National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Natural Sounds Program

Sand Creek Massacre National Historic Site
Acoustical Monitoring Snapshot

July 2009

Background Information

In 2009, the Natural Sounds Program (NSP) received a request to collect baseline acoustical data at Sand Creek Massacre National Historic Site (SAND). During the months of July and August, 2009, one acoustic monitoring system was deployed for 45 days. The baseline data collected during this period will help park managers, planners, and tribal representatives develop desired conditions for soundscapes in the park's first general management plan (GMP). Data will also inform decision makers about the potential impacts of noise from military jets during the Colorado Air National Guard's (COANG) National Environmental Policy Act (NEPA) process for the proposed expansion of the Cheyenne Military Operations Area. The NSP is working with the COANG to document the nature and extent of impacts from the current level of military overflights. To this end, the COANG has provided the NSP with a detailed log of nearby military overflights during the monitoring period. Sand Creek Massacre National Historic site is a unique case in terms of soundscape monitoring because the park was opened to the public. . This is the first time the NSP has collected data at a new park. The monitoring site was chosen to fulfill the needs of the GMP baseline measurements and the proposed airspace expansion, but it may serve an additional purpose because of its proximity to a proposed footpath through the park.

This briefing is a preliminary snapshot of the acoustical conditions at the monitored site. A full acoustical monitoring report will follow, pending further data analysis. The metrics presented in this snapshot are calculated solely from sound pressure level data, and do not distinguish between intrinsic and extrinsic sound sources. Sound source identification, an estimate of the natural ambient condition, and the summary of attended listening sessions will be included in the full report. Table 1describes the location and characteristics of the monitoring site.

Table 1. Study areas

Site	Site Name	Dates Deployed	Vegetation	Elevation	Latitude	Longitude
SAND001	Massacre Site	7/13/09 - 8/26/09	Blue grama w/ sage. Near riparian area.	1208m	38.55259	102.50508

Data & Metrics

At the monitoring site, sound pressure level (SPL) measurements were taken, along with digital audio recordings and meteorological data. The Natural Sounds Program equipment makes 33 SPL measurements for a set of frequency bands that span the range of human hearing (12.5 - 20,000 Hz). These 33 measurements approximate the capacity of human listeners to independently sense signals in different parts of the audible spectrum. The SPL is measured in decibels (dB), a logarithmic scale where 0 dB represents the threshold of human hearing. The logarithmic scale is a useful way to express the wide range of sound pressure levels over which the auditory system functions. Microphone measurements can be adjusted according to a weighted scale (A-weighting) such that they resemble the response of the human ear (Harris, 1998, p. 116).

The logarithmic dB scale can be difficult to interpret, and the functional effect of a seemingly small change in SPL can be greater than anticipated. When noise interferes with hearing natural sounds, the noise is said to *mask* the natural sounds, and this affects the extent of the listening area. For example, if the ambient SPL is 30 dB, and transportation noise raises the ambient to 33 dB (a 3 dB increase), the listening area or auditory horizon for humans (and many birds and mammals) would be reduced by 50%. Increasing the ambient SPL an additional 3 dB (to 36 dB) would reduce the listening area by half again, to 25% of the initial area. Note however, that changes in SPL do not proportionately translate to changes in perceived loudness. The rate of change of loudness is complex and dependent on the stimulus itself (SPL, frequency, bandwidth, duration, background, etc.). At a minimum, each 10 dB increase in SPL causes a doubling of perceived loudness (Crocker, 1997, p.1481). Table 2 presents park sound sources and common sound sources with their corresponding A-weighted decibel values (dBA).

Table 2. Sound pressure level examples

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Snowcoach at 30m (YELL)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL(YUCH)	Train horn at 1m	120

Table 3 summarizes sound pressure levels that relate to human health and speech, as documented in the scientific literature. Human responses can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper, 2007, p. 5). To help interpret the acoustical data collected within the park, and to better understand the implications of the data, it may be helpful to consider sound pressure levels in relation to the functional effects listed in Table 3.

Table 3. Effects of sound pressure levels on humans

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)
45	World Health Organization’s recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

For a given frequency range, the *time above* metric indicates the amount of time that the SPL exceeds a specified decibel value. By comparing the amount of time that sound pressure levels are above certain values, variations in levels can be observed over time (or between sites). Table 4 reports the percent of time that measured levels were above the values in Table 3. These values are useful for making comparisons, but should not be construed as thresholds of impact. The top value in each split-cell of Table 4 reports the *time above* for the 20 - 800 Hz range.

Transportation is often a major contributor of low frequency sound, but the 20 - 800 Hz range does not correspond to a specific vehicle or type of transportation. Note that natural sources such as flowing water also produce low frequency sounds. The bottom *time above* value in each split-cell is calculated from the full 12.5-20,000 Hz range.

Table 4. Percent time above metrics

		% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
Site	Frequency (Hz)	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
SAND001	20-800	9.7	0.5	0.1	0.0	3.3	0.1	0.0	0.0
	12.5-20,000	74.1	21.1	6.3	0.9	42.2	6.8	1.7	0.1

Exceedence levels (L_x) represent the sound pressure levels exceeded **x** percent during the given measurement period (e.g. L_{90} is the SPL that has been exceeded 90% of the time). Table 5 reports the L_{90}, L_{50}, and L_{10} values for the sites measured in SAND. For each split-cell in Table 5, the top value reports the L_x for the 20 – 800 Hz subset of the frequency range, and the bottom L_x value is calculated from the 12.5 – 20,000 Hz spectrum.

Table 5. Exceedence levels for existing conditions

		Exceedence levels (dBA): 0700 to 1900			Exceedence levels (dBA): 1900 to 0700		
Site	Frequency (Hz)	L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
SAND001	20-800	18.3	24.6	32.6	13.0	18.3	25.5
	12.5-20,000	34.1	38.6	45.8	29.6	33.6	37.6

High frequency sounds (e.g. a cricket chirping) and low frequency sounds (e.g. transportation noise) often occur simultaneously, and do not always occur constantly throughout the day. Figure 1 illustrates these concepts by dividing the full frequency spectrum into 33 smaller frequency bands (each encompassing a one-third octave range), and by plotting the daytime and nighttime SPL range for each band. The grayed area in the background of the graph represents sound pressure levels outside of the typical range of human hearing. The typical frequency ranges for transportation, conversation and songbirds are presented on the figure as examples for interpretation of the data. These ranges are estimates and are not vehicle-, species-, or habitat-specific.

Figure 1. Day and night dB levels for 33 one-third octave bands at SAND001

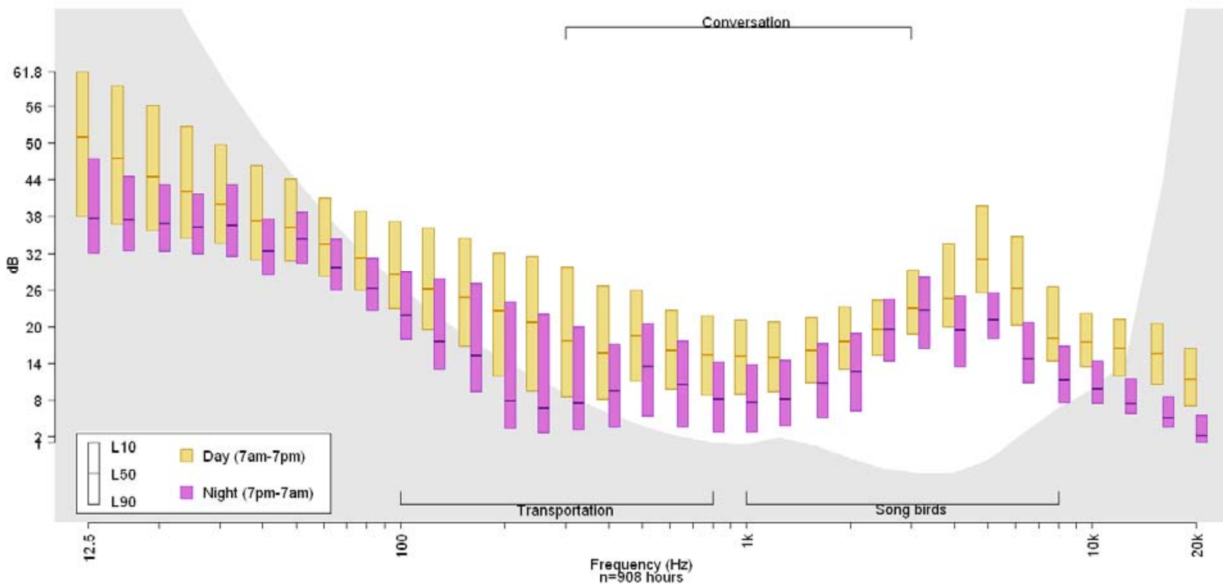

Table 6. National Guard overflight log

Date	Time Local	Location in airspace West	Location in airspace South	Altitude Block Bottom	Altitude Block Top	Type & number F-16	Type & number F-5	Remarks
14-Jul	1010-1050	x	x	10,000	29,000		2	
14-Jul	1345-1415	x		10,000	29,000	1	2	
15-Jul	0940-1105		x	500	29,000	2		Low Level 10nm of SC at 500' above ground ~1050L
16-Jul	1400-1440	x		10,000	29,000	4		
16-Jul	1020-1100		x	5,000	20,000	2	1	Low pass within 5nm of SC @ 5,000' above ground
17-Jul	1400-1440	x	x	10,000	29,000		4	
17-Jul	1010-1050	x	x	10,000	29,000		3	
22-Jul	0935-1035	x		9,000	20,000	3		
12-Aug	0915-1005	x		10,000	26,000	4		
13-Aug	0905-0945	x		5,000	29,000	2		

The overflight times and dates displayed in Table 6 were compared against the preliminary spectral data from SAND001. One flight was noticeable on July 16 at approximately 10:25 a.m. Based on the overflight log, it appears this was the flight conducted within 5 nautical miles of the park at 5,000 feet above ground level. The flight registered 58 to 60 dB on the sound level meter and lasted for less than a minute. The other COANG flights were not noticeable in the spectral data.

Note: *This is a preliminary snapshot designed to get salient acoustical information back to the park as quickly as possible. This does not replace a full acoustical report, which will follow, pending further data analysis. If there are any questions or concerns about the information in this document, please contact the Natural Sounds Program. Thank you for your interest and participation in acoustical resource monitoring.*

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