NOISE REVIEW

HOUGHTON ROAD

VALENCIA RD TO MARY ANN CLEVELAND WAY

TUCSON, ARIZONA

Prepared for:

CITY OF TUCSON

Prepared by:

CENSEO
AV+Acoustics

Kailua, Hawaii : 808-726-2999
Denver, Colorado : 303-309-1178
Seattle, Washington : 206-866-9020
Email : info@censeo.design

Jeanette Hesedahl, PE, INCE Bd. Cert.
Senior Project Manager

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1.0 Summary

This noise impact report is evaluating the projected noise impacts from the proposed roadway improvement project for Houghton Road between Valencia Road and Mary Ann Cleveland Way in Tucson, Arizona.

The predicted Future Build noise levels are within the Regional Transportation Authority (RTA) noise limits at all evaluation locations for the project.

Short-term noise impacts may be experienced during the construction of the proposed improvements within the project Study Area. Properties in the vicinity of the project area would be exposed to noise from construction activities.

2.0 Proposed Road Improvement

This project includes a six lane divided roadway, multi-use lanes, median, multi-use paths, and drainage improvements on Houghton Road between Valencia Road and Mary Ann Cleveland Way. The overall study area is shown in Figure 1.

3.0 Noise Regulation

This project is funded by RTA which uses the Pima County Department of Transportation (PCDOT) noise criteria.

Potential negative impact from traffic noise is assessed on the basis of predicted noise levels approaching or exceeding Noise Abatement Criteria (NAC). RTA NAC is described below.

The PCDOT Procedure Number 03-5, entitled "Traffic Noise Analysis and Mitigation Guidance for Major Roadway Projects," dated December 1, 2003, was developed to provide guidance for the development of noise mitigation for Pima County's major roadway projects and adopted by the RTA for all their roadway projects. The procedure, commonly called the Pima County Noise Abatement Procedure (PC NAP), contains methods for noise analysis, criteria for traffic noise abatement, and requirements for noise reports. Effective April 7, 2008, the Pima County "Revision of Traffic Noise Analysis and Mitigation Guidance for Major Road Projects" was implemented to address changes in the cost of noise mitigation measures. This report reflects the updated mitigation costs per benefited receiver and barrier construction cost per square foot.

According to the PC NAP, noise abatement should be considered if noise levels reach 66 dBA or higher at noise-sensitive properties. Additionally, mitigation measures will be considered for noise-sensitive properties if predicted traffic noise levels substantially exceed existing levels. "Substantially exceed" is defined as a 15 dBA increase between the existing noise levels and the future noise levels. The area at noise-sensitive properties from which the noise level is used to determine abatement consideration, is at an out-of-doors location assumed to be most frequented by the residents. For example, the noise levels used in consideration for abatement at a residence would be from a location outside of the house, but near the house. Noise abatement is only considered for the first floor of multi-floor units.

Noise-sensitive properties include single family or multi-family housing units. Each first floor apartment in an apartment complex or duplex is counted as a separate housing unit. Noise-sensitive properties may also include facilities such as picnic areas, recreation areas, playgrounds, active sports areas, parks, schools, churches, libraries, hospitals, places of worship, and cemeteries.

The PC NAP noise limit for traffic noise reaching commercial properties (and other properties not described above) is 71 dBA. At or above which noise abatement should be considered.

The PC NAP contains a provision allowing a noise reduction credit of 3 dBA for the use of Rubberized Asphalt Concrete (RAC). As part of the noise abatement procedure described in the PC NAP, this credit is applied during the mitigation determination process as described below.

The PC NAP provides criteria for use of noise walls for noise abatement mitigation. Where a sound wall is considered all of the following criteria must be met in order to recommend the barrier:

- A reduction of at least 5 dBA must be achieved at noise sensitive receivers
- The barrier must benefit two or more adjacent receivers
- The cost of the barrier will not exceed $35,000 per benefitted receiver (using a cost of $\$25/ft^2$)
- A majority of the property owners must approve the mitigation
- Mitigation is for only the first floor of multi-story residences
- Barriers must be less than 10 feet tall
- No mitigation will be provided for undeveloped properties unless building permit issued prior to the final environmental document

4.0 Noise Model Approach and Assumptions

For this study, the methods for determining the future noise levels and identifying possible mitigation measures to address future noise levels involved the following series of steps:

- Assess the existing and planned land uses (residential, commercial, industrial, etc.) and determination of sensitive noise receivers within the project corridor.
- Assess the existing conditions (including: traffic volumes; vehicle types; vehicle speeds; roadway layout; area topography; existing walls, and; locations of residences relative to the roadway).
- Predict the existing and future build scenario for a reasonable worst case noise condition using the Federal Highway Administration (FHWA) Traffic Noise Model version 2.5 (TNM 2.5).
- Verify the noise model by measuring the existing noise levels at representative noise sensitive receivers.
- Compare the modeled results with the noise abatement criteria established by the RTA. Based on the results of the noise monitoring and modeling, potential noise mitigation was examined. This task included noise barrier modeling for noise mitigation as warranted by the results of the noise analysis. Reasonable and feasible mitigation, based on current RTA Procedures, is then recommended.

4.1 Overview

An assessment of existing and planned land uses (residential, commercial, industrial, etc.) and determination of sensitive noise receivers was undertaken within the project corridor. Aerial photographs and field reconnaissance were used to determine the approximate locations and land use activities of potential sensitive receivers near the roadway. Field measurements were used to determine the existing noise levels throughout the Study Area, as described in Section 5.0, *Noise Model Verification*. Noise levels were measured at five sensitive receiver locations within the project area. The noise measurement locations are representative locations selected to determine the noise impacts along the project.

The TNM 2.5 model was used to predict the noise levels that would occur with the proposed improvements to Houghton Road receiver locations. Roadway geometry and topography, traffic volumes, existing barriers, land features, and the representative sites were entered into TNM 2.5 to replicate the conditions under which the noise level measurements were taken. Modeled noise levels were calculated and compared with the noise levels measured at sensitive receiver locations. This process examines the accuracy of the traffic noise model in performing noise level calculations for this project. Discrepancies in the model's calculations were addressed prior to using it for predicting future noise levels. Traffic volumes and speeds used in the modeling for this project represent "worst case" peak-hour traffic conditions.

Two conditions were modeled using TNM 2.5. Traffic volumes and mix used in the model were based on a traffic counts done by Psomas. Future predictions were based on the Psomas Traffic Study Addendum dated January 17, 2018. The model estimated the peak-hour traffic noise levels for:

- Existing traffic conditions – the model included the current street configuration and 2017 traffic volumes.
- Future build condition – the model included proposed road improvements and future projected 2045 traffic volumes.

Noise levels for the 2045 traffic and improved roadway conditions were compared with the appropriate noise abatement criterion to determine whether traffic noise mitigation should be considered. Generally, the mitigation considerations consist of rubberized asphalt concrete (RAC) and/or noise barriers in the right-of-way (R/W). Although other mitigation considerations are possible, RAC and noise barriers are considered the most cost-effective and accepted technique when they are warranted.

4.2 TNM 2.5 Modeling

The TNM 2.5 model translated the roads in the Study Area into a series of endpoints on a three-dimensional X, Y, and Z coordinate system. This computer model was developed to comply with FHWA noise regulations and is considered the current standard for roadway noise analyses.

The TNM model requires input data regarding the geometry of roadways in the Study Area, vehicle mix, traffic volumes, and vehicle speeds. The following data were used in the models:

- Vehicle Speeds – the modeled traffic speed was 10 mph higher than the posted speed
  - For existing conditions (2017), Houghton Road northbound is 50 mph from Mary Ann Cleveland Way to Valencia Road.
  - For existing conditions (2017), Houghton Road southbound is 45 mph from Valencia Road to Rita Road and 50 mph from Rita Road to Mary Ann Cleveland Way.
  - For future conditions (2045), Houghton Road is 45 mph, northbound and southbound, from Mary Ann Cleveland Way to Valencia Road.
- Traffic Volumes were provided by Psomas, shown in Table 2.
- Vehicle Mix used for the analysis was:
  - 95.8% automobiles
  - 1% Medium Trucks
  - 2.5% Heavy Trucks
  - 0.2% Buses
  - 0.5% Motorcycles
- Elevations – topographic information was used for the roads and receivers. Topographic information was provided by Psomas.
- Ground – "Hard soil" (the ground type was selected in TNM to represent current conditions and to provide predictions that are close to the measurement results)
- Receiver heights – 5 feet above the ground

The proposed roadway and the surrounding arterial streets were defined by a series of roadway segment endpoints. Existing barriers, including residential privacy walls, were included in the model. Receivers were identified as single points and assigned an elevation of 5 feet above the ground to simulate the average height of human hearing. The sound levels were modeled using the A-weighted decibel (dBA), which is the measurement of sound that most closely approximates the sensitivity of the human ear. The noise level results are presented in LAeq1h, the equivalent average sound level measured for 1 hour, approximating the sensitivity of the human ear.

Table 2: Peak Hour Traffic Volumes AM (PM)

Road		Existing Volumes (2017)	Future Volumes (2045)
Houghton Road - Northbound	North of Rita Road	877 (901)	1987 (2042)
Houghton Road - Southbound		842 (1056)	1902 (2427)
Houghton Road - Northbound	South of Rita Road	844 (992)	1838 (2146)
Houghton Road - Southbound		1103 (1042)	2568 (2436)
Rita Road - Eastbound	East of Houghton Road	91 (104)	616 (710)
Rita Road - Westbound		185 (122)	1189 (785)
Rita Road – Eastbound	West of Houghton Road	897 (645)	1154 (833)
Rita Road – Westbound		697 (768)	912 (1003)

The vehicles were classified as automobiles (four wheels), medium trucks (2-axle long, 2-axle 6 tire), heavy trucks (3 to 6-axle vehicles), buses, and motorcycles. Each of these vehicle types generates noise from a different height above the roadway, called the source height.

TNM 2.5 uses the above-described information to calculate the noise contribution from each roadway segment to each receiver and then determine the cumulative effect of all roadway noise sources for each receiver. Validation studies conducted at the Volpe National Transportation Systems Center, a facility of the United States Department of Transportation Research and Innovative Technology Administration, show that the TNM 2.5 model typically predicts noise levels within an acceptable range of accuracy.

4.3 Analysis Limitations

This noise analysis is based on design and traffic information available at the time of the analysis. The following assumptions were made to reach conclusions during the analysis phase:

- The project designs as evaluated in this report will not change.
- Future traffic volumes and vehicle mix will remain consistent with those used for this study analysis.
- The nature of the land use will remain consistent with current use and planned development (i.e., industrial businesses will not be constructed where retail and professional offices are currently planned)
- The area where people are most likely to spend time outside of their homes is in their yards, near their homes.

While the TNM 2.5 model has been calibrated and tested against actual noise measurements for several years, it should be noted that it is still a noise prediction model. The results of this analysis assume the predicting capabilities of TNM are sufficient. Assumptions have been made to simplify the calculations for TNM.

- The receiver (representing human hearing) is 5 feet above ground.
- The angle of view from the receiver to the road is 180 degrees.
- The terrain between the roadway and the receiver is flat.
- The ground type is consistent throughout the project area.

The noise levels used in the predictions are measured as peak hour A-weighted Leq (LAeq1h), described in Appendix C. The A-weighted average that represents the steady level over 1 hour that would produce the same energy as the actual signal. The actual instantaneous noise levels fluctuate above and below the measured Leq during the measurement period (e.g., a police siren, a particularly noisy truck, or unusually high traffic volumes). Therefore, the use of LAeq1h for predicting noise levels and conducting the noise evaluation does not consider the noise levels as they may occur in their full range. The fluctuation of instantaneous noise levels will result in sounds that temporarily exceed (and be below) the Leq noise levels as they have been presented in the noise evaluation.

5.0 Noise Model Verification

Noise measurements are conducted to verify and calibrate the noise model. Noise measurement locations are selected in each representative area with varying traffic conditions, topography, distance from the noise source and obstructions (FHWA "Measurements of Highway Related Noise"). There is no clearly defined number or location of required noise measurements; however, each distinct part of a project should be verified with at least one noise level measurement.

Table 3 shows the measured and predicted noise levels at the five locations. Noise measurements were made on Thursday, June 28, 2018 between 6:30 AM and 12:00 PM. The purpose of the noise level measurements was to document the existing noise level environment in the project area and capture the contribution of traffic noise from Houghton Road.

The equipment used for the noise level measurements was a Larson Davis (LD) Models LxT sound level meter (SLM). The SLM was calibrated in the field before use with an LD Model CAL-200 acoustical calibrator. The SLM used for noise level measurements complies with the American National Standards Institute (ANSI) S1.4-1971 for a Type 1 SLM. The methodology used for the noise level measurements complied with procedures specified in Section 4 of the FHWA document FHWA-PD-96-046/DOT-VNTC-FHWA-96-5, Measurement of Highway-Related Noise (FHWA, 1996).

Noise measurements were made at Locations A to E, as shown in Figure 2. Noise measurement forms are located at the back of this report. The measured and predicted noise levels at these locations is shown in Table 3.

Table 3: June 28, 2018 Noise Measurements and Predictions
Adjacent to Houghton Rd in ROW

Site ID	Location Description	Measured Noise Level (Leq)	Predicted Noise Level
A	West side of Houghton Road, approximately 1500’ north of intersection with Mary Ann Cleveland Way	64	63
B	West side of Houghton Road, Approximately 2600’ north of intersection with Mary Ann Cleveland Way	64	64
C	West side of Houghton Road, Approximately 180’ south of intersection with Jumping Cholla Drive	71	70
D	East side of Houghton Road, Approximately 690’ north of intersection with Rita Road	63	63
E	West side of Houghton Road, Approximately 1440’ north of intersection with Rita Road	67	66

The predicted noise levels are within 1 dBA of the measured noise level. This verifies the accuracy of the noise model.

6.0 Noise Model Predictions Results

Noise levels were evaluated at ten locations in the project area, as shown on Figure 2. Existing concrete block barriers at residential properties, with approximate height of six feet, were assumed for these predictions.

Table 4: Predicted Noise Levels from Houghton Road

Receiver ID	Receiver Location	Predicted Before Project (2017) Hourly Leq (dBA)	Predicted Future (2045) Hourly Leq (dBA)	Noise Limit (dBA)
1	8857 S Desert Rainbow Dr	63	65	66
2	8765 S Desert Rainbow Dr	59	62	66
3	8625 S Desert Rainbow Dr	60	63	66
4	8541 S Camino Bengala	61	63	66
5	8437 S Camino Bengala	61	64	66
6	8349 S Camino Bengala	60	63	66
7	10316 E Danwood Way	59	62	66
8	8118 S Woodfrost Way	58	61	66
9	10286 E Rainbow Meadow Dr	60	63	66
10	10282 E Hummingbird Meadow Way	58	61	66

As shown in Table 4, the predicted future noise levels are below the RTA noise limit at all locations.

For the predictions shown in Table 4, the prediction locations are in the back yard of the residence. For the predictions shown in Table 3, the prediction locations are at the measurement location, which is closer to Houghton and without a barrier

7.0 Construction Noise

Short-term noise impacts may be experienced during the construction of any part of the proposed improvements within the project Study Area. Properties in the vicinity of the project area would be exposed to noise from construction activities.

Construction noise differs from traffic noise in several ways:

- Construction noise lasts only for the duration of the construction contract, with most construction activities in noise-sensitive areas being conducted during hours that are least disturbing to adjacent and nearby residents.
- Construction activities generally are of a short-term nature, and depend on the nature of construction operations.
- Construction noise also is intermittent and depends on the type of operation, location, and function of the equipment, and the equipment usage cycle. Traffic noise, on the other hand, is present in a more continuous fashion after construction activities are completed.

Adjacent properties in the project area would be exposed to noise from construction activity.

Table 6 shows the noise levels produced by various types of construction equipment. The types of construction equipment used for this project will typically generate noise levels of 80 to 90 dBA at a distance of 15 meters (50 feet) while the equipment is operating. Construction equipment operations can vary from intermittent to fairly continuous, with multiple pieces of equipment operating concurrently.

Table 6: Typical Construction Equipment Noise Levels

Type of Equipment	Noise Level in dBA at 50 Feet
Bulldozer	80
Front Loader	72 – 84
Jack Hammer or Rock Drill	81 – 98
Crane with Headache Ball	75 – 87
Backhoe	72 – 93
Scraper and Grader	80 – 93
Electrical Generator	71 – 82
Concrete Pump	81 – 83
Concrete Vibrator	76
Concrete and Dump Trucks	83 – 90
Air Compressor	74 – 87
Pile Drivers (Peaks)	95 – 106
Pneumatic Tools	81 – 98
Roller (Compactor)	73 – 75
Saws	73 – 82
Source: U.S. EPA Noise from Construction Equipment and Operations	

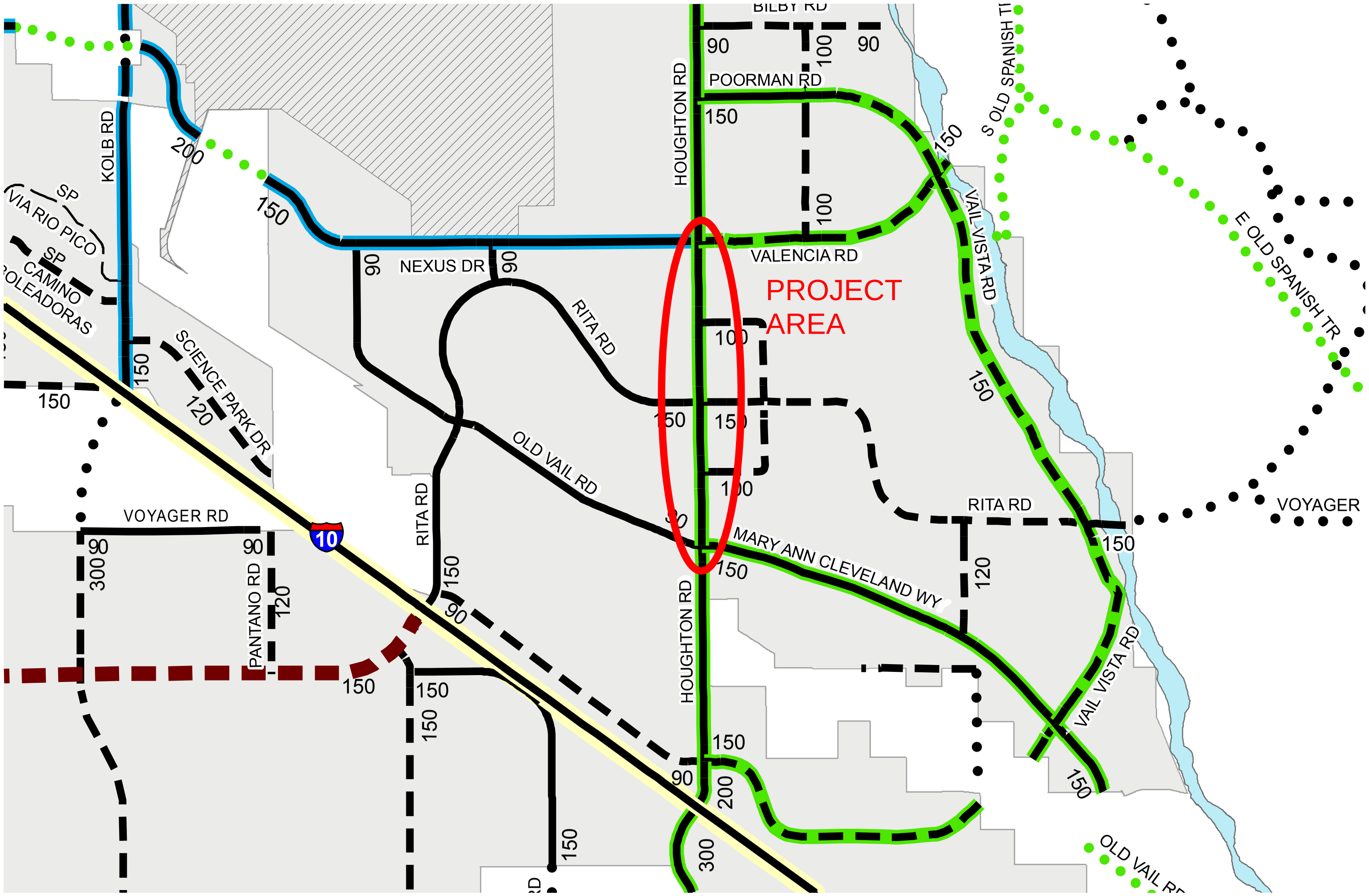
Locations within about 500 meters (1,650 feet) of a construction site are expected to experience occasional episodes of noise levels greater than 60 dBA. Areas within about 150 meters (500 feet) of a construction site will experience episodes with noise levels greater than 70 dBA. Such episodes of high noise levels will not be continuous throughout the day and will generally be restricted to daytime hours.

The following noise mitigation measures are recommended to reduce impacts from construction noise; however, not all measures may be feasible for the project:

- Re-route truck traffic away from residential streets, if possible. Select streets with fewest homes, if no alternatives are available.
- Locate equipment on the construction lot as far away from noise sensitive receivers as possible.
- Combine noisy operations to occur in the same time period. The total noise will not increase significantly and the duration of the noise impact will be less.
- Avoid nighttime activities. Sensitivity to noise increases during the nighttime hours at residential receivers.
- Use specially quieted equipment when possible, such as quieted and enclosed air compressors, residential or critical grade mufflers on all engines.
- Stationary equipment will be located as far away from sensitive receptors as possible. Loud, disrupting construction activities in noise sensitive areas will be conducted during hours that are least disturbing to adjacent and nearby residents.

APPENDIX A

Figures



VICINITY MAP			FIGURE 1
HOUGHTON ROAD - VALENCIA TO MAC		PROJECT NO: 18052	
SCALE: NTS	DRAWN BY: JLH	DATE: 08/27/2018	

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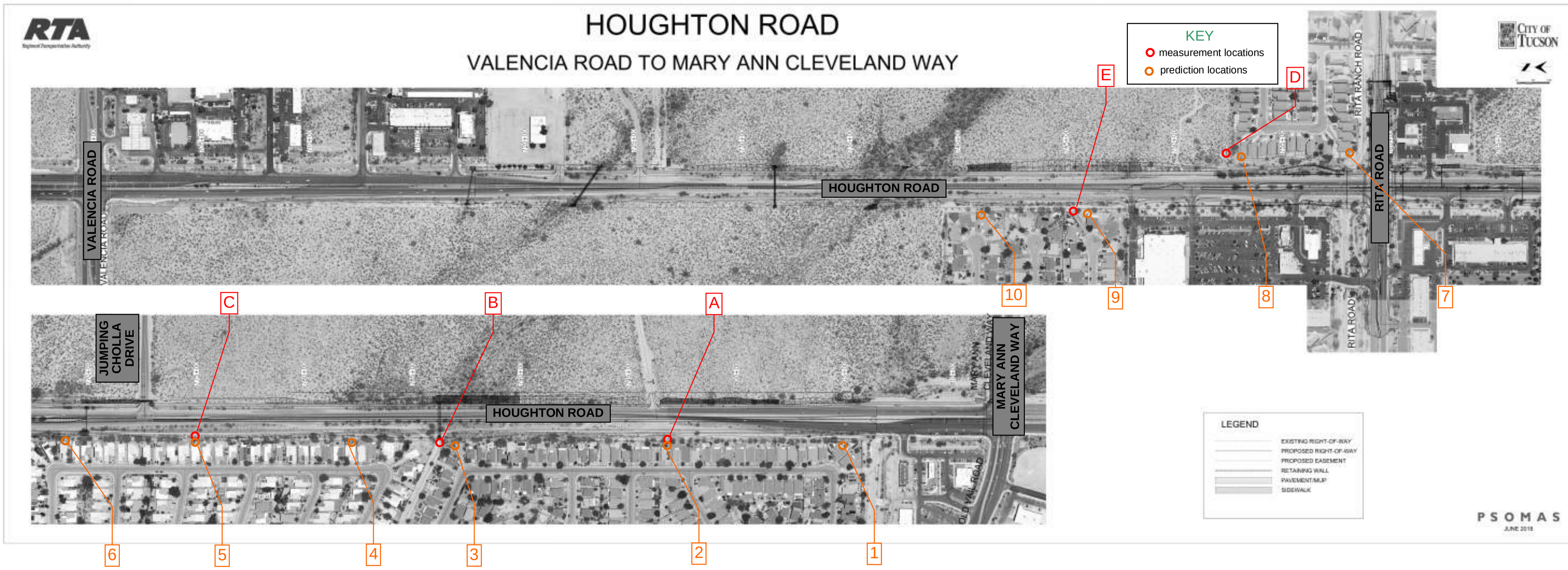

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MEASUREMENT AND PREDICTION LOCATIONS	
HOUGHTON ROAD - VALENCIA TO MAC	PROJECT NO: 18052
SCALE: NTS	DRAWN BY: JLH	DATE: 08/27/2018

FIGURE 2

APPENDIX B

Noise Measurement Field Forms

Traffic Counting And Noise Monitoring Log For Houghton Rd_Valencia Road To Mary Ann Cleveland Way

A	Date	Sky	Temp °F	Humidity %	Wind Speed/Dir	Project	Day Of Week	Staff	Meter	Batt Check	Calibraton	# Traffic Lanes	Receptor Above, Below Or Same Elevation As Roadway
	6/28/18	Sunny	79	19%	ESE 4 Mph	Hughton Rd	Thursday	MO	Larson Davis LXT	Yes	Yes	2	Same

Receiver 1 32° 5'33.05"N- 110°46'23.02"W	Sample	Axis	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Start Time	End Time	Duration	LaEQ	LaMin	LaMax
	1	NB	70	0	3	1	1	75	6:35:00	6:50:00	0:15:00	63.5	46.5	78.1
	1	SB	111	1	3	1	0	116						
	2	NB	103	0	2	0	0	105	8:05:00	8:20:00	0:15:00	63.8	48.1	78.8
	2	SB	135	0	3	5	1	144						
	3	NB	110	0	4	4	1	119	8:22:00	8:37:00	0:15:00	55.1	54.9	55.6
	3	SB	151	3	2	2	1	159						
	Total		680	4	17	13	4	718						




Traffic Counting And Noise Monitoring Log For Houghton Rd_Valencia Road To Mary Ann Cleveland Way

B		Date	Sky	Temp °F	Humidity %	Wind Speed/Dir	Project	Day Of Week	Staff	Meter	Batt Check	Calibraton	# Traffic Lanes	Receptor Above, Below Or Same Elevation As Roadway
		6/28/2018	Sunny	85	19%	SSE 3mph	Hughton Rd	Wednesday	MO	Larson Davis LXT	Yes	Yes	2	Below
Receiver 2 32° 5'43.11"N-110°46'22.78"W	Sample	Axis	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Start Time	End Time	Duration	LaEQ	LaMin	LaMax
	1	NB	147	5	4	1	0	157	7:35:00	7:50:00	0:15:00	61.2	60.7	62.4
	1	SB	154	2	9	0	1	166						
	2	NB	124	1	2	1	0	128	7:51:00	8:06:00	0:15:00	64.1	44	78.4
	2	SB	118	1	1	2	0	122						
	3	NB	100	1	8	1	2	112	8:07:00	8:22:00	0:15:00	63.8	49.4	73.8
	3	SB	130	3	3	1	0	137						
	Total		773	13	27	6	3	822						

Traffic Counting And Noise Monitoring Log For Houghton Rd_Valencia Road To Mary Ann Cleveland Way

C		Date	Sky	Temp °F	Humidity %	Wind Speed/Dir	Project	Day Of Week	Staff	Meter	Batt Check	Calibraton	# Traffic Lanes	Receptor Above, Below Or Same Elevation As Roadway
		6/28/2018	Sunny	88	18%	WSW 7 mph	Hughton Rd	Wednesday	MO	Larson Davis LXT	Yes	Yes	4	Same
Receiver 32° 5'54.60"N-110°46'22.93"W	Sample	Axis	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Start Time	End Time	Duration	LaEQ	LaMin	LaMax
	1	NB	177	2	5	1	0	185	8:41:00	8:56:00	0:15:00	71.5	51.3	80.1
	1	SB	152	1	4	0	0	157						
	2	NB	154	0	1	2	0	157	8:57:00	9:12:00	0:15:00	71.3	49.1	80.3
	2	SB	125	2	5	3	0	135						
	3	NB	161	3	3	1	1	169	9:13:00	9:28:00	0:15:00	70.8	44.1	82
	3	SB	112	5	3	2	1	123						
	Total		881	13	21	9	2	926						

Traffic Counting And Noise Monitoring Log For Houghton Rd_Valencia Road To Mary Ann Cleveland Way

D		Date	Sky	Temp °F	Humidity %	Wind Speed/Dir	Project	Day Of Week	Staff	Meter	Batt Check	Calibraton	# Traffic Lanes	Receptor Above, Below Or Same Elevation As Roadway
		6/28/2018	Sunny	92	16%	W 8mph	Hughton Rd	Thursday	MO	Larson Davis LXT	Yes	Yes	2	Same
Receiver 4 32° 6'16.42"N-110°46'20.45"W	Sample	Axis	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Start Time	End Time	Duration	LaEQ	LaMin	LaMax
	1	NB	153	3	9	1	0	166	9:52:00	10:07:00	0:15:00	62.7	46.9	74.9
	1	SB	141	3	1	6	0	151						
	2	NB	143	0	5	6	0	154	10:09:00	10:24:00	0:15:00	63.2	76.6	48.5
	2	SB	139	2	4	2	0	147						
	3	NB	170	1	4	4	0	179	10:25:00	10:40:00	0:15:00	62.7	46.2	73.8
	3	SB	165	1	1	2	1	170						
	Total		911	10	24	21	1	967						




Traffic Counting And Noise Monitoring Log For Houghton Rd_Valencia Road To Mary Ann Cleveland Way

E		Date	Sky	Temp °F	Humidity %	Wind Speed/Dir	Project	Day Of Week	Staff	Meter	Batt Check	Calibraton	# Traffic Lanes	Receptor Above, Below Or Same Elevation As Roadway
		6/28/2018	Sunny	92	15%	W 11 mph	Hughton Rd	Thursday	MO	Larson Davis LXT	Yes	Yes	2	Same
Receiver 5 32° 6'23.51"N-110°46'23.11"W	Sample	Axis	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Start Time	End Time	Duration	LaEQ	LaMin	LaMax
	1	NB	141	5	6	0	0	152	10:52:00	11:07:00	0:15:00	67.2	40.5	76.3
	1	SB	148	1	5	1	0	155						
	2	NB	138	0	2	2	0	142	11:16:00	11:31:00	0:15:00	67	41.3	75.5
	2	SB	157	1	3	3	0	164						
	3	NB	136	1	6	3	0	146	11:32:00	11:47:00	0:15:00	67.4	43.4	76.3
	3	SB	156	1	4	0	0	161						
	Total		876	9	26	9	0	920						




APPENDIX C

Acoustic Terminology

Sound Pressure Level

Sound, or noise, is the term given to variations in air pressure that are capable of being detected by the human ear. Small fluctuations in atmospheric pressure (sound pressure) constitute the physical property measured with a sound pressure level meter. Because the human ear can detect variations in atmospheric pressure over such a large range of magnitudes, sound pressure is expressed on a logarithmic scale in units called decibels (dB). Noise is defined as "unwanted" sound.

Technically, sound pressure level (SPL) is defined as:

$$SPL = 20 \log (P/P_{ref}) \text{ dB}$$

where P is the sound pressure fluctuation (above or below atmospheric pressure) and P_{ref} is the reference pressure, 20 μPa, which is approximately the lowest sound pressure that can be detected by the human ear.

The sound pressure level that results from a combination of noise sources is not the arithmetic sum of the individual sound sources, but rather the logarithmic sum. For example, two sound levels of 50 dB produce a combined sound level of 53 dB, not 100 dB. Two sound levels of 40 and 50 dB produce a combined level of 50.4 dB.

Human sensitivity to changes in sound pressure level is highly individualized. Sensitivity to sound depends on frequency content, background noise, time of occurrence, duration, and psychological factors such as emotions and expectations. However, in general, a change of 1 or 2 dB in the level of sound is difficult for most people to detect. A 3 dB change is commonly taken as the smallest perceptible change and a 6 dB change corresponds to a noticeable change in loudness. A 10 dB increase or decrease in sound level corresponds to an approximate doubling or halving of loudness, respectively.

A-Weighted Sound Level

Studies have shown conclusively that at equal sound pressure levels, people are generally more sensitive to certain higher frequency sounds (such as made by speech, horns, and whistles) than most lower frequency sounds (such as made by motors and engines) at the same level. To address this preferential response to frequency, the A-weighted scale was developed. The A-weighted scale adjusts the sound level in each frequency band in much the same manner that the human auditory system does. Thus the A-weighted sound level (read as "dBA") becomes a single number that defines the level of a sound and has some correlation with the sensitivity of the human ear to that sound. Different sounds with the same A-weighted sound level are perceived as being equally loud. The A-weighted noise level is commonly used today in environmental noise analysis and in noise regulations. Typical values of the A-weighted sound level of various noise sources are shown below.

Equivalent Sound Level

The Equivalent Sound Level (L_{eq}) is a type of average which represents the steady level that, integrated over a time period, would produce the same energy as the actual signal. The actual *instantaneous* noise levels typically fluctuate above and below the measured L_{eq} during the measurement period. The A-weighted L_{eq} is a common index for measuring environmental noise.

Common Sound Levels in dBA

Common Outdoor Sounds	Sound Pressure Level (dBA)	Common Indoor Sounds	Subjective Evaluation
Auto horn at 10' Jackhammer at 50'	**100**	Printing plant	Deafening
Gas lawn mower at 4' Pneumatic drill at 50'	**90**	Auditorium during applause Food blender at 3'	Very Loud
Concrete mixer at 50' Jet flyover at 5000'	**80**	Telephone ringing at 8' Vacuum cleaner at 5'	
Large dog barking at 50' Large transformer at 50'	**70**	Electric shaver at 1'	Loud
Automobile at 55 mph at 150' Urban residential	**60**	Normal conversation at 3'	
Small town residence	**50**	Office noise Dishwasher in adjacent room	Moderate
	40	Soft stereo music in residence Library	
Rustling leaves	**30**	Average bedroom at night Soft whisper at 3'	Faint
Quiet rural nighttime	**20**	Broadcast and recording studio	
	10	Human breathing	Very Faint
	0	Threshold of hearing (audibility)	
Source: Noise Expert measurements and reference library			