



Sound Levels in Saguaro National Park, Arizona, 2004-2005

February 2006

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Executive Summary

Sound levels were measured at three locations in Saguaro National Park in November 2004 and April 2005. Two locations were in the western Tucson Mountain District, and one was in the eastern Rincon Mountain District. The SAGU001 site was near Picture Rocks Road, SAGU002 was near Golden Gate Road, and SAGU003 was near the old Madrona Ranger Station. Commonly used acoustic metrics are explained at the end of this summary.

Near Picture Rocks Road, L_{eq} sound levels averaged 55.3 dBA; at the Golden Gate Road, L_{eq} averaged 39.9 dBA; and at Madrona, L_{eq} averaged 30.2 dBA. L_{eq} sound levels along Picture Rocks Road were about four times greater than levels near Golden Gate Road, and about 16 times greater than at Madrona. This difference is attributable to traffic sounds along Picture Rocks Road. Sound levels near Picture Rocks Roads were slightly higher on weekdays, and near Golden Gate Road, sound levels were slightly higher on weekends. Differences in weekday and weekend acoustic metrics were relatively small (<3 dBA), and differences in the number of vehicles on weekdays compared to weekends, on both roads, was also small.

At west side measurement locations, non-natural sounds, mostly vehicles, were audible throughout the measurement period. As a result, true natural ambient sound levels for this area could not be determined. Hourly L_{90} values, commonly used to express natural ambient sound levels, averaged 35.2 dBA near Picture Rocks Road and 31.4 dBA near Golden Gate Road, but these calculated values include non-natural sounds and thus are not good estimations of the natural ambient for this habitat.

At the east side location, non-natural sounds were much less audible during the measurement period, and a reasonable estimation of the natural ambient sound level could be made. The mean L_{90} for this location (for all hours during the measurement period) was 22.6 dBA (range 18.9 dBA to 26.7 dBA).

The extent of the influence of sounds from vehicles on Picture Rocks Road on natural ambient sound levels in areas away from the road is difficult to ascertain. However, based on data collected during this study, it appears that traffic sounds attenuate at the rate of roughly 10 dB per mile in this vegetation type and terrain. Assuming natural ambient conditions in the Tucson District would be similar to natural ambient conditions in the Rincon District (absent non-natural sounds), it appears that sounds from traffic on Picture Rocks Road influence sound levels up to approximately 2 miles from the road.

In order to achieve sound levels closer to natural levels in the Tucson Mountain District, a substantial reduction in the number of vehicles as well as lowering the speed limit along Picture Rocks would be required.

Summary Acoustic Metrics (L_{eq} , L_{50} , and L_{90}) for three measurement locations, Saguaro National Park, 2004-2005

	Location	Mean	Min	Max
L_{eq}	SAGU001	55.3	47.8	58.7
	SAGU002	39.8	34.4	44.7
	SAGU003	30.2	19.6	38.9

L_{50}	SAGU001	45.4	30.5	53.5
	SAGU002	34.7	28.8	39.5
	SAGU003	25.4	19.5	31.1

L_{90}	SAGU0001	35.2	27.6	40.4
	SAGU0002	31.4	24.1	35.1
	SAGU0003	22.6	18.9	26.7

Acoustic Metrics Explanation

Acoustic metrics commonly calculated include L_{eq} , L_{50} , and L_{90} . The L_{eq} is useful for quantifying intruding sounds because its magnitude depends heavily on the loudest periods of a time-varying sound. Exceedence values (L_x) are commonly used to describe ambient sound conditions. The L_{50} value represents the sound level exceed 50 percent of the measurement period (L_{50} is the same as the median). The L_{90} value represents the sound level exceeded 90 percent of the time during the measurement period. L_{50} and L_{90} are useful measures for describing ambient sound conditions. The L_{50} is a good descriptor of the “existing ambient” sound level. The “existing ambient sound level” consists of all sounds in a given area, and includes all natural and non-natural sounds. The L_{90} is often used to estimate the “natural ambient sound level,” which consists of all natural sounds in a given area, excluding all mechanical and electrical sounds. When L_{50} and L_{90} values are reasonably close (<3 dBA), this suggests that sound levels were relatively stable. When the L_{eq} value is much greater than either the L_{50} or L_{90} value, this suggests that events much greater in amplitude than the “ambient” conditions occurred during the measurement period. Because acoustic data are logarithmic, a single, very loud event can have a large influence on the L_{eq} value, but could have little or no influence on the L_{50} or L_{90} value (because L_{eq} is an energy equivalent level and L_x are simple ranked values).

A change of 1 dB is considered “detectable” by humans with normal hearing when intently listening, while a change of 3 dB is considered “noticeable” by humans when engaged in some activity other than intently listening.

Introduction

A 2.9 mile section of Picture Rocks Road bisects the northern part of the Tucson Mountain District (TMD) of Saguaro National Park (SAGU). The road connects Avra Valley (west of TMD) with Tucson (east of TMD), and approximately 7,000 vehicles use the road daily (David Evans and Associates, Inc. 2004). Wilderness is located immediately adjacent to the road on both sides. Sounds from vehicles traveling on Picture Rocks Road have the potential to significantly impact natural soundscapes in this area of SAGU.

Objectives

The objectives of this study were to:

1. Establish natural ambient sound levels in the primary vegetation type in the Tucson Mountain District of Saguaro National Park (specifically in areas near Picture Rocks Road); and
2. Assess the relative influence of vehicle sounds on the natural ambient sound levels.

Methods

Acoustic monitors used in this study included options for collecting the following types of data: continuous 1-second decibel data (L_{eq} for all one-third octave bands, 20-20,000 Hz); high-quality digital audio recordings (16-bit/44100 Hz) of events that exceeded a user-defined threshold, and high-quality digital recording collected at regular, user-defined intervals. Each monitor included:

1. Type 1, sound level meter, meeting requirements of IEC 804:1985, Integrating-Averaging Sound Level Meters. This project used Larson-Davis Model 824 sound level meters, which meet Type 1 standards and are capable of collecting 1/3 octave band data.
2. Acoustic calibrator to establish acoustical sensitivity of the sound measuring system, to comply with Class 1 accuracy requirements of ANSI S1.40-1984 ® (1980), American National Standard Specification for Acoustical Calibrators, or IEC 942:1988, Sound Calibrators.
3. IBM-compatible notebook computer with a minimum of 40 GB data storage. The notebook computer stored 1-second L_{eq} values (one-third octave band data, 20-20,000 Hz), digital recordings of loud events, and digital recordings of sample periods during the measurement period.

Two acoustic monitors were deployed in northern part of the Tucson Mountain District to measure weekday and weekend sound levels. One monitor was placed near Picture Rocks Road, 100 feet from centerline (SAGU001; Figures 1) and one was placed near Golden Gate Road, 250 feet from centerline (SAGU002; Figures 2). SAGU002 was approximately 1.6 miles (2.7 km) south-southwest of SAGU001.

Standard acoustic measurements for highway sounds are made 50 feet (15 m) from centerline of the road. However, for security reasons, acoustic monitors were not placed and left unattended at this distance. Using standard assumptions for sound attenuation (approximately 3 dBA less with every doubling of distance for line sources; Bruel & Kjaer. 2000), sound levels at other distances from the road can be calculated.

Acoustic data were collected for four days, two weekday days and two weekend days. Acoustic data collected were continuous 1-second one-third octave band data and dBA data. High-quality, digital recordings (16-bit, 44100 Hz) were made throughout the measurement period; some recordings were made for sound events exceeding a user-defined threshold, and other recordings were made at regular intervals (a 10-second recording was made every 2 minutes).

Initial analysis of these data revealed that non-natural sounds were almost always audible at both of these measurement locations in the Tucson Mountain District. For this reason, a third measurement location was selected to collect data in a similar saguaro cactus/desert scrub habitat but without such a large influence of non-natural sounds. The location chosen was in the eastern unit of SAGU, the Rincon Mountain District, near the old Madrona Ranger Station (Figure 3).

Maps with measurement locations in both the Tucson Mountain District and Rincon Mountain District are shown in Figures 4 and 5.

Photographs of the acoustic monitors are presented in Figures 6-8.

Measurement Location Information

SAGU001 (Figures 1 and 2).

Location Data:

Latitude: 32.32473

Longitude: 111.14005

Elevation: 2419 feet

Habitat:

50% mesquite/low shrub

30% cactus

10% rock

10% road

Equipment Data:

SLM: Larson Davis 824; SN: A1230

Preamp: Larson Davis 902; SN: 2493

Microphone: Larson Davis 2560; SN: 2858

Calibrator: B & K 4231; SN: 2439047

Notebook: Panasonic CF-18

Software: SoundMonitor 030101 (©Far North Aquatics, Fairbanks, AK)



Figure 1. SAGU001 (Picture Rocks Road) measurement location.

SAGU002 (Figures 3 and 4)

Location Data:

Latitude: 32.30496

Longitude: 111.15639

Elevation: 2654 feet

Habitat:

55% mesquite/low shrub

35% cactus

5% rock

5% road

Equipment Data:

SLM: Larson Davis 824; SN: A2549

Power: GRAS 12HF; SN: 39163

Preamp: GRAS 26HH; SN: 45945

Microphone: GRAS 40AH; SN: 44840

Calibrator: B & K 4231; SN: 2439047

Notebook: Panasonic CF-18

Software: SoundMonitor 030101 (©Far North Aquatics, Fairbanks, AK).



Figure 2. SAGU002 (Golden Gate Road) measurement location.

SAGU003 (Figures 5 and 6)

Location Data:

Latitude: 32.14987

Longitude: 110.6085

Elevation: 3260 feet

Habitat:

75% desert scrub (mesquite, creosote bush)

25% cactus

Equipment Data:

SLM: Larson Davis 824; SN: 3038

Preamp: Larson Davis 902; SN: 3182

Microphone: GRAS 40AE; SN: 47450

Calibrator: B & K 4231; SN: 2439047

Notebook: Panasonic CF-18

Software: SoundMonitor 050329 (©Far North Aquatics, Fairbanks, AK).



Figure 3. SAGU003 (Madrona) measurement location.

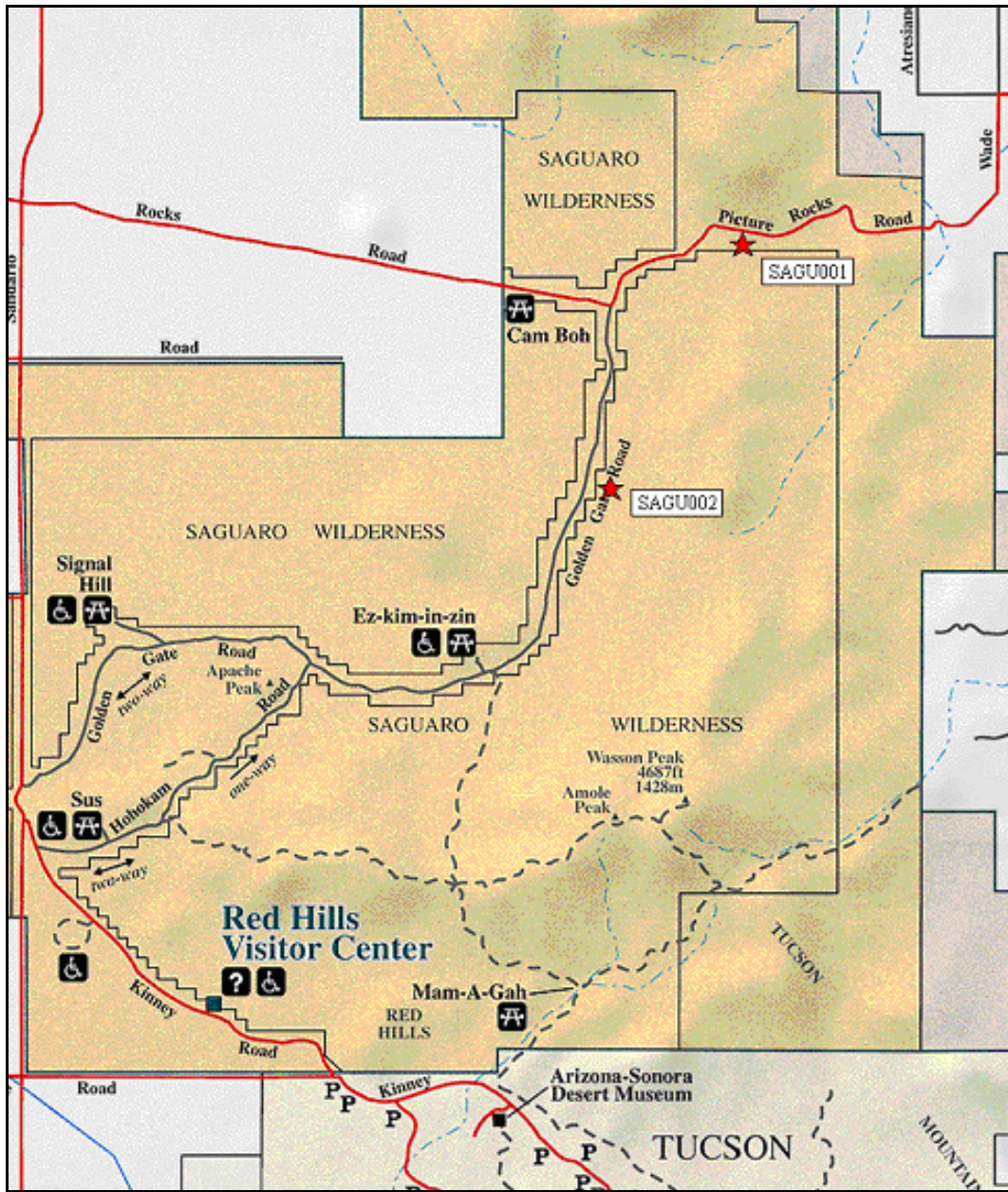


Figure 4. Acoustic monitor locations (SAGU001, SAGU002) in SAGU Tucson Mountain District, November 2004.

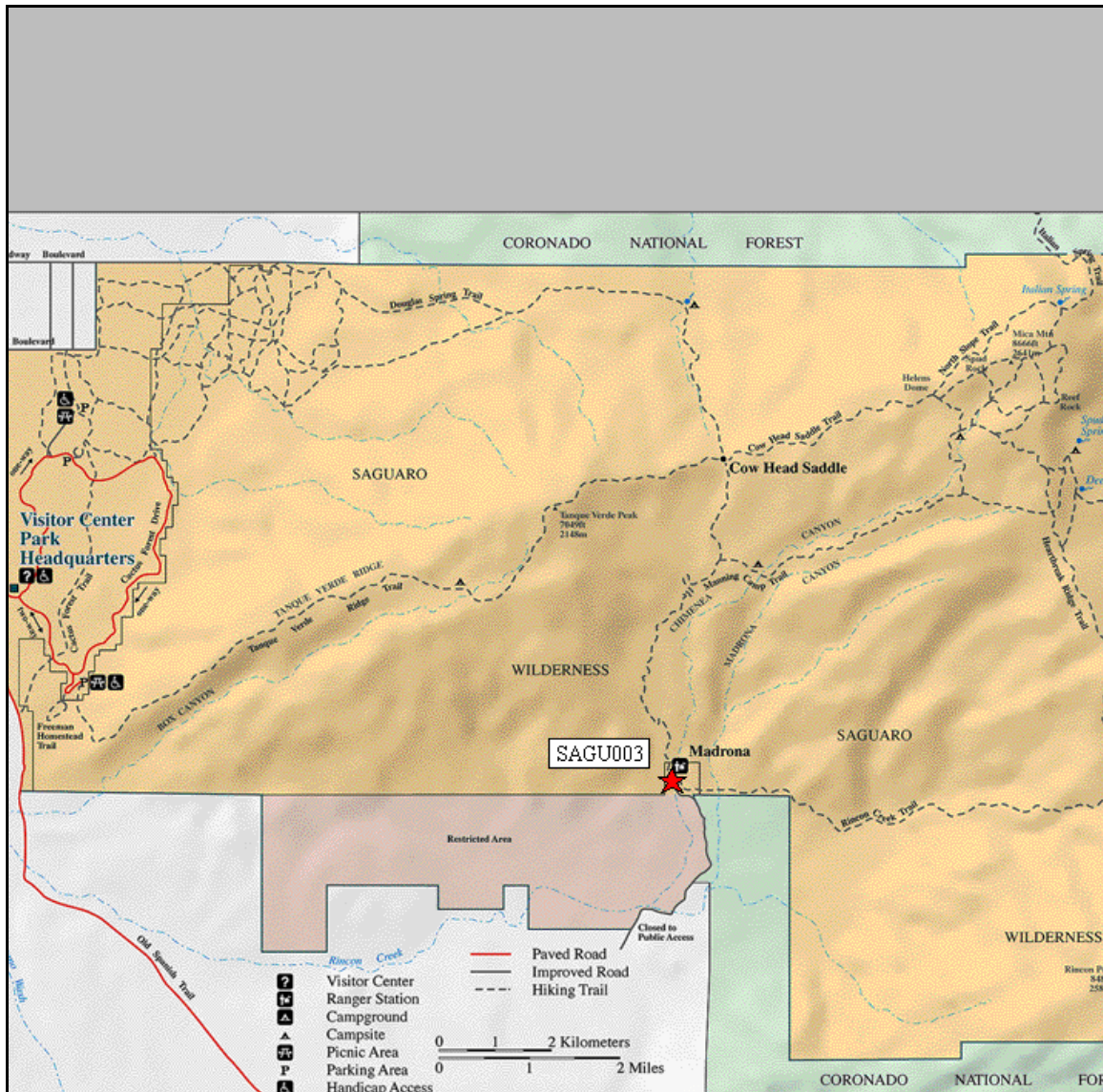


Figure 5. Acoustic monitor location (SAGU003) in SAGU Rincon Mountain District, April 2005.



Figure 6. Acoustic monitor, sound level meter, data logger, and batteries.



Figure 7. Acoustic monitor, microphones and system boxes.



Figure 8. Acoustic monitors, microphone and covered system boxes.

Definition of Acoustic Terms

Acoustic metrics calculated included L_{eq} , L_{50} , and L_{90} . The L_{eq} is useful for quantifying intruding sounds because its magnitude depends heavily on the loudest periods of a time-varying sound. Exceedence values (L_x) are commonly used to describe ambient sound conditions. The L_{50} value represents the sound level exceed 50 percent of the measurement period (L_{50} is the same as the median). The L_{90} value represents the sound level exceeded 90 percent of the time during the measurement period. L_{50} and L_{90} are useful measures for describing ambient sound conditions. The L_{50} is a good descriptor of the “existing ambient” sound level. The “existing ambient sound level” consists of all sounds in a given area, and includes all natural and all human-caused sounds. The L_{90} is often used to describe the “natural ambient sound level,” which consists of all natural sounds in a given area, excluding all mechanical and electrical human-produced sounds. Natural ambient sound is considered synonymous with the term “natural quiet,” although “natural ambient sound” is more appropriate because nature is not always quiet.

When the L_{50} and L_{90} values are reasonably close (<3 dBA), this suggests that sound levels are relatively stable. When the L_{eq} value is much greater than either the L_{50} or L_{90} value, this suggests events much greater in amplitude than the “ambient” conditions occurred during the measurement period. Because acoustic data are logarithmic, a single, very loud event can have a large influence on the L_{eq} value, but would have little or no influence on the L_{50} or L_{90} value (because L_{eq} is an energy equivalent level and L_x are simple ranked values).

Results, Acoustic Data

Acoustics measurements were made at three locations in Saguaro National Park, two in the western Tucson Mountain District (SAGU001, Picture Rocks Road, and SAGU002, Golden Gate Road) November 11-15, 2004, and one in the eastern Rincon Mountain District (SAGU003 Madrona Ranger Station), April 6-11, 2005. Summary acoustic metrics for these locations are presented in Table 1. Detailed, hourly acoustic metrics for these locations are in Appendix I.

Table 1. Summary metrics (Leq, L50, and L90) for SAGU001, SAGU002, and SAGU003, Saguaro National Park, 2004 and 2005.

		Mean	Min	Max
L _{eq}	SAGU001	55.3	47.8	58.7
	SAGU002	39.8	34.4	44.7
	SAGU003	30.2	19.6	38.9

L ₅₀	SAGU001	45.4	30.5	53.5
	SAGU002	34.7	28.8	39.5
	SAGU003	25.4	19.5	31.1

L ₉₀	SAGU0001	35.2	27.6	40.4
	SAGU0002	31.4	24.1	35.1
	SAGU0003	22.6	18.9	26.7

Mean values were calculated for all hours, and also for those hours generally with and without traffic (0500-2300 with and 0000-0500 without; traffic activity patterns were estimated from acoustic data, Figures 9-11). Although no traffic was present at the SAGU003 location near the Madrona Ranger station, summary metrics for like hours are presented for comparison purposes. Summary metrics and hourly metrics are presented for all three locations in Tables 2-4 and Figures 9-11.

The SAGU003 location, in the eastern district near the old Madrona Ranger Station, was the farthest away from non-natural sound sources such as highways and airports. Acoustic metrics for this location were the lowest of all three locations, and likely are the most representative of natural sound levels in a saguaro cactus vegetation type.

The SAGU001 location, 100 feet from Picture Rocks Road, was greatly influenced by vehicle traffic, and the SAGU002 location, about 0.9 miles from Picture Rocks Road, was also, but to a lesser degree, influenced by vehicle sounds on Picture Rocks Road.

From these limited data, it appears that the mean natural ambient sound level for a saguaro cactus vegetation type during the summer season is between about 22 dBA and 25 dBA for all hours. Night hours (1800-0600) at SAGU averaged 5-6 dBA quieter than day hours (0600-1800). Based on available year-round data from other desert vegetation types, it is likely that winter values are somewhat less than summer values, about 5 dBA less in winter (NPS unpublished data, Arches National Park), due primarily to fewer animals vocalizing (insects, birds, mammals) and less vegetation sounds in winter (fewer leaves thus less wind interactions) in winter.

Table 2. Mean hourly L_{eq} for SAGU001, SAGU002, and SAGU003, Saguaro National Park, 2004 and 2005 (0:00 hour = 00:00-01:00; 1:00 hour = 1:00-2:00; etc.).

Hour	SAGU001 Leq	SAGU002 Leq	SAGU003 Leq
0:00	52.7	34.4	24.8
1:00	48.9	36.1	20.0
2:00	47.8	39.8	20.5
3:00	48.4	34.8	21.0
4:00	51.3	37.9	20.2
5:00	54.9	39.6	28.3
6:00	57.2	42.4	32.4
7:00	57.8	38.5	32.4
8:00	56.9	38.2	36.5
9:00	57.2	43.8	35.2
10:00	57.1	44.5	37.4
11:00	56.8	44.7	37.4
12:00	57.2	38.0	33.7
13:00	57.6	41.4	38.9
14:00	57.2	41.0	36.8
15:00	58.2	42.8	33.4
16:00	58.6	36.6	33.6
17:00	58.7	36.8	33.7
18:00	58.4	40.5	28.1
19:00	56.2	41.7	33.6
20:00	55.9	38.4	30.9
21:00	55.4	40.4	30.3
22:00	55.1	40.4	25.7
23:00	52.4	41.3	19.6
Mean	55.3	39.8	30.2

Table 3. Mean hourly L_{50} for SAGU001, SAGU002, and SAGU003, Saguaro National Park, 2004 and 2005

Hour	SAGU001 L50	SAGU002 L50	SAGU003 L50
0:00	38.1	34.8	19.6
1:00	30.6	34.0	19.7
2:00	30.5	34.5	19.8
3:00	31.8	33.7	20.5
4:00	35.3	36.3	19.7
5:00	42.8	35.5	23.4
6:00	48.5	37.7	26.0
7:00	49.0	37.2	25.6
8:00	48.8	35.1	28.0
9:00	49.4	36.2	27.9
10:00	48.3	39.5	29.0
11:00	49.4	38.0	28.7
12:00	49.5	30.8	28.9
13:00	50.9	31.4	31.1
14:00	49.6	32.5	30.6
15:00	49.6	28.8	28.9
16:00	52.4	29.3	28.1
17:00	53.5	34.0	25.7
18:00	52.5	36.2	23.7
19:00	48.8	36.2	30.5
20:00	47.8	35.5	30.8
21:00	46.6	36.0	22.2
22:00	46.5	35.4	21.5
23:00	40.3	35.0	19.5
Mean	45.4	34.7	25.4

Table 4. Mean hourly L_{90} for SAGU001, SAGU002, and SAGU003, Saguaro National Park, 2004 and 2005.

Hour	SAGU0001 L90	SAGU0002 L90	SAGU0003 L90
0:00	28.9	26.4	19.0
1:00	27.9	31.6	19.1
2:00	27.6	33.8	18.9
3:00	28.3	31.5	19.3
4:00	29.5	33.3	19.1
5:00	33.3	31.1	20.0
6:00	38.4	33.4	21.8
7:00	38.3	35.1	23.3
8:00	38.7	32.6	25.2
9:00	38.0	34.3	25.6
10:00	37.6	33.3	26.1
11:00	36.3	31.8	26.1
12:00	35.5	28.7	25.8
13:00	39.3	28.5	26.7
14:00	39.8	26.2	26.2
15:00	38.7	24.1	25.8
16:00	40.4	24.4	24.8
17:00	40.3	32.2	24.1
18:00	39.8	33.4	20.6
19:00	35.7	34.1	21.3
20:00	33.9	32.3	25.7
21:00	34.9	33.6	19.4
22:00	32.9	33.8	19.7
23:00	30.4	34.3	18.9
Mean	35.2	31.4	22.6

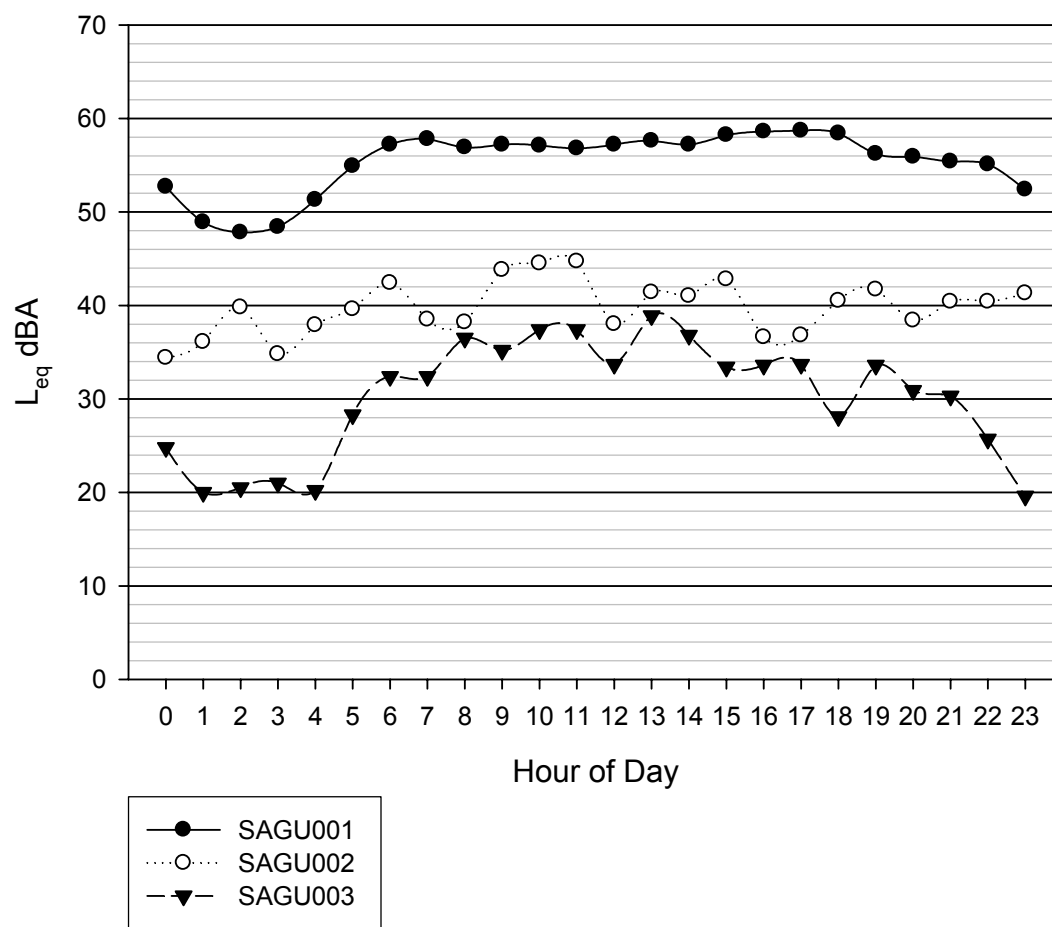


Figure 9. Mean hourly L_{eq} dBA, 0-23 hours for SAGU001, SAGU002, and SAGU 003.

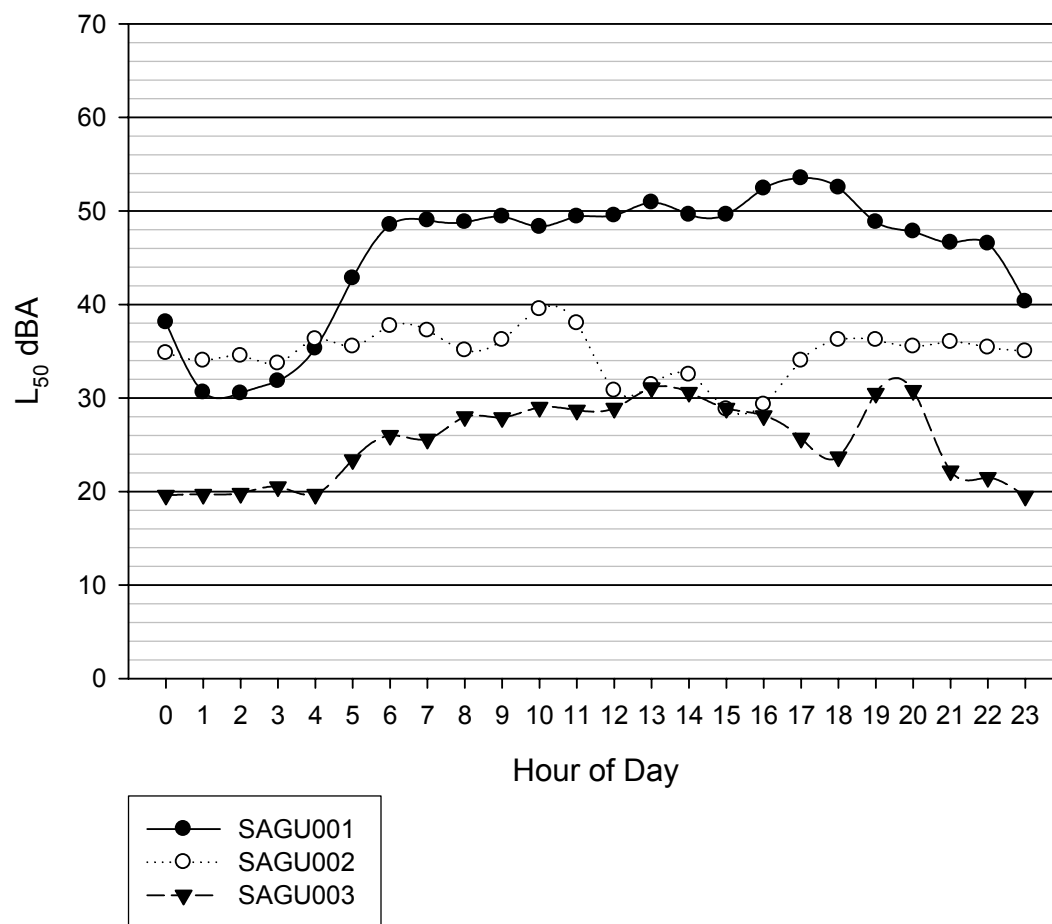


Figure 10. Mean hourly L_{50} dBA, 0-23 hours, for SAGU001, SAGU002, and SAGU 003.

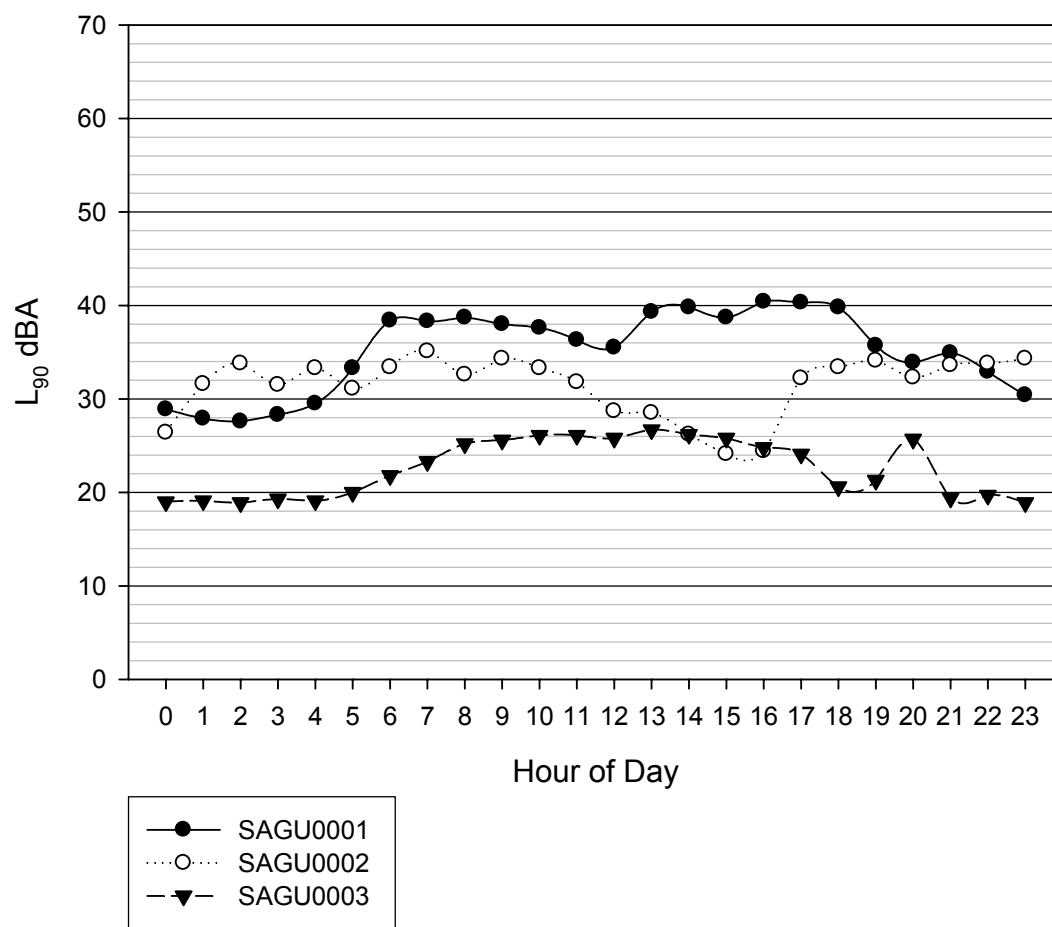


Figure 11. Mean hourly L_{90} dBA, 0-23 hours, for SAGU0001, SAGU0002, and SAGU 003.

Results, Traffic Noise Model

The Volpe Center's Traffic Noise Model (TNM, Version 1.0) was used to estimate sound levels for current traffic numbers and speeds. Annual average daily traffic data for Picture Rocks Road (7710 vehicles weekdays; 6560 vehicles weekend) and Golden Gate Road (80 vehicles weekdays; 110 vehicles weekend) (David Evans & Associates 2004) are presented in Appendix II. Using these traffic data and assuming most traffic occurred on Picture Rocks Road between 0500-2300 (based on acoustic data) and on Golden Gate Road between 0800-2000 (this road is closed at night), sound levels were calculated using TNM. Results are presented in Appendix III. Examples of vehicle types and sound levels (dBA) at different speeds are presented in Appendix IV.

For Picture Rocks Road, modeled results predict an hourly average L_{eq} of 60.6 dBA @ 100 feet for weekday traffic volume, and 60.0 dBA @ 100 feet for weekend traffic volume. These values are similar to measured hourly averages (0500-2300) of 57.9 dBA @ 100 feet (weekday) and 55.6 dBA @ 100 feet (weekend) (SAGU001).

For Golden Gate Road (SAGU002), 0.9 miles south of Picture Rocks Road, modeled results predict hourly average L_{eq} of 39.5 dBA @ 100 feet (0500-2300) for weekdays and 41.1 dBA @ 100 feet for weekends. These values were similar to the measured hourly averages (0500-2300) of 39.0 dBA @ 240 feet for weekdays and 41.1 dBA @ 240 feet for weekends.

From the measured acoustic data at SAGU001 and SAGU002, it appears that attenuation of the traffic sounds on Picture Rocks Road is about 10 dB per mile in this vegetation type and terrain. Mean L_{eq} levels were 55.3 dBA at SAGU001, 39.8 at SAGU002, and, as a baseline natural ambient comparison, 30.2 dBA at SAGU003. Mean L_{50} levels were 45.4 dBA at SAGU001, 34.7 dBA at SAGU002, and 25.4 dBA at SAGU003. Based on these measured data, traffic sounds on Picture Rocks Road likely influence sound levels out to a distance of about 2 miles from the road (at current traffic volume and speeds).

Discussion, Acoustic Metrics

At the two measurement locations in the western district, human-caused sounds were audible throughout the measurement period, although at times at very low levels (distant sounds of Interstate 10, local traffic, sounds of the city of Tucson, aircraft). As a result, true natural ambient sound levels for this area could not be determined. At the measurement location in the east side district, non-natural sounds were much less audible, and a more accurate estimated natural ambient (L_{90}) could be calculated. The mean hourly L_{90} value, commonly used to express natural ambient sound levels, was as follows for the three measurement locations:

Location:	Mean L_{90} (all hours):
SAGU001	35.2 dBA
SAGU002	31.4 dBA
SAGU003	22.6 dBA

Natural ambient sound levels in backcountry areas of many parks are often in the low-20s dBA, and sound levels at SAGU003 likely reflect a reasonable natural ambient for saguaro cactus vegetation type. Sound levels at both sites on the west side were almost always influenced by non-natural sounds, thus a natural ambient sound level for this area could not be determined.

Mean L_{eq} sound levels along Picture Rocks Road (55.3 dBA) were about four times greater than levels near Golden Gate Road (39.8 dBA), and about 16 times greater than levels near the old Madrona Ranger Station (30.2 dBA). Since habitats and natural sources of sound are similar at all locations, the differences in L_{eq} , L_{50} , and L_{90} are largely attributable to the road sounds along Picture Rocks Road. Slightly higher weekday sound levels near Picture Rock Road likely reflect that this road is used for commuting during weekdays and somewhat less on weekends. Slightly higher weekend levels near Golden Gate Road likely reflect this area is used more on weekends by park visitors. For both of these areas, differences in weekday and weekend sound levels were small (<3 dBA).

Discussion, Traffic Sounds, Current and Projected

Higher sound levels along Picture Rocks Road are attributable to the high number of vehicles using the road. Daily traffic volumes along Picture Rocks Road are projected to double by 2025 (Pima Association of Governments 2004). The acoustic consequence of this growth is shown in Table 5. Sound levels would increase from approximately 60 dBA currently to approximately 64 dBA.

Table 5. TNM results with double number of current vehicles, 35 mph.

Automobile volume (v/h):	848.0
Average automobile speed (mph):	35.0
Motorcycle volume (v/h):	8.0
Average motorcycle speed (mph):	35.0
Distance from center of roadway (ft):	100.0
Hourly Equivalent Sound Level without Barrier (dB):	63.7

One method to reduce sound levels due to vehicles is to lower speed limits. The current speed limit on Picture Rocks Road is 35 mph, and current mean daily L_{eq} dBA is about 60 dBA. If the speed limit was reduced to 25 mph, sound levels (L_{eq} dBA) would drop to about 56 dBA (Table 6).

Table 6. TNM results with current number of vehicles, speed lowered to 25 mph.

Automobile volume (v/h):	424.0
Average automobile speed (mph):	25.0
Motorcycle volume (v/h):	4.0
Average motorcycle speed (mph):	25.0
Distance from center of roadway (ft):	100.0
Hourly Equivalent Sound Level without Barrier (dB):	56.5

A change of 1 dB is barely detectable by humans with normal hearing, and a change of 3 dB is considered noticeably by humans with normal hearing (Brueel & Kjaer. 2000). Thus, in either scenario (a doubling in current traffic volume, or lowering the speed limit for current traffic volume), the change in sound levels (+ 3 dBA and -3 dBA, respectively) would likely be noticed by humans.

In order to achieve sound levels near natural levels (approximately 23 dBA) in this area of the Tucson Mountain District, a substantial reduction in the number of vehicles as well as lowering the speed limit along Picture Rocks would be required.

The extent of the influence of sounds from vehicles on Picture Rocks Road on natural ambient sound levels in areas distant from the road is difficult to ascertain. However, based on data collected during this study, it appears that traffic sounds attenuate at the rate of about 10 dB per mile. Assuming natural ambient conditions in the Tucson District would be similar to natural ambient conditions in the Rincon District (absent non-natural sounds), it would appear that sounds from traffic on Picture Rocks Road influence sound levels up to distances approximately 2 miles from the road.

It is reasonable to assume that natural ambient sound levels in the Tucson Mountain District (natural sounds only) would be about the same as at SAGU003 (a similar vegetation type but with little influence from non-natural sounds), about 22 dBA. At this level of natural ambient sounds, the distance at which vehicle sounds from Picture Rocks Road attenuated to levels at or less than natural ambient sound levels would be considerable, at least 2 miles based on data collected during this study.

Examples of sounds recorded in National Parks and approximate dBA levels are presented in Table 7. It is important to remember that the audibility of a given sounds depends on both the amplitude of that sound as well as the frequency content of the sound relative to the amplitude and frequency content of ambient. It is not unusual to be able to hear vehicle sounds at sound levels below natural ambient sound levels due the frequency content of the vehicle (commonly low frequencies) relative to natural ambient sound levels (often mid to high frequencies, such as bird calls or insects).

Table 7. Sounds recorded in National Parks and approximate dBA level and distance.

	dBA
Threshold of human hearing	0
Haleakala National Park: Volcano crater	10
Canyonlands National Park: Leaves rustling	20
Zion National Park: Crickets (5 m)	40
Whitman Mission National Historic Monument: Conversational speech (5 m)	60
Yellowstone National Park: Snowcoach (30 m)	80
Arches National Park: Thunder	100
Yukon-Charley Rivers National Monument: Military jet (100 m above ground)	120

Acknowledgements

Kerri Cahill, National Park Service, Denver, was responsible for initiating this project. Kerri Cahill, Elizabeth Meyer, and Meg Wessner reviewed drafts of this report and offered several valuable improvements. Bob Love, Todd Roeder, and John Williams, all National Park Service, Saguaro National Park, assisted in measurement site selection and coordinating access to measurement locations.

Dr. Mike Donaldson, Far North Aquatics, Fairbanks, AK, assisted in data analysis.

We appreciate the help of all of these individuals.

Literature Cited

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Appendix I. Acoustic data from SAGU001, SAGU002, and SAGU003, Saguaro National Park, November 2004 and April 2005.

Table I-1. Mean hourly sound levels, SAGU0001, Nov. 11, 12, and 15, 2004 (weekday).

SiteName	Hour	Leq	L10	L50	L90
SAGU001	0	52.5	53.6	37.3	29.4
SAGU001	1	47.8	47.3	31.6	27.9
SAGU001	2	47.4	46.5	29.6	27.8
SAGU001	3	48.7	47.4	31.8	28.6
SAGU001	4	52.1	54.4	38.0	31.0
SAGU001	5	56.8	62.5	46.5	36.2
SAGU001	6	59.2	64.1	52.9	43.2
SAGU001	7	59.0	63.8	51.8	41.5
SAGU001	8	57.7	62.8	49.2	38.7
SAGU001	9	57.9	63.0	49.4	38.0
SAGU001	10	57.5	62.8	48.7	35.6
SAGU001	11	57.3	62.3	49.4	34.7
SAGU001	12	57.5	62.6	49.5	34.3
SAGU001	13	57.7	62.8	50.9	36.7
SAGU001	14	59.3	63.7	53.7	42.1
SAGU001	15	59.2	63.3	53.3	39.0
SAGU001	16	59.0	63.3	54.1	41.3
SAGU001	17	59.4	63.6	55.1	42.7
SAGU001	18	59.4	63.8	55.3	43.8
SAGU001	19	57.1	62.2	50.4	36.1
SAGU001	20	56.7	61.7	49.2	36.1
SAGU001	21	56.4	61.7	48.2	35.4
SAGU001	22	56.1	60.4	46.7	32.0
SAGU001	23	52.7	56.5	39.2	29.3
Mean (all hours)		56.0	59.8	46.7	35.9
Mean (0500-2300)		57.9	62.8	50.8	38.2
Mean (2300-0500)		50.2	50.9	34.6	29.0
Min		47.4	46.5	29.6	27.8
Max		59.4	64.1	55.3	43.8

Table I-2. Mean hourly sound levels, SAGU001, Nov. 13 and 14, 2004 (weekend).

SiteName	Hour	Leq	L10	L50	L90
SAGU001	0	53.4	57.0	41.0	28.9
SAGU001	1	50.2	52.6	32.8	27.9
SAGU001	2	48.2	48.2	30.7	27.6
SAGU001	3	48.4	47.3	31.2	27.9
SAGU001	4	49.2	48.7	33.2	29.0
SAGU001	5	51.6	53.3	37.3	30.3
SAGU001	6	53.0	56.8	40.9	33.0
SAGU001	7	55.2	60.5	44.5	35.1
SAGU001	8	55.5	60.7	47.8	39.5
SAGU001	9	56.1	61.0	48.8	39.9
SAGU001	10	56.5	61.1	50.4	41.7
SAGU001	11	56.7	61.1	50.0	40.9
SAGU001	12	57.1	61.1	49.9	40.2
SAGU001	13	57.0	61.6	50.6	41.2
SAGU001	14	56.6	61.1	49.6	38.4
SAGU001	15	57.0	61.4	49.5	38.1
SAGU001	16	57.4	62.2	50.7	38.5
SAGU001	17	57.1	62.1	50.8	38.5
SAGU001	18	56.7	61.6	49.8	37.8
SAGU001	19	55.3	60.8	47.2	35.1
SAGU001	20	54.5	59.7	44.9	33.7
SAGU001	21	53.7	57.9	42.8	34.0
SAGU001	22	53.7	57.8	43.8	33.7
SAGU001	23	51.6	54.7	40.5	31.5
Mean (all hours)		54.2	57.9	44.1	35.1
Mean (0500-2300)		55.6	60.1	47.2	37.2
Mean (2300-0500)		50.1	51.4	34.9	28.8
Min		48.2	47.3	30.7	27.6
Max		57.4	62.2	50.8	41.7

Table I-3. Mean hourly sound levels, SAGU002, Nov. 11, 12, and 15, 2004 (weekday).

SiteName	Hour	Leq	L10	L50	L90
SAGU002	0	43.6	43.7	36.5	31.6
SAGU002	1	36.1	38.8	34.0	31.6
SAGU002	2	40.9	41.8	36.8	34.4
SAGU002	3	41.0	44.3	36.4	34.0
SAGU002	4	40.6	44.4	36.4	33.3
SAGU002	5	39.6	43.4	35.5	29.8
SAGU002	6	42.4	42.7	37.7	36.1
SAGU002	7	38.5	39.0	37.2	35.7
SAGU002	8	38.2	37.9	34.9	32.6
SAGU002	9	43.8	44.2	34.8	33.1
SAGU002	12	32.7	35.1	30.8	28.7
SAGU002	13	36.0	34.4	30.6	28.5
SAGU002	14	41.0	44.5	32.5	26.2
SAGU002	15	44.0	42.1	30.3	23.8
SAGU002	16	33.2	35.5	29.3	24.3
SAGU002	17	36.8	36.2	34.0	32.2
SAGU002	18	40.6	40.8	37.1	35.3
SAGU002	19	37.9	39.3	36.2	33.9
SAGU002	20	40.9	37.4	34.6	32.8
SAGU002	21	39.1	38.5	36.0	33.6
SAGU002	22	39.9	37.1	35.4	34.4
SAGU002	23	41.7	36.0	34.9	30.4
Mean (all hours)		39.5	39.9	34.6	31.6
Mean (0500-2300)		39.0	39.2	34.2	31.3
Mean (2300-0500)		40.6	41.5	35.8	32.5
Min		32.7	34.4	29.3	23.8
Max		44.0	44.5	37.7	36.1

Table I-4. Mean hourly sound levels, SAGU002, Nov. 13 and 14, 2004 (weekend).

SiteName	Hour	Leq	L10	L50	L90
SAGU002	0	32.0	32.6	30.7	25.8
SAGU002	1	33.8	31.3	29.8	28.5
SAGU002	2	37.2	34.1	32.7	31.1
SAGU002	3	33.3	36.0	30.0	27.3
SAGU002	4	34.7	37.6	32.3	28.9
SAGU002	5	37.4	39.3	35.9	32.5
SAGU002	6	39.0	41.8	37.4	30.5
SAGU002	7	40.6	42.0	35.5	30.9
SAGU002	8	43.7	46.7	41.7	34.4
SAGU002	9	47.6	50.8	43.4	40.3
SAGU002	10	44.5	47.1	39.5	33.3
SAGU002	11	44.7	46.8	38.0	31.8
SAGU002	12	46.8	46.4	37.5	32.6
SAGU002	13	43.0	46.2	36.6	30.7
SAGU002	14	41.1	42.5	33.9	28.5
SAGU002	15	44.6	43.6	32.7	27.8
SAGU002	16	39.4	41.7	31.9	27.9
SAGU002	17	39.4	41.0	33.2	29.5
SAGU002	18	39.0	39.6	34.4	31.0
SAGU002	19	47.6	43.2	37.8	34.1
SAGU002	20	38.4	39.8	36.0	32.1
SAGU002	21	42.5	41.7	34.0	31.1
SAGU002	22	41.5	39.9	35.4	31.1
SAGU002	23	38.4	39.6	36.6	34.7
Mean (all hours)		40.4	41.3	35.3	31.1
Mean (0500-2300)		41.1	42.1	35.7	31.4
Mean (2300-0500)		34.9	35.2	32.0	29.4
Min		33.3	34.1	30.0	27.3
Max		47.6	50.8	43.4	40.3

Table I-5. Mean hourly sound levels, SAGU003, April 6-11, 2005.

SiteName	Hour	Leq	L10	L50	L90
SAGU003	0	24.8	25.5	19.6	19.0
SAGU003	1	20.0	21.8	19.7	19.1
SAGU003	2	20.5	21.3	19.8	18.9
SAGU003	3	21.0	22.0	20.5	19.3
SAGU003	4	20.2	21.0	19.7	19.1
SAGU003	5	28.3	30.9	23.4	20.0
SAGU003	6	32.4	32.7	26.0	21.8
SAGU003	7	32.4	33.7	25.6	23.3
SAGU003	8	36.5	35.8	28.0	25.2
SAGU003	9	35.2	35.1	27.9	25.6
SAGU003	10	37.4	38.3	29.0	26.1
SAGU003	11	37.4	36.7	28.7	26.1
SAGU003	12	33.7	35.5	28.9	25.8
SAGU003	13	38.9	38.3	31.1	26.7
SAGU003	14	36.8	38.4	30.6	26.2
SAGU003	15	33.4	35.6	28.9	25.8
SAGU003	16	33.6	36.9	28.1	24.8
SAGU003	17	33.7	32.9	25.7	24.1
SAGU003	18	28.1	27.8	23.7	20.6
SAGU003	19	33.6	32.6	30.5	21.3
SAGU003	20	30.9	32.0	30.8	25.7
SAGU003	21	30.3	27.0	22.2	19.4
SAGU003	22	25.7	26.7	21.5	19.7
SAGU003	23	19.6	20.4	19.5	18.9
Mean (all hours)		30.2	30.8	25.4	22.6
Mean (0500-2300)		33.2	33.7	27.3	23.8
Mean (2300-0500)		21.0	22.0	19.8	19.1
Min		19.6	20.4	19.5	18.9
Max		38.9	38.4	31.1	26.7

Appendix II. Annual average daily traffic Picture Rocks Road, February 2004 (David Evans and Associates, Inc. 2004) and estimated breakdown by hour:

	Picture Rocks Road	Golden Gate Road
February 2004 (AADT)		
Weekday	7710	80
Weekend	6560	110
Primary time of use:	0500-2300	0800-2000
Hours per day:	18	12
February 2004 weekday:		
Automobiles (percent):	7633 (99%)	100
Automobiles/hour:	424	8
Motorcycles (percent)	77 (1%)	0
Motorcycles/hour estimate:	4	0
February 2004 weekend:		
Automobiles (percent):	6494 (99%)	110
Automobiles/hour:	361	10
Motorcycles (percent):	66 (1%)	0
Motorcycles/hour estimate:	4	0

Appendix III. Results from Traffic Noise Model for SAGU001 and SAGU002, for weekday and weekend traffic, November 2004.

Assumptions: February 2004 annual average daily traffic: weekday = 7710; weekend = 6560; most traffic occurs between 0500 and 2300 (based on acoustic data); traffic breakdown: 99 percent automobiles and 1 percent motorcycles. These annual average daily traffic counts did not report light duty trucks, medium duty trucks, or SUVs; however these types of vehicles were observed on Picture Rocks Road. All surfaces were “hard” and no barriers were considered.

It is important to note that vehicle speed is assumed to be the posted speed limit. It is very likely that vehicle speeds were often over and/or below the posted speed limit. Higher speeds were result in higher sound levels.

SAGU001 weekday:

Automobile volume (v/h):	424.0
Average automobile speed (mph):	35.0
Motorcycle volume (v/h):	4.0
Average motorcycle speed (mph):	35.0
Distance from center of roadway (ft):	100.0
Hourly Equivalent Sound Level without Barrier (dB):	60.6

SAGU001 weekend:

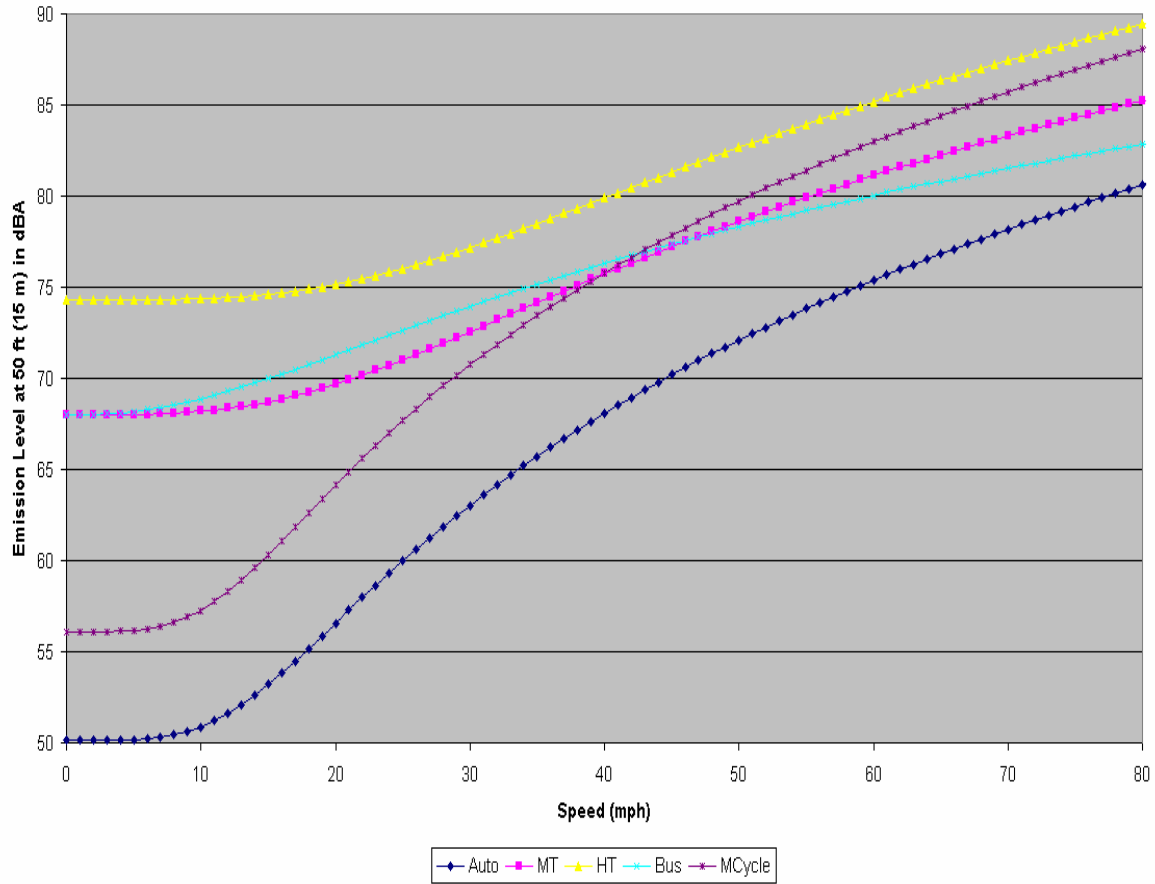
Automobile volume (v/h):	361.0
Average automobile speed (mph):	35.0
Motorcycle volume (v/h):	4.0
Average motorcycle speed (mph):	35.0
Distance from center of roadway (ft):	100.0
Hourly Equivalent Sound Level without Barrier (dB):	60.0

SAGU002 all days:

Automobile volume (v/h):	10.0
Average automobile speed (mph):	25.0
Distance from center of roadway (ft):	100.0
Hourly Equivalent Sound Level without Barrier (dB):	39.9

Note: Golden Gate Road is closed to traffic at night.

Appendix IV. FHWA Traffic Noise Model Reference Mean Emission Levels.



Source: FHWA Traffic Noise Model (FHWA TNM) Technical Manual, Report No. FHWA-PD-96-010, Washington, D.C.; Federal Highway Administration, January, 1998.