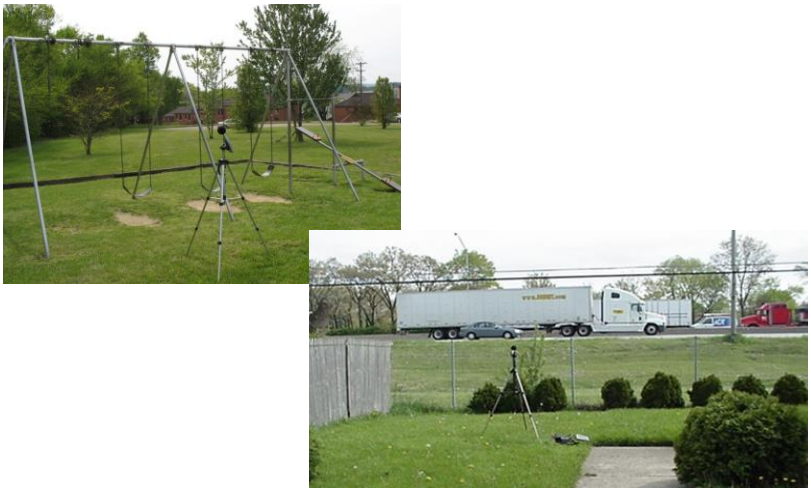
FHWA-HEP-18-066

FINAL REPORT

Noise Measurement Field Guide

6.1.2018



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Federal Highway Administration

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Cover images source: Bowlby and Associates

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
ASA	Acoustical Society of America
ASTM	American Society of Testing and Materials
CTIM	Continuous-Flow Traffic Time-Integrated Method
DAT	Digital Audio Tape
DNL	Day-Night Average Sound Level
DOT	Department of Transportation
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
HT	Heavy Trucks
IL	Insertion Loss
MT	Medium Trucks
NAC	Noise Abatement Criteria
NCHRP	National Cooperative Highway Research Program
OBSI	On-Board Sound Intensity
OINR	Outdoor-Indoor Noise Reduction
PPV	Peak Particle Velocity
REMEL	Reference Energy Mean Emission Level
SAE	Society of Automotive Engineers
SEL	Sound Exposure Level
SHA	State Highway Agency
SIP	Statistical Isolated Pass-By
SLM	Sound Level Meters
SPB	Statistical Pass-By
SPL	Sound Pressure Level
TNM	Traffic Noise Model

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16. Abstract

This field guide provides a series of checklists and steps for the proper development, planning, preparation, and execution of a noise measurement effort for many of the measurement methodologies in the FHWA Noise Measurement Handbook. Each chapter is intended to be a standalone set of pages to aid the person(s) conducting noise or vibration measurements. Included for each methodology are sets of steps for pre-trip planning, pre-trip preparations and on-site field data collection and sample data sheets. More information on measurement study planning is in the Noise Measurement Handbook, as are details on post-measurement data analysis and reporting. The handbook also contains detailed appendices on equipment and terminology. The information in this field guide is meant to serve as a baseline set of information that includes all the steps to conduct a successful field effort. This field guide should be viewed as best-practice guidance and not direction as to how the work must be done. Some project sponsors have established and use their own procedures, which typically would be followed in the event of a conflict.

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Introduction

This field guide provides a series of checklists and steps for the proper development, planning, preparation, and execution of a noise measurement effort for many of the measurement methodologies in the FHWA *Noise Measurement Handbook*. Each chapter is intended to be a standalone set of pages to aid the person(s) conducting noise or vibration measurements. Included for each methodology are sets of steps for pre-trip planning, pre-trip preparations and on-site field data collection and sample data sheets. More information on measurement study planning is in the *Noise Measurement Handbook*, as are details on post-measurement data analysis and reporting. The handbook also contains detailed appendices on equipment and terminology. The information in this field guide is meant to serve as a baseline set of information that includes all the steps to conduct a successful field effort. **This field guide should be viewed as best-practice guidance and not direction as to how the work must be done. Some project sponsors have established and use their own procedures, which typically would be followed in the event of a conflict.**

1.0 Determination of Existing Noise Levels

The purpose of this type of measurement is to establish existing noise levels within a project study area. Examples of the application of this method include:

- Establishment exist noise levels to evaluate substantial increase determinations as part of the impact assessment for a proposed highway project along new alignment.
- Establish existing noise levels to help determine the effectiveness of noise abatement measures.

The field guidance below includes pre-trip planning, pre-trip preparation, and on-site set-up, data collection, documentation, and storage.

Determination of Existing Noise Levels (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Determine measurement areas ☐ Determine measurement sites ☐ Select primary noise measurement locations using available online aerial imagery and panoramic views. ***Tip:*** *Avoid choosing locations with permanent, localized, noise sources (pump houses, generators, HVAC or ventilation fans) that do not represent the general noise environment for project area.* ***Tip:*** *Consider difficulty in access to the site while choosing locations.* ☐ Identify secondary or alternative noise measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ***Tip:*** *Be mindful that localized noise sources that interfere with data collection at a primary noise measurement location may influence levels for adjacent properties. Choose secondary locations that are at least one residence or land use away from the primary noise measurement location.*
Field review	☐ Visit each planned measurement site to confirm access. ☐ Observe local noise environment and evaluate if there are any potential noise sources that might interfere with data collection.
Noise Descriptors	☐ Use L_{eq} as primary measurement descriptor. ☐ Consider collecting other descriptors that may help understand the measured noise during post processing (L_{max}, L_{min}, L_{10}, L_{90}).
Sampling Period	☐ Determine appropriate sampling period for data collection. Periods of 1 minute, repeating intervals are suggested.
Timing and Duration of Measurements	☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration of the noise measurements based on SHA requirements.

Category	Tasks
Permissions	☐ Submit preliminary list of all potential addresses and locations for noise measurements to SHA. ☐ Contact owners 1-2 weeks ahead of data collection effort seeking permission for property access.
Measurement Plan approval	☐ Develop and submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare adequate number of copies of data sheets. ☐ Prepare copies of mapping for note taking in the field. ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Determination of Existing Noise Levels (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Test the instrumentation that will be used for data collection, adjusting settings as needed.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Determination of Existing Noise Levels (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Visit each planned measurement site to confirm access and observe local conditions.
Site Appropriateness	☐ Determine if there are any localized, non-representative noise sources that interfere with the data collection. ☐ Move to alternative noise measurement location if needed.
Instrumentation Setup	☐ Attach pre-amp and microphone (with microphone extension, if needed) to sound level meter. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, set and synchronize the time on all instrumentation (sound level meters, traffic counters, video cameras, cameras, watches). ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Set microphone height at 5 ft (1.5 m) above the ground, unless another height has been specified in the plan. ***Tip:*** *Make sure the tripod is level and secure. Weigh the tripod down if there is a slope or if breezy wind conditions are expected.*
Documentation	☐ Fill out general information on the Measurement Summary Sheet (date, measurement site name, identifying information, observer name). ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app. ☐ Note weather conditions on Measurement Summary Sheet: o Temperature o Cloud cover o Wind speed o Wind direction ☐ Create site sketch on Measurement Summary Sheet showing noise measurement location and any identifying structures, roadways and noise sources. ***Tip:*** *Sketch should be of sufficient detail that another person can return to the site and set up at the same spot.* ☐ Take photographs of the microphone location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting dominant noise sources.

Category	Tasks
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Keep minute by minute notes of observed sound levels and sources. ***Tip:*** *Develop and use a consistent shorthand for easier note-taking.* ☐ Note the typical levels for predominant noise sources (man-made and natural sources). ☐ Note any changes in sound levels or weather conditions during the data collection. ☐ Take traffic counts for nearby roadways contributing to noise level (if needed). ☐ End data collection. ***Tip:*** *If it is suspected or known that certain unrepresentative minutes' data will need to be eliminated from the result, then extend the data collection for the same number of additional minutes.* ☐ Save or store the data to the instrument's memory if that is not an automated function. ☐ Note the data file name or number on the Measurement Summary Sheet. ☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Measurement Summary Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Determination of Existing Levels Pack List

Instrumentation	☐ Sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Calibrator ☐ Tripods (include at least one spare) ☐ Windscreens (include at least one spare) ☐ Anemometer ☐ Compass
Equipment	☐ Camera ☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Traffic cones ☐ Ground tarp ☐ Camp chair
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for sound level meters, speed detection instrumentation, count boards and cameras) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Determination of Existing Noise Levels—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	

SLM/Analyzer Information

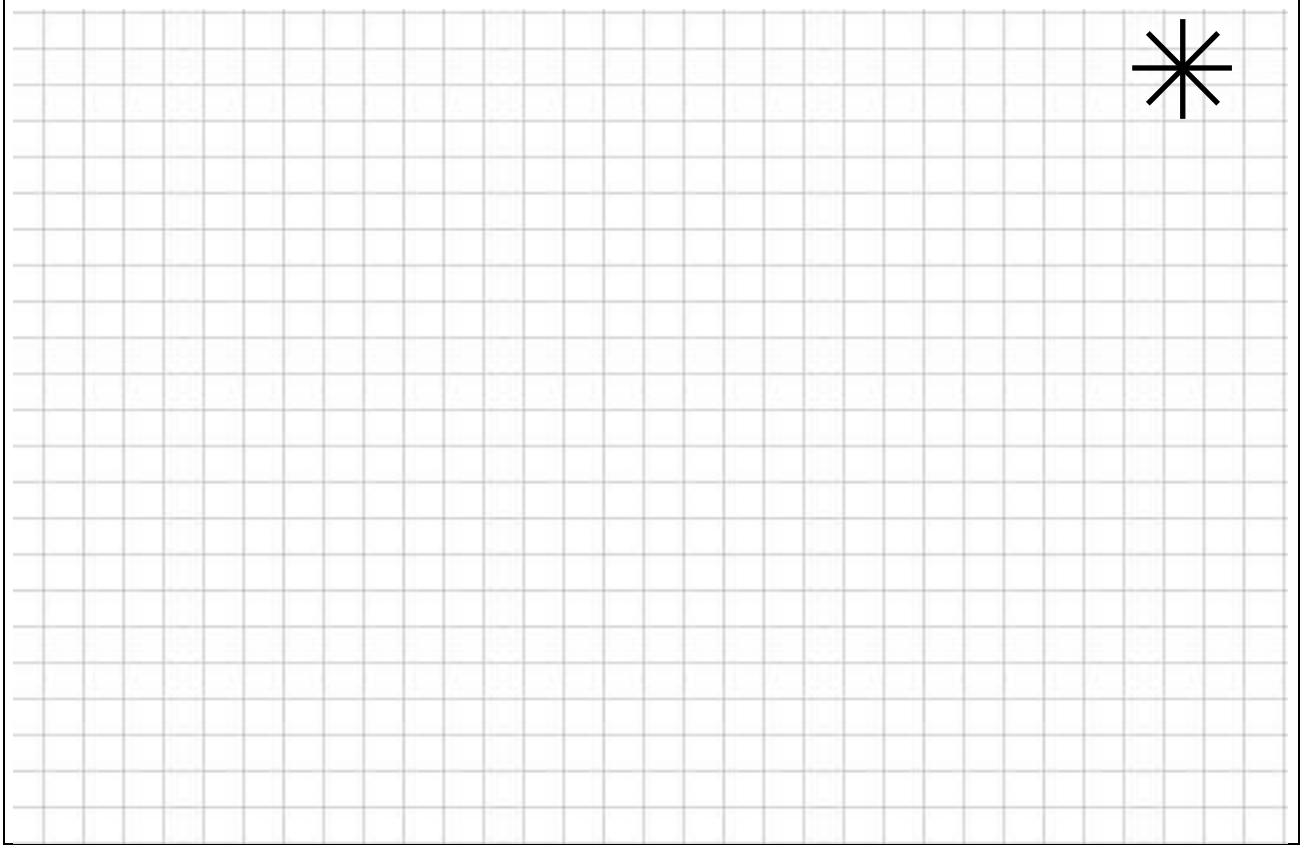
SLM Model		SLM Serial #	
Mic. Height		Mic. Serial #	
Mic. Extension?		Data File Name/Number	

Calibration Information

	Pre-Measurement	Post-Measurement
Calibration Time		
Calibration Level		

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Determination of Existing Noise Levels—Field Log

Period #	Period Start Time	Event Description(s) (include event start and stop)
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Site_____

Determination of Existing Noise Levels—Field Log

Period #	Period Start	Event Description(s) (include event start and stop)
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2.0 Validation of the FHWA TNM for a Proposed Highway Project on Existing Alignment

The purpose of this measurement method is establishing noise levels for use in validating an FHWA TNM model run of the existing condition, which is done by comparison of the predicted existing levels to measured noise levels. The field guidance below includes pre-trip planning, pre-trip preparation, and on-site set-up, data collection, documentation, and storage.

Validation of the FHWA TNM for a Proposed Highway Project on Existing Alignment (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Determine noise study areas where measurements will be needed. ☐ Determine approximate number of measurement sites. ☐ Select primary noise measurement locations. ***Tip:*** *Avoid choosing locations with any permanent, localized, noise sources (pump houses, generators, HVAC or ventilation fans) that would interfere with measurement of the roadway noise source.* ***Tip:*** *Consider difficulty in access to the site while choosing locations.* ☐ Identify secondary or alternative noise measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ***Tip:*** *Be mindful that localized noise sources that interfere with data collection at a primary noise measurement location may influence levels for adjacent properties. Choose secondary locations that are at least one residence or land use away from the primary noise measurement location.* ☐ Identify primary and secondary locations for collecting traffic counts. ☐ Identify primary and secondary locations for collecting speed data.
Field review	☐ Visit each planned measurement site to confirm access. ☐ Visit each planned traffic count and speed data collection site to confirm access and visibility. ☐ Observe local noise environment and evaluate if there are any potential noise sources that might interfere with data collection.
Noise Descriptors	☐ Use L_{eq} as primary measurement descriptor. ☐ Consider collecting other descriptors that may help evaluate the measured noise during post processing (L_{max}, L_{min}, L_{10}, L_{90}).
Sampling Period	☐ Determine appropriate sampling period for data collection. 1 minute, repeating intervals suggested.
Timing and Duration of Measurements	☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration of the noise measurements based on SHA requirements.

Category	Tasks
Permissions	☐ Submit preliminary list of all potential addresses and locations for noise measurements to SHA. ☐ Contact owners 1-2 weeks ahead of data collection effort seeking permission for property access.
Measurement Plan approval	☐ Submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare adequate number of copies of data sheets. ☐ Prepare copies of mapping for note taking in the field. ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Validation of the FHWA TNM for a Proposed Highway Project on Existing Alignment (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Test the instrumentation that will be used for data collection, adjusting settings as needed.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Validation of the FHWA TNM for a Proposed Highway Project on Existing Alignment (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Visit each planned measurement site to confirm access and observe local conditions. ☐ Visit each traffic count location to confirm there is an unobstructed view of traffic. ☐ Visit each speed data collection location and test radar gun at the location.
Site Appropriateness	☐ Determine if there are any localized, non-representative noise sources that interfere with the data collection. ☐ Move to alternative noise measurement location if needed.
Instrumentation Setup	☐ Attach pre-amp and microphone (with microphone extension, if needed) to sound level meter. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, reset and synchronize the time on all instrumentation (sound level meters, traffic counters, video cameras, cameras, watches). ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Set microphone height at 5 ft (1.5 m) above the ground. ***Tip:*** *Make sure the tripod is level and secure. Weigh the tripod down if there is a slope or if breezy wind conditions are expected.* ☐ Position speed detection instrumentation and staff at speed data collection station. ☐ Position traffic counting instrumentation and staff (or video camera) at the vehicle count station location.
Documentation	☐ Fill out general information on the Measurement Summary Sheet (date, measurement site name, identifying information, observer name). ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app. ☐ Note weather conditions on Measurement Summary Sheet. o Temperature o Cloud cover o Wind speed o Wind direction

Category	Tasks
	☐ Create site sketch on Measurement Summary Sheet showing noise measurement location and any identifying structures, roadways and noise sources. ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the microphone location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting dominant noise sources.
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Keep minute by minute notes of observed sound levels and sources. ☐ Note the typical levels for predominant noise sources (man-made and natural sources). ☐ Note any changes in sound levels or weather conditions during the data collection. ☐ Take traffic counts for roadways contributing to noise level. ***Tip:*** *If traffic is being recorded via video camera make sure to periodically visit the site to confirm that the camera is operating properly.* ☐ Collect speed data concurrent with sound level data collection. ***Tip:*** *Collect speed data for all lanes of traffic and all vehicle types.* ☐ End data collection. ***Tip:*** *If it is suspected or known that certain unrepresentative minutes' data will need to be eliminated from the result, then extend the data collection for the same number of additional minutes.* ☐ Save or store the data to the instrument's memory if that is not automatically done. ☐ Note the data file name or number on the Field Data Sheet. ☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Field Data Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Validation Measurements Pack List

Instrumentation	☐ Integrating sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Calibrator ☐ Tripods for sound level meters, speed detection station and traffic video station (include at least one spare) ☐ Windscreens (include at least one spare) ☐ Vehicle speed detection unit (laser or radar gun) ☐ Vehicle count boards ☐ Camera ☐ Video camera ☐ Anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Traffic cones ☐ Ground tarp ☐ Camp chair
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for sound level meters, speed detection instrumentation, count boards and camera(s)) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Validation of Modeled Sound Levels—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	

SLM/Analyzer Information

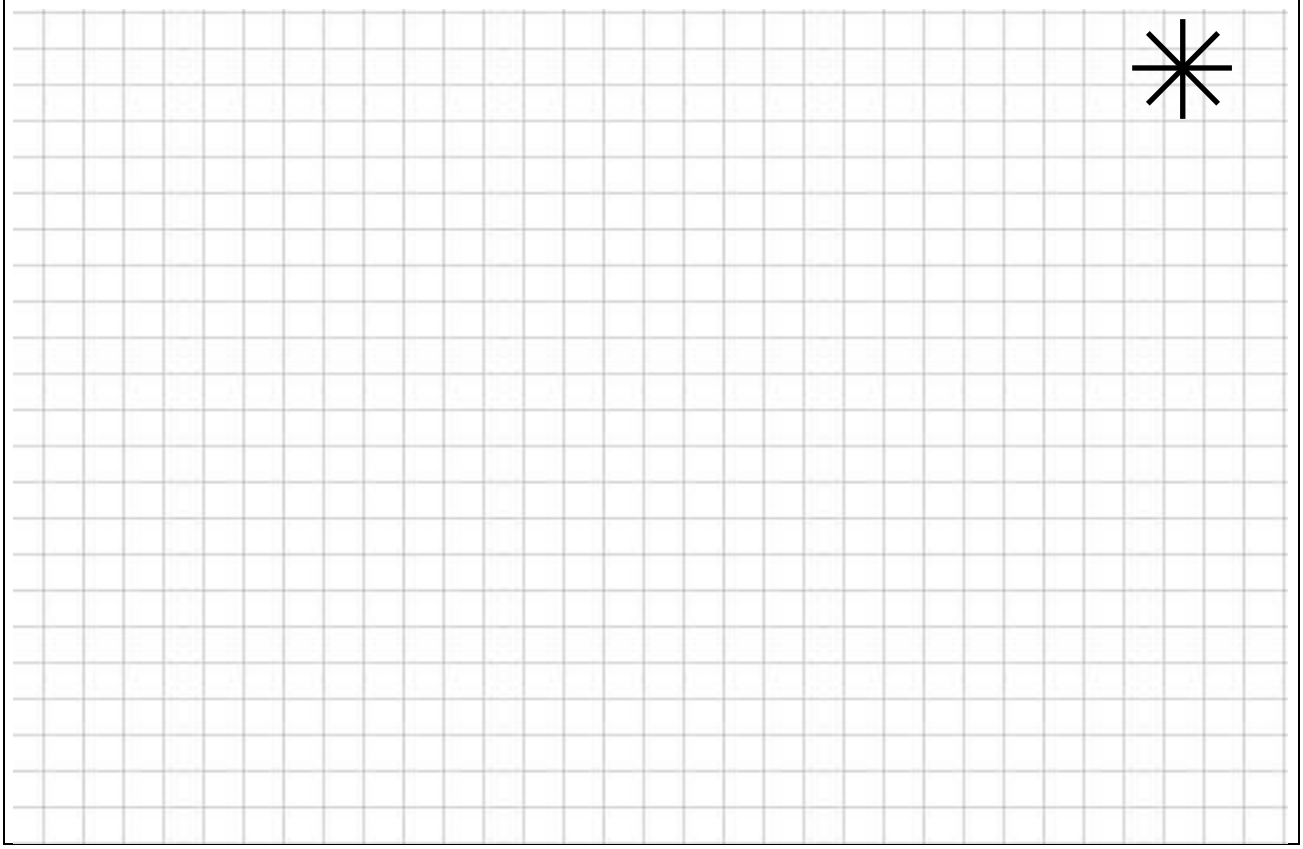
SLM Model/Ser #	
File numbers	
Microphone Ht.	

Calibration Information

	Pre-Measurement	Post-Measurement
Calibration Time		
Calibration Level		

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Validation of Modeled Sound Levels—Field Log

Period #	Start Time	Event Description(s) (include event start and stop)
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Site_____

Validation of Modeled Sound Levels—Field Log

Period #	Start Time	Event Description(s)
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Site_____

Validation of Modeled Sound Levels—Traffic Speed Data Sheet

Roadway:	Roadway:
Direction:	Direction:

	↓	↓	↓	↓	↓	↑	↑	↑	↑	↑
Lane number:										
Distance to lane:										

Log #	Time	Speed	Vehicle type	Lane #	Log #	Time	Speed	Vehicle type	Lane #

Notes:

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Site_____

Validation of Modeled Sound Levels—Traffic Count Data Sheet

Roadway:	Roadway:
Direction:	Direction:

Time Start	Auto	MT	HT	Bus	MC	Auto	MT	HT	Bus	MC

Notes:

3.0 Including Other Noise Sources for Highway Noise Projects

Projects with multimodal noise sources (e.g., sources near a train line or airport) may require consideration or determination of train and aircraft noise levels. Applications include:

- Establish noise levels from other transportation sources for purposes of input to or validation of rail or aircraft noise models or for combining with traffic noise.
- Establish noise levels from other transportation sources to determine their influence on noise abatement measure effectiveness or the general noise environment.

Field guidance in relation to train and aircraft noise targets: 1) awareness of these sources when measuring existing noise, or 2) measuring isolated train or aircraft noise events. For the former, log train or aircraft events as part of notes taken during noise measurements. Include the start and stop time of hearing the train or aircraft event and a description of the source in the event log. The description could include general train type (e.g., light rail, commuter rail, freight rail, etc.) or aircraft type (e.g., commercial jet, small propeller aircraft, helicopter, etc.) and other relevant details such as direction of travel. Also, optimize sample size for data collection to properly identify train and aircraft events and potentially remove them from the measured data. A one-minute sample size is well suited for both train and aircraft events. For trains, a light rail event may last only a few seconds, and a freight train event may last several minutes. For aircraft, typical flyover events last about 30 seconds.

For measuring isolated train events, follow measurement guidance in the FTA's Transit Noise and Vibration Impact Assessment guidance manual. As with other methods in this field guide, proper pre-trip planning and preparation is recommended, as well as completing all field data sheets and properly storing/backing up data. For aircraft, it is suggested to extract measured levels from noise contours or airport monitoring systems rather than conducting field measurements.

4.0 Building Noise Level Reduction Measurements and Interior Noise Measurements

The purpose of this measurement method is to establish an outdoor-indoor noise reduction (OINR) or to evaluate interior noise from exterior noise sources. Applications include the following:

- Type I highway project noise studies where a more accurate OINR is desired for a specific building in lieu of using typical noise reductions or where an interior noise level is needed for impact assessment.
- Possibly, construction noise studies where interior noise levels are of concern or when the effectiveness of a construction noise abatement measure such as sound insulation is being evaluated.
- In rare cases, studies where the effectiveness of a traffic noise abatement measure such as sound insulation is being evaluated.

The field guidance below includes pre-trip planning, pre-trip preparation, and on-site set-up, data collection, documentation, and storage.

Building Noise Level Reduction Measurements and Interior Noise Measurements (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Determine noise study location(s) where measurements will be needed. ☐ Determine approximate number of measurement sites for exterior and interior for each location. ☐ Select interior noise measurement locations that face the existing or proposed highway. ☐ Select exterior noise measurement locations using available online aerial imagery and panoramic views. ***Tip:*** *Avoid choosing exterior locations with a permanent, localized, noise sources (pump houses, generators, HVAC or ventilation fans) that do not represent the subject noise source* ***Tip:*** *Consider difficulty in access to the site while choosing locations.* ☐ Identify secondary or alternative exterior noise measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ***Tip:*** *Be mindful that localized noise sources that interfere with data collection at a primary noise measurement location may influence levels for adjacent properties. Choose secondary locations that are at least one residence or land use away from the primary noise measurement location.*
Field review	☐ Visit each planned measurement site to confirm access. ☐ Confirm that interior background levels are at least 10dB below expected maximum level for pass-by vehicles. ***Tip:*** *Bring a sound level meter along on the field review to confirm this.* ☐ Determine appropriate number of microphones and approximate locations for interior and exterior locations o Interior < 5,300 ft^3 (1 mic) >5,300 ft^3 (2 mics) o Exterior Position 1

Category	Tasks
	at least 10 ft (3.0 m) from side of the building same height above road as the interior mic (but not less than 5 ft (1.5 m) above ground) ○ Exterior Position 2 6.6 ft (2 m) from the façade in the middle of facade same height above road as the interior mic (but not less than 5 ft (1.5 m) above ground) ○ Exterior Position 3 At the approximate center of the façade and close to but not touching the façade ☐ Determine loudspeaker location (if applicable). ☐ Observe local noise environment and evaluate if there are any potential noise sources that might interfere with data collection. ☐ Confirm that there are no reflecting surfaces within 100 ft (30.5 m) of the vehicle path or microphone locations.
Noise Descriptors	☐ Use L_{eq} as primary measurement descriptor. ☐ For evaluation of noise reduction for single pass-by events consider collecting SEL(LAE) and L_{AFmax} .
Sampling Period	☐ Determine appropriate sampling period for data collection. ☐ For highway noise, periods of 1minute, repeating intervals is suggested. ☐ For single event pass-by noise reduction evaluation 1 second repeating intervals is suggested.
Timing and Duration of Measurements	☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration (or minimum number of events) for the noise measurements.
Permissions	☐ Submit preliminary list of all potential addresses and locations for noise measurements to SHA. ☐ Contact owners 1-2 weeks ahead of data collection effort seeking permission for property access.
Measurement Plan approval	☐ Develop and submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare adequate number of copies of data sheets. ☐ Prepare copies of mapping for note taking in the field. ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Building Noise Level Reduction Measurements and Interior Noise Measurements (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Test the instrumentation that will be used for data collection, adjusting settings as needed.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Building Noise Level Reduction Measurements and Interior Noise Measurements (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Visit each planned measurement site to confirm access and observe local conditions.
Site Appropriateness	☐ Determine if there are any localized, non-representative, exterior noise sources that will interfere with the data collection. ☐ Move to alternative noise measurement location if needed.
Instrumentation Setup	☐ Attach pre-amp and microphone (with microphone extension, if needed) to sound level meter. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, reset and synchronize the time on all instrumentation (sound level meters, video cameras, cameras, watches). ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Place and test loudspeaker before data collection. ☐ Set microphone height at 5 ft (1.5 m) above the ground.
Microphone Placement	☐ Place microphones for interior and exterior locations o Interior Mics 1 and 2 (if necessary): at least 5 ft (1.5 m) above floor at least 3 ft (0.9 m) from any wall o Exterior Position 1 at least 10 ft (3.0 m) from side of the building same height above road as the interior mic (but not less than 5 ft (1.5 m) above ground) o Exterior Position 2 6.6 ft (2 m) from the façade in the middle of facade same height above road as the interior mic (but not less than 5 ft (1.5 m) above ground) o Exterior Position 3 Approximately in the middle of the façade and close but not touching the façade

Category	Tasks
Documentation	☐ Fill out general information on the Measurement Summary Sheet (date, measurement site name, identifying information, observer name). ***Tip:*** *All boxes on Field Data Sheet should be completed by the end of the measurement.* ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app. ☐ Note weather conditions on Measurement Summary Sheet: o Temperature o Cloud cover o Wind speed o Wind direction ☐ Create site sketch on Measurement Summary Sheet showing noise measurement locations, subject noise sources, distance to the subject noise sources and any identifying structures or roadways. ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the microphone location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting each noise source.
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Keep minute by minute notes of observed sound levels and sources. ☐ Keep single event pass-by notes (if necessary) including start time, end time and $L_{max.}$ ☐ Note L_{max} for any exterior or interior events. ☐ Note any data periods when an interior noise source interferes with the measurement. ☐ Note background levels (when there is no traffic or speaker noise source) for both interior and exterior locations. ☐ Note any changes in sound levels or weather conditions during the data collection. ☐ End data collection. ☐ Save or store the data to the instrument's memory if that is not an automated function. ☐ Note the data file name or number on the Measurement Summary Sheet.

Category	Tasks
	☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Measurement Summary Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Building Noise Level Reduction and Interior Noise Measurements Pack List

Instrumentation	☐ Integrating sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Calibrator ☐ Loudspeaker (if needed) ☐ Tripods for sound level meters (include at least one spare) ☐ Windscreens (include at least one spare) ☐ Camera ☐ Video camera ☐ Anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Traffic cones ☐ Ground tarp ☐ Camp chair
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for sound level meters, speed detection instrumentation, count boards and camera(s)) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Building Noise Level Reduction and Interior Noise Measurements—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	

SLM/Analyzer Information

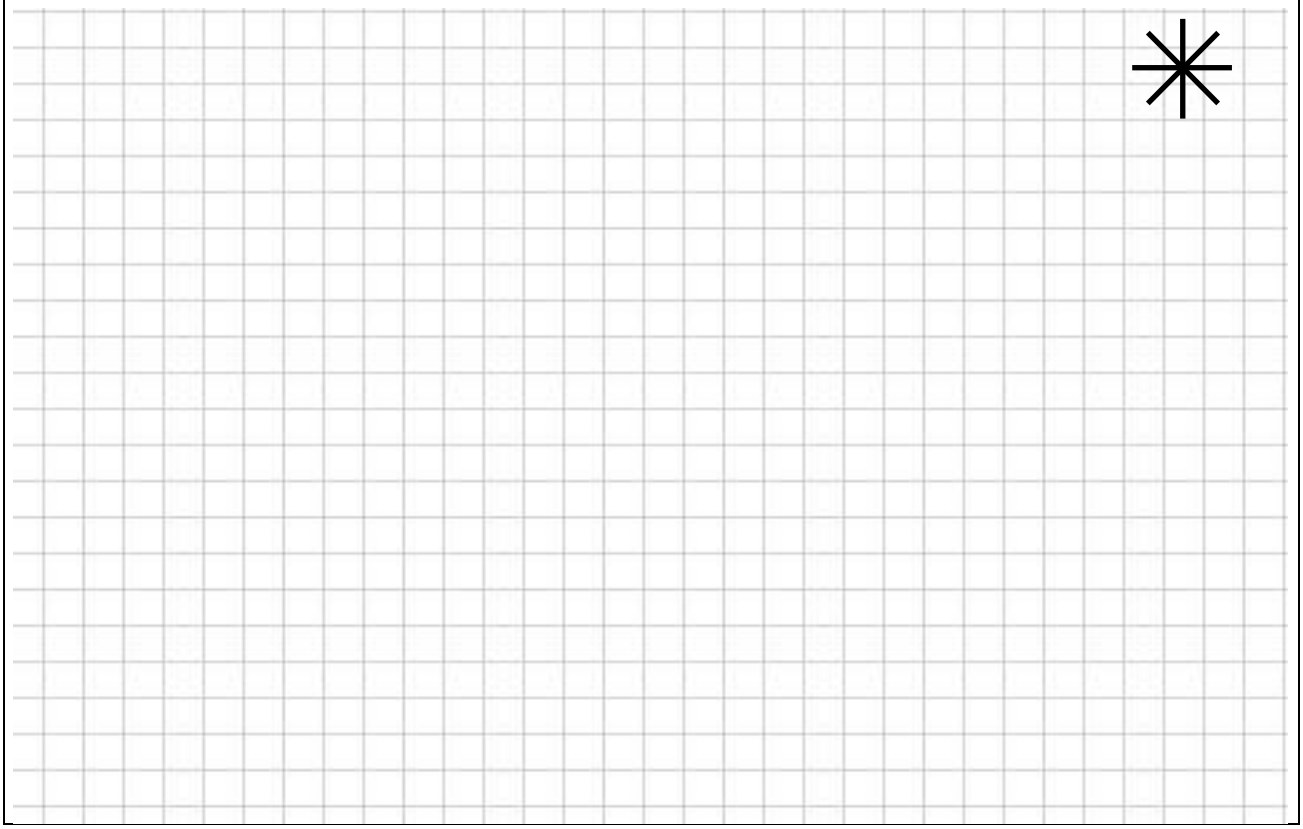
SLM Model/Ser #		Location (circle one)	Interior/Exterior
Mic. Ht.		Mic. Ht. above Roadway	
Data File.		Source (circle one)	Traffic/Speaker

Calibration Information

	Pre-Measurement	Post-Measurement
Calibration Time		
Calibration Level		

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Building Noise Level Reduction and Interior Noise Measurements—Field Log

Period #	Start Time	Event Description(s) (include event start and stop)
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Notes:

5.0 Existing Vibration Measurements

This section describes field measurement of groundborne vibration. The purpose of this measurement is to document the existing ground vibration levels near highway projects. Existing vibration may be desired for highly vibration sensitive structures, if the project causes train tracks to move within FTA[1] screening distance of the receptors, or if the highway is close and has irregularities. The field guidance below includes pre-trip planning, pre-trip preparation, and on-site set-up, data collection, documentation, and storage.

Existing Vibration Levels (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Public Outreach_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Identify vibration sensitive receptors and vibration sources. ☐ Determine approximate number of measurement sites. ☐ Consult aerial photos, maps/mapping software to identify candidate vibration measurement locations. ☐ Conduct field reconnaissance to review measurement sites. ☐ Select primary vibration measurement locations. ☐ Identify secondary or alternative vibration measurement locations in the event that local conditions prevent data collection.
Sensor Placement	☐ Identify any vibration sources at each site (i.e., highway vehicles, railway vehicles, construction equipment, other machinery). ☐ Select preferred placement of sensor, relative to nearby receptors and vibration sources. ☐ Identify type of ground and appropriate mounting for sensor (i.e., soil/groundstake, pavement/plate and epoxy).

[1] Hanson, et al., *Transit Noise and Vibration Impact Assessment*, Report No. FTA-VA-90-1003-06, Federal Transit Administration, Washington, DC, 2006.

Category	Tasks
Timing and Duration of Measurements	☐ Determine descriptor for data collection, if other than $L_{eq.}$ ☐ Determine appropriate sampling period for data collection. ☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration of the vibration measurements. Consult with SHA.
Permissions	☐ Submit preliminary list of all potential addresses and locations for vibration measurements to SHA. ☐ Contact owners/tenants 1-2 weeks ahead of data collection effort seeking permission for property access.
Measurement Plan approval	☐ Submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare Field Data Sheets. ☐ Prepare copies of mapping for note taking in the field (prior to field review). ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Existing Vibration Levels (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Adjust settings for instrumentation to the expected field use. ☐ Test the instrumentation that will be used for data collection.
Documentation	☐ Prepare adequate number of copies of Field Data Sheets.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Existing Vibration Levels (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Identify any vibration sources at each site (i.e., highway vehicles, railway vehicles, construction equipment, other machinery). ☐ Select preferred placement of sensor, relative to nearby receptors and vibration sources. ☐ Identify type of ground and appropriate mounting for sensor (i.e., soil/groundstake, pavement/plate and epoxy).
Site Appropriateness	☐ Determine if there are any localized, non-representative vibration sources that interfere with the data collection. ☐ Move to alternative vibration measurement location if needed.
Instrumentation Setup	☐ Mount sensor to ground using appropriate method. ☐ Attach sensor to data recorder. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Set the time on the instrumentation. ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ***Tip:*** *Power or current supply settings for geophones and accelerometers may be different from standard microphones.* ***Tip:*** *Accelerometers must have their signal integrated to vibration velocity. Check that the data recorder can do this, or indicate that it will be on during data processing.* ☐ Verify that the signals from sensor are operating.
Documentation	☐ Fill out general information on the Field Data Sheet (date, measurement site name, identifying information, observer name). ***Tip:*** *All boxes on Field Data Sheet should be completed by the end of the measurement.* ☐ Obtain vibration measurement location coordinates using a GPS device or cell phone app. ☐ Create site sketch on Field Data Sheet showing vibration measurement location and any identifying structures, roadways and vibration sources. ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the sensor location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting dominant vibration sources.

Category	Tasks
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Keep minute by minute notes of observed vibration levels and sources. ☐ Note the typical levels for predominant vibration sources (man-made and natural sources). ☐ Take traffic counts for nearby roadways contributing to vibration level (if needed). ☐ End data collection. ☐ Save or store the data to the instrument's memory if that is not automatically done. ☐ Note the data file name or number on the Field Data Sheet.
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Existing Vibration Levels Measurement Pack List

Instrumentation	☐ Vibration Sensor(s) (geophone or accelerometer) ☐ Vibration digital signal recorder ☐ Vibration calibrator (shaker) ☐ Museum wax, earthquake gel, or epoxy to mount sensor ☐ Ground stake(s) (for mounting transducer in soil) ☐ Plate or block (for mounting transducer on hard surface) ☐ Integrating sound level meter(s) ☐ Sound level meter calibrator ☐ Tripod(s) (include at least one spare) ☐ Vehicle speed detection unit (laser or radar gun), if needed ☐ Vehicle count boards, if needed ☐ Camera ☐ Video camera ☐ Anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Ground tarp
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for all instrumentation and equipment) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Determination of Existing Vibration Levels—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	
Date	

Vibration System Information

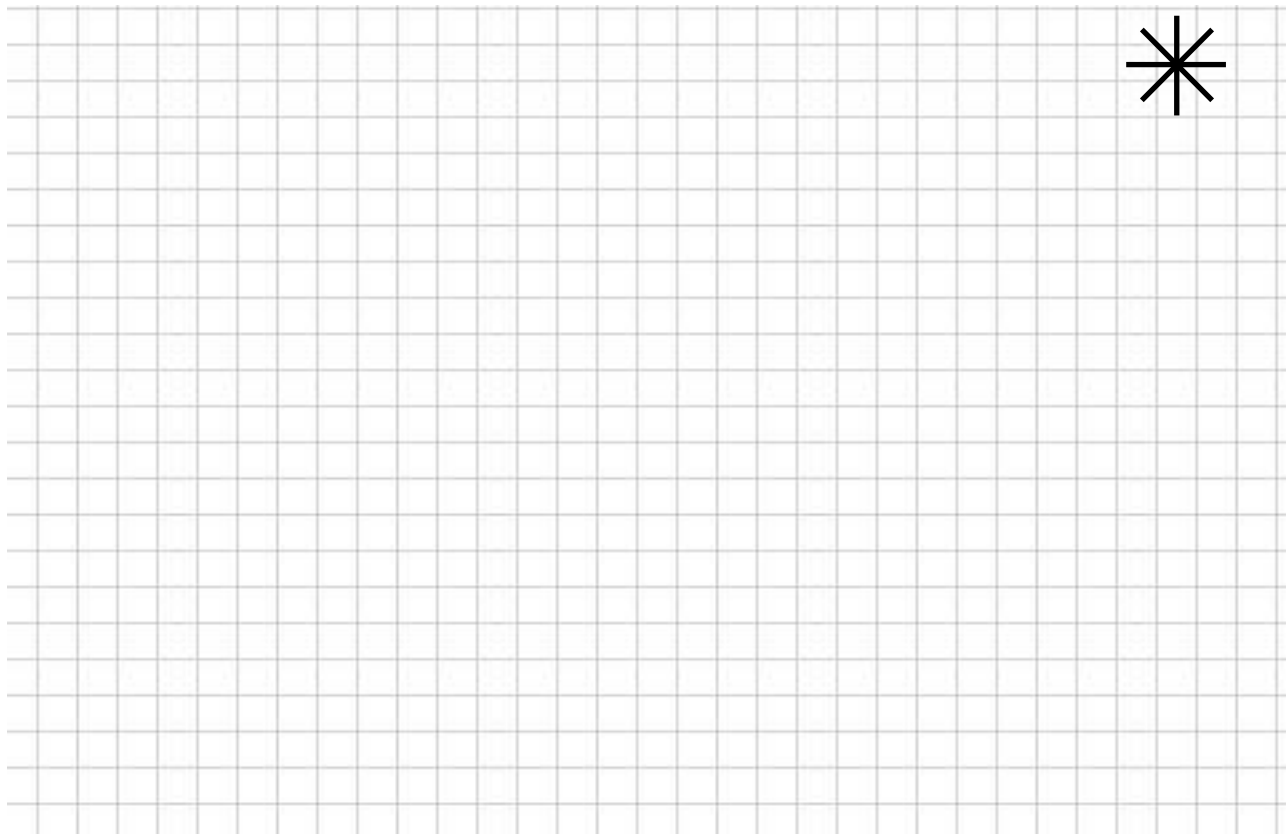
Data Recorder Type		Sensor Channel	
Data Recorder Model		Sensor Type	
Data Recorder ID/SN		Sensor Model	
Verified signals? (circle)	yes / no	Sensor ID/SN	
		Sensor Mounting	

Data Collection

Description	Data File Name/Number	Start Time	End Time/Duration

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Determination of Existing Vibration Levels—Field Log

Period #	Period Start Time	Event Description(s) (include event start and stop)
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Notes:

Date_____ Page ____ of _____

Site_____

Existing Vibration—Traffic Speed Data Sheet

Roadway:	Roadway:
Direction:	Direction:

	↓	↓	↓	↓	↓	↑	↑	↑	↑	↑
Lane number:										
Distance to lane:										

Log #	Time	Speed	Vehicle type	Lane #	Log #	Time	Speed	Vehicle type	Lane #

Notes:

Date_____ Page ____ of _____

Site_____

Existing Vibration—Traffic Count Data Sheet

Roadway:	Roadway:
Direction:	Direction:

Time Start	Auto	MT	HT	Bus	MC	Auto	MT	HT	Bus	MC

Notes:

6.0 Construction Equipment Noise and Vibration Measurements

This section describes field measurement of construction equipment noise and vibration. The purpose of this measurement is to establish construction equipment noise and vibration levels to help predict construction operational impacts or to determine compliance with local ordinances, other regulations, or construction contract specifications or special provisions. The field guidance below includes pre-trip planning, pre-trip preparation, and on-site set-up, data collection, documentation, and storage.

Construction Noise and Vibration Levels (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions _____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members
Site Selection	☐ Determine equipment for which measurements will be needed. ☐ Determine the mode of operation that each piece of equipment will be used in. ☐ Select primary measurement locations based on equipment location and mode of operation. o Flat open space with no reflecting surfaces within 100 ft (30.5 m). o The ground surface within the measurement area acoustically representative of hard or soft surfaces, and free of snow. o Line of site from microphones unobscured for 150°. o Background level 10 dB below lowest anticipated equipment operation levels. o Located away from other noise/vibration sources. ***Tip:*** *Consider access to the site.* ☐ Identify secondary or alternative vibration measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ☐ Conduct field reconnaissance to review measurement sites, if possible.

Category	Tasks
Sensor Placement	☐ Stationary Noise, Active and Passive o Microphones 50 ft (15.2 m) from equipment. o Microphone 5 ft (1.5 m) high. o 4 positions separated by 90°. ☐ Mobile Noise, Active and Passive o Microphone 5 ft (1.5 m) high. o Microphone 50 ft (15.2 m) from center of travel of equipment. o 1 position to measure right-to-left and left-to-right operation. ☐ Stationary Vibration (if needed) o 1 position 50 ft (15.2 m) from equipment ☐ Mobile Vibration (if needed) o 1 position 50 ft (15.2 m) from equipment ***Tip:*** *Vibration is typically measured on the ground directly below the microphone for the same type of measurement.*
Timing and Duration of Measurements	☐ Determine descriptor for data collection, depending on mode of operation o Stationary operation 30-second L_{eq}. o Mobile operation L_{max}. ☐ Determine appropriate sampling period for data collection. ☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration of the vibration measurements.
Permissions	☐ Arrange measurement and operation of equipment with relevant parties (site owner, foreman, etc.).
Measurement Plan approval	☐ Submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare Field Data Sheets. ☐ Prepare copies of mapping for note taking in the field (prior to field review, if applicable). ☐ Prepare equipment pack list. ☐ Prepare contact list that includes relevant parties.

Construction Noise and Vibration Levels (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Adjust settings for instrumentation to the expected field use. ☐ Test the instrumentation that will be used for data collection.
Documentation	☐ Prepare adequate number of copies of Field Data Sheets.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project, if applicable. ☐ Make copies of any agreements with construction equipment owner or operator. ☐ Contact local law enforcement the day before the measurements, if required. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Construction Noise and Vibration Levels (On-site)

Category	Tasks
Site Appropriateness	☐ Determine if there are any localized, non-representative noise or vibration sources that interfere with the data collection. ☐ Move to alternative measurement location if needed. ☐ Verify that equipment can be operated in the desired mode.
Instrumentation Setup	☐ Attach sensor (microphone, geophone, or accelerometer) to data recorder ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, set the time on the instrumentation. ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Deploy microphone to appropriate position, depending on mode of operation. Verify that background levels are sufficiently low (10 dB below lowest expected levels of equipment).
Documentation	☐ Fill out general information on the Field Data Sheet (date, measurement site name, identifying information, observer name) ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app ☐ Note weather conditions on Field Data Sheet o Temperature o Cloud cover o Wind speed o Wind direction ☐ Create site sketch on Field Data Sheet showing noise measurement location and any identifying structures, roadways and noise sources ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the sensor locations (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting dominant noise sources.

Category	Tasks
Data Collection	☐ Without construction equipment operating, begin background noise and vibration data collection. Sample at least 10 seconds, longer if the levels are fluctuating. ☐ End background level data collection and document. ☐ Begin operating construction equipment in appropriate mode. ☐ Begin data collection. ☐ Note start time of data collection. ☐ Note any changes weather conditions during the data collection. ☐ End data collection. ☐ Save or store the data to the instrument's memory if that is not automatically done. ☐ Note the data file name or number on the Field Data Sheet. ☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Field Data Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Construction Noise and Vibrations Levels Measurement Pack List

Instrumentation	☐ Vibration sensor(s) (geophone or accelerometer) ☐ Vibration digital signal recorder ☐ Vibration calibrator (shaker) ☐ Museum wax, earthquake gel, or epoxy to mount sensor ☐ Ground stake(s) (for mounting transducer in soil) ☐ Plate or block (for mounting transducer on hard surface) ☐ Sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Sound level meter calibrator ☐ Tripods (include at least one spare) ☐ Windscreens (include at least one spare) ☐ Vehicle count boards ☐ Camera ☐ Video camera ☐ Anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Traffic cones ☐ Ground tarp
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Construction Equipment Noise—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	
Date	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	
Cloud Cover	

Noise System Information

SLM/Analyzer Model		Mic. Model	
SLM/Analyzer ID/SN		Mic. ID/SN	
		Mic. Height (ft)	

Vibration System Information

Data Recorder Type		Sensor Channel	
Data Recorder Model		Sensor Type	
Data Recorder ID/SN		Sensor Model	
Verified signals?	yes / no	Sensor ID/SN	
		Sensor Mounting	

Construction Equipment Information

Type	
Make/Model	
Operation Model (circle)	Stationary / Mobile Active / Passive
Notes	

Data Collection

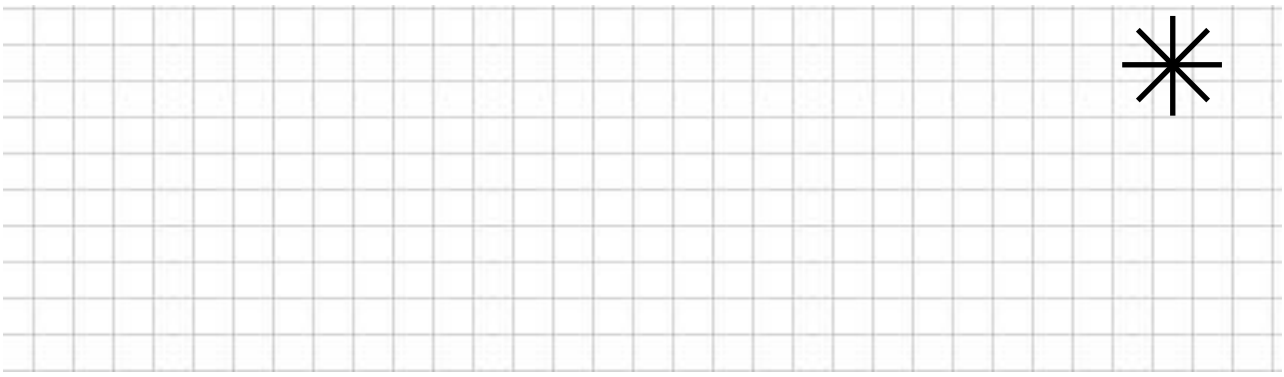
Description	Data File Name/Number	Start Time	End Time/Duration	Level
Pre-Meas. Calibration				
Background				
Measurement 1				
Measurement 2				
Measurement 3				
Measurement 4				
Post-Meas.				

Date_____ Page ____ of _____

Site_____

Site Sketch

(plan/profile view, meas. locations, distances, reflecting surfaces, ground type as appropriate) (Indicate North)



List of general ground types between source and receiver: dirt road, field grass, gravel, lawn, pavement, soil (hard), soil (loose), snow (powder), water

Measurement 1 Parameters and Notes

Distance to Source (ft)	Observations and Notes
Distance to Reflective Surface	
Predominant Ground Type	

Measurement 2 Parameters and Notes

Distance to Source (ft)	Observations and Notes
Distance to Reflective Surface	
Predominant Ground Type	

Measurement 3 Parameters and Notes

Distance to Source (ft)	Observations and Notes
Distance to Reflective Surface	
Predominant Ground Type	

Measurement 4 Parameters and Notes

Distance to Source (ft)	Observations and Notes
Distance to Reflective Surface	
Predominant Ground Type	

7.0 Noise Barrier Insertion Loss Measurements

This section outlines the field measurement procedures for the measurement of noise barrier insertion loss (IL). IL is the difference in sound level at a receptor location with and without the presence of a noise barrier, assuming no change in the sound level of the source. The following project types could use noise barrier IL measurement procedures:

- Post-installation evaluation of the effectiveness of a Type I highway project noise barrier.
- Pre-installation and post-installation evaluation of the effectiveness of a Type II noise barrier.
- Evaluation of the effectiveness of construction site noise barriers, including barriers for stationary pieces of equipment (with appropriate procedure modifications).
- Evaluation of noise barrier effectiveness for highway facilities such as rest areas or truck weigh stations (with appropriate procedure modifications).

Noise Barrier Insertion Loss Measurements (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Determine candidate sites for measurements. ☐ Determine approximate number of measurement locations for each site. ☐ Obtain elevation or contour mapping for the candidate sites. ☐ Select primary noise measurement locations. ***Tip:*** *Avoid choosing locations with any permanent, localized, noise sources (pump houses, generators, HVAC or ventilation fans) that would interfere with measurement of the roadway noise source.* ***Tip:*** *Consider difficulty in access to the site while choosing locations.* ☐ Identify secondary or alternative noise measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ***Tip:*** *Be mindful that localized noise sources that interfere with data collection at a primary noise measurement location may influence levels for adjacent properties. Choose secondary locations that are at least one residence or land use away from the primary noise measurement location.* ☐ Evaluate geometric conditions for site equivalency (if the Indirect Measured method is used. ☐ Identify primary and secondary locations for collecting traffic counts. ☐ Identify primary and secondary locations for collecting speed data.
Field review	☐ Visit each planned measurement site to confirm access. ☐ Observe local noise environment and evaluate if there are any potential noise sources that might interfere with data collection. ☐ Locate reference and study microphone locations. ☐ Use elevation and contour mapping and field observations to estimate height above ground for reference microphone. ☐ Confirm access path to the barrier location.
Noise Descriptors	☐ Use L_{eq} as primary measurement descriptor. ☐ Consider collecting other descriptors that may help evaluate the measured noise during post processing (L_{max}, L_{min}, L_{10}, L_{90}).

Category	Tasks
Sampling Period	☐ Determine appropriate sampling period for data collection. 1 minute, repeating intervals is suggested.
Timing and Duration of Measurements	☐ Determine appropriate time (peak hours or off-peak hours, day or night) and required duration of the noise measurements based on SHA requirements.
Permissions	☐ Submit preliminary list of all potential addresses and locations for noise measurements to SHA. ☐ Contact owners 1-2 weeks ahead of data collection effort seeking permission for property access.
Measurement Plan approval	☐ Submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare adequate number of copies of data sheets. ☐ Prepare copies of mapping for note taking in the field. ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Noise Barrier Insertion Loss Measurements (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Test the instrumentation that will be used for data collection, adjusting settings as needed.
Permissions	☐ Make copies of permission letter from SHA authorizing your work for the project. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Noise Barrier Insertion Loss Measurements (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Visit each planned measurement site to confirm access and observe local conditions. ☐ Confirm site equivalency for the Indirect Measured method, if necessary. ☐ Visit each traffic count location to confirm there is an unobstructed view of traffic. ☐ Visit each speed data collection location and test laser/radar gun to ensure locations provide adequate site lines for speed data collection.
Site Appropriateness	☐ Determine if there are any localized, non-representative noise sources that interfere with the data collection. ☐ Move to alternative noise measurement location if needed.
Instrumentation Setup	☐ Attach pre-amp and microphone (with microphone extension, if needed) to sound level meter. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, set and synchronize the time on all instrumentation (sound level meters, traffic counters, meteorological instrumentation, video cameras, cameras, watches). ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Deploy reference microphone(s). ☐ Set microphone height at 5 ft (1.5 m) above the ground for study microphone locations. ***Tip:*** *Make sure the tripod is level and secure. Weigh the tripod down if there is a slope or if breezy wind conditions are expected.* ☐ Position speed detection instrumentation and staff at speed data collection station. ☐ Position traffic counting instrumentation and staff (or video camera) at the vehicle count station location. ☐ Deploy meteorological instrumentation.
Documentation	☐ Fill out general information on the Measurement Summary Sheet (date, measurement site name, identifying information, observer name). ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app. ☐ Note weather conditions on Measurement Summary Sheet o Temperature

Category	Tasks
	○ Cloud cover ○ Wind speed ○ Wind direction ☐ Create site sketch on Measurement Summary Sheet showing noise measurement location and any identifying structures, roadways and noise sources. ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the microphone location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting dominant noise sources.
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Keep minute by minute notes of observed sound levels and sources. ☐ Note the typical levels for predominant noise sources (man-made and natural sources). ☐ Note any changes in sound levels or weather conditions during the data collection. ☐ Take notes on meteorological conditions every 15 minutes using the Meteorological Observations Sheet ☐ Take traffic counts for roadways contributing to noise level. ☐ End data collection. ☐ Save or store the data to the instrument's memory if that is not automatically done. ☐ Note the data file name or number on the Measurement Summary Sheet. ☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Measurement Summary Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method

Noise Barrier Insertion Loss Measurements Pack List

Category	Tasks
Instrumentation	☐ Sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Calibrator ☐ Meteorological station(s) ☐ Tripods for sound level meters, speed detection station and traffic video station (include at least one spare) ☐ Extension poles or telescoping tall tripod for elevating reference microphone above noise barrier ☐ Windscreens (include at least one spare) ☐ Vehicle speed detection unit (laser or radar gun) ☐ Vehicle count boards ☐ Camera ☐ Video camera ☐ Audio recorder(s) (if needed) ☐ Meteorological station ☐ Handheld anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Ladder (if access to top of barrier is needed for a reference microphone) ☐ Traffic cones ☐ Ground tarp(s) ☐ Guy-wires ☐ Stakes (to anchor guy wires for mast/pole assembly or meteorological station ☐ Camp chair(s)

Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for sound level meters, speed detection instrumentation, count boards and camera(s)) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Highway Barrier Insertion Loss—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	

SLM/Analyzer Information

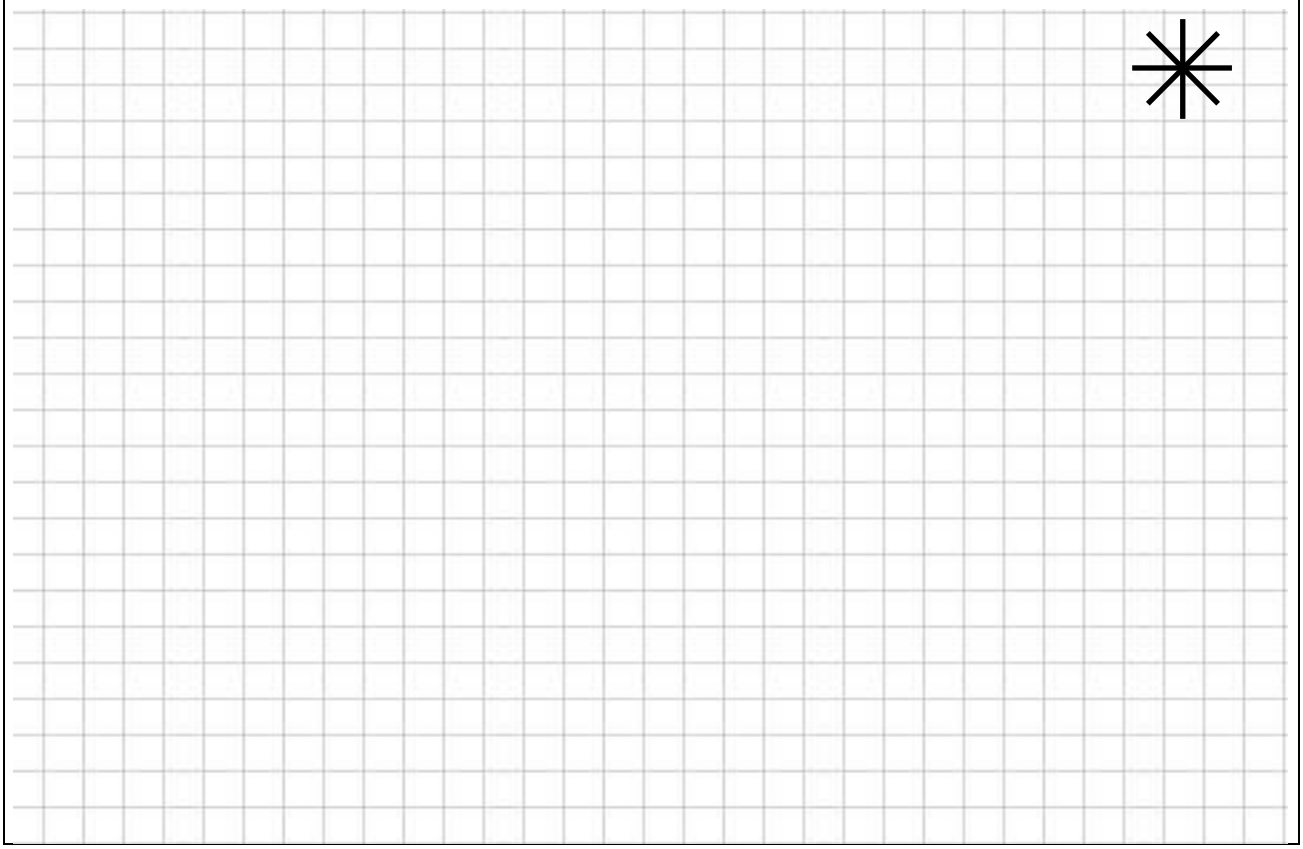
SLM Model		SLM Serial #	
Mic. Height		Mic. Serial #	
Mic. Extension?		Data File Name/Number	

Calibration Information

	Pre-Measurement	Post-Measurement
Calibration Time		
Calibration Level		

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Highway Barrier Insertion Loss—Meteorological Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

Meteorological Instrumentation Information

Serial #		Serial #	
Height (circle one)	5 ft / 15 ft	Height (circle one)	5 ft / 15 ft
Data File Name/Number		Data File Name/Number	

Site Sketch

(plan/profile view, distances, roadways, buildings) (Indicate North)

Notes:

Date_____ Page ____ of _____

Site_____

Highway Barrier Insertion Loss—Meteorological Observations Sheet

Project Name	
Site/Address	
Observer Name	

Meteorological Observations

Hour	Minute	Wind Direction	Wind Condition (C=calm; LB= light breeze; G=gusty; MW= moderately windy; VW=very windy)	Cloud Cover Class
	:00			
	:15			
	:30			
	:45			
	:00			
	:15			
	:30			
	:45			
	:00			
	:15			
	:30			
	:45			
	:00			
	:15			
	:30			
	:45			
	:00			
	:15			
	:30			
	:45			

Notes:

Cloud Cover Class Descriptions

Cloud Class	Description
1	Heavily overcast
2	Lightly overcast (with continuous sun or the sun obscured intermittently by clouds 20 to 80% of time
3	Sunny (sun essentially unobscured by clouds at least 80% of the time)
4	Clear night (less than 50% cloud cover)
5	Overcast night (50% or more cloud cover)

Date_____ Page ____ of _____

Site_____

Noise Barrier Insertion Loss—Field Log

Period #	Period Start Time	Event Description(s) (include event start and stop)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		

Notes:

Date_____ Page ____ of _____

Site_____

Noise Barrier Insertion Loss—Field Log

Period #	Period Start	Event Description(s) (include event start and stop)
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
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52		
53		
54		
55		
56		
57		
58		
59		
60		

Notes:

Date_____ Page ____ of _____

Site_____

Noise Barrier Insertion Loss—Traffic Speed Data Sheet

Roadway:	Roadway:
Direction:	Direction:

	↓	↓	↓	↓	↓	↑	↑	↑	↑	↑
Lane number:										
Distance to lane:										

Log #	Time	Speed	Vehicle type	Lane #	Log #	Time	Speed	Vehicle type	Lane #

Notes:

Date_____ Page ____ of _____

Site_____

Noise Barrier Insertion Loss—Traffic Count Data Sheet

Roadway:	Roadway:
Direction:	Direction:

Time Start	Auto	MT	HT	Bus	MC	Auto	MT	HT	Bus	MC

Notes:

8.0 Vehicle Noise Emission Level Measurements

This section outlines the field measurement procedures for vehicle noise emission levels. These procedures should not be used in the determination of existing sound levels or model validation as part of a traffic noise study done under 23 CFR 772. Instead, use these specialized procedures to accomplish the following:

- Characterize the sound generated by vehicles traveling on different pavement types as part of a research study.
- Create user-defined vehicles for input into the FHWA TNM, which is used to predict sound levels from traffic and to design traffic noise barriers

Vehicle Noise Emission Level Measurements (Pre-trip Planning)

Category	Tasks
Personnel	☐ Identify the personnel that will work on each task: ☐ Measurement Planning_____ ☐ Permissions_____ ☐ Field Work_____ ☐ Data Review_____ ☐ Brief team members.
Site Selection	☐ Determine approximate number of measurement sites. ☐ Select primary noise measurement locations. ***Tip:*** *Avoid choosing locations with any permanent, localized, noise sources (pump houses, generators, HVAC or ventilation fans) that would interfere with measurement of the roadway noise source.* ***Tip:*** *Consider difficulty in access to the site while choosing locations.* ☐ Identify secondary or alternative noise measurement locations in the event that local conditions prevent data collection at a primary noise measurement location. ***Tip:*** *Be mindful that localized noise sources that interfere with data collection at a primary noise measurement location may influence levels for adjacent properties. Choose secondary locations that are at least one residence or land use away from the primary noise measurement location.* ☐ Identify primary and secondary locations for the vehicle observer and speed data collection.
Field review	☐ Visit each planned measurement site to confirm access. ☐ Locate and identify the minimum vehicle separation distances in the field. ☐ Observe local noise environment and evaluate if there are any potential noise sources that might interfere with data collection.
Noise Descriptors	☐ Use $L_{eq\ and}$ L_{AFmax} as primary measurement descriptors with fast response exponential time averaging.
Sampling Period	☐ Determine appropriate sampling period for data collection. Continuous or repeating 1 second intervals suggested.
Timing and Duration of Measurements	☐ Determine appropriate time (peak hours or off-peak hours, day or night).
Permissions	☐ Submit preliminary list of all locations for noise measurements to SHA. ☐ Contact any property owners 1-2 weeks ahead of data collection effort seeking permission for property access.

Category	Tasks
Measurement Plan approval	☐ Submit a detailed measurement plan to SHA (if required).
Documentation	☐ Prepare adequate number of copies of data sheets. ☐ Prepare copies of mapping for note taking in the field. ☐ Prepare equipment pack list. ☐ Prepare contact list that includes SHA contact and local law enforcement.

Vehicle Noise Emission Level Measurements (Pre-trip Preparation)

Category	Tasks
Instrumentation	☐ Assemble instrumentation, accessories and supplies according to the pack list for this measurement technique. ☐ Test the instrumentation that will be used for data collection, adjusting settings as needed.
Permissions	☐ Make copies of permission letter from SHA authorizing personnel to be on right-of-way. ☐ Contact local law enforcement the day before the measurements. ***Tip:*** *Describe planned locations, time(s) of day, vehicle make and model*

Vehicle Noise Emission Level Measurements (On-site)

Category	Tasks
Field review (if not conducted during pre-trip planning)	☐ Visit each planned measurement site to confirm access and observe local conditions. ☐ Visit each vehicle observation and speed data collection location and test radar gun at the location.
Site Appropriateness	☐ Determine if there are any localized, non-representative noise sources that interfere with the data collection. ☐ Move to alternative noise measurement location if needed.

Category	Tasks
Instrumentation Setup	☐ Attach pre-amp and microphone (with microphone extension, if needed) to sound level meter. ☐ Turn on instrumentation and allow equipment to acclimate to outside conditions for several minutes. ☐ Check and, if needed, reset and synchronize the time on all instrumentation (sound level meters, traffic counters, video cameras, cameras, watches). ☐ Check battery power level. ☐ Check that instrumentation settings are correct. ☐ Calibrate instrument before starting data collection (note initial calibration level and time on Field Data Sheet). ☐ Set microphone height at 5 ft (1.5 m) above the roadway surface. ***Tip:*** *Make sure the tripod is level and secure. Weigh the tripod down if there is a slope or if breezy wind conditions are expected.* ☐ Setup traffic cones upstream and downstream from microphone position to indicate minimum separation distance. ☐ Position speed detection instrumentation and staff at speed data collection station. ***Tip:*** *Conduct a "dry run" of data collection and communication procedure after instrumentation is setup.* ☐ Setup meteorological station, if needed.
Documentation	☐ Fill out general information on the Measurement Summary Sheet (date, measurement site name, identifying information, observer name). ☐ Obtain noise measurement location coordinates using a GPS device or cell phone app. ☐ Note weather conditions on Field Data Sheet o Temperature o Cloud cover o Wind speed o Wind direction ☐ Create site sketch on Measurement Summary Sheet showing noise measurement location and any identifying structures, roadways and noise sources. ***Tip:*** *Sketch should be of sufficient detail that another person to return to the site and set up at the same spot* ☐ Take photographs of the microphone location (with instrumentation in place) from multiple directions. ☐ Take photographs and/or video documenting background noise sources.

Category	Tasks
Data Collection	☐ Begin data collection. ☐ Note start time of data collection. ☐ Note the background level when no traffic is audible. ☐ Keep detailed notes for each potential pass-by event. ☐ Indicate the quality of each pass-by event based on the rise and fall above the background level. ☐ Note any changes in background sound levels or weather conditions during the data collection. ☐ Obtain the recommended minimum number of samples for each speed range, if possible. ☐ Save or store the data to the instrument's memory if that is not automatically done. ☐ Note the data file name or number on the Field Data Sheet. ☐ Perform a post-measurement calibration or calibration check before moving or shutting off the instrumentation (note post-measurement calibration level and time on Measurement Summary Sheet).
Data Storage	☐ Download data files from instrumentation before leaving site. ☐ Create PDFs of all data sheets at the end of the day using phone camera to PDF app. ☐ Download photos from camera or cell phone. ☐ Back-up all data files and photos to thumb drive or external drive or email all files as an alternative backup method.

Vehicle Noise Emissions Level Measurements Pack List

Instrumentation	☐ Integrating one third octave band sound level meters (include a spare if possible) ☐ Microphone extensions (if needed) ☐ Microphone mounts (if needed) ☐ Calibrator ☐ Tripods for sound level meters, speed detection station and traffic video station (if needed). Include at least one spare tripod. ☐ Windscreens (include at least one spare) ☐ Vehicle speed detection unit (laser or radar gun) ☐ Vehicle count boards ☐ Camera ☐ Video camera ☐ Meteorological station or hand-held anemometer ☐ Compass
Equipment	☐ Laptop ☐ Data storage (USB flash drives or SD cards, if needed) ☐ Clipboards ☐ Cell phone ☐ Radios ☐ Digital watches (one for each field team member) ☐ Headlamps/flashlights ☐ Pocket knife/utility tool ☐ Tape measure ☐ Safety vests ☐ Hardhats ☐ Traffic cones ☐ Ground tarp(s) ☐ Camp chair(s)
Field Supplies	☐ Data sheets ☐ Mapping ☐ Contact list ☐ Notepads ☐ Batteries (including spares for sound level meters, speed detection instrumentation and camera(s)) ☐ Pens ☐ Duct tape ☐ Zip ties

Date_____ Page ____ of _____

Site_____

Vehicle Noise Emission Level Measurements—Measurement Summary Sheet

Project Name	
Site/Address	
Observer Name	

General Meteorological Conditions

Temperature(s)	
Wind Speed(s)	
Wind Direction(s)	

SLM/Analyzer Information

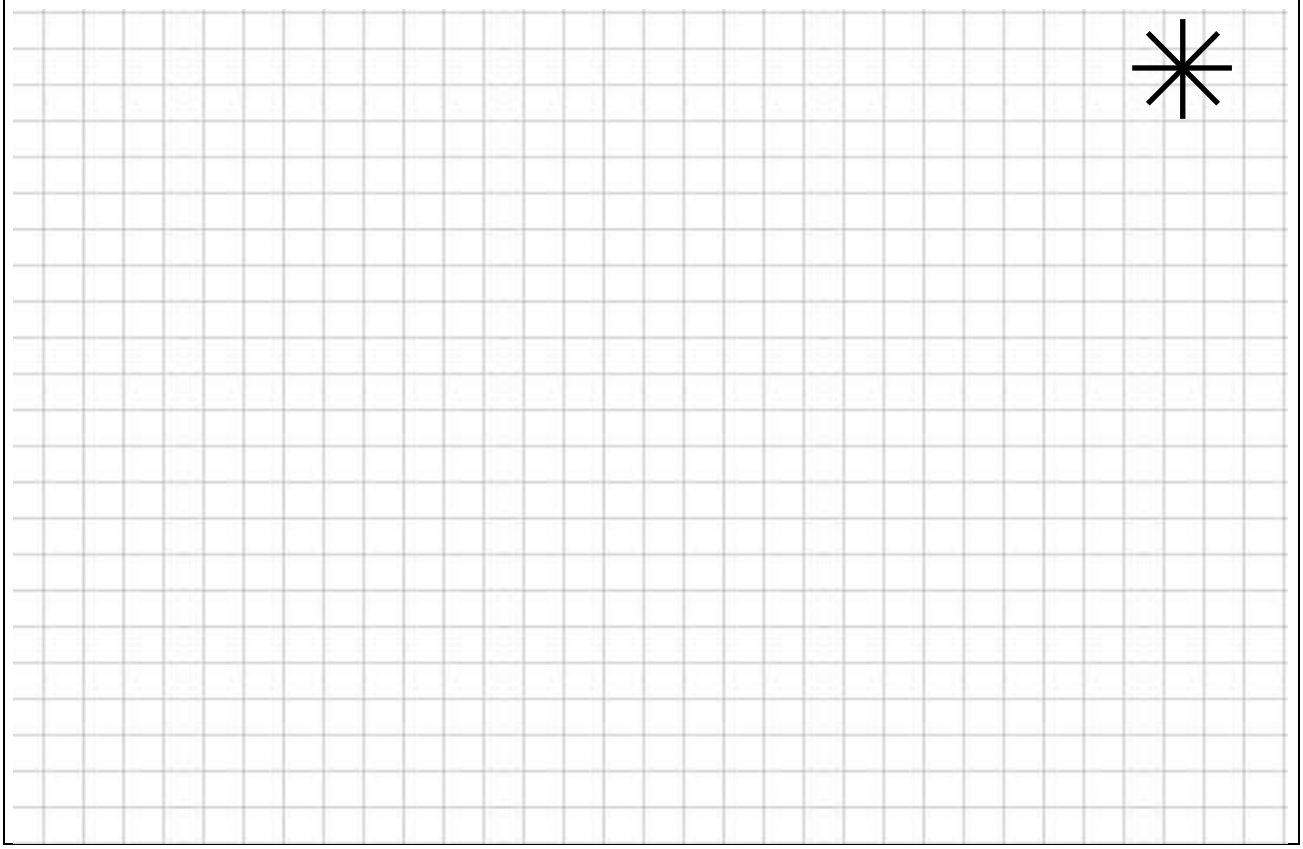
SLM Model		SLM Serial #	
Mic. Height		Mic. Serial #	
Mic. Extension?		Data File Name/Number	

Calibration Information

	Pre-Measurement	Post-Measurement
Calibration Time		
Calibration Level		

Site Sketch

(plan/profile view, distances, roadways, buildings, reflecting surfaces, ground type as appropriate) (Indicate North)



Date_____ Page ____ of _____

Site_____

Vehicle Noise Emission Level Measurements—Data Log Sheet

Project Name	
Location	
Observer Name	

Log #	Start Time	End Time	Vehicle Type	L_{AFmax}	Event Quality *Rise and fall of <6dB=0; 6-10 dB=1;>10 dB = 2*	Comment (include vehicle make, model and color)

Notes:

Date_____ Page ____ of _____

Site_____

Vehicle Noise Emission Level Measurements—Speed Data Log Sheet

Project Name	
Location	
Observer Name	

Log #	Time	Vehicle type	Speed	Comment (include vehicle make, model and color)

Notes:

9.0 Determining the Influence of Pavement on Tire-Pavement Noise

The purpose of this measurement is to determine the influence of pavement on tire-pavement noise. Applications include:

- Help to validate FHWA TNM (if model is not validating well, pavement may be the cause).
- Gain understanding of influence of pavement on a project.
- Allow mapping of noise levels along roadways.
- Allow for pavement ranking (loudest to quietest).
- Help to establish longevity of noise reducing benefits of pavement.
- Help to choose measurement sites for pavement influence wayside methods (e.g., SPB, SIP, CTIM, etc.)

There are two standardized methods of directly measuring tire-pavement noise source levels:

- ISO 11819-1, Acoustics—Measurement of influence of road surfaces on traffic noise—Part 2: The close-proximity [CPX] method.
- AASHTO T360-6 Standard Method of Test for Measurement of Tire/Pavement Noise Using the OBSI Method. (Related, SAE J2920 Measurement of Tire/Pavement Noise Using Sound Intensity, based on the OBSI method, is currently being developed and is focused on characterizing tires rather than pavements).

These procedures isolate tire noise generation from other sources of the exterior vehicle noise. They use a vehicle or vehicle with trailer to collect data on in-service highway lanes or test roadways, which allows for acquisition of data at any desired location along a roadway, or any travel lane, assuming all method criteria are met.

Specifics on the procedures for CPX and OBSI can be found in documentation for those methods. Here is a review of the key steps in conducting associated measurements:

- Pre-trip planning.
  - Screen for possible study areas and measurement sites using online or other resources.
  - If possible, conduct site visit to confirm measurement locations.
  - Write test plan, including personnel duties (recommended minimum of 2 people), schedule, and data collection procedures.
  - Prepare equipment list.
  - Make travel arrangements, if applicable.
- Pre-trip preparation.
  - Assemble and test instrumentation/equipment.
  - Pack/ship equipment, if applicable.
- On-site set-up.
  - Deploy stationary instrumentation/equipment, as appropriate (may include markers alongside road for start of test sections).
  - Prepare vehicle/trailer for testing.

  - Complete appropriate portions of field data sheets (would include site information, calibration of systems, tire parameters, etc.).
- Data collection.
  - Deploy vehicle/trailer and collect data at appropriate locations.
  - Complete data collection portions of field data sheets.
- Documentation and storage.
  - Finalize field data sheets with any remaining information.
  - Backup all electronic files.
  - Note any equipment difficulties or failures and tag equipment as appropriate.

10.0 Determining the Influence of Pavement on Highway Vehicle Noise

The purpose of this measurement is to determine the influence of pavement on highway vehicle noise. Applications include:

- Help to validate FHWA TNM (if model is not validating well, pavement may be the cause).
- Gain understanding of influence of pavement on a project.
- Allow for pavement ranking (loudest to quietest).
- Help to establish longevity of noise reducing benefits of pavement.

There are multiple standardized methods of measuring highway vehicle noise in relation to pavements, each involving measurement of single vehicle pass-by events, either isolated in existing traffic or controlled. The methods include:

- ISO 11819-1, Acoustics—Measurement of influence of road surfaces on traffic noise—Part 1: Statistical pass-by (SPB) method. Related, ISO-11819-4 is the same as SPB but with a backing board placed behind the microphone.
- AASHTO TP 98 (this number designation may change when it becomes a full specification) Standard method of test for determining the influence of road surfaces on vehicle noise using the statistical isolated pass-by (SIP) method.
- SAE J2805_201511 Measurement of noise emitted by accelerating road vehicles (same as ISO 362-1:2015).
- These are pass-by methods that focus on tire-pavement noise: SAE J57_201405 Sound level of highway truck tires, ISO 13325:2003 Coast-by methods for measurement of tyre-to-road sound emission.

These procedures measure noise on the side of the road as vehicles drive by passing over the pavement of interest.

Specifics on the procedures can be found in documentation for the various methods. Here is a review of the key steps in conducting associated measurements:

- Pre-trip planning.
  - Screen for possible study areas and measurement sites using online or other resources.
  - If possible, conduct site visit to confirm measurement locations.
  - Write test plan, including personnel duties (recommended minimum of 2 people), schedule, and data collection procedures.
  - Obtain site access permissions.
  - Prepare equipment list.
  - Make travel arrangements, if applicable.
- Pre-trip preparation.
  - Assemble and test instrumentation/equipment.
  - Pack/ship equipment, if applicable.

- On-site set-up.
  - Deploy instrumentation/equipment (may include sound measurement systems, meteorological system, speed instrumentation, etc.).
  - Complete appropriate portions of field data sheets (would include site information, calibration of systems, etc.).
- Data collection.
  - Collect data, including vehicle pass-by time, identification, and speed and maximum pass-by sound levels.
  - Complete data collection portions of field data sheets.
- Documentation and storage.
  - Finalize field data sheets with any remaining information.
  - Backup all electronic files.
  - Note any equipment difficulties or failures and tag equipment as appropriate.

11.0 Determining the Influence of Pavement on Highway Traffic Noise

The purpose of this measurement is to determine the influence of pavement on highway traffic noise. Applications include:

- Help to validate FHWA TNM (if model is not validating well, pavement may be the cause).
- Gain understanding of influence of pavement on a project.
- Help with pavement ranking (loudest to quietest).
- Help to establish longevity of noise reducing benefits of pavement.

There are different types of standardized method of measuring highway vehicle noise in relation to pavements. The methods include:

- AASHTO TP 99 (this number designation may change when it becomes a full specification) Standard method of test for determining the influence of road surfaces on traffic noise using the continuous-flow traffic time-integrated method (CTIM).
- ISO 11819-1, Acoustics—Measurement of influence of road surfaces on traffic noise—Part 1: Statistical pass-by (SPB) method. Related, ISO-11819-4 is the same as SPB but with a backing board placed behind the microphone.

CTIM involves measurement of free-flowing highway traffic. The ISO methods, statistical pass-by with and without a backing board, involve measurement of single vehicle pass-by events. These procedures measure noise on the side of the road as vehicles/traffic drive by passing over the pavement of interest.

Specifics on the procedures can be found in documentation for the various methods. Here is a review of the key steps in conducting associated measurements:

- Pre-trip planning.
  - Screen for possible study areas and measurement sites using online or other resources.
  - If possible, conduct site visit to confirm measurement locations.
  - Write test plan, including personnel duties (recommended minimum of 2 people, 3 people being far more efficient), schedule, and data collection procedures.
  - Obtain site access permissions.
  - Prepare equipment list.
  - Make travel arrangements, if applicable.
- Pre-trip preparation.
  - Assemble and test instrumentation/equipment.
  - Pack/ship equipment, if applicable.
- On-site set-up.
  - Deploy instrumentation/equipment (may include sound measurement systems, meteorological system, video camera(s), speed instrumentation, etc.).

  - Complete appropriate portions of field data sheets (would include site information, calibration of systems, etc.).

- Data collection.
  - Collect data
    - includes continuous data collection with potential noise intrusions logged.
    - includes vehicle pass-by time, identification, and speed and maximum pass-by sound levels for single vehicle pass-by events.
  - Complete data collection portions of field data sheets.

- Documentation and storage.
  - Finalize field data sheets with any remaining information.
  - Backup all electronic files.
  - Note any equipment difficulties or failures and tag equipment as appropriate.

12.0 Determining the Influence of Ground or Pavement Surface on Sound Propagation

The purpose of this measurement is to determine the influence of ground or pavement surface on sound propagation. Applications include:

- Help to validate FHWA TNM (if model is not validating well, ground type or pavement type may be the cause).
- Gain understanding of influence of ground/pavement surface on a project.
- Gain understanding of influence of ground/pavement surface on measured emission noise levels.
- Gain understanding of influence of ground type on barrier insertion loss (loss of soft ground effect).
- Gain understanding of influence of ground/pavement surface on sound propagation for the purpose of determining pavement effects.

There are several different types of standardized methods that measure absorption parameters of ground or pavement surfaces. The main types are in-situ methods and laboratory methods. The former methods are done on ground and pavement surfaces found at/near the highway sites of interest; these include:

- ANSI/ASA S1.18, American National Standard Method of Test for Determining the Acoustic Impedance of Ground Surfaces (previously known as Template Method for Ground Impedance). (This method could be used in a laboratory if the sample is large enough and the room has proper acoustical absorption.)
- Loudspeaker intensity method (described in Judith L. Rochat, Paul Donavan, Andrew Seybert, and Tyler Dare, "Pavement sound absorption measurements in the U.S.," Proceedings of Inter-Noise 2012).
- ISO 13472-1, Acoustics—Measurement of sound absorption properties of road surfaces in situ—Part 1: Extended surface method.
- ISO 13472-2, Acoustics—Measurement of sound absorption properties of road surfaces in situ—Part 2: Spot method for reflective surfaces.

The laboratory methods analyze a sample extracted from the field or constructed in a lab; these include:

- ISO 10534-1, Acoustics—Determination of sound absorption coefficient and impedance in impedance tubes—Part 1: Method using standing wave ratio.
- ISO 10534-2, Acoustics—Determination of sound absorption coefficient and impedance in impedance tubes—Part 2: Transfer-function method.
- ASTM E1050, Standard test method for impedance and absorption of acoustical materials using one tube, two microphones, and a digital frequency analysis system.
- ASTM C384, Standard test method for impedance and absorption of acoustical materials by impedance tube method.

- A laboratory method adapted from ANSI S1.18 (described in Judith L. Rochat, Paul Donavan, Andrew Seybert, and Tyler Dare, "Pavement sound absorption measurements in the U.S.," Proceedings of Inter-Noise 2012).

Specifics on the procedures can be found in documentation for the various methods. Here is a review of the key steps in conducting associated measurements:

- Pre-trip planning.
  - Screen for possible study areas and measurement sites using online or other resources. (Alternate for laboratory methods, determine where/how to obtain sample.)
  - If possible, conduct site visit to confirm measurement locations. (Alternate for laboratory methods, obtain sample from field, where applicable).
  - Write test plan, including personnel duties (recommended minimum of 2 people for efficiency), schedule, and data collection procedures. (For laboratory methods, 1 person possible).
  - Obtain site access permissions; note that active highway pavement data collection requires lane closure.
  - Prepare equipment list.
  - Make travel arrangements, if applicable.
- Pre-trip preparation.
  - Assemble and test instrumentation/equipment.
  - Pack/ship equipment, if applicable.
- On-site (in field or in laboratory) set-up.
  - Deploy instrumentation/equipment (may include sound measurement systems, meteorological system, etc.).
  - Complete appropriate portions of data sheets (would include site information for field data collection, calibration of systems, etc.).
- Data collection.
  - Data collection, including received sound levels associated with a sound source.
  - Complete data collection portions of data sheets.
- Documentation and storage.
  - Finalize data sheets with any remaining information.
  - Backup all electronic files.
  - Note any equipment difficulties or failures and tag equipment as appropriate.

13.0 Vehicle Interior Noise Measurements

The purpose of this measurement is to determine the vehicle interior. Applications include:

- Evaluate the effect of road surfaces on interior noise.
- Evaluate the effect of pavement surface modifications, such as rumble strips, on interior noise.

There are two standardized methods for measuring vehicle interior noise:

- SAE J1447 Measurement of interior sound levels of light vehicles.
- ISO 5128:1980, Acoustics—Measurement of noise inside motor vehicles.

These procedures measure noise inside a vehicle with specified microphone locations and operating speeds.

Specifics on the procedures can be found in documentation for the methods. Here is a review of the key steps in conducting associated measurements:

- Pre-trip planning.
  - Screen for possible study areas and measurement sites using online or other resources.
  - If possible, conduct site visit to confirm measurement locations.
  - Write test plan, including personnel duties (recommended minimum of 2 people), schedule, and data collection procedures.
  - Prepare equipment list.
  - Make travel arrangements, if applicable.
- Pre-trip preparation.
  - Assemble and test instrumentation/equipment.
  - Pack/ship equipment, if applicable.
- On-site set-up.
  - Deploy stationary instrumentation/equipment, as appropriate (may include markers alongside road for start of test sections and meteorological instrumentation).
  - Prepare vehicle for testing.
  - Complete appropriate portions of field data sheets (would include site information, calibration of systems, road conditions, etc.).
- Data collection.
  - Deploy vehicle and collect data at appropriate locations.
  - Complete data collection portions of field data sheets.
- Documentation and storage.
  - Finalize field data sheets with any remaining information.
  - Backup all electronic files.
  - Note any equipment difficulties or failures and tag equipment as appropriate.