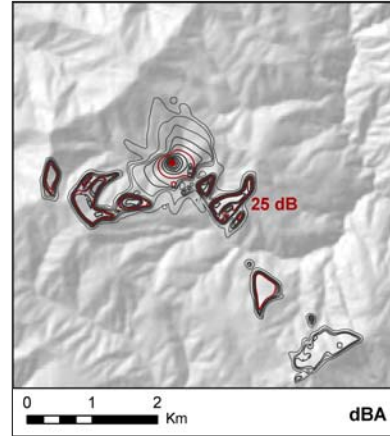
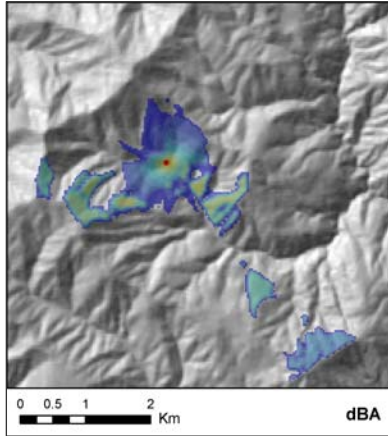
Calculates the difference between introduced noise and background sound levels. The excess noise calculation can be used to identify areas where introduced noise is likely to be audible, or where it may impact species of concern.

The two types of results will appear in the 'C:\SPreAD\_model\results' folder. Noise propagation patterns will be calculated for each of the eight frequency bands (e.g., '400\_prop'), and also summarized for A-weighted sound levels (e.g., 'dba\_prop'). Each result will be in the format of a floating-point raster dataset, with a cell size of 100 ft (30.49 m) and an extent equal to the model extent specified during the first module. Cells where the noise propagation is expected to be greater than zero will have a value equal to the predicted sound level (for a particular frequency or dBA) at that distance from the source. All other cells will have a value of 0.

There are many different ways to display the noise propagation results. For example, the raster datasets could be symbolized to display the decline in sound levels with changes in shade or color. Or, you could use the Surface toolset of the Spatial



Analyst extension to create a contour map around the source, as we did for the examples shown in this guide:



To examine how different environmental factors contributed to the predicted noise propagation patterns in your study area, you may want to look at data for some of the intermediate steps in the SPreAD-GIS calculation process. A key to the intermediate datasets is included as an appendix (Appendix B) to this document.

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## **Appendix A**

### **Overview of Sound Modeling Packages**

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March 7, 2008

Eight sound modeling software packages were surveyed with the goal of developing a spatial model of noise propagation from off-highway vehicle (OHV) activity in California National Forests. Reviewed software included domestic and foreign as well as publicly- and privately-developed packages. Results of the survey are arranged in a spreadsheet matrix for comparison.

Survey considerations included: the original intent or application of the software package; data formats for model inputs and outputs; the capacity of the model to incorporate various factors affecting sound propagation in a forest landscape, including topography, barriers, vegetation, ground surface characteristics and weather effects; options for different types of vehicle noise sources, including roads, traffic and aircraft; ease of use; compatibility with geographic information system (GIS) software; cost; operating system; and date of most recent version or update. Contact information for software distributors is included in the matrix.

#### **CadnaA – Computer Aided Noise Abatement**

Originally developed for industrial, urban, or freeway noise applications in Europe, this program is fully-featured and appears to integrate well with GIS. It would likely be adaptable to forecast acoustic disturbances from OHV activity in a forest landscape. Software licenses cost between \$6,000 and \$10,000 depending on features selected. The distributor has offered a full working version, including technical support, to TWS for up to two months when needed.

#### **INM – Integrated Noise Model**

An FAA-developed program for use in modeling aircraft noise impacts near airports. It does not handle roads or vehicular traffic and apparently lacks compatibility with GIS software or data formats. INM is not likely to be useful for modeling noise propagation around OHV routes.

## **Noise Map**

A UK-based package for modeling and mapping noise from roads, railways, industrial, construction, and other open sites. Noise Map appears to be of similar quality and functionality (and one might assume, cost) as the CadnA and LIMA packages. It would likely have a good amount of functionality for assessing OHV impacts, although some model factors were unstated in the product literature. We have not yet received a response to requests for pricing or demo version information.

## **NMSim – Noise Model Simulation**

Developed by Wyle Labs in southern California for modeling aircraft, railroad, and highway noise, NMSim has been used for some National Park Service (NPS) applications, including modeling aircraft flights over Grand Canyon National Park. The package claims compatibility with GIS, but we have found integration to be difficult in practice. The software is available for free, but the downloadable version was updated several years ago and is somewhat archaic. Working with NMSim would require back-versioning GIS data for use with the program (e.g., the program uses DEM files in a non-SDTS format only). Further developments to the program are in use by Wyle Labs, but they are not included in the free, publicly-available version.

## **SoundPLAN / SP Essential**

Developed in Germany and sold by NAVCON engineering in southern California. It has full functionality, although though compatibility for input and output of GIS data is unclear. Licenses cost between \$3,000 and \$7,000, and a discount is possible.

## **TNM – Traffic Noise Model**

U.S. Federal Highway Administration (FHWA) program for modeling noise from highway development projects, including the design of effective, cost-efficient highway noise barriers. Although many public agencies use TNM, including the California Department of Transportation, it is very highway-specific in scope and has poor GIS compatibility.

## **LIMA**

German-developed package for evaluating noise distribution for environmental planning, city planning, preservation of silent areas, and noise reduction measures. LIMA appears to have full functionality for modeling acoustic disturbances from OHV activity, including GIS compatibility and direct integration with ArcGIS. We have not yet received a response from the U.S. sales representative, but estimate the cost will be in the \$6,000 to \$10,000 range.

## **SPreAD – System for the Prediction of Acoustic Detectability**

Spreadsheet routine developed by the U.S. Forest Service (USFS) and Environmental Protection Agency (EPA) to evaluate acoustic impacts in conjunction with the USFS Recreation Opportunity Spectrum (ROS). SPreAD was developed with the explicit objective of modeling acoustic impacts from OHV sources and includes most of the important factors affecting sound in a forest landscape, except topography or terrain effects. The hand calculation method was updated to a computerized version in a Linux operating system in 1998, but this version is not publicly-available. It is important to note that the current version of SPreAD is not spatially-explicit. It is a method for calculating the potential propagation of sound from a single point source to a single point receiver. It may be possible, however, to adapt these calculations to a contemporary ArcGIS modeling process, as the acoustic science underlying SPreAD is well-researched and specifically tailored to the vehicles and environments to be modeled.

	CadnaA	Integrated Noise Model (INM)	Noise Map	Noise Model Simulation (NMSim)	SoundPLAN / SP Essential	Traffic Noise Model (TNM)	LIMA	SPreAD
<b>Intended Use / Applications</b>	urban / industrial / airport noise prediction and assessment.	aircraft noise impacts near airports developed by FAA	modeling and mapping noise from roads, railways, industrial construction, and other open sites	modeling noise from aircraft, railroads, and highways	calculates noise from roads, railways or industry	modeling highway noise, including the design of effective, cost-efficient highway noise barriers	environmental planning, preservation of silent areas, noise reduction measures	evaluate acoustic impacts in conjunction with Recreation Opportunity Spectrum (ROS)
<b>Inputs</b>	arcview shapefiles, ASCII Polys, ASCII Grid	not stated	DXF, shapefile	DEM, DLG, ASCII	DXF, ASCII, GIS (?)	DXF	GIS	tabular data
<b>Outputs</b>	shapefiles, tabular and graphic results	not stated	export results in choice of ASCII formats: DXF, shapefile, maps	grid noise maps; animated flyovers	grid noise maps	tabular	GIS	tabular data
<b>Weather and Atmosphere Effects</b>	not stated	not stated	not stated	vertical temperature and wind profiles in new version (not publicly-available)	not stated	not stated	not stated	yes (temp, humidity, elevation, wind)
<b>Ground Effects</b>	implied	not stated	not stated	yes	yes	yes	yes	yes
<b>Vegetation Effects</b>	"foliage areas can be modeled as distinct objects with arbitrary shape"	not stated	not stated	not explicitly	yes - "mitigation areas"	"Attenuation over/through rows of buildings and dense vegetation"	"screen" and "attenuation areas"	yes
<b>Topography</b>	contour lines, points (TIN-style)	not stated	"ground contour points"; "vertical noise contour cross-sections"	"account for different types of terrain when computing noise propagation," including water or soft dirt	topo and spot elevations, digital ground model (DGM)	sound berms, terrain lines	yes	yes
<b>Barriers</b>	yes, variable	not stated	not stated	yes	Variable reflectivity values for soundwalls.	yes	yes	yes
<b>Roads / Traffic</b>	yes	no	yes	yes	yes	yes (including user-defined vehicles)	yes	yes (single point source, including frequency spectrum)
<b>Aircraft</b>	yes	yes	not stated	yes	not stated	no	yes	no
<b>GIS Compatibility</b>	auto in/out available as a run-time calculation program	not stated	import/export of shapefiles	possible, somewhat archaic	unknown	not stated	yes (extension that embeds LIMA into ArcGIS as an extension or geoprocessing tool)	no (not spatially explicit)
<b>Operating System</b>	Windows	Windows	Windows	Windows	Windows	Windows	Windows	Linux
<b>Last update</b>	2008	2007	unsure	early 2000s	2006	2004	2008	1988
<b>Cost</b>	\$6,000 - \$9,500 (depending on options)	\$300	not available	free	\$3,000 - SP essential \$6,500 - SP full	\$695	unknown (comparable to CadnaA)	free (in print form, not computerized)
<b>Demo Version</b>	yes (1 - 2 months)	no	unknown	free	SP Essential	unknown	unknown	free
<b>Origin / Contact</b>	Richard Peppin 410-290-7726 RPeppin@aol.com	FAA / ATAC / VOLPE - United States	Atkins Acoustics - UK	Wyle Laboratories - CA US	Braunstein + Berndt - Germany/ Dist. By Navcon Engineering, CA US	McTrans - Univ of Florida US	Bruel & Kjaer	USFS SDTC (San Dimas) 909-599-1287 mailto:com_w_sdtc@fs.fed.us
<b>Web Address</b>	<a href="http://www.aec-sib.com.au/cadna">http://www.aec-sib.com.au/cadna</a>	<a href="http://www.faa.gov/about/office_of_headsquarters_offices/aipmodel/gisform_model">http://www.faa.gov/about/office_of_headsquarters_offices/aipmodel/gisform_model</a>	<a href="http://www.noisemap.com/">http://www.noisemap.com/</a>	<a href="http://www.wielabs.com/products/acousticsofwaterproducts/nmsim">http://www.wielabs.com/products/acousticsofwaterproducts/nmsim</a>	<a href="http://www.navcon.com/SoundPLAN">http://www.navcon.com/SoundPLAN</a>	<a href="http://www.fhwa.dot.gov/enviro/entnoise/nm/index">http://www.fhwa.dot.gov/enviro/entnoise/nm/index</a>	<a href="http://www.stapelhof.de/framesta">http://www.stapelhof.de/framesta</a>	<a href="http://www.fs.fed.us/eng/pubs/hm/1982213089231308">http://www.fs.fed.us/eng/pubs/hm/1982213089231308</a>

## **Appendix B**

### ***Definitions of Intermediate Datasets***

The following is a list of the intermediate and results datasets produced from running each of the SPreAD-GIS modules. Where applicable, raster datasets are listed for propagation at the 800 Hz frequency level only (e.g., all800), but nomenclature for rasters representing other frequencies is the same (e.g., aal400, aal500, aal630, aal1000, aal1250, aal1600, aal2000).

Definitions are given for key datasets, and an asterisk (\*) indicates the final result grid for each module. If you would like to follow SPreAD-GIS' calculation of the effects of different factors on noise propagation at 800 Hz, for instance, then load each of the datasets marked with an asterisk (\*)

#### **C:\SPreAD\_model\intermediate\**

euclidist – euclidean distance from sound source (m), up to the model extent  
euclidist\_ft – euclidean distance from sound source, converted to feet (ft)  
sound\_src – sound source location, converted to a raster dataset  
diveucdis100

#### **C:\SPreAD\_model\intermediate\ssl\** (*Module 1 – Spherical Spreading Loss*)

\*ssl800 – decline in sound levels due to spherical spreading loss at 800Hz  
div\_euclidist  
int\_divdist  
source800  
ssl\_neg  
ssl\_reclass

#### **C:\SPreAD\_model\intermediate\aal\** (*Module 2 – Atmospheric Absorption Loss*)

aac800 – constant raster of atmospheric absorption coefficient for input elevation, temperature, and humidity at 800 Hz  
aal800 – decline in sound levels due to atmospheric absorption at 800 Hz  
\*sslaal800 – cumulative spherical spreading loss and atmospheric absorption at 800Hz

#### **C:\SPreAD\_model\intermediate\veg\** (*Module 3 – Foliage & Ground Cover Loss*)

landcov\_final – decline in sound levels due to scattering by vegetation and absorption by the ground  
\*salveg800 – cumulative spherical spreading loss, atmospheric absorption, and vegetation loss at 800Hz

euclidist\_neg  
euclidist\_z  
landcovplus1  
landcov\_perft  
max\_euclidist  
pathdist1  
pathdist3  
veg\_divdist  
veg\_lossrate  
zonegrid1

**C:\SPreAD\_model\intermediate\veg\** (*Module 4 – Downwind & Upwind Loss*)

\*salvegwin800 – cumulative spherical spreading loss, atmospheric absorption,  
vegetation loss, and downwind and upwind loss at 800Hz

wind800 – downwind and upwind loss at 800 Hz

800rcl\_div100

800xdist

con\_euclidir\_1

con\_euclidir\_2

dist2shdw\_1

dist2shdw\_2

dist2shdw\_3

distshadowdiv

distshad\_int

downwind

dw800\_1

dw800\_2

dw800\_3

dw800\_4

euclidist2\_ft

euclidir\_wind

euclidist\_wind

finalmeanw

fltshdwfc800

ln\_800xdist

ln\_800xdist\_2

meanwind

minus\_con\_eu1

minus\_con\_eu2

phi

propwinang



prop\_angle  
shdwfct800dbf  
times\_800rcl1  
updownwind  
upwind  
upwind\_rcls  
windang2

**C:\SPreAD\_model\intermediate\topo\** (*Module 5 – Terrain Effects*)

barloss\_800 – calculated barrier loss values due to topography at 800 Hz  
\*savgwntop800 – cumulative spherical spreading loss, atmospheric absorption,  
vegetation loss, wind loss, and terrain effects at 800Hz  
topo\_zones – areas of the landscape dominated by barrier (1), atmospheric (2), and  
ground (3) effects on noise propagation  
bf\_800  
bpd  
constant\_0  
constant\_3  
dist1-12  
elev1-12  
elev\_sr  
elev\_src  
eucdir\_class  
eucdir\_dist  
eucdir\_elev  
eucdir\_src  
extent\_pts\_elev  
h\_b  
h\_b\_rc  
l\_800  
slope  
sound\_source  
topo\_zones  
topo\_zones\_1  
topo\_zones\_2  
vicinity  
vicinity\_line  
vicinity\_pts  
vicinity\_pts\_class1-12  
vicinity\_pts\_elev\_dist  
vicinity\_pts\_elev\_dist\_dir

vshed\_all\_polygon  
vshed\_src  
vshed\_src\_rc  
vshed\_vicinity\_polygon  
vshed\_vicinity\_polygon\_buff\_50ft

**C:\SPreAD\_model\intermediate\amb\** (*Module 6 – Noise Propagation Results*)

amb800 – constant raster of ambient sound level at 800 Hz  
amb\_dba – constant raster of summary A-weighted sound level (dBA)

**C:\SPreAD\_model\results\** (*Module 6 – Noise Propagation Results*)

800\_excess – noise levels exceeding ambient sound conditions at 800 Hz  
800\_prop – final noise propagation patterns at 800z  
dba\_excess – A-weighted noise levels exceeding ambient sound conditions  
dba\_prop – final noise propagation patterns for A-weighted sound levels

**C:\SPreAD\_model\results\prelim\**

800\_dba\_1  
800\_dba\_2  
800\_dba\_3  
800\_excess\_1  
800\_excess\_2  
800\_result\_1  
800\_result\_2  
dba\_excess\_1  
dba\_excess\_2  
dba\_result\_1  
dba\_result\_2

## **Sample Exercise**

### **Preparing ArcMap project for SPreAD-GIS analysis:**

- 1) Open ArcCatalog. Copy all files in the 'SPreAD-GIS v.1.2\sample\_exercise\sample\_data' folder to C:\SPreAD\_model\source\_data. These files should include: source\_point, model\_extent, veg, and dem\_ft.
- 2) Open ArcMap
- 3) Add all data from the C:\SPreAD\_model\source\_data to the project.
- 4) Add toolbox:
  - a. Right click in ArcToolbox and Select *Add Toolbox...*
  - b. Navigate to C:\SPreAD\_model\toolbox and select *SPreAD-GIS\_v1.2*
- 5) Define Scratch Workspace:
  - a. Right Click in ArcToolbox and select *Environments...*
  - b. Expand General Settings
  - c. Define Scratch workspace as a folder that has sufficient space for intermediary data.

### **Running the SPreAD-GIS model:**

- 6) Expand *SPreAD-GIS\_v1.2*. Double-click *1. Spherical Spreading Loss*
  - a. Fill in parameters as follows (as seen in Figure 1):
    - Sound Source: source\_point.shp
    - Model Extent: model\_extent.shp
    - Type of Engine: Motorcycle
    - Measurement Distance (ft): 50
    - Input Custom Source Sound Level Data: No
    - Sound Level of Source (dBA): 83
  - b. Press *OK*

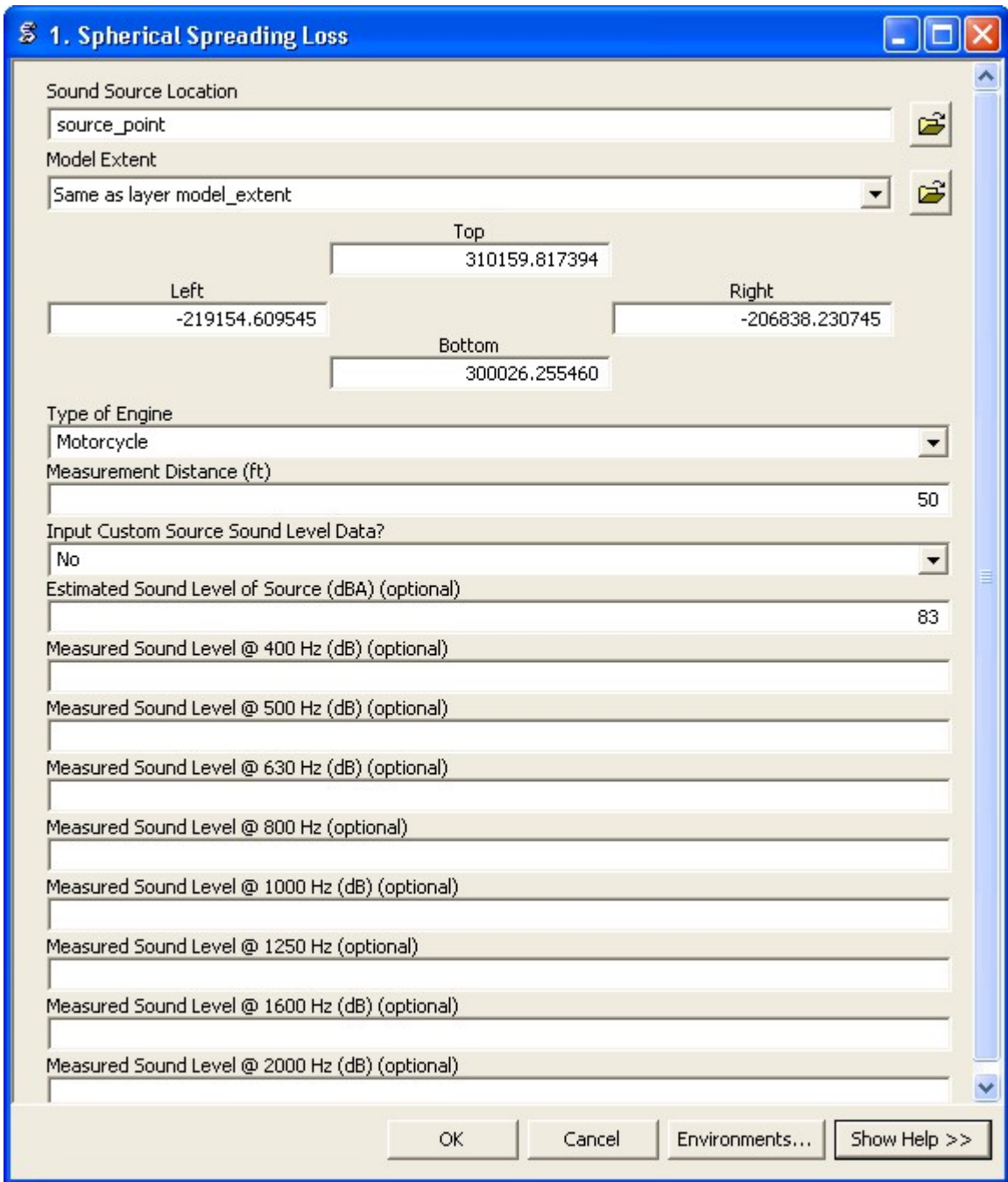


Figure 1

7) Double click 2. *Atmsopheric Absorption*

a. Fill in parameters as follows (as seen in Figure 2):

- Elevation Dataset: dem\_ft
- Temperature: 81
- Humidity: 31

b. Press OK

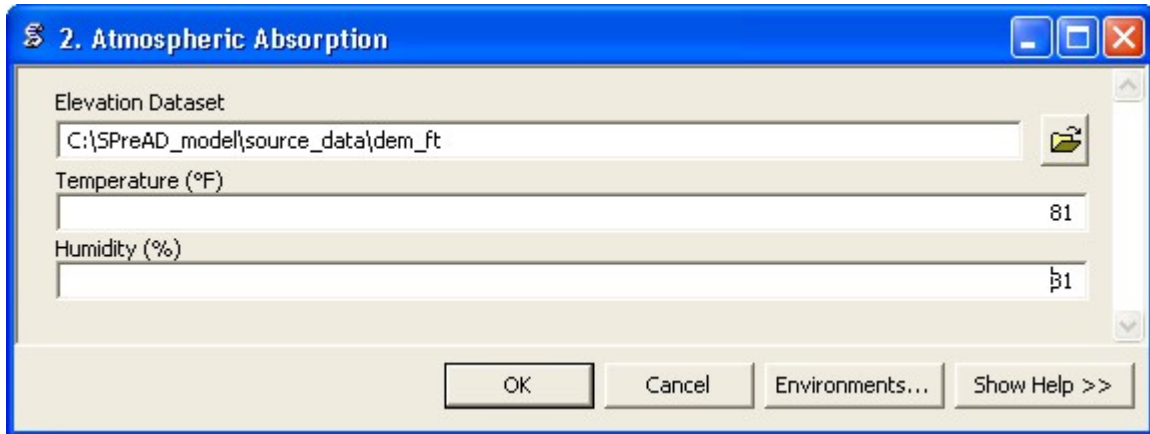


Figure 2

8) Double Click 3. *Foliage & Ground Cover Loss*

a. Fill in the parameter as follows (as seen in Figure 3):

- Land Cover Dataset: veg

b. Press OK

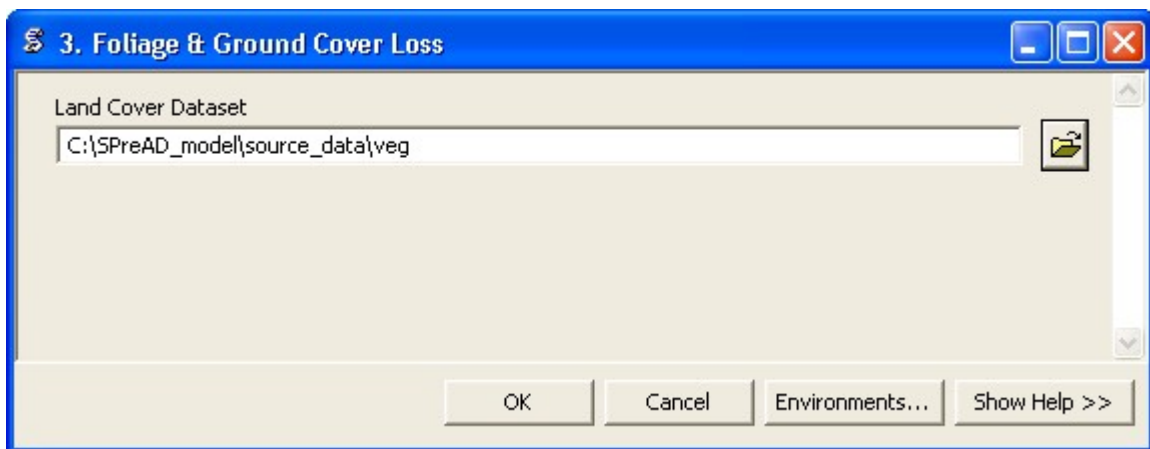


Figure 3

9) Double Click 4. *Upwind & Downwind Loss*

a. Fill in parameters as follows (as seen in Figure 4):

- Prevailing Wind Direction (degrees): 0
- Wind Speed (mph): 6
- Seasonal Conditions: Clear, calm summer day

b. Press *OK*

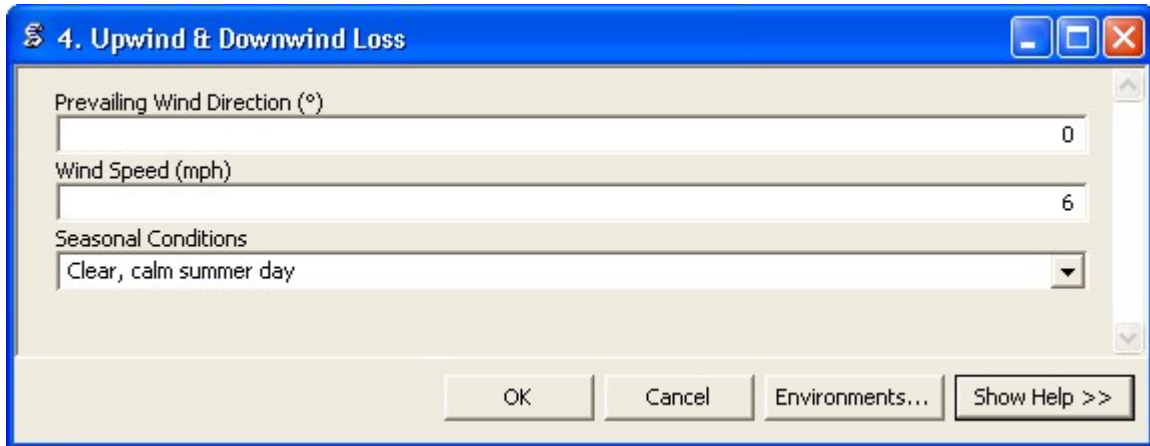


Figure 4

10) Double Click 5. *Terrain Effects* (Figure 5)

a. Press *OK*

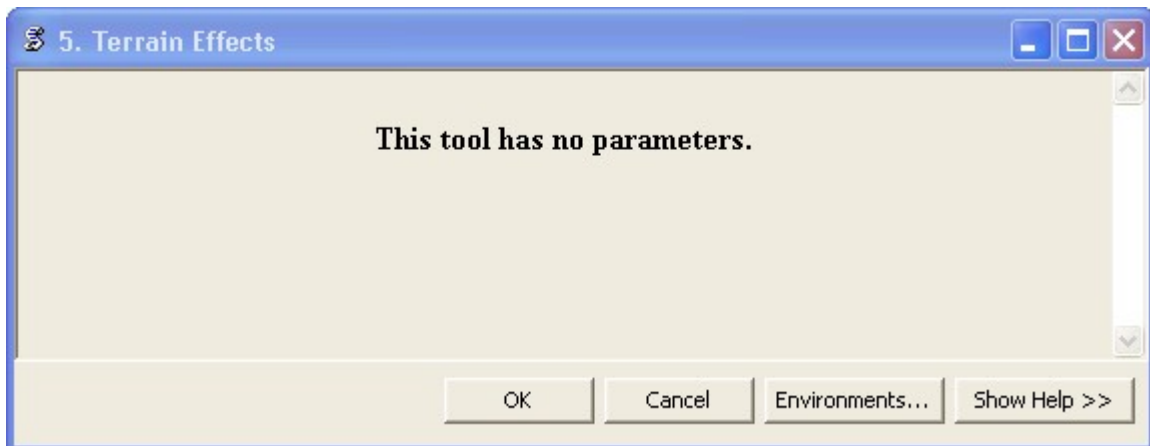


Figure 5

11) Double Click 6. *Noise Propagation Results*

a. Fill in parameters as follows (as seen in Figure 6):

- Input Custom Ambient Sound Level Data: No
- Ecosystem Type: Hardwood forest, grassland or shrubland
- Measured Ambient Sound Level (dBA): 23

b. Press *OK*

6. Noise Propagation Results

Input Custom Ambient Sound Level Data?  
No

Ecosystem Type (optional)  
Hardwood forest, grassland or shrubland

Estimated Ambient Sound Level (dBA) (optional)  
23

Measured Ambient Sound Level @ 400 Hz (dB) (optional)

Measured Ambient Sound Level @ 500 Hz (dB) (optional)

Measured Ambient Sound Level @ 630 Hz (dB) (optional)

Measured Ambient Sound Level @ 800 Hz (dB) (optional)

Measured Ambient Sound Level @ 1000 Hz (dB) (optional)

Measured Ambient Sound Level @ 1250 Hz (dB) (optional)

Measured Ambient Sound Level @ 1600 Hz (dB) (optional)

Measured Ambient Sound Level @ 2000 Hz (dB) (optional)

OK Cancel Environments... Show Help >>

Figure 6

***Viewing model results:***

12) Add data from the C:\SPreAD\_model\results.

- a. There are two types of results for each of the eight frequency bands, as well as for A-weighted sound levels: baseline noise propagation values (e.g., 400\_prop), and excess noise above ambient conditions (e.g., 400\_excess).

13) To compare your results to previously executed sample results, open the files in the 'SPreAD-GIS v1.2\sample\_exercise\sample\_results' folder.