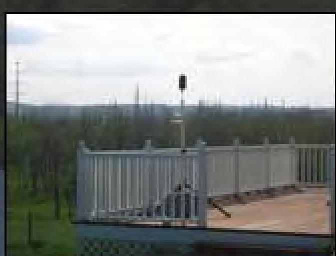
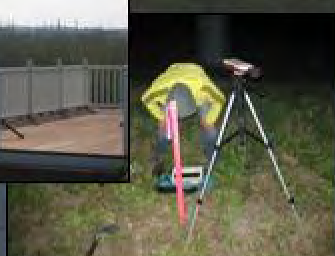




Basin Electric Intertie Noise & Vibration Study and Land Use Assessment

HDR

3820 Jackson Blvd.
Suite 2
Rapid City, SD 57702

September 2007

Executive Summary and Recommendations

Black Hills Power and Basin Electric Power Cooperative constructed an Intertie outside of Rapid City, South Dakota (Facility). The Facility is a high voltage direct current power link (also referred to as an asynchronous tie) across the East-West electrical divide of the United States, and occupies approximately 40 acres southeast of Rapid City. After the Facility began operating, residents in the immediate vicinity began to complain to the city about noise and vibration. Rapid City subsequently hired HDR to measure noise and vibration in the vicinity of the Facility. The project area is defined as an area measuring 1-mile by 1-mile, centered on the Facility (1/2-mile in each direction from the Facility fence line). The project area also includes several residences slightly farther than ½-mile from the Facility.

HDR performed these measurements along a grid centered on the Facility. Measurements occurred at distances of 0, 330, 660, 1320, 1980, and 2640 feet in each direction from the Facility. The zero-foot measurement was performed at the edge of the gravel-filled area that lies outside the Facility fence line, roughly 10 feet beyond the fence. The noise measurements collected spectral data. This is noise data processed through filters that separate sound into frequency bands to allow an evaluation of both overall levels and tonal levels. Vibration measurements also collected spectral data. The duration of these measurements was two minutes for each noise and vibration measurement. HDR also measured noise and vibration levels at five homes in the project area.

Monitoring data was compared with criteria for acceptable levels of noise and vibration for different land uses, including residential lands. Those comparisons produced the following conclusions.

- Hourly average noise levels measured at residences in the project area are compatible with acceptable noise levels for residential land use.
- Average noise levels measured near the Facility are compatible with acceptable noise levels for residential land use at distances beyond 660 feet.
- Pure tones or near pure tones were measured at different locations near the Facility. Pure tones stand out from background noise levels and can sometimes annoy people. For the purposes of this report, the terms pure tones and prominent discrete tones are assumed to be interchangeable, although HDR recognizes subtle differences in their definitions exist.
- Vibration levels measured outdoors in the ground at all of the residences in the project area are compatible with acceptable vibration levels for residential land use.
- Vibration levels measured outdoors in the ground at Receptor 4 are also acceptable for residential land uses. However, monitoring data suggests there is more efficient propagation occurring at this location than at other residences in the project area. Coupling between the foundation and bedrock, and also between the exterior walls and the soil may combine with building amplification to produce higher vibration levels in the second floor than measured in the ground outside at this location.

Vibration from sources outside of the project area was not considered in this report, therefore potential exists that sources other than the Facility contributed to ground-borne vibration velocities measured in the project area (particularly at Receptor 4).

- Vibration levels measured at the ground surface near the Facility are compatible with acceptable vibration levels for residential land use at all locations. Subsurface soil conditions, shallow bedrock, soil-foundation coupling, and building amplification may result in higher levels inside future buildings than measured at the ground surface during this study.

Observations

HDR offers the following observations that are based on our understanding of the monitoring data and other factors in the project area. Statements referring to subsurface conditions are somewhat speculative, and are based on observations in the field and while processing monitoring data. No subsurface investigations were performed.

- Factors that affect vibration levels at receivers include soil conditions, depth of bedrock, and building type.
- There appear to be areas where ground-borne vibrations travel more efficiently than in other areas.
- Vibration waves travel at the ground surface and below the ground. Stiff soils and shallow bedrock help vibration waves travel more efficiently.
- Subsurface conditions, soil-foundation coupling, and building amplification may result in levels of vibration that could be annoying to residents at some locations in the project area.

Recommendations

HDR offers the following recommendations.

- Areas closest to the Facility should be developed with industrial, commercial, or other land uses that are not noise-sensitive or vibration-sensitive. Ideally, these areas closest to the Facility would be developed before residential areas are developed elsewhere in the project area. The goal is for the industrial or commercial lands to act as a barrier and break the line of sight between the Facility and areas where residences will be built. In doing so, they will also act as a noise barrier.
- If highly vibration sensitive land uses are proposed for the project area, subsurface investigations should be performed in an assessment of suitability for the proposed land use. Appropriate mitigation measures (isolation, etc.) should also be evaluated.
- Future residential development should avoid areas of shallow bedrock, and limit soil-foundation coupling to as small a surface area as is reasonably possible.
- To assess a given site for suitability for use as future residential development, subsurface soil conditions and depth to bedrock should be identified, and foundations

should be designed to minimize coupling and the transfer of ground-borne vibration energy.

- Due to variables beyond HDR's control such as the dimensions of future buildings, their ability to break the line of sight between the Facility and future residential development, and subsurface and meteorological conditions, these recommendations may not produce the desired results and are not offered as a guarantee.

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

Black Hills Power and Basin Electric Power Cooperative constructed an Intertie outside of Rapid City, South Dakota (Facility). The Facility is a high voltage direct current power link (also referred to as an asynchronous tie) across the East-West electrical divide of the United States, and occupies approximately 40 acres southeast of Rapid City. The Facility began operating in October 2003. After the Facility began operating, residents in the immediate vicinity began to complain to the city about noise and vibration. Rapid City subsequently hired HDR in December 2006 to measure noise and vibration in the vicinity of the Facility. The project area is defined as an area measuring 1-mile by 1-mile, centered on the Facility (1/2-mile in each direction from the Facility fence line). The project area also includes several residences slightly farther than ½-mile from the Facility.

HDR performed these measurements along a grid centered on the Facility. Measurements occurred at distances of 0, 330, 660, 1320, 1980, and 2640 feet in each direction from the Facility. The zero-foot measurement was performed at the edge of the gravel-filled area that lies outside the Facility fence line, roughly 10 feet beyond the fence. The noise measurements collected spectral data. This is noise data processed through filters that separate sound into frequency bands to allow an evaluation of both overall levels and tonal levels. The duration of these measurements lasted two minutes. Vibration measurements also collected spectral data. Additionally, HDR measured noise and vibration levels at five homes in the project area. Monitoring data was compared with criteria for acceptable levels of noise and vibration for different land uses, including residential lands.

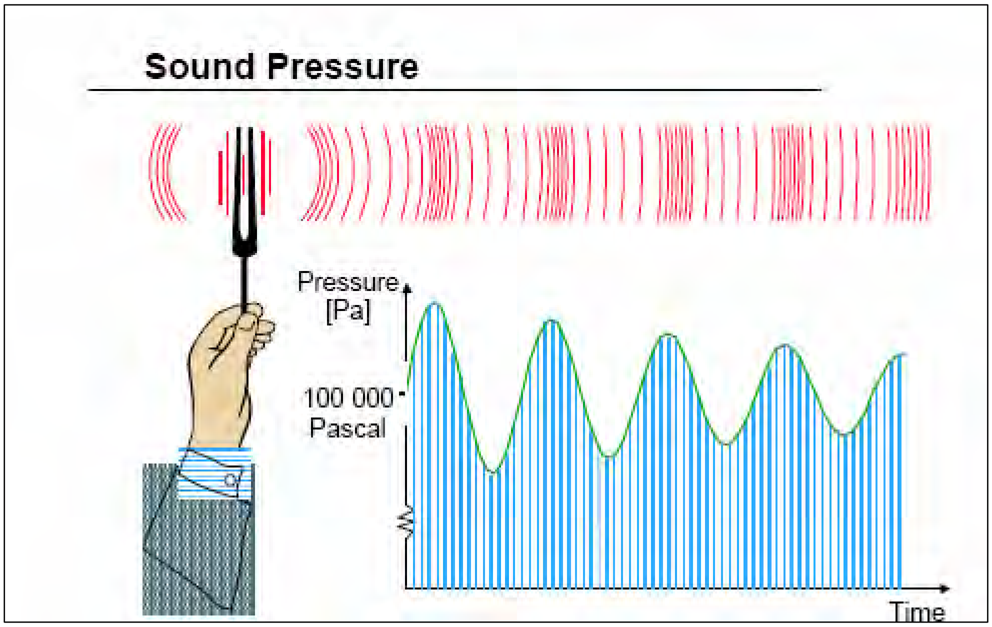
Figure 1-1 shows the project area. Terrain in the Project area consists of steeply to shallowly sloping regions that are cut by intermittent streams. Elevations increase roughly 150 feet from East to West. Elevations also increase to the North, though only by approximately 50 feet. Terrain South of the Facility is relatively flat, with a gentle slope to the East. Intermittent stream channels are present on all sides of the Facility. Residences where noise monitoring was performed are 20 to 50 feet lower in elevation than the Facility.

In addition to the fenced-in Facility, Basin Electric owns enough additional land, adjacent to the Facility, to expand the Facility should future energy needs require such an expansion.

Figure 1-1
Facility Location Map
Rapid City, South Dakota

2.0 Fundamentals of Noise & Vibration

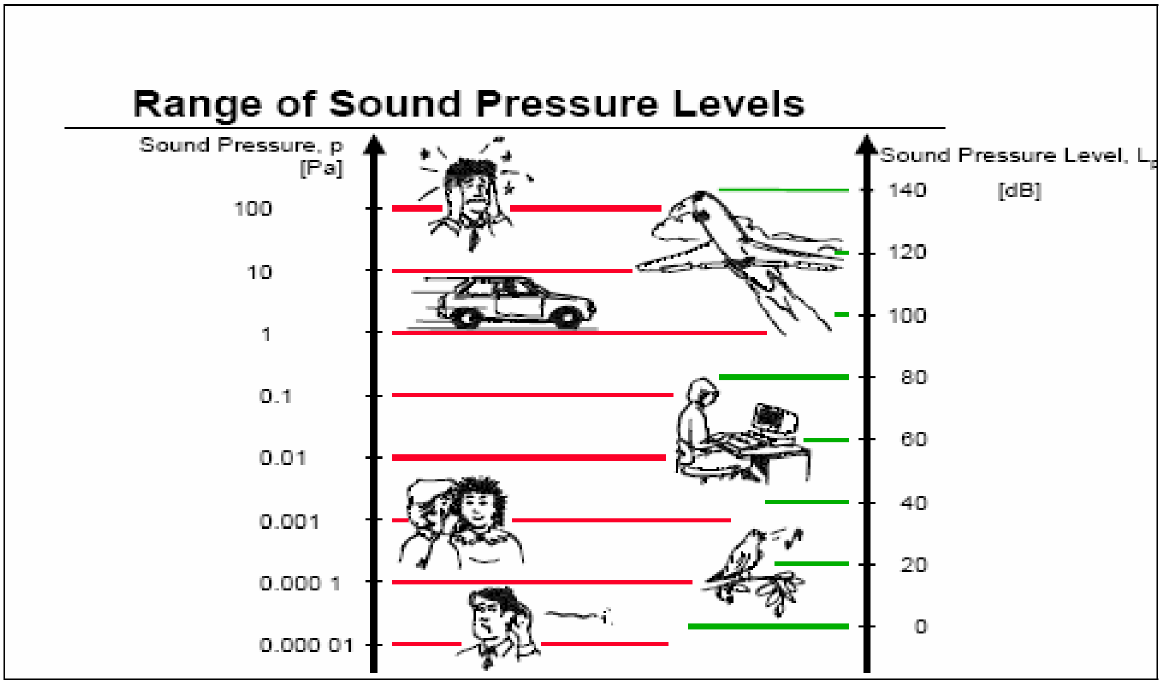
Sound consists of tiny pressure waves in the air that are created by the movement of an object. Figure 2-1 uses a tuning fork to illustrate that the motion of an item creates tiny pressure waves – like ripples in a pond. The figure expresses pressure in units of Pascal.



Source: Brűel & Kjær

Figure 2-1
Sound Pressure Waves

The range in sound pressure levels is tremendous, as shown by Figure 2-2. Sound can vary in intensity by over one million times within the range of human hearing. Therefore, a logarithmic scale, known as the decibel scale (dB), is used to quantify sound intensity and to compress the scale to a more manageable range. Using decibels, the range of sounds that humans perceive is expressed as being between approximately zero dB (near the threshold of hearing) and 130 dB (threshold of pain).

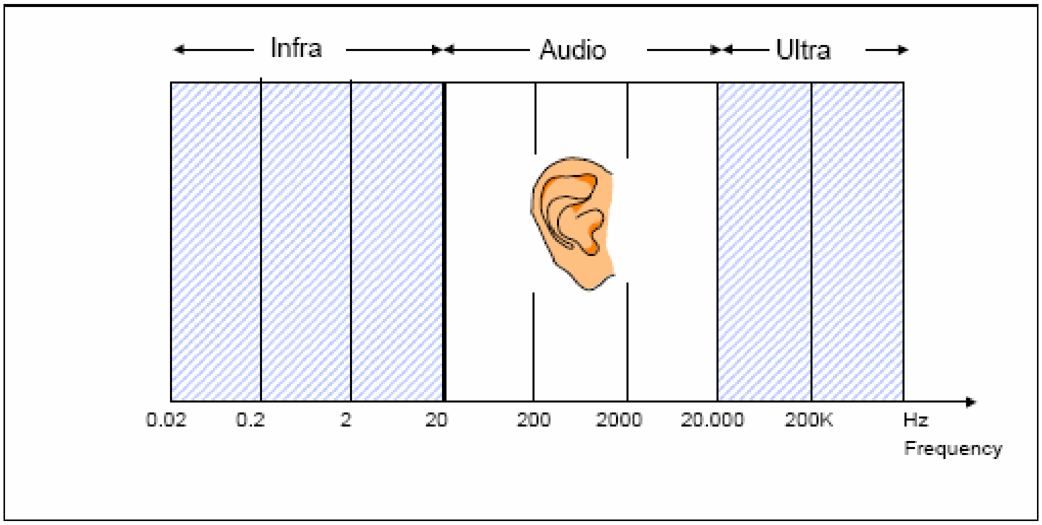


Source: Brűel & Kjær

Figure 2-2
Range of Sound Pressure Levels

Sound is characterized by both its amplitude and frequency (or pitch). The human ear does not hear all frequencies equally. In particular, the ear deemphasizes low and very high frequencies. To better approximate the sensitivity of human hearing, the A-weighted decibel scale (dBA) has been developed.

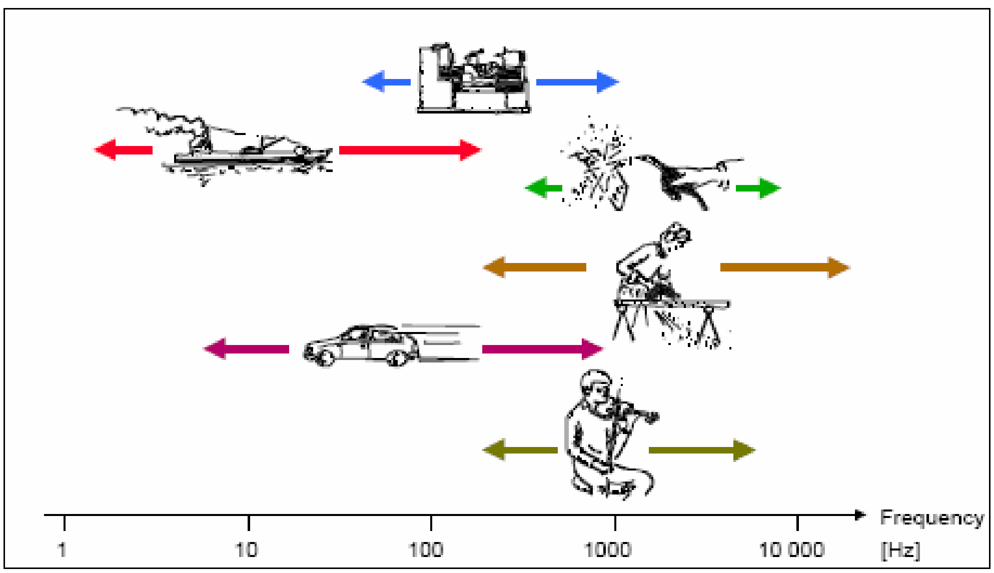
When noise levels are not A-weighted, we call them linear or unweighted. The human ear can not divide incoming sounds into their frequency-specific components. However, octave band filters on sound analyzers can. The frequency range of the sounds that humans are exposed to varies considerably. Normally, young human beings can detect sounds ranging from 20 to 20000 Hz, as shown in Figure 2-3. However, infrasound in the range from 1 to 20 Hz and ultrasounds between 20,000 to 40,000 Hz can affect other human senses and cause discomfort.



Source: Brűel & Kjær

Figure 2-3
Sound Frequencies

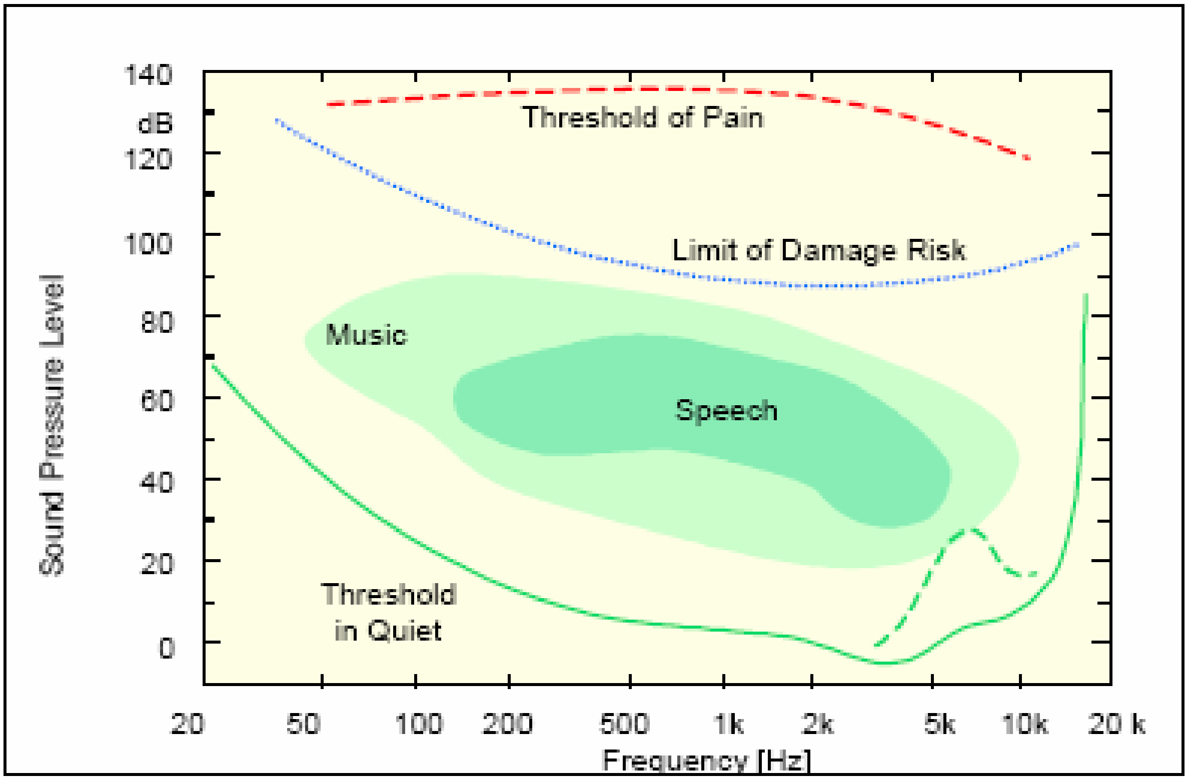
Figure 2-4 illustrates the range in frequencies among common noise sources. Note that none of the illustrated sound examples cover the entire frequency range. That is why knowledge of frequency range and the need for frequency analysis is important.



Source: Brűel & Kjær

Figure 2-4
Frequency Range of Common Noises

Figure 2-5 combines the concepts of frequency and sound pressure level to summarize the auditory field a typical person can perceive. In the figure, the solid line denotes the threshold at which a musical note (a pure tone) is audible. The upper dashed line represents the threshold of pain. If the limit of damage risk is exceeded for a longer time, permanent hearing loss can occur. This could result in the threshold of quiet moving up– as illustrated by the dashed curve in the lower right hand corner of the figure. To more fully understand these concepts, the range in frequency and sound pressure level for speech and music are shown as shaded areas.



Source: Brűel & Kjær

Figure 2-5
Auditory Field

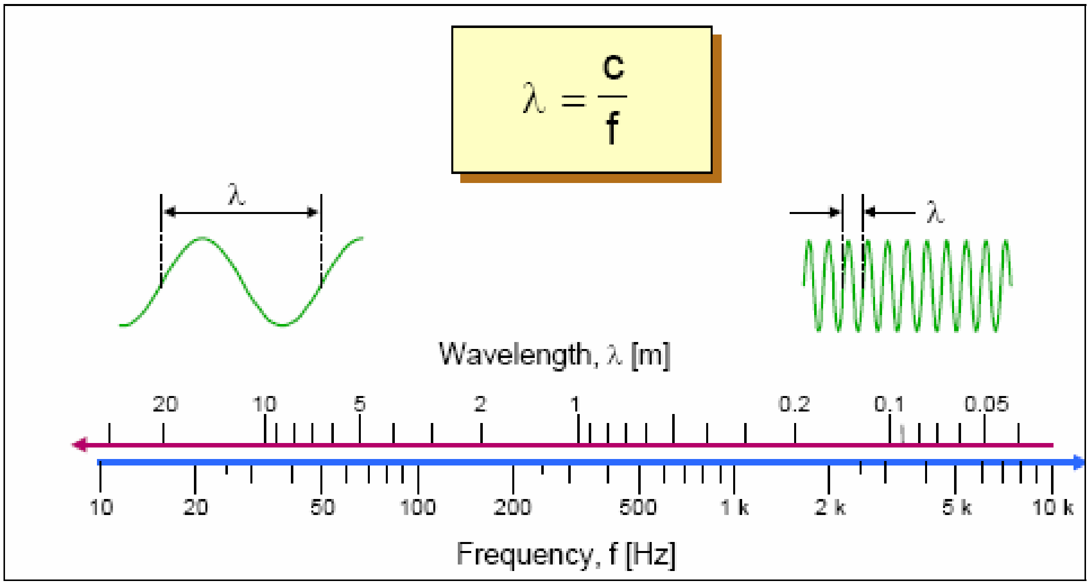
Using the decibel scale, sound levels from two or more sources cannot be directly added together to determine the overall sound level. Rather, the combination of two sounds at the same level yields an increase of 3 dBA. The average person cannot perceive a change in noise levels of less than 3-dBA. Changes of 5-dBA are considered clearly noticeable, and a 10-dBA change is generally considered to be a doubling or halving of the perceived loudness.

As the distance between a noise source and a noise receiver is increased, sound waves spread out and lose intensity (weaken), as illustrated in Figure 2-1. This is called geometric spreading, and is the primary factor that reduces levels of environmental noise.

Other factors that reduce levels of environmental noise include having intervening obstacles such as walls, buildings, or terrain features that block the direct path between the sound source and the receiver (called shielding). Factors that act to make environmental sounds louder include moving the sound source closer to the receiver, sound enhancements caused by reflections, and focusing caused by various meteorological conditions.

Below are brief definitions of terms used in this report:

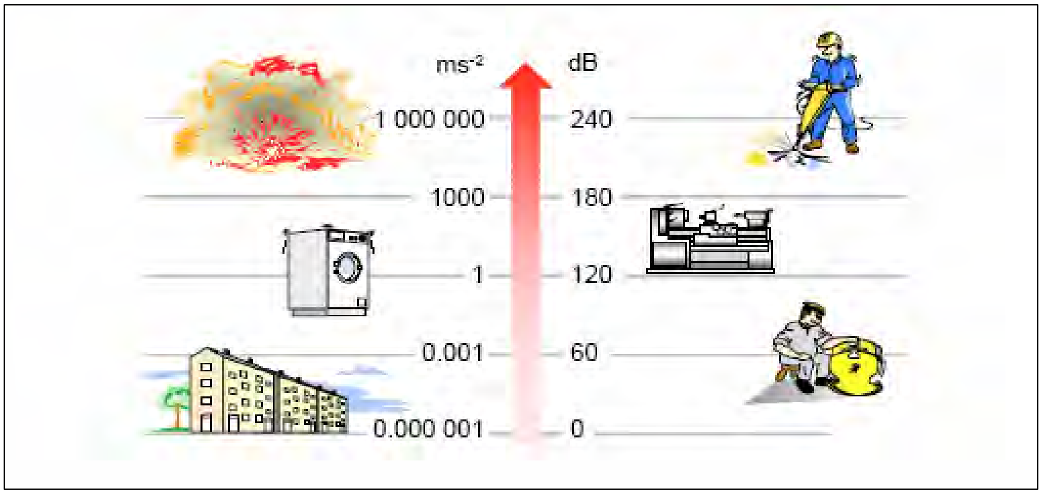
- **Equivalent Sound Level (L_{eq}):** The Leq is an average noise level. Noise levels in the ambient acoustic environment fluctuate constantly. The equivalent sound level (Leq), sometimes referred to as the energy average sound level, is the most common means of characterizing community noise. Leq represents a constant sound that, over the specified period, has the same sound energy as the time-varying sound.
- **Maximum Sound Level (L_{max}):** Lmax is the maximum sound level over the measurement period.
- **Day-Night Sound Level (L_{dn}):** Ldn is basically a 24-hour Leq with an adjustment to reflect the greater sensitivity of most people to nighttime noise. The adjustment is a 10-dB penalty for all sound that occurs between the hours of 10 p.m. and 7 a.m. The effect of the penalty is that, when calculating Ldn, any event that occurs during the nighttime is equivalent to 10 of the same event during the daytime. Ldn is the most common measure of total community noise over a 24-hour period and is used by the Federal Transit Administration (FTA) to evaluate residential noise impacts from proposed transit projects.
- **Frequency and Octave:** Frequency can be considered as the number of complete vibrations a source makes in one second. For example if a speaker cone moves in and out 100 times per second, the frequency of the tone it is producing is 100 cycles per second, or 100 Hertz (Hz). When the frequency is doubled, the resulting tone is similar to the original. Musicians recognize this as a change in octave. The audible frequency range contains ten octave bands, which are named by their geometric center frequency (octave band center). They are: 31.5, 63, 125, 250, 500, 1,000, 2,000, 4,000, 8,000 and 16,000 Hz.
- **Wavelength:** The physical distance from a given point of a wave through one complete cycle. Wavelength and frequency are related; lower frequencies have longer wavelengths, and higher frequencies have shorter wavelengths as shown by Figure 2-6. At 20 Hz the wavelength is approximately 65.5 feet. A 1,000 Hz (or 1 kHz) frequency has a wavelength of approximately 1 foot. A 20 kHz frequency has a wavelength of approximately 0.65 inch. In the figure below, wavelength is denoted using the Greek symbol Lambda (λ). Mathematically, the wavelength can be calculated by dividing the speed of sound (C) by the frequency (f).



Source: Brűel & Kjær

Figure 2-6
Relationship between Frequency and Wavelength

Vibration: An oscillatory motion which can be described in terms of the displacement, velocity or acceleration. There is no net movement of a vibrating particle and the average of any of the motion descriptors is zero. Figure 2-7 illustrates the range of common vibrations expressed as vibration accelerations (meters per second^2). The range of vibrations is over one million units.



Source: Brűel & Kjær

Figure 2-7
Range of Common Vibration Sources

- **PPV:** Peak Particle Velocity is the maximum instantaneous positive or negative peak velocity of a vibration signal. Typically used in relation to structural response to vibration.
- **RMS:** Root Mean Square is the average of the squared amplitude of a noise or vibration signal.
- **Pure tones:** The sound radiated by a source vibrating at a single discrete frequency. Examples include a tuning fork, a single note on a piano or guitar, or the sound a person makes when he/she whistles a single note. In the context of this report, a pure tone is also defined as being an octave band that is 5 dB higher than the previous and the next octave band. A difference of 5 dB is considered clearly audible. Therefore, a pure tone is an audible tone (hum, whistle, etc.) that stands out from background noise levels. It is discernable in the ambient acoustic environment. Tones that stand out from the background noise are generally considered to be more annoying. Pure tones are sometimes defined as having a difference of more than 5 dB between successive octave bands. Use of the 5 dB threshold in this report is considered conservative. In this report, the terms pure tone and prominent discrete tone are considered interchangeable – although HDR recognizes some differences in their definitions.
- **Broadband noise:** A complex mixture of sounds of different frequencies. Often the mixture of frequencies changes rapidly – like the sound of a waterfall or heavy traffic passing by a listener.

3.0 Acceptable Noise Levels

The next step in the analysis is to identify criteria for acceptable levels of environmental noise. There are a number of different agencies that define acceptable levels of outdoor noise. Some agencies address hourly noise levels, often expressed as an hourly Leq. Other agencies address 24-hour average noise levels using the Ldn descriptor. The Ldn is a 24-hour average noise level that penalizes nighttime noise by adding 10 dB to hourly Leq values between the hours of 10:00 p.m. and 7:00 a.m. Following is a brief discussion of a representative sample of agencies whose noise criteria may be helpful in evaluating noise levels in the project area.

The **Federal Highway Administration (FHWA)** and **South Dakota Department of Transportation (SDDOT)** Noise Abatement Criteria (NAC) establishes acceptable and unacceptable levels for traffic noise (expressed as an hourly Leq in dBA). When peak hour traffic noise levels approach or exceed the NAC, methods to mitigate traffic noise must be evaluated.

The **Federal Aviation Administration (FAA)** established maximum allowable levels of aviation noise. FAA regulates noise using the Ldn descriptor.

The **Federal Transit Administration (FTA)** established maximum allowable levels of noise from transit operations when added to existing noise levels. The FTA criteria take into account existing background noise levels and limit overall noise levels.

The **Federal Railroad Administration (FRA)** essentially adopted FTA's environmental noise limits. FRA also regulates noise from specific train vehicles and activities. That portion of the FRA program is not directly relevant for the purposes of this report.

The **Surface Transportation Board (STB),** formerly the Interstate Commerce Commission, enforces regulations on the maximum amount of noise from freight train activities. STB rules primarily affect train activities associated with the construction of new rail lines and railroad merger/acquisitions.

The **United States Environmental Protection Agency (EPA)** coordinated all federal noise control activities through its Office of Noise Abatement and Control. EPA established recommended noise levels that would protect human health and welfare.

The Department of House and Urban Development (HUD) established maximum acceptable noise levels.

The following table summarizes the maximum allowable levels of noise advocated by the agencies discussed above. The last line in this table presents HDR's recommendation for maximum allowable noise limits; these represent the limits for use during noise-compatible land use planning. The recommended limits are expressed as a range, reflecting the range of allowable noise levels advocated by various agencies.

Table 3-1
Acceptable Levels of Outdoor Noise

Agency	Residential		Commercial		Industrial	
	L_{eq} (dBA)	L_{dn} (dBA)	L_{eq} (dBA)	Ldn (dBA)	Leq (dBA)	Ldn (dBA)
SDDOT (FHWA)	66	NA	72	NA	72	NA
FTA	NA	65	65	NA	65	NA
FRA	NA	65	65	NA	65	NA
STB	NA	65	NA	NA	NA	NA
EPA	NA	55	NA	NA	NA	NA
FAA	NA	65	NA	NA	NA	NA
HUD	NA	65	NA	NA	NA	NA
Recommended limits	55-66	55-65	65-72	65-72	65-72	65-72

The acceptable levels of outdoor noise shown in the table above assume that noise levels are broadband. This means they are not dominated by tones or impulsive noises that stand out from the background acoustic environment.

Noise with distinct tones, for example, noise from sawing, is generally considered to be more annoying than broadband noise (like traffic noise). Impulsive noise, like noise from hammering, is also considered to have greater potential to annoy people than a typical broadband noise. This annoyance factor is not taken into account in a broadband measurement. Therefore a spectral analysis may be needed to assess the potential for annoyance. In this report, assessments of noise-compatible land use in the project area will reflect knowledge of tonal emissions from the Facility.

4.0 Acceptable Vibration Levels

In previous sections, this report discussed the frequency range of human hearing – the auditory range of sounds we can hear. Below that range, sound pressures produce a tactile experience – they are perceived as vibrations. Similarly, ground-borne vibrations may produce a tactile experience, or they can also rattle windows and create an auditory experience. This section identifies criteria for acceptable levels of ground-borne vibration. There are a number of different studies and organizations that have defined acceptable levels of vibration for various situations.

A primary area of concern with ground-borne vibration is the human response, which differs for transient vibrations (short term) versus steady state (long term) vibrations. Figure 4-1 graphically shows the results of studies done in the field of human response to different types of vibration. Data in Figure 4-1 is grouped into three categories: steady-state vibration, continuous traffic vibration, and transient vibration. The figure illustrates that the thresholds of perception and annoyance vary for continuous traffic and steady state vibrations - demonstrating the different responses to these two types of stimuli. The lowest threshold of perception occurs at vibration velocities of approximately 0.008 in/sec. To facilitate comparison with different data sets, the figure expresses vibrations using peak particle velocity (ppv) rather than RMS, and is for illustration purposes only.

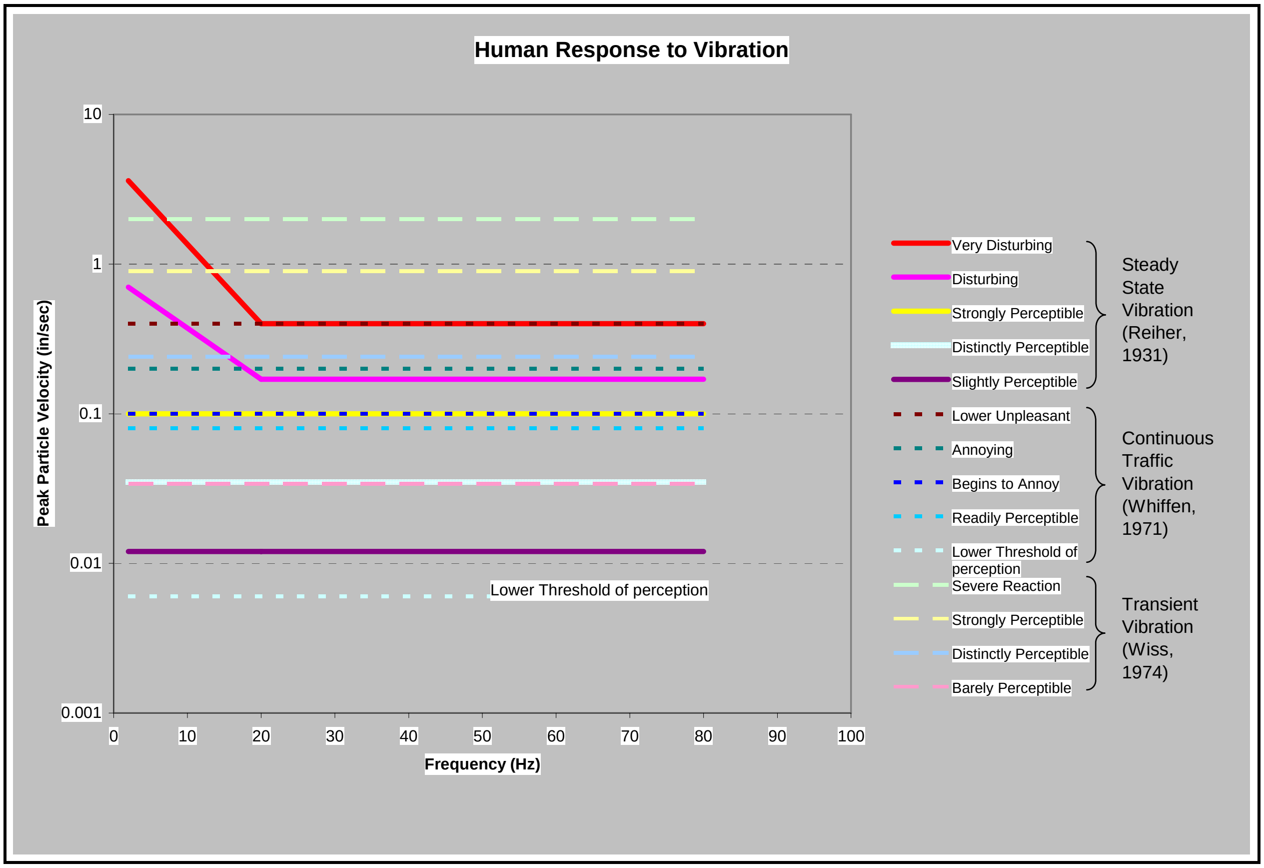


Figure 4-1
Human Response to Vibration Criteria

One subject of extensive research has been the effect of vibration, especially blasting, on structures. Table 4-1 shows published vibration levels above which structural damage at different types of buildings may occur.

Table 4-1
Published Vibration Criteria for Building Damage

Category	Source	Peak Particle Velocity (in/sec)
Industrial Buildings	Wiss (1981)	4
Buildings of Substantial Construction	Chae (1978)	4
Residential	Nicholls, et al. (1971), Wiss (1981)	2
Residential, New Construction	Chae (1978)	2
Residential, Poor Condition	Chae (1978)	1
Residential, Very Poor Condition	Chae (1978)	0.5
Buildings Visibly Damaged	DIN 4150	0.16
Historic Buildings	Swiss Standard	0.12
Historic and Ancient Buildings	DIN 4150	0.08

Vibration levels from the Facility are not expected to reach these damage thresholds. Therefore an alternative metric is the evaluation of potential interference with activities inside a building. These activities include sleep, and equipment or industries whose performance could be adversely affected by vibration (electron microscopes, high-tech printing operations, laser eye surgery, etc.). There are two sets of criteria that have been established for this: One created by the International Standards Organization (ISO) and the vibration criteria (VC) curves that were developed based on years of experience vibration analyses performed for equipment siting purposes. Table 4-2 presents the ISO and VC thresholds for common and vibration-sensitive facilities and activities. The table expresses vibration criteria in terms of Peak Particle Velocity (ppv) in inches per second (in/sec). Refer to Section 2.0 for a definition of ppv.

Table 4-2
Vibration Criteria for Sensitive Equipment

Criterion Curve	Max Level[1] (inches/sec)	Detail Size[2] (microns)	Description of Use
Workshop (ISO)	0.032	NA	Distinctly feelable vibration. Appropriate to workshops and nonsensitive areas.
Office (ISO)	0.016	NA	Feelable vibration. Appropriate to offices and nonsensitive areas.
Residential Day (ISO)	0.008	75	Barely feelable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment, and low-power (to 50X) microscopes.
Op. Theatre (ISO)	0.004	25	Vibration not feelable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A	0.002	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	0.001	3	An appropriate standard for optical microscopes to 1,000X, inspection and lithography equipment (including steppers) to 3 micron line widths.
VC-C	0.0005	1	A good standard for most lithography and inspection equipment (including electron microscopes) to 1 micron detail size.
VC-D	0.00025	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.
VC-E	0.000125	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems, and other systems requiring extraordinary dynamic stability.

[1] As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz. The dB scale is referred to 1 micro-inch/second.
[2] The detail size refers to the line width in the case of microelectronics fabrication, the particle (cell) size in the case of medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items of the equipment depend upon the detail size of the process.

This report uses the ISO criteria for acceptable levels of vibration at a residence as the metric against which vibration monitoring data is compared. Other criteria in this table are also incorporated into discussions of the monitoring data, as appropriate.

5.0 Existing Noise Levels

HDR performed two types of noise measurements to assess existing noise levels near the Facility and at residences in the project area. Near the Facility, HDR performed short-term *spectral* noise measurements at 24 locations. Using an aerial photograph, HDR created a Cartesian coordinate grid with the Facility at the origin. Measurements occurred at distances of 0, 330, 660, 1320, 1980, and 2640 feet in each of the four cardinal directions from the Facility. The zero-ft measurement was performed at the edge of the gravel-filled area that lies outside the Facility fence line, roughly 10 feet beyond the fence. These measurements collected spectral data: noise data processed through filters that separate sound into octave bands to allow an evaluation of both overall levels and tonal levels.

HDR also performed 24-hour noise measurements at five residences in the project area. At the end of each hour, the sound level meters stored monitoring data. These measurements continued for 24 continuous hours. Figure 5-1 shows the monitoring locations. During the 24-hour noise measurements, operational load levels at the Facility fluctuated. Measurements were performed on May 16th and May 17th, starting at approximately 11:00 p.m. and ending between 5:00 and 6:00 a.m. the next morning. During the monitoring periods, the Facility was running at maximum rated capacity. Appendix D shows the load flow data for the monitoring period; this information was provided by Black Hills Power. Measuring noise and vibration during peak operational conditions is considered to produce worst-case noise and vibration data.

Meteorological conditions included clear skies, with the exception of a short thunderstorm on the last day of monitoring (July 15). Temperatures ranged from 38 to 83 degrees Fahrenheit on the days when HDR collected monitoring data in May and 53 to 99 degrees Fahrenheit during the monitoring event in July.

Background noises included birds, insects, cows, wind noise, and minor amounts of traffic noise from the nearby highway.

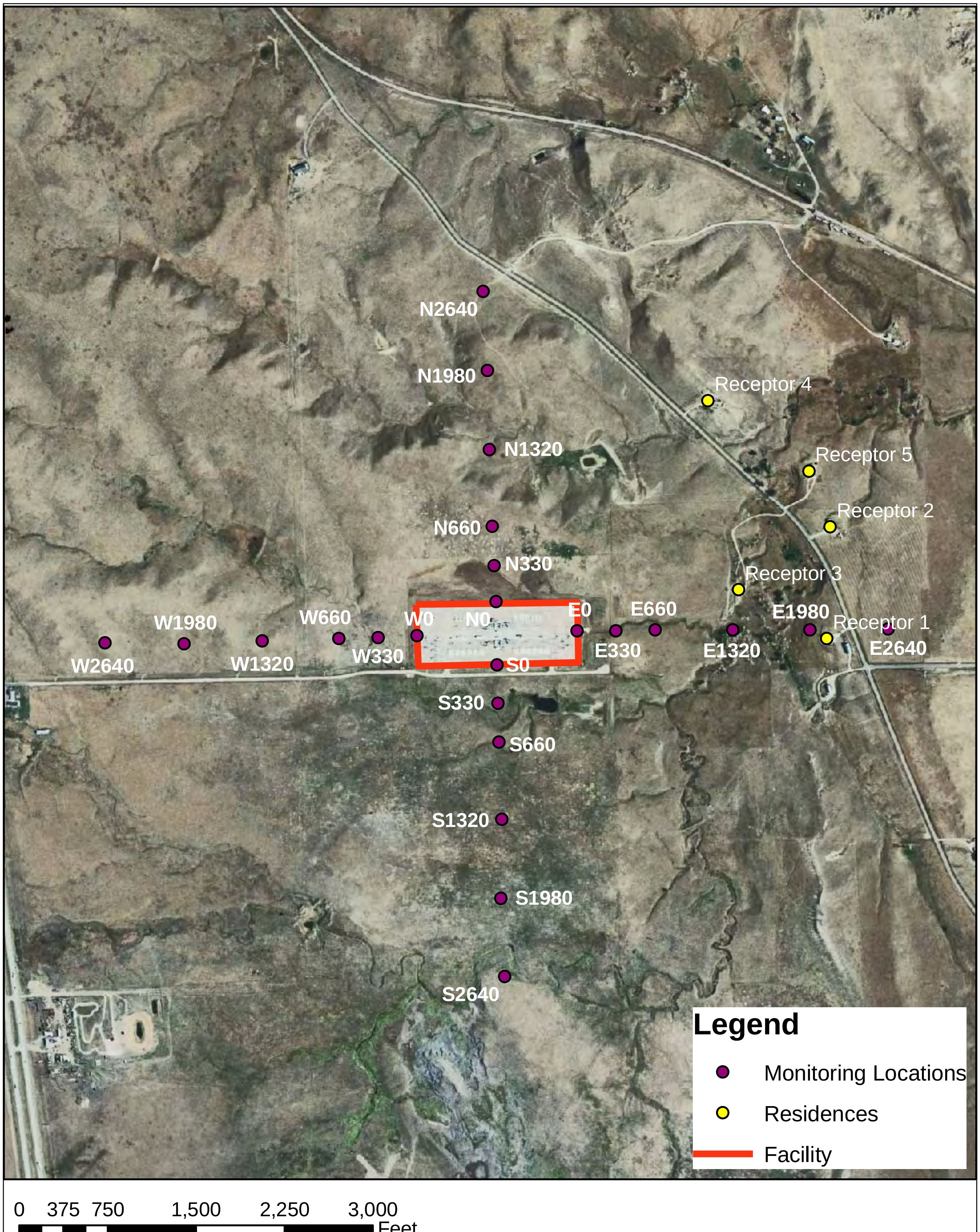
5.1 *Spectral Noise Levels*

This section discusses measurements performed at fixed distances from the Facility, in each of the four cardinal directions. Each section discusses the overall A-weighted broadband noise level (what humans hear) in Leq. The overall broadband noise level is not the only potential issue: pure tones also have potential to be annoying. Therefore each section discusses the presence or absence of pure tones in the monitoring data. Because operational and meteorological conditions affect sound propagation, the following sections also identify when elevated noise levels occurred and were close, but did not meet the definition of pure tones. Appendix A contains detailed noise monitoring data

5.1.1 Noise Levels North of the Facility

Table 5-1 presents the Leq values measured at each of the six monitoring locations north of the Facility. The Leq descriptor, used below, is an energy-based average noise level.

The table also indicates whether or not the spectral data includes pure tones or noise levels that are close to pure tones. Pure tones may be perceivable to some people, and could potentially be considered annoying. This annoyance would be very subjective and difficult to predict.



N

Figure 5-1
Monitoring Locations Map
Rapid City, South Dakota

Table 5-1
Spectral Noise Measured North of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet North	55	Yes
330 feet North	45	Yes
660 feet North	44	Yes
1320 feet North	42	No (a)
1980 feet North	41	Yes
2640 feet North	41	No (a)

(a) Some noise levels measured at this location did not meet the criteria for a pure tone. However, noise levels appear close to meeting this criterion. Pure tones could potentially occur under different operational or meteorological conditions.

Data in the table shows that broadband noise levels are consistent with acceptable noise levels for residential land uses beyond the edge of gravel at the Facility (where the zero measurement occurred). However, pure tones and near-pure tones were measured at all locations north of the Facility. In the absence of background noise that masks these pure tones, these could potentially annoy residents if those tones are audible. Noise levels decrease with increasing distance from the Facility – as is expected. Noise levels beyond 2640 feet are likely to be comparable to 41 dBA, a typical noise level for quiet nighttime conditions.

5.1.2 Noise Levels South of the Facility

Table 5-2 presents the Leq values measured at each of the six monitoring locations south of the Facility.

Table 5-2
Spectral Noise Measured South of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet South	68	Yes
330 feet South	68	No
660 feet South	58	No
1320 feet South	41	Yes
1980 feet South	42	Yes
2640 feet South	41	Yes

Data in the table shows that broadband noise levels are consistent with acceptable noise levels for residential land uses at distances beyond a point somewhere between 330 feet and 660 feet from the edge of gravel at the Facility (where the zero measurement occurred). South of the Facility, terrain is generally low and flat. While noise levels typically drop off with increasing distance from the noise source, monitoring data in Table 5-2 shows no reduction in noise levels between zero feet and 330 feet. This may reflect the fact that the measurement performed at 330 feet received a noise contribution from the entire Facility, whereas the measurement performed at zero feet received a noise contribution from a more localized portion of the Facility.

The monitoring data does show a decrease in Facility-related noise between 330 and 660-feet. The monitoring data does not show a continued decrease in Facility-related noise at

1320 feet. HDR does not consider noise levels at distances between 1320 and 2640 feet to be dominated by Facility-related noise. Rather, it is a combination of noise from natural and man-made sources and activities.

5.1.3 Noise Levels East of the Facility

Table 5-3 presents the Leq values measured at each of the six monitoring locations east of the Facility.

Table 5-3
Spectral Noise Measured East of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet East	46	No (a)
330 feet East	43	No
660 feet East	42	No (a)
1320 feet East	41	Yes
1980 feet East	44	Yes
2640 feet East	40	Yes

(a) Some noise levels measured at this location did not meet the criteria for a pure tone. However, noise levels appear close to meeting this criterion. Pure tones could potentially occur under different operational or meteorological conditions.

Data in the table shows that broadband noise levels are consistent with acceptable noise levels for residential land uses at distances beyond the edge of gravel at the Facility (where the zero measurement occurred). As expected, data in the table above show that noise levels are highest at the zero-ft measurement location. The table also shows that noise levels are fairly consistent between 330 and 2640 feet from the Facility. Pure tones, or near-pure tones were measured at zero, 1320, 1980 and 2640 feet. In the absence of background noise levels that can mask these tones, or buildings that can shield them, they have potential to be annoying. Noise from cows was audible while HDR staff measured along the East axis.

5.1.4 Noise Levels West of the Facility

Table 5-4 presents the Leq values measured at each of the six monitoring locations west of the Facility.

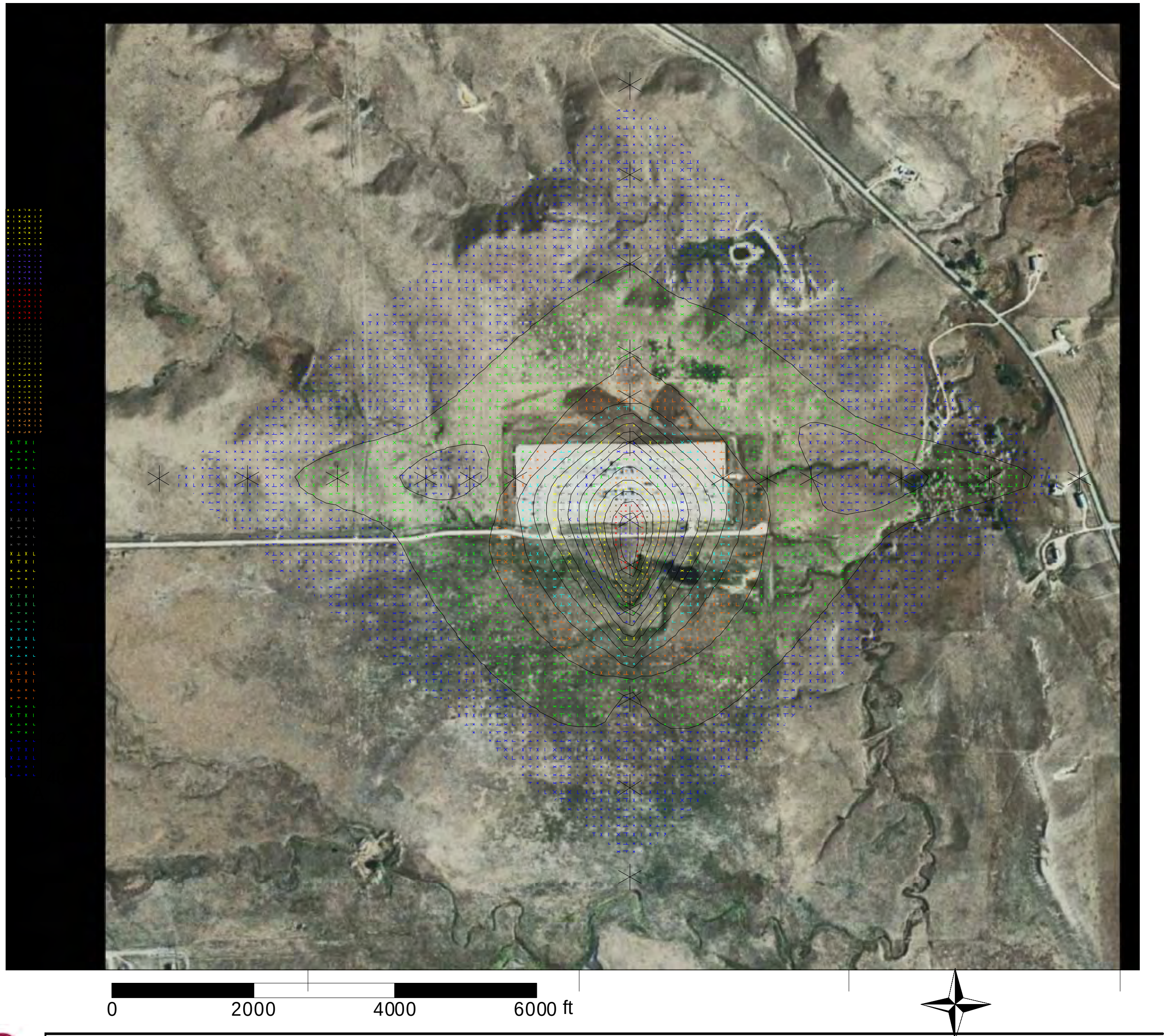
Table 5-4
Spectral Noise Measured West of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet West	44	Yes
330 feet West	41	Yes
660 feet West	41	Yes
1320 feet West	44	Yes
1980 feet West	40	Yes
2640 feet West	41	Yes

Data in the table shows that broadband noise levels are consistent with acceptable noise levels for residential land uses at distances beyond the edge of gravel at the Facility (where the zero measurement occurred). Data in the table above also show that noise levels decreased with increasing distance out to 1320 feet. At this location, terrain rose slightly and therefore ground absorption effects were minimized – potentially explaining the elevated noise level measured at this location. Noise levels drop off at 1980 feet, a location that is partially shielded from the Facility by terrain. Traffic noise became audible as HDR approached the Western-most monitoring location. Pure tones exist in the monitoring data at all the monitoring locations.

5.1.5 Plot of Facility-related Noise Levels

At the request of the City, HDR entered the noise monitoring data into software called SURFER. SURFER mathematically interpolates noise levels between data points, and created the following figure. The goal of this exercise was to produce a graphical figure showing noise contours that are based on the noise monitoring data. Figure 5-2 uses different colored areas to represent the different noise levels measured near the Facility. The figure shows that Facility-related noise spreads out along the East-West axis a little more than it does along the North-South axis.



HDR
HDR Engineering, Inc.

Existing Noise Contours
Black Hills Power/Basin Electric Power Cooperative Intertie
Rapid City, South Dakota

Sept. 2007

Figure 5-2

5.2 *24-Hour Noise Levels*

HDR performed unattended 24-hour noise measurements at five residences in the project area. A single configuration file was created to program the sound level meters for data collection and to store data at the end of each hour. The identical file was downloaded into each of the meters. The metrics of primary interest are the hourly Leq and the Ldn. The Ldn was manually calculated. This calculation includes adding 10 decibels to the hourly Leq values stored between 10:00 p.m. and 7:00 a.m. Table 5-5 compares the range of hourly Leq values and Ldn values measured at five residences in the project area with the recommended Leq and Ldn for residential land uses (shown in Table 5-4). The recommended limits are expressed as a range, reflecting the range of acceptable noise levels advocated by various agencies. An equipment malfunction resulted in HDR repeating the 24-hour measurement at Location 4. This additional measurement was performed during a period when the Facility was running at or near rated capacity.

Table 5-5
Noise Levels Measured at Residences

	Residential Noise Levels	
	Range of Hourly Leq (dBA)	**Ldn (dBA)**
Recommended limit	55 to 65	55 to 65
Location 1 - 7825 Old Folsom Road	38-57	53
Location 2 - 7760 Old Folsom Road	37-56	55
Location 3 - 7751 Old Folsom Road	39-57	54
Location 4 - 7700 Old Folsom Road	35-57	54
Location 5 - 7756 Old Folsom Road	37-59	56

By inspection, data in Table 5-5 indicates that noise levels measured at the residences in the project area are in the range of noise levels considered acceptable for residential land uses. The 24-hour measurements were unattended. While in the project area, HDR staff observed that noise levels in the project area are dominated by noise from wind, occasional vehicular traffic, typical human activities such as lawn maintenance, (at Location 5) swimming pool filter pump (at Location 4), pets, play activities, etc.). Noise from the Facility is also sometimes audible at these residential locations. Appendix B contains detailed 24-hour noise monitoring data.

6.0 Existing Vibration Levels

To assess existing vibration levels near the Facility HDR performed short-term vibration measurements at 24 locations. The duration of all vibration measurements was two minutes. Using an aerial photograph, HDR created a Cartesian coordinate grid with the Facility at the origin. Measurements occurred at distances of 0, 330, 660, 1320, 1980, and 2640 feet in each of the four cardinal directions from the Facility. HDR also performed short-term vibration measurements at residences in the project area. Vibrations from sources outside the project area were not taken into account.

A grid of grounding conductors exists beneath the gravel (both inside and outside the fence line). HDR performed the 0-ft measurement beyond the edge of the gravel for two reasons: to avoid any potential interference between the accelerometer and the grounding conductors, and; to ensure proper coupling between the accelerometer and the soil – the measurement was performed in soil located beyond the edge of the gravel. The following sections discuss the ground-borne vibration data. Appendix C contains detailed noise monitoring data. Appendix D contains Facility power load flow data for the monitoring periods, as provided by Black Hills Power. HDR performed noise and vibration measurements at night when the Facility was operating at its rated capacity. During the night background noise and vibration levels from other activities were expected to be minimized.

6.1 *Vibration Levels North of the Facility*

Table 6-1 presents the maximum vibration values (in both RMS and PPV) measured at each of the six monitoring locations north of the Facility. The table also indicates whether or not the measured spectral vibration levels include any frequency spikes. These spikes could potentially be a concern if highly vibration-sensitive land uses were developed in their respective portions of the project area.

Table 6-1
Maximum Vibration Velocities Measured North of the Facility

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	6.42×10^{-6}	9.07×10^{-6}	NA
330 feet	1.28×10^{-5}	1.80×10^{-5}	31.5
660 feet	7.72×10^{-6}	1.09×10^{-5}	NA
1320 feet	1.31×10^{-5}	1.85×10^{-5}	31.5
1980 feet	1.10×10^{-5}	1.56×10^{-5}	31.5
2640 feet	8.94×10^{-6}	1.26×10^{-5}	31.5
Recommended limit	0.011	0.008	NA

Data in Table 6-1 above show that measured ground-borne vibration levels are below the recommended limit for residential land uses. Figure 6-1 shows the vibration monitoring data measured north of the Facility and compares it to the ISO and VC criteria curves for reference. The data is graphed in PPV.

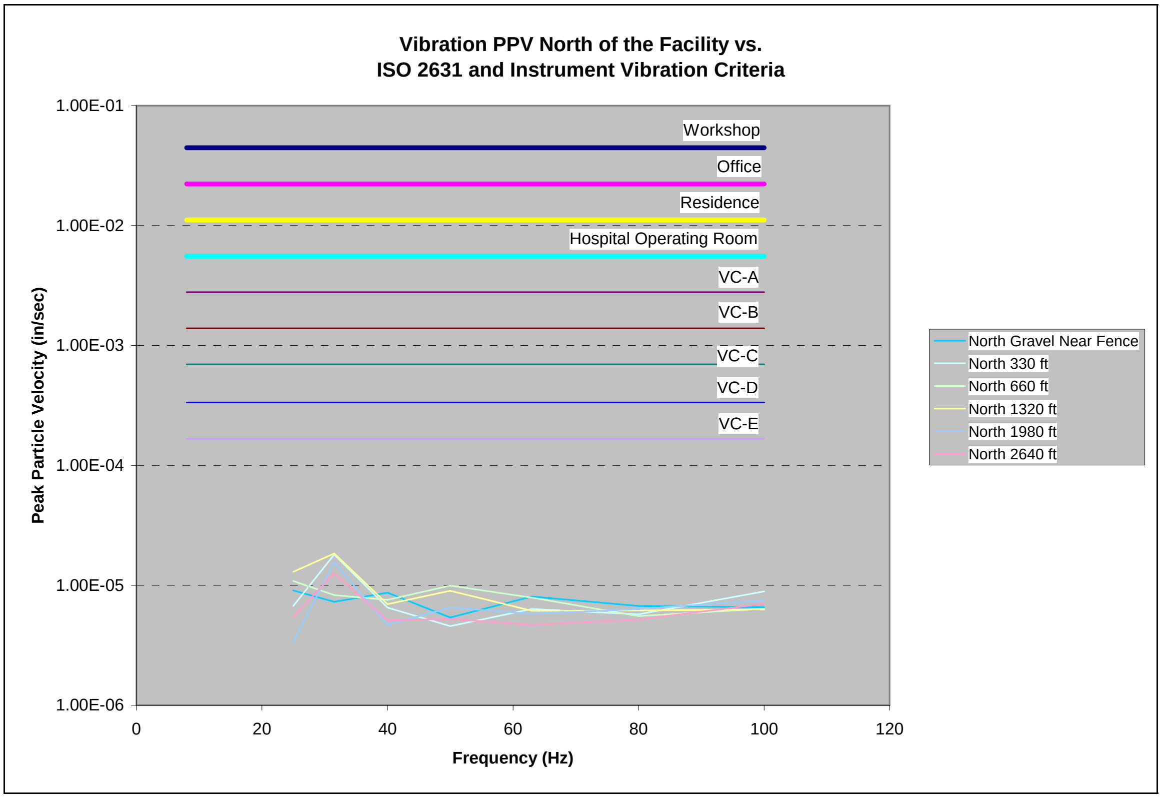


Figure 6-1
Vibration PPV North of the Facility

Data in the table and graph shows that vibration levels are significantly below the criteria curve for acceptable vibration levels for residential land use to the North of the Facility. Given the almost three orders of magnitude difference between the measured maximum values and the HDR limit (ISO residential limit), it is unlikely that the observed frequency spikes at 31.5 Hz would be perceived by anyone standing outdoors at these locations.

6.2 *Vibration Levels South of the Facility*

Table 6-1 presents the maximum vibration values (in both RMS and PPV) measured at each of the six monitoring locations south of the Facility. The table also indicates whether or not the measured spectral vibration levels include any frequency spikes. These spikes could potentially be a concern if highly vibration-sensitive land uses were developed in their respective portions of the project area.

Table 6-2
Maximum Vibration Velocities Measured South of the Facility

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	3.79×10^{-5}	5.36×10^{-5}	25
330 feet	1.00×10^{-4}	1.41×10^{-4}	63
660 feet	9.06×10^{-6}	1.28×10^{-5}	63
1320 feet	6.93×10^{-6}	9.80×10^{-6}	63
1980 feet	1.44×10^{-5}	2.04×10^{-5}	31.5
2640 feet	8.39×10^{-6}	1.19×10^{-5}	31.5
Recommended limit	0.011	0.008	NA

Data in Table 6-2 show that measured ground-borne vibration levels are below the recommended limit for residential land uses. Figure 6-2 shows the vibration monitoring data measured south of the Facility and compares it to the ISO and VC criteria curves for reference. The data is graphed in PPV.

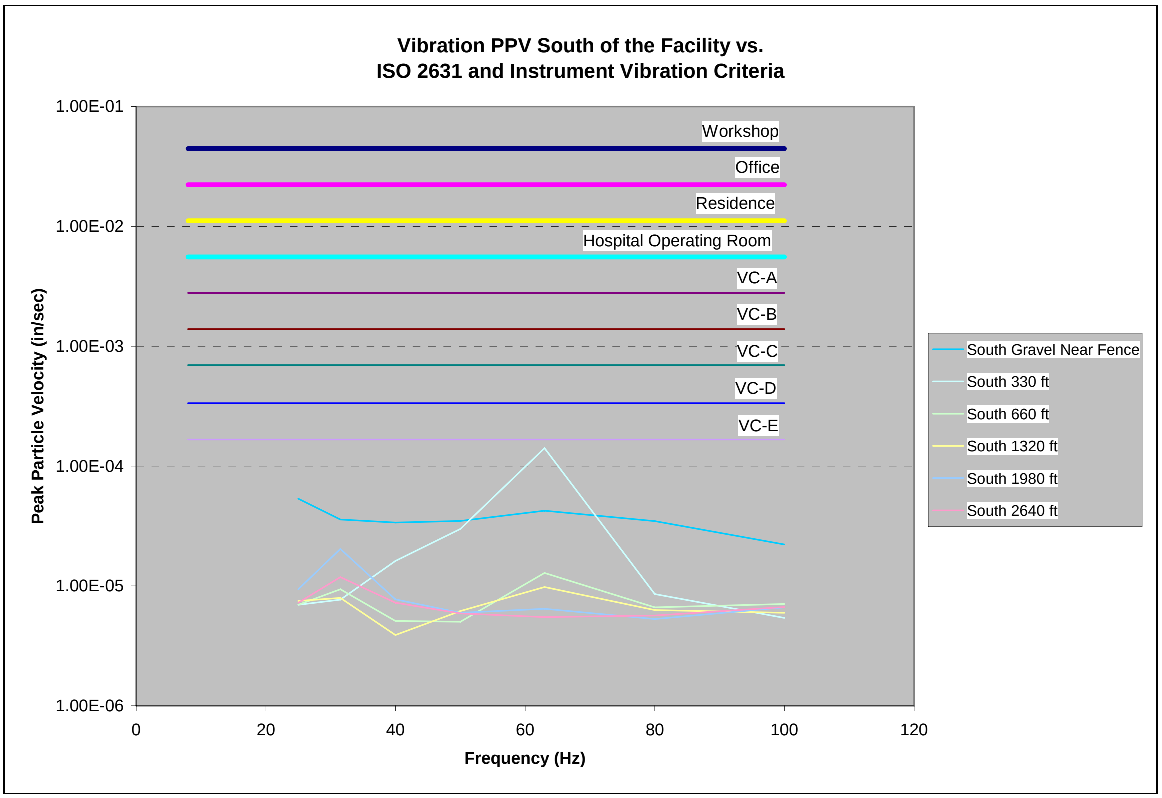


Figure 6-2
Vibration PPV South of the Facility

Data in the table and graph shows that vibration levels are significantly below the criteria curve for acceptable vibration levels for residential land use to the South of the Facility. While there are frequency spikes seen at all six locations, approximately two orders of magnitude difference exists between the HDR limit and the measured maximum value, as such, it is unlikely that the observed frequency spikes would be perceived by anyone standing on the ground at these locations. The spike at 63 Hz in data collected at the 330-feet South location is assumed to reflect the 60-cycle hum typically associated with electrical circuits. Interestingly, this spike is not present at the zero feet measurement, and it is one order of magnitude lower at the 660-foot measurement location. The spike is visible again at 1320 feet, although it is somewhat lower in magnitude than at the 660-foot measurement. The magnitude of the 63 Hz vibration velocity at 330 feet in this location suggests there might be subsurface condition that is conducive to vibration propagation; however this is a speculative statement. Future land uses that are extremely sensitive to vibration (such as nano-scale technology applications) evaluate the suitability of this location for the proposed application.

6.3 *Vibration Levels East of the Facility*

Table 6-3 presents the maximum vibration values (in both RMS and PPV) measured at each of the five monitoring locations east of the Facility (no data was recovered at 660 feet east of the Facility). The table also indicates whether or not the measured spectral vibration levels include any frequency spikes. These spikes could potentially be a concern if highly vibration-sensitive land uses were developed in their respective portions of the project area.

Table 6-3
Maximum Vibration Velocities Measured East of the Facility

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	4.37×10^{-5}	6.18×10^{-5}	25, 63
330 feet	1.78×10^{-5}	2.52×10^{-5}	25, 63
660 feet	No Data	No Data	NA
1320 feet	6.93×10^{-6}	9.80×10^{-6}	31.5
1980 feet	1.62×10^{-5}	2.29×10^{-5}	63
2640 feet	1.73×10^{-5}	2.44×10^{-5}	63
Recommended limit	0.011	0.008	NA

Table 6-3 shows that measured ground-borne vibration levels are below the recommended limit for residential land uses. The Figure 6-3 shows the vibration monitoring data measured east of the Facility and compares it to the ISO and VC criteria curves for reference. The data is graphed in PPV.

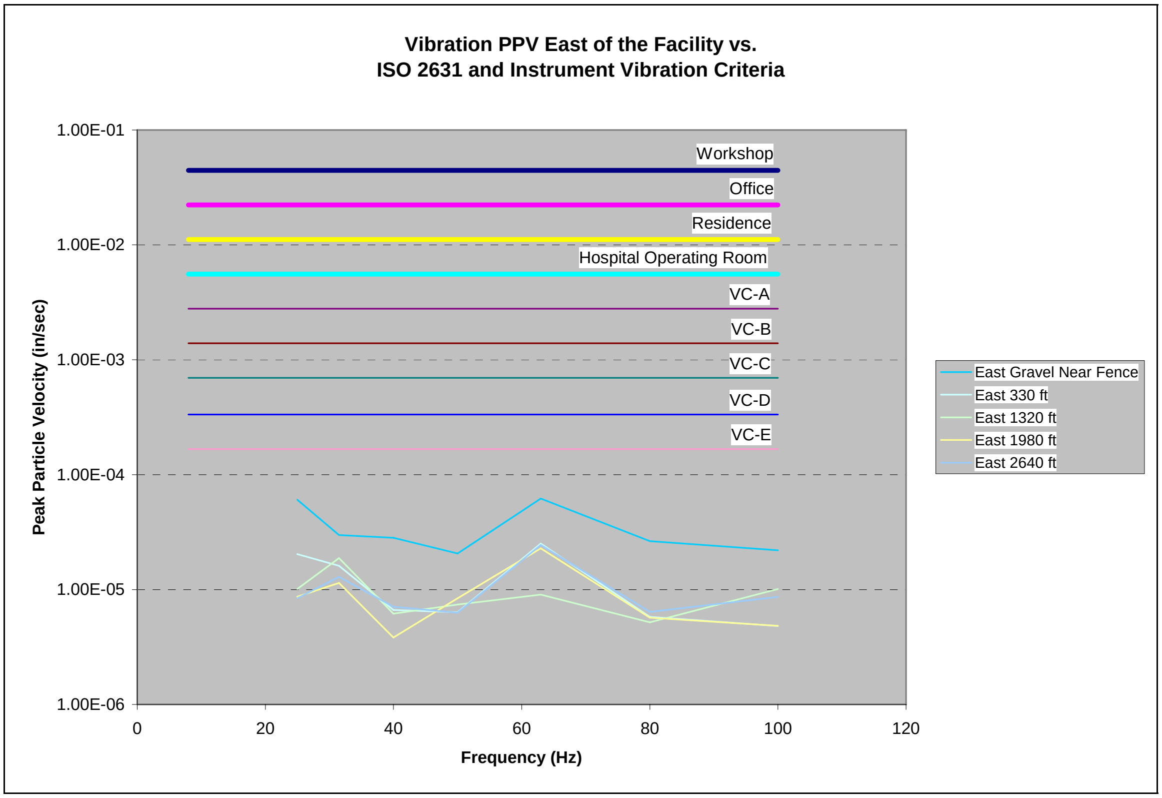


Figure 6-3
Vibration PPV East of the Facility

Data in the table and graph shows that vibration levels are significantly below the criteria curve for acceptable vibration levels for residential land use to the East of the Facility. While there are frequency spikes seen at all five locations, more than two orders of magnitude difference exists between the HDR limit and the measured maximum value, as such, it is unlikely that the observed frequency spikes would be perceived by anyone.

6.4 *Vibration Levels West of the Facility*

Table 6-4 presents the maximum vibration values (in both RMS and PPV) measured at each of the six monitoring locations west of the Facility. The table also indicates whether or not the measured spectral vibration levels include any frequency spikes. These spikes could potentially be a concern if highly vibration-sensitive land uses were developed in their respective portions of the project area.

Table 6-4
Maximum Vibration Velocities Measured West of the Facility

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	3.46×10^{-4}	4.89×10^{-4}	63
330 feet	1.02×10^{-4}	1.44×10^{-4}	63
660 feet	3.25×10^{-5}	4.60×10^{-5}	63
1320 feet	1.70×10^{-5}	2.40×10^{-5}	63
1980 feet	2.90×10^{-5}	4.10×10^{-5}	63
2640 feet	2.20×10^{-5}	3.11×10^{-5}	63
Recommended limit	0.011	0.008	NA

Table 6-4 shows that measured ground-borne vibration levels are below the recommended limit for residential land uses. Figure 6-4 shows the vibration monitoring data measured west of the Facility and compares it to the ISO and VC criteria curves for reference. The data is graphed in PPV.

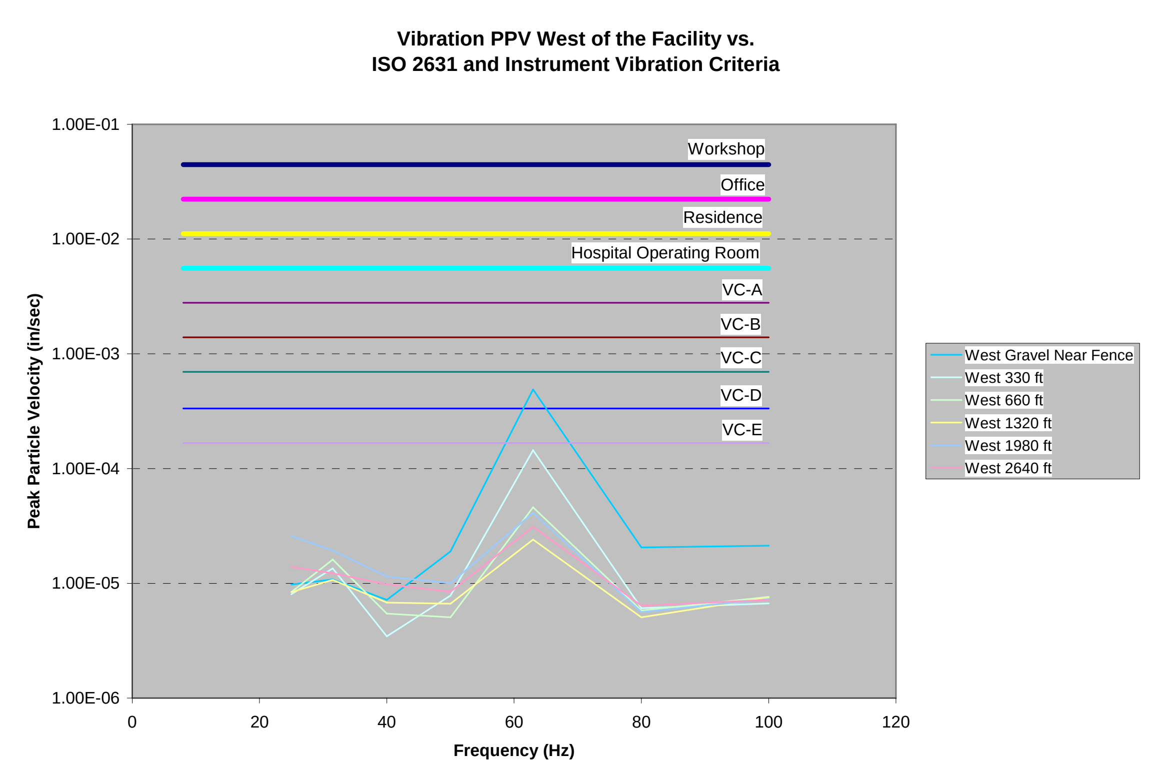


Figure 6-4
Vibration PPV West of the Facility

Data in the table and graph shows that vibration levels are significantly below the criteria curve for acceptable vibration levels for residential land use to the West of the Facility. There are significant frequency spikes seen at 63 Hz at all locations. The spike at 63 Hz in data collected at the 330-feet West location is assumed to reflect the 60-cycle hum typically associated with electrical circuits. It suggests that land uses that are extremely sensitive to vibration (such as nano-scale technology applications) evaluate the suitability of this location for the proposed application.

While there are frequency spikes seen at all six locations, more than two orders of magnitude difference exists between the HDR limit and the measured maximum value, as such, it is unlikely that the observed frequency spikes would be perceived by anyone standing on the ground at these locations.

6.5 *Vibration Levels at Residences near the Facility*

Table 6-5 presents the maximum vibration values (both RMS and PPV) measured at four residences near the Facility. The table also indicates whether or not the measured spectral vibration levels include any frequency spikes. Spikes may be perceivable to some people, and could potentially be considered annoying. This annoyance would be very subjective and difficult to predict.

Table 6-5
Maximum Vibration Velocities Measured at Residences

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
Receptor 1	6.22×10^{-6}	8.80×10^{-6}	40
Receptor 2	4.45×10^{-5}	6.29×10^{-5}	25,31.5,63
Receptor 3	2.31×10^{-5}	3.26×10^{-5}	25,63
Receptor 4	7.80×10^{-3}	1.10×10^{-2}	NA
Recommended limit	0.011	0.008	NA

HDR was unable to translate the data file containing vibration monitoring data at Receptor 5. It may have become corrupted during transport from the project area. Data collected at Receptors 2, 3, and 4 adequately represent the range of vibration levels measured at Receptor 5. Table 6-5 shows that vibration levels measured in the ground outside the residences is below the maximum vibration velocity level recommended for residential land uses by ISO. Figure 6-5 shows the data for the residences relative to the ISO and VC criteria curves for reference. The data is graphed in PPV.

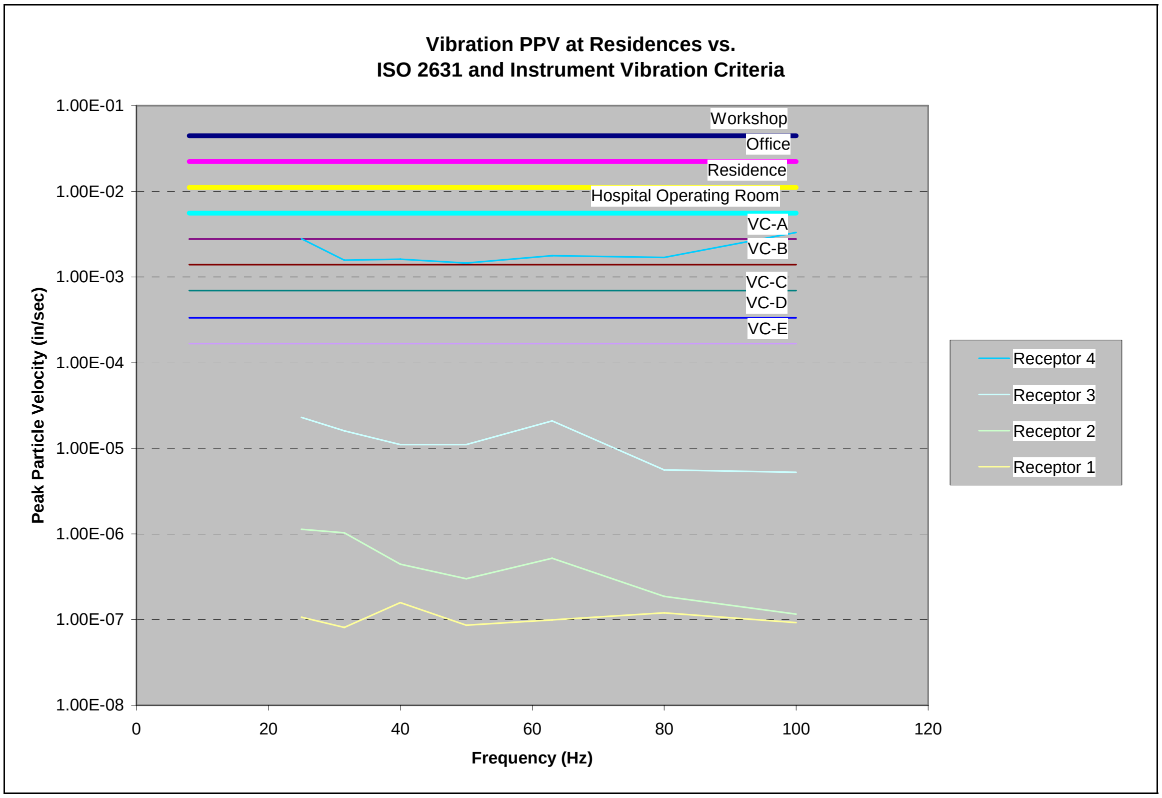


Figure 6-5
Vibration PPV at Residences

Data in the table and graph show that vibration levels are significantly below the criteria curve for acceptable vibration levels for residential land.

Vibration levels measured at Receptor 4 merit additional discussion because they are higher than the vibration levels measured throughout the project area. HDR was not allowed inside the house, so the vibration measurement was performed in the ground outside of the house. It is also important to note that vibration from sources outside of the project area was not considered in this report, therefore potential exists that sources other than the Facility contributed to ground-borne vibration velocities measured in the project area (particularly at Receptor 4).

6.5.1 Factors that Influence Ground-Borne Vibration

Several factors can influence the levels of ground-borne vibration at a receiver. Soil and subsurface conditions are known to have a strong influence on the levels of ground-borne vibration. The primary factors include the stiffness and internal dampening of the soil, and depth to bedrock. Ground-borne vibration propagates more efficiently in stiff clay soils, and shallow rock seems to concentrate the vibration energy close to the surface and can result in ground-borne vibration problems at large distances from the source.

The receiving building is another key factor that influences vibration perception. Vibration levels inside a building are dependant on the vibration energy that reaches the foundation, the coupling of the foundation to the soil, and the propagation of the vibration throughout the building. In general, the heavier the building, the less it will respond to vibration energy that reaches it.

Some ground-borne vibration energy is typically lost at the point where the foundation touches the earth outside it (coupling losses). Once vibration energy reaches a foundation, it is absorbed and radiated throughout the structure. A heavy stone or brick structure will absorb more, and transmit less, energy than a typical wooden frame house. The structural members inside the walls can act as a conduit, and transmit vibration energy throughout the structure. Resonances of the structure, particularly floors, will cause some amplification of the vibration energy. Upper floors (above the first floor) can provide additional resonance and amplification. This can lead to window rattling, etc. Typically coupling losses and building-induced amplification almost cancel each other out. But circumstances can exist where their net effects is not zero.

While not based on data collected in the field, HDR offers the following observation based on our understanding of the circumstances occurring at Receptor 4. The presence of higher ground-borne vibration levels than found elsewhere in the project area seems to indicate that something in the pathway between the Facility and this receptor might provide efficient ground-borne vibration propagation. It is possible that the depth to bedrock near Receptor 4 is shallow. Ground-borne vibration waves also travel at the ground surface. The combination of potentially shallow bedrock, combined with the house being partially built into a hillside (additional coupling beyond just the foundation) could result in efficient transmission of ground-borne vibration energy into the house. Under these circumstances, building amplification could occur on the second floor, and manifest itself as window rattling.

To determine the net effect of coupling and building amplification, simultaneous vibration measurements inside and outside the house have to be performed. Such measurements are beyond the scope of this project and can be performed at the request of the City. HDR recognizes that no subsurface investigations were performed, and that discussions of subsurface conditions and the potential role of bedrock are somewhat speculative.

7.0 Mitigation Analysis

At the request of Rapid City, HDR evaluated the potential to mitigate noise emissions from the Facility using a noise wall. Using Cadna-A, an acoustical analysis software tool, HDR performed a three-dimensional noise analysis. The analysis depicted the Facility by modeling noise emissions coming from two six-foot high point sources (transformers) inside the Facility. Noise emissions measured at the zero-foot location were input into the noise model to represent noise coming from the Facility. The Cadna-A computer model calculated noise how loud Facility-related noise levels are as sound travels away from the Facility. Cadna-A uses different colored bands to represent different noise levels.

HDR modeled a wooden noise wall along the footprint of the exiting fence line at the Facility. The purpose of the analysis was to determine if a noise wall located along the fence line of the Facility could provide a meaningful amount of noise reduction in areas outside the fence line. HDR modeled a 10-foot wall and a 20-foot tall wooden noise wall.

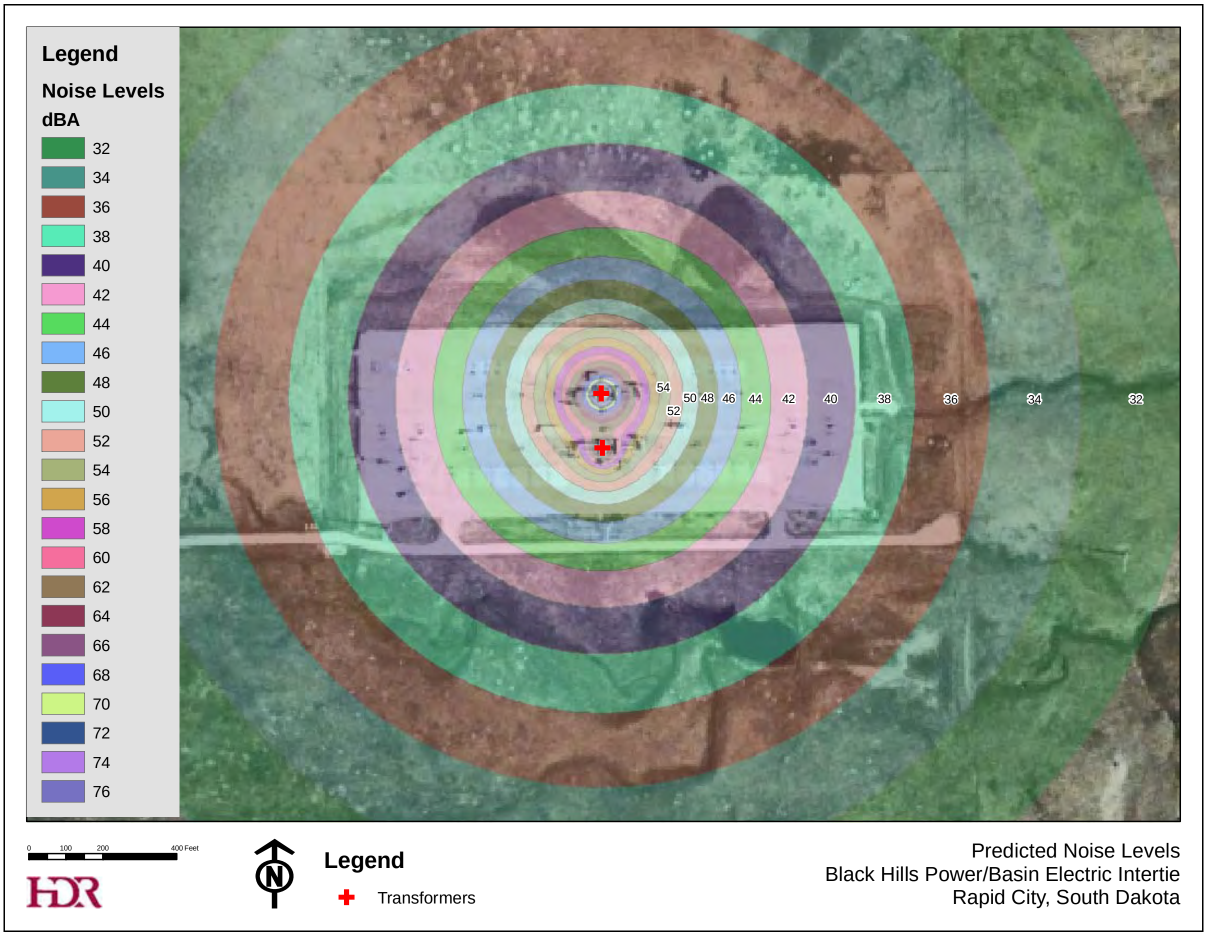


Figure 7-1
Predicted Noise Levels – Base Condition

Figure 7-1 depicts predicted noise levels from the transformers at the Facility without a noise wall present.

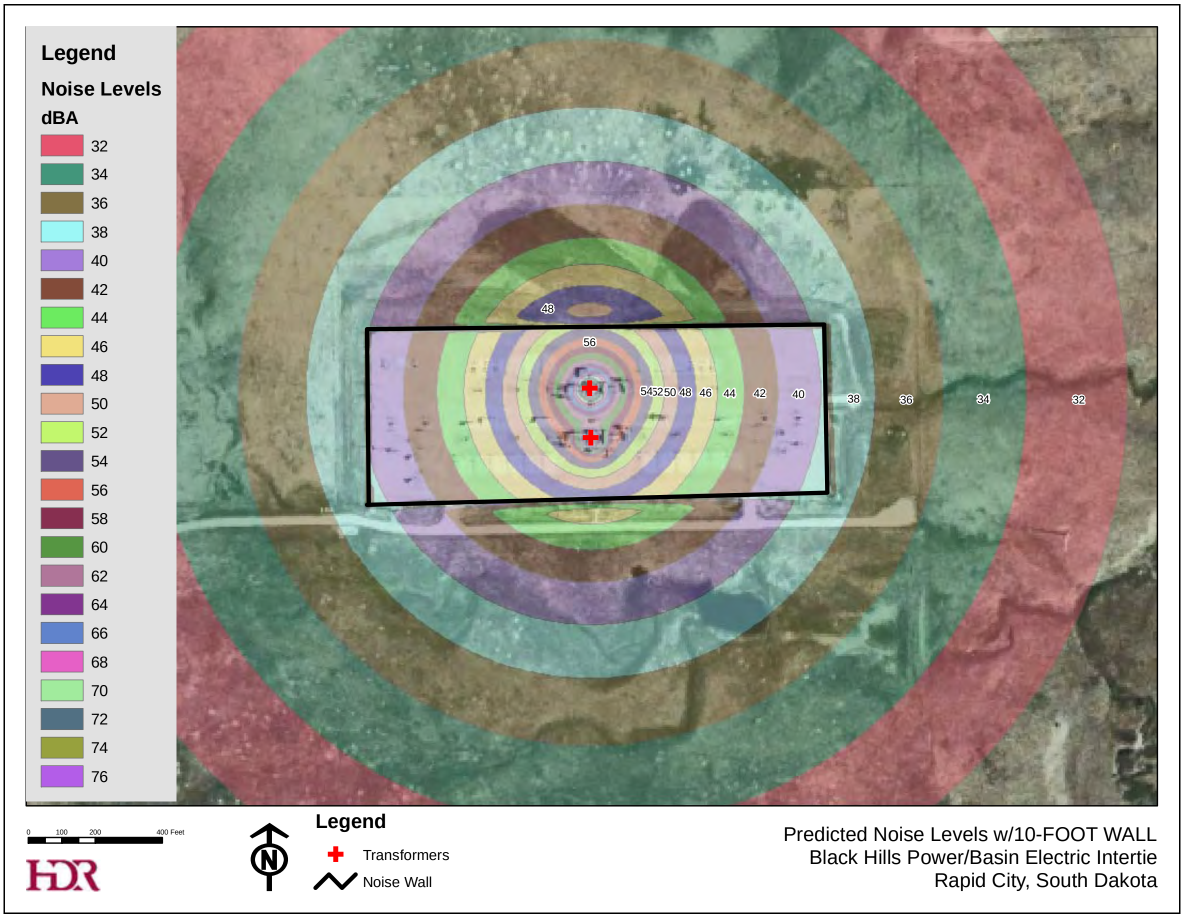


Figure 7-2
Predicted Noise Levels – 10-foot Wall

Figure 7-2 depicts Facility-related noise levels with a 10-foot wall. Note the subtle changes between noise contours on the following figures.

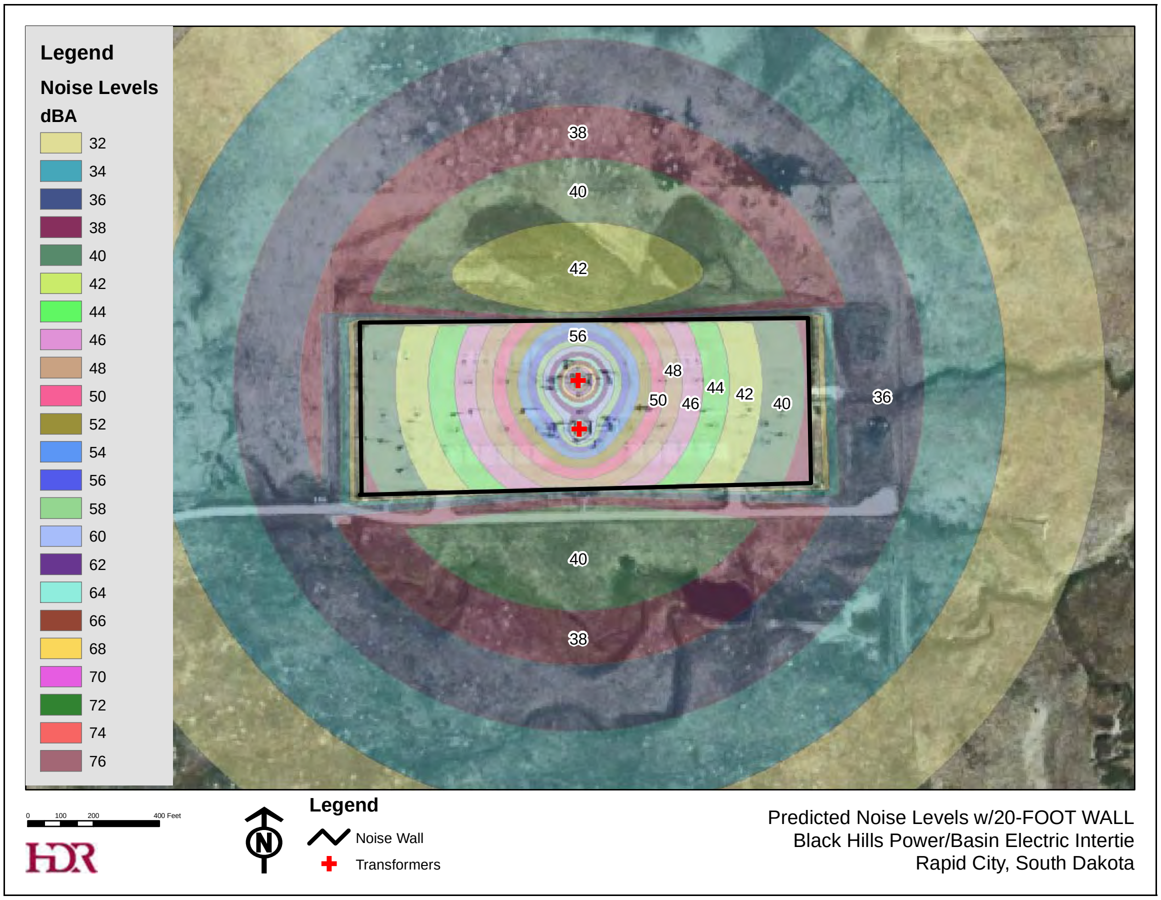


Figure 7-3
Predicted Noise Levels – 20-foot Wall

Figure 7-3 depicts Facility-related noise levels from the transformers with a 20-foot wall.

Noise modeling results indicate that a 10-foot wall will provide roughly 0-6 dBA reduction immediately behind the wall. A 20-foot wall will provide roughly 4-18 dBA reduction immediately behind the wall.

However, at a distance of approximately 400 feet from the fence line, noise levels are basically the same for all 3 scenarios. Noise walls provide an acoustic shadow zone for several hundred feet behind them. Noise levels in this shadow zone are reduced by the wall. However at distances greater than 400 feet the shielding effects of the noise wall are minimal, potentially unnoticeable.

Results of this analysis indicate that the noise reduction provided by a noise wall may not be perceivable at locations beyond the Facility property line. Furthermore, a typical wooden noise wall does not have enough mass to obstruct low-frequency noise emissions in the 31.5 Hz octave band. Low-frequency noise in this octave band has potential to cause windows and dishes to rattle if the levels reach above 60 dB. A review of the monitoring data shows that levels in the 31.5 Hz octave band do not reach this level, therefore low-frequency noise is not expected to be annoying to people in the project area.

8.0 Land Use

The goal of this section is to identify land uses that are compatible with the noise and vibration levels measured in the project area by HDR. The future land use map for the Southeast Connector Neighborhood identifies planned commercial, industrial, and residential land uses – and also public land uses (parks & open spaces). There are numerous subcategories in the residential, commercial, and industrial land use categories. Assessing the noise and vibration compatibility of each individual land use classification requires a lengthy discussion. In order to efficiently and effectively meet the intended purpose of this study, a more straightforward assessment of land use compatibility is available by simplifying the metrics.

Among the land use classifications used in the Southeast Connector Neighborhood land use planning map, residential lands are the most sensitive to noise and vibration. Therefore noise and vibration levels that are acceptable for residential land use are also acceptable for most other commercial and industrial land uses. Exceptions include high-tech applications like laser eye surgery clinics, high-tech printing operations, facilities that make computer chips, nanotechnology laboratories.

Following is a discussion of measured noise and vibration levels and acceptable land uses in the project area. Also included in the sections below are recommendations based on HDR's monitoring data. In consideration of all the information HDR obtained during this project, one general observation merits discussion. It is possible that ground-borne noise and vibration from the Facility is being transmitted through bedrock in the project area. To minimize the potential for land use compatibility conflicts, the depth to bedrock should be determined prior to developing parcels in the project area. Where the bedrock is shallow (less than 30 feet below the surface), building foundations should be designed and constructed to minimize the transmission of energy from the bedrock.

The following land use recommendations apply.

- In order to reduce impact from Pure Tones, HDR recommends creation of a noise compatible buffer of industrial or commercial land use (that is not noise or vibration-sensitive) immediately adjacent to the Facility.

- Ideally, the buffer of noise and vibration compatible commercial or industrial land uses should be developed prior to residential development. HDR does not recommend a specific distance from the Facility that this buffer should extend. Rather HDR emphasizes that the buffer of buildings should completely block the line of sight between the Facility and points 13 to 15 feet above the ground where residential land uses might occur (the approximate height of second story windows). By blocking the line of sight, the buildings will also block noise emissions from the facility. This is called building-induced shielding. The shielding provided by this buffer will increase if there is more than one row of buildings in the buffer.

- Depth to bedrock should be taken into consideration as development is planned. If foundations are excavated, and as a result become closer to bedrock, potential exists for vibration levels to be higher than those documented in this report.

- Future development should include site-specific determination of sub-surface conditions and their ability to transmit ground-borne vibration energy. Foundation designs should reflect knowledge of subsurface conditions to minimize land use conflicts and potential annoyance.

8.1 *Land Use North of the Facility*

Overall broadband noise levels measured between zero feet and 2,640 feet north of the Facility fence line are suitable for residential development. However, the potential for pure tones at all monitoring locations to the North of the Facility has potential to annoy future residents. Ground-borne vibration levels measured at the ground surface north of the Facility are below the VC-E curve, which is the lowest limit of acceptable ground-borne vibration levels for nano-scale research laboratories. This suggests that the most vibration-sensitive types of facilities could be sited here.

8.2 *Land Use South of the Facility*

Overall broadband noise levels measured between 0 feet and 2,640 feet south of the Facility fence line are suitable for residential development. However, the presence of pure tones at monitoring locations between 1,320 and 2,640 feet south of the Facility have potential to annoy future residents and may be problematic for highly sensitive equipment. Ground-borne vibration levels measured at the ground surface south of the Facility are also below the VC-E curve, which is the lowest limit of acceptable ground-borne vibration levels for nano-scale research laboratories. This suggests that the most vibration-sensitive types of facilities could be sited here.

8.3 *Land Use East of the Facility*

Overall broadband noise levels measured between at all locations east of the Facility fence line are suitable for residential development. However, the presence of pure tones at monitoring locations between 1,320 and 2,640 feet east of the Facility have potential to annoy future residents. Ground-borne vibration levels measured at the ground surface east of the Facility are also below the VC-E curve, which is the lowest limit of acceptable ground-borne vibration levels for nano-scale research laboratories. This suggests that the most vibration-sensitive types of facilities could be sited here.

8.4 *Land Use West of the Facility*

Overall broadband noise levels measured between at all locations west of the Facility fence line are suitable for residential development. However, the presence of pure tones at all monitoring locations west of the Facility has potential to annoy future residents. With one exception, ground-borne vibration levels measured at the ground surface west of the Facility are also below the VC-E curve, which is the lowest limit of acceptable ground-borne vibration levels for nano-scale research laboratories. This suggests that the most vibration-sensitive types of facilities could be sited here.

The exception lies in areas between 330 feet and the edge of the gravel west of the Facility fence line. Ground-borne vibration levels measured at the ground surface west of the Facility exceed the VC-E and VC-D curves. This suggests that lands in this portion of the project area may not be suitable for siting highly vibration-sensitive facilities. Facilities that can tolerate VC-C amounts of vibration (a tolerance limit of 0.0005 in/sec) include most lithography and inspection equipment, including electron microscopes. With proper site investigation and design, these areas could be developed for applications that are more vibration-sensitive. These areas may currently be part of the Facility parcel, and not available for development.

8.5 *Future Expansion of the Facility*

The Facility exists on a parcel that was intentionally designed to be large enough to accommodate an expanded Facility. Assuming such an expansion occurred, and the Facility capacity doubled, Facility-related noise levels could increase by 3-dBA. Facility-related vibration levels could also increase, however the expansion could also be designed to minimize the increase in Facility-related ground-borne vibration.

9.0 Health Effects

As stated earlier in this report, the results of the noise measurements taken for this study indicate that, with the exception of noise levels measured very close to the Facility, all existing noise levels in the project area are within established thresholds and considered acceptable for residential land uses. And also stated earlier in this report, the vibration velocities measured at the ground surface throughout the project area are below the threshold of perception, with one exception. That exception was measured at Receptor 4 where the vibration velocity was slightly above this threshold and feedback from property owners regarding vibration levels at this location was consistent with HDR's monitoring data.

However, the response and tolerance to noise and vibration effects varies from person to person. And while the Facility-related noise does not reach levels that have potential to cause hearing damage, there is a potential for annoyance. The exposure to any vibration velocities above the threshold of perception also has potential to be annoying, and perhaps induce effects in people who are less tolerant of ground-borne vibration stimuli.

This annoyance has the possibility to lead to stress and in other study cases where environmental noise measurements were higher than established thresholds and above what was measured in the project area, it was found that there was a variety of potential health effects, including:

- disturbance of rest and sleep;
- startle and defense reactions;
- performance reductions;
- cardiovascular effects (anger-related elevated blood pressure) and stress;
- effects on residential behavior including disengagement and increases in aggressive behavior and annoyance responses;
- interference with intended activities, and;
- speech interference.

10.0 References

"Vibration Measurement and Analysis" lecture notes, Copyright© 1998, Brüel & Kjær Sound and Vibration Measurement A/S

"Basic Frequency Analysis of Sound" lecture notes, Copyright© 1998, Brüel & Kjær Sound and Vibration Measurement A/S

"Basic Concepts of Sound" lecture notes, Copyright© 1998, Brüel & Kjær Sound and Vibration Measurement A/S

Chae, Y., 1978. "Design of Excavation Blasts to Prevent Damage," Civil Engineering, ASCE, Vol. 48, No. 4, pp 77-79.

German Standards Organization, Vibrations in Building Construction, DIN 4150, 1970.

Gordon, C. 1991. Generic criteria for vibration-sensitive equipment. *Proceedings of International Society of Optical Engineering* 1619.

International Standards Organization. 1989. *Guide to the evaluation of human exposure to vibration and shock in buildings (1 Hz to 80 Hz).*

Nicholls, H.R., et al., 1971. "Blasting Vibrations and Their Effects on Structures," BuMines Bulletin 656.

Reiher, H., and F. J. Meister. 1931. The effects of vibration on people. *Forschung auf dem Gebiete des Ingenieurwesens* 2(2).

Swiss Association of Standardization, "Effects of Vibration on Construction," Seefeldstrasse9, CH 8008, Zurich, Switzerland.

Whiffen, A. C. 1971. *A survey of traffic-induced vibrations.* (Report LR419.) Crowthorne, Berkshire, England: United Kingdom Department of Environment, Road Research Laboratory.

Wiss, J. F. 1974. Vibrations during construction operations. *Journal of the Geotechnical Division* 100(CO3):239–246.

Wiss, J. F.,1981. "Construction Vibrations: State-of-the art," Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 107, No. GT2, February, pp 167-181.

Appendix A
Detailed Noise Monitoring Data

The following sections present the raw monitoring data in graphical and table format. The graphs were created using data processing software, and all data is A-weighted (however the software does not show dBA on the Y-axes). One feature in that software allowed the identification of pure tones. Graphs below show "pure tone" labels on some data peaks. HDR recognizes that some peaks appear to meet the pure tone definition, but are not labeled as such. HDR assumes this occurs due to the way raw data values are rounded by the analyzer and processed by the software. HDR also recognizes that although some levels approach or meet the definition, they would not be audible because their overall level is too low. In particular, pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Noise Levels North of the Facility

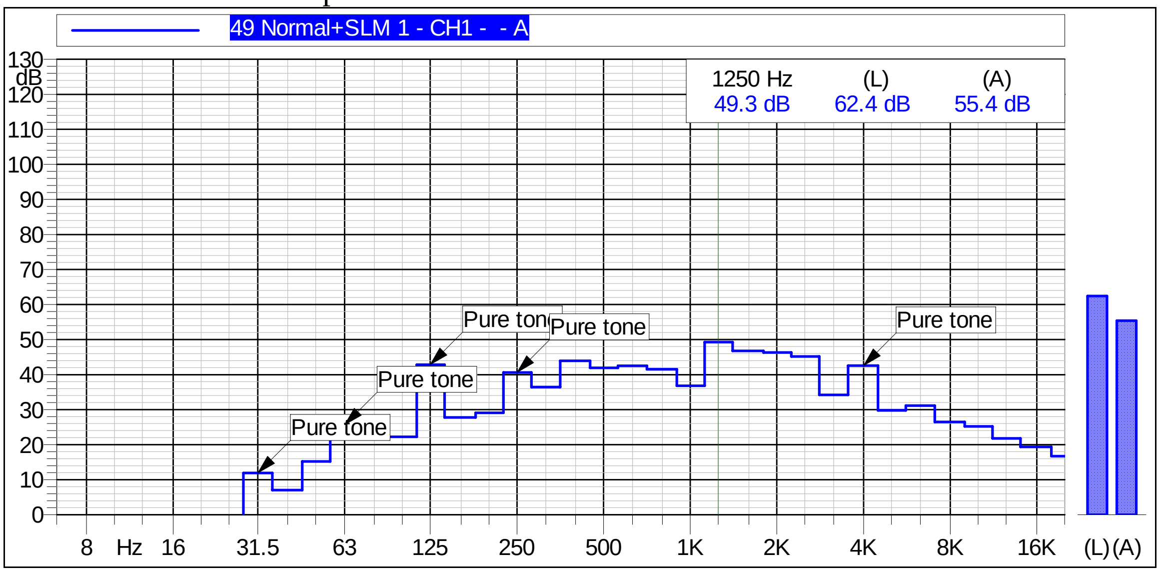
Table A-1
Spectral Data Measured North of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet North	55	Yes
330 feet North	45	Yes
660 feet North	44	Yes
1320 feet North	42	No (a)
1980 feet North	41	Yes
2640 feet North	41	No (a)

Notes:
(a) Noise levels measured at this location did not meet the criteria for a pure tone. However, noise levels appear close to meeting this criterion. Pure tones could potentially occur under different operational or meteorological conditions.

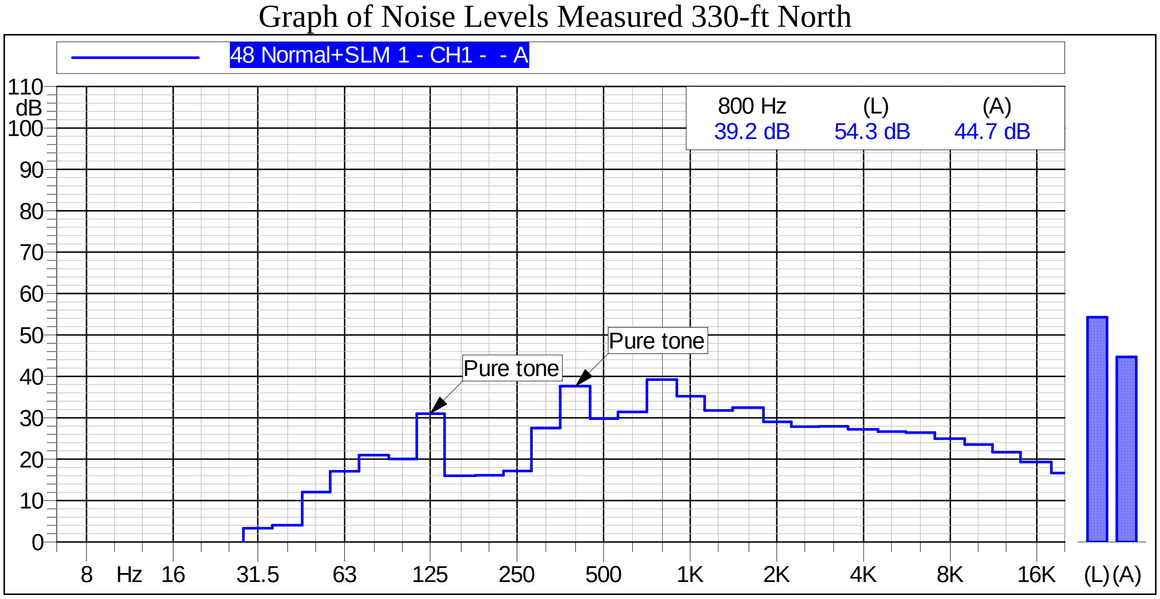
The following graphs show the spectral noise measured at each monitoring location near the Facility. Pure tones in low frequencies, particularly 31.5 Hz, can be perceived as vibrations at levels exceeding 65 dB. Upon inspection, sound pressure levels in the 31.5 octave band do not reach 65 dB at any location. Therefore noise emissions in these frequencies are not expected to cause vibrations at nearby structures. Some potential exists that these frequencies could affect highly vibration-sensitive equipment. HDR encourages the assessment of site suitability when highly vibration-sensitive applications are proposed in the project area.

Figure A-1
Graph of Noise Levels Measured 0-ft North



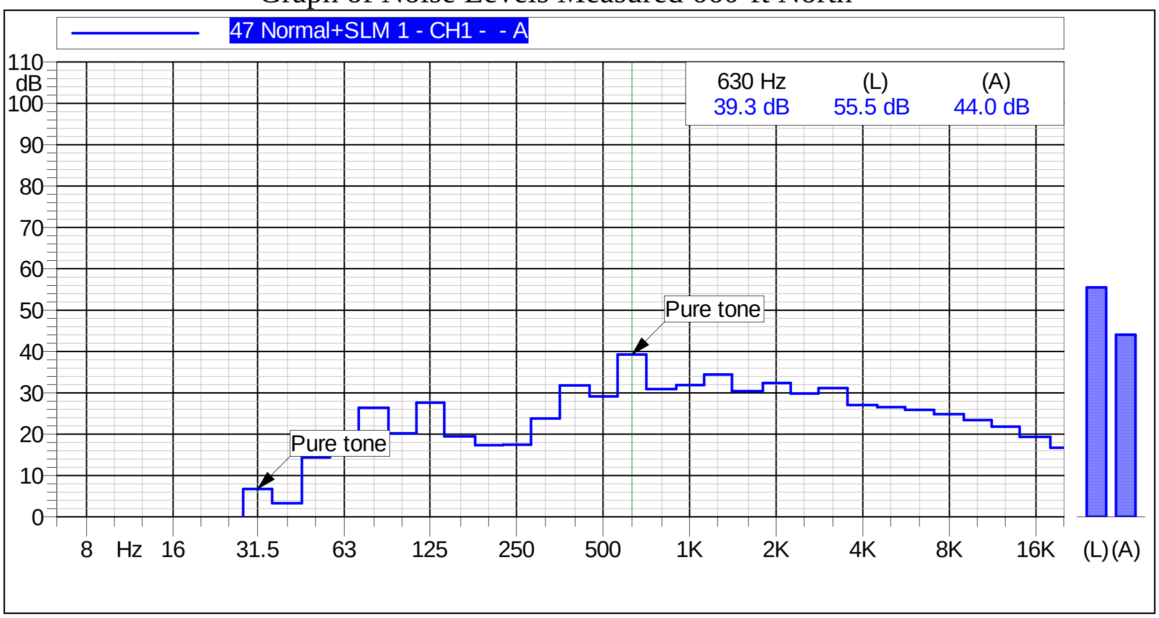
This figure shows that the Leq was 55.4 dBA and that the maximum sound pressure level of 49.3 dBA was measured at 1250 Hz. A number of pure tones appear on this graph – first in the octave band centers at 31.5, 63, 125, and 250 Hz. An additional pure tone appears at 4 kHz. These are all harmonics of the typical 60 Hz hum associated with high voltage transformers; a distinct hum is clearly audible at this location. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-2
Graph of Noise Levels Measured 330-ft North



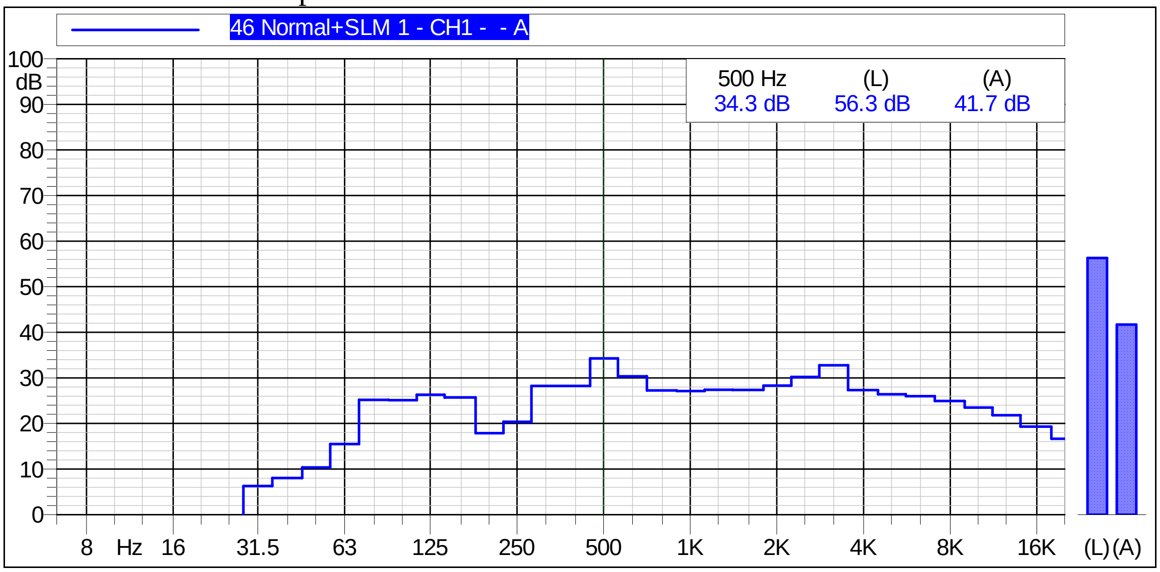
This figure shows that the Leq was 44.7 dBA and that the maximum sound pressure level of 39.2 dBA was measured at 800 Hz. Two pure tones appear on this graph – first at the octave band center at 125 Hz and again at 400 Hz. There also appears to be something close to a pure tone at 800 Hz In the absence of background noises that can mask these tones, the tones may be considered annoying to some people.

Figure A-3
Graph of Noise Levels Measured 660-ft North



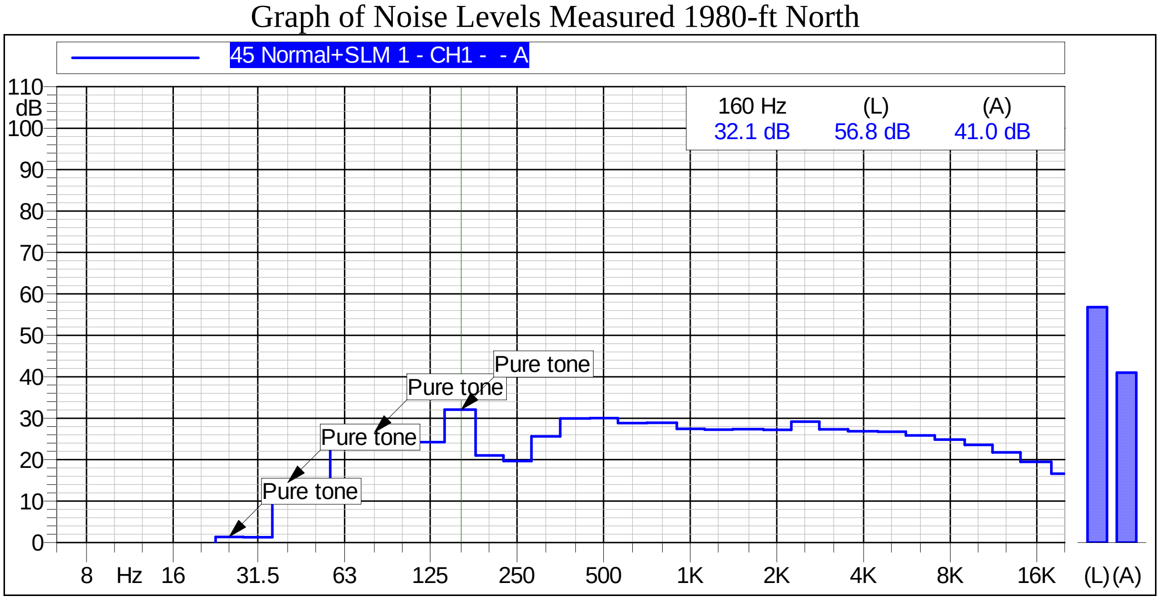
This figure shows that the Leq was 44 dBA and that the maximum sound pressure level of 39.3 dBA was measured at 630 Hz. Two pure tones appear on this graph – first at 31.5 Hz and again at 630 Hz. There also appears to noise that approaches the definition of a pure tone at 80 Hz In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-4
Graph of Noise Levels Measured 1320-ft North



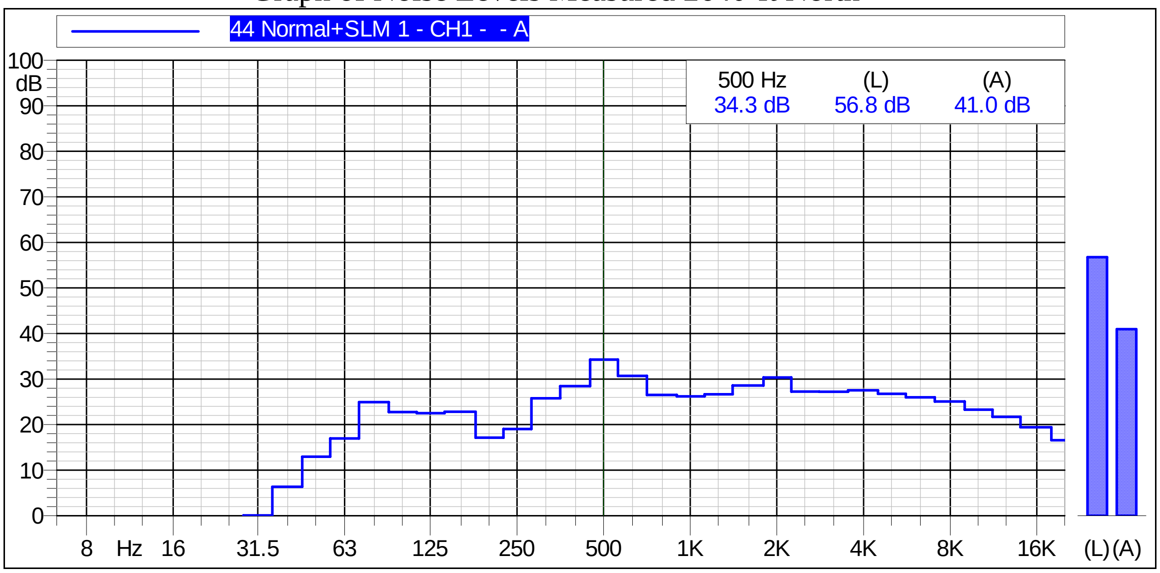
This figure shows that the Leq was 41.7 dBA and that the maximum sound pressure level of 34.3 dBA was measured at 500 Hz. No pure tones appear on this graph, though there is a peak at the 500 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people.

Figure A-5
Graph of Noise Levels Measured 1980-ft North



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 32.1 dBA was measured at 160 Hz. Four pure tones appear on this graph – at 25, 40, 80, and 160 Hz In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-6
Graph of Noise Levels Measured 2640-ft North



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 34.3 dBA was measured at 500 Hz. No pure tones appear on this graph, though there is a peak at the 500 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people

Noise Levels South of the Facility

Table A-2 presents the Leq values measured at each of the six monitoring locations South of the Facility.

Table A-2
Spectral Data Measured South of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet South	68	Yes
330 feet South	68	No
660 feet South	58	No
1320 feet South	41	Yes
1980 feet South	42	Yes
2640 feet South	41	Yes

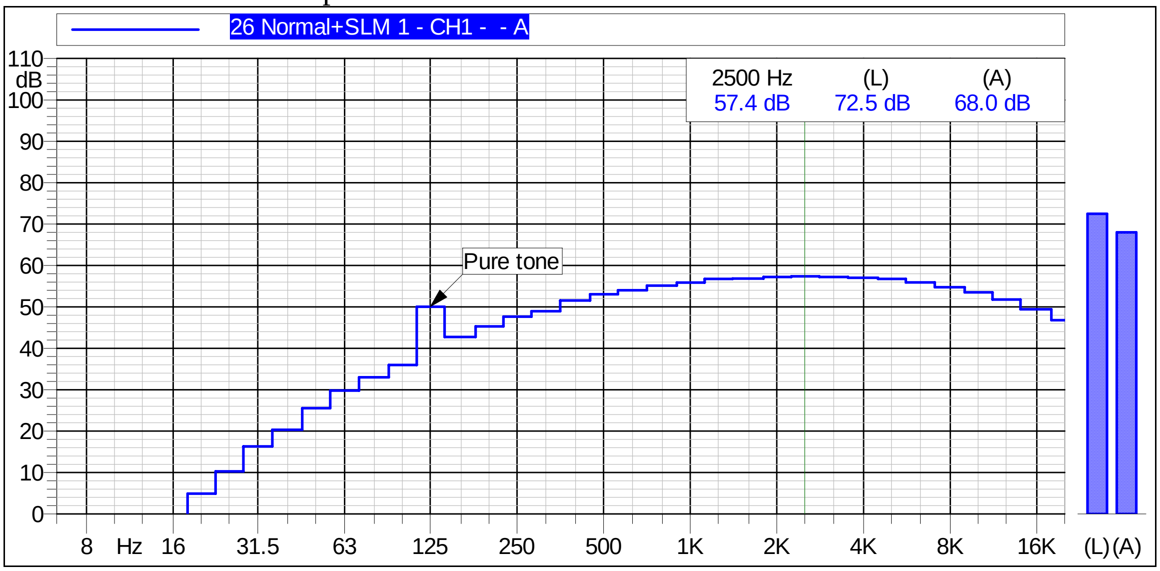
While noise levels typically drop off win increasing distance from the noise source, monitoring data in Table A-2 above shows no reduction in noise levels between zero feet and 330 feet. This may reflect the fact that the measurement performed at 330 feet received a noise contribution from the entire Facility, whereas the measurement performed at zero feet received a noise contribution from a more localized portion of the Facility.

The monitoring data does show a decrease in Facility-related noise at 660-feet. Monitoring data dos not show a continued decrease in Facility-related noise at 1320 feet. HDR attributes this to slightly elevated terrain at 1320 feet, and the resulting decrease in ground-attenuation that resulted in a clearer line of sight between the monitoring location and principle noise sources at the Facility.

Measured noise levels at 1980 and 2640 feet are considered representative of background noise levels. HDR does not consider noise levels at these distances to be dominated by Facility-related noise. Rather, it is a combination of noise from natural and man-made sources and activities.

Figure A-7 shows a graph of spectral noise monitoring data collected at 0-ft South of the Facility.

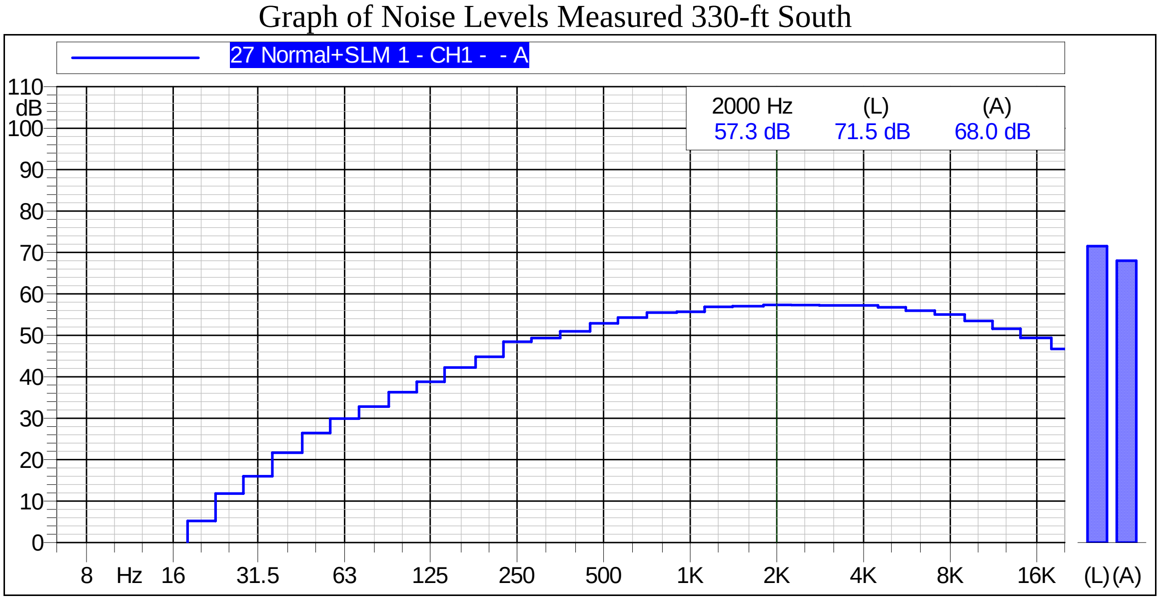
Figure A-7
Graph of Noise Levels Measured 0-ft South



This figure shows that the Leq was 68 dBA and that the maximum sound pressure level of 57.4 dBA was measured at 2500 Hz. A pure tone appears on this graph, at 125 Hz In the absence of background noises that can mask these tones, the tone may be considered annoying to some people

Figure A-8 shows a graph of spectral noise monitoring data collected at 330-ft South of the Facility.

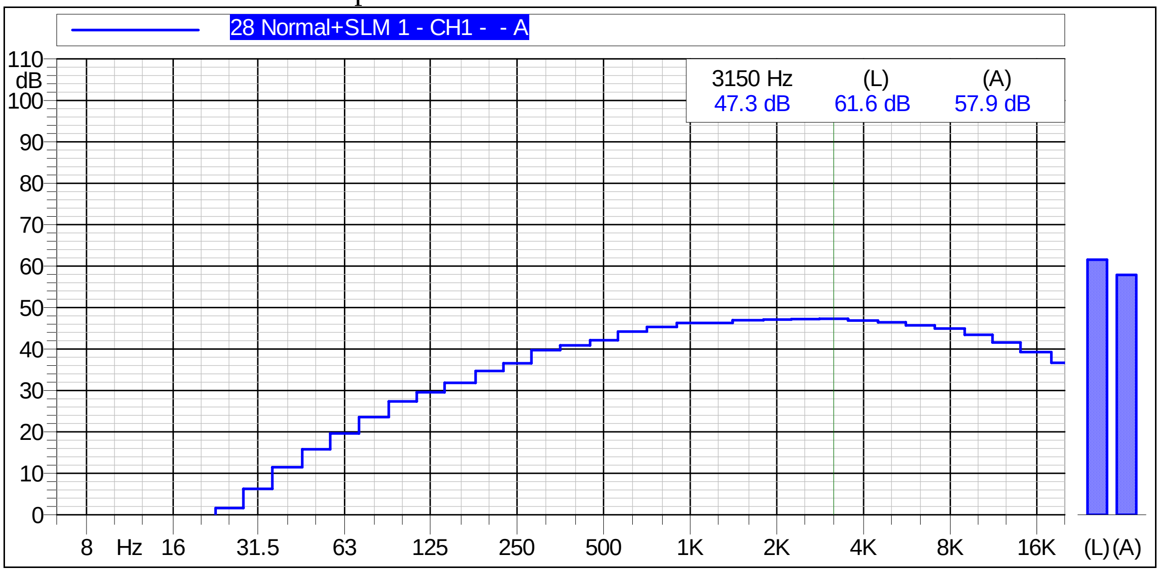
Figure A-8
Graph of Noise Levels Measured 330-ft South



This figure shows that the Leq was 68 dBA and that the maximum sound pressure level of 57.3 dBA was measured at 2000 Hz.. No pure tones appear on this graph.

Figure A-9 shows a graph of spectral noise monitoring data collected at 660-ft South of the Facility.

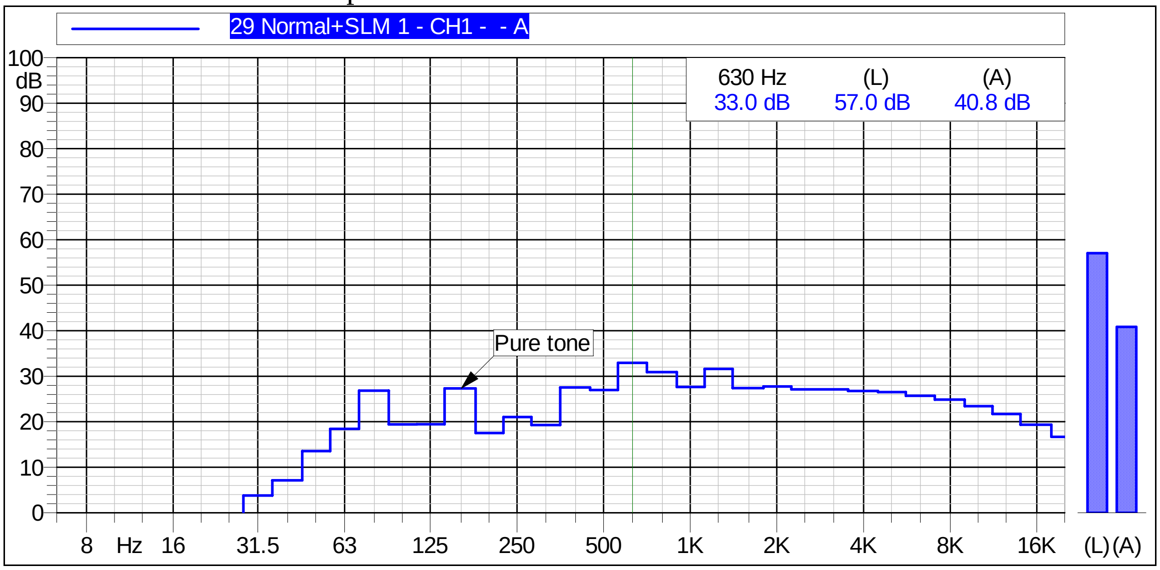
Figure A-9
Graph of Noise Levels Measured 660-ft South



This figure shows that the Leq was 57.9 dBA and that the maximum sound pressure level of 47.3 dBA was measured at 3150 Hz. No pure tones appear on this graph.

Figure A-10 shows a graph of spectral noise monitoring data collected at 1320-ft South of the Facility.

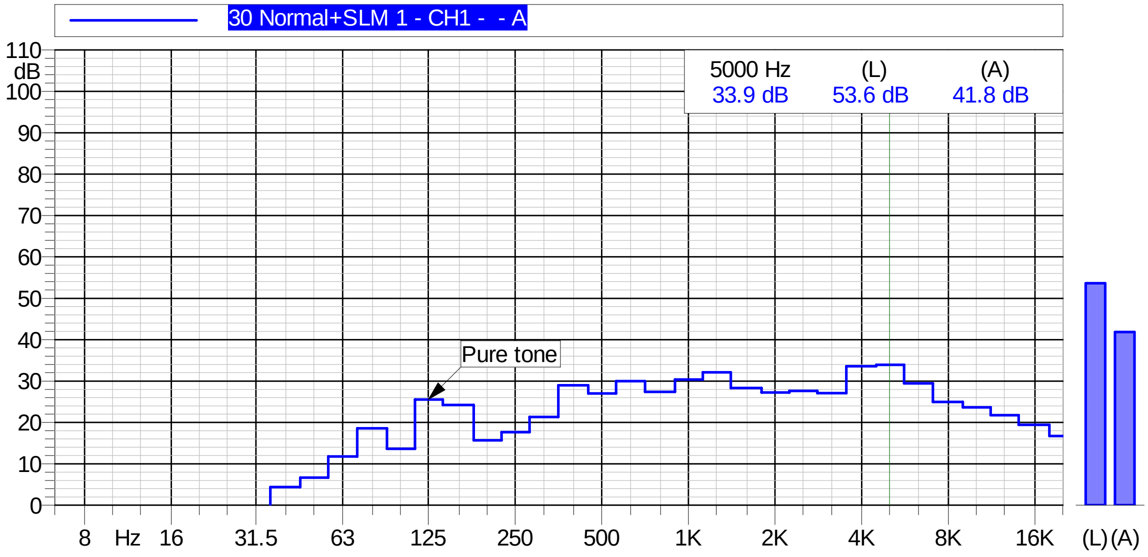
Figure A-10
Graph of Noise Levels Measured 1320-ft South



This figure shows that the Leq was 40.8 dBA and that the maximum sound pressure level of 33 dBA was measured at 630 Hz. A pure tone appears on this graph, at 160 Hz. There is also a peak at the 80 Hz octave band center. In the absence of background noises that can mask these tones, the tone may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-11 shows a graph of spectral noise monitoring data collected at 1980-ft South of the Facility.

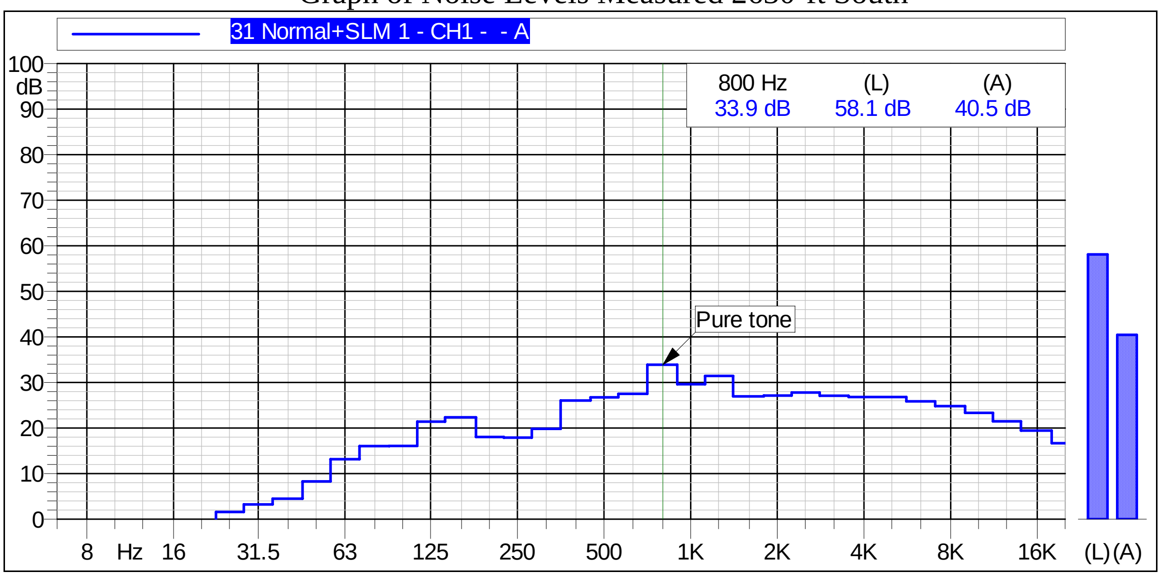
Figure A-11
Graph of Noise Levels Measured 1980-ft South



This figure shows that the Leq was 42 dBA and that the maximum sound pressure level of 33.9 dBA was measured at 5000 Hz. The data processing software identified a pure tone at 125 Hz. There is also smaller peak at the 80 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-12 shows a graph of spectral noise monitoring data collected at 2630-ft South of the Facility.

Figure A-12
Graph of Noise Levels Measured 2630-ft South



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 33.9 dBA was measured at 800 Hz. A pure tone appears on this graph, at 800 Hz.

Noise Levels East of the Facility

Table A-3 presents the Leq values measured at each of the six monitoring locations East of the Facility.

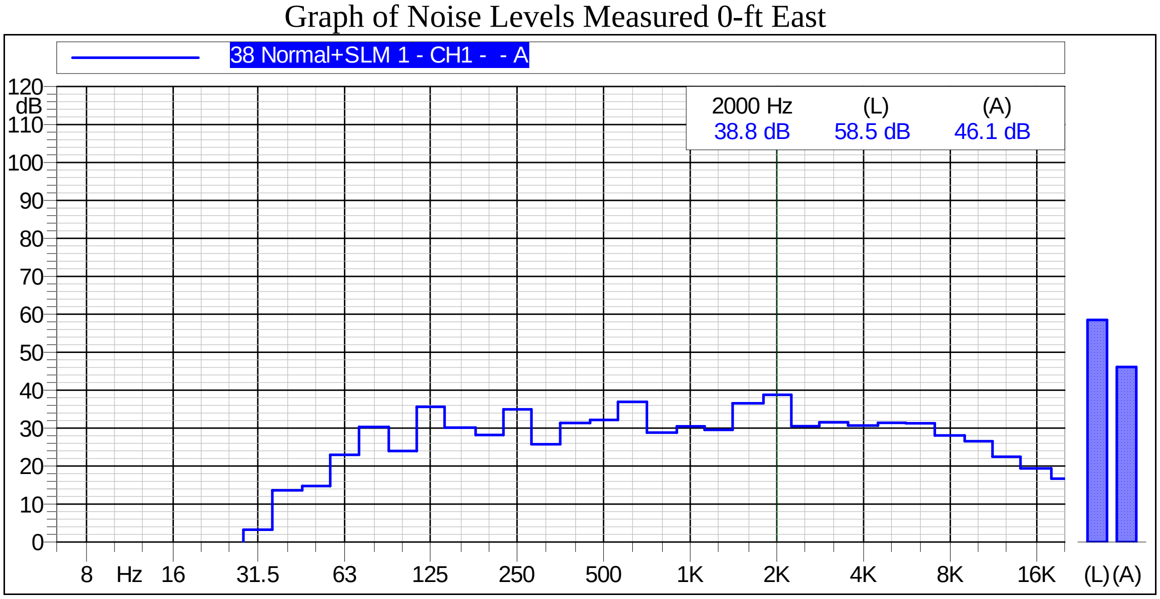
Table A-3
Spectral Data Measured East of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet East	46	No (a)
330 feet East	43	No
660 feet East	42	No (a)
1320 feet East	41	Yes
1980 feet East	44	Yes
2640 feet East	40	Yes

(a) Noise levels measured at this location did not meet the criteria for a pure tone. However, noise levels appear close to meeting this criterion. Pure tones could potentially occur under different operational or meteorological conditions.

Figure A-13 shows a graph of spectral noise monitoring data collected at 0-ft East of the Facility.

Figure A-13
Graph of Noise Levels Measured 0-ft East

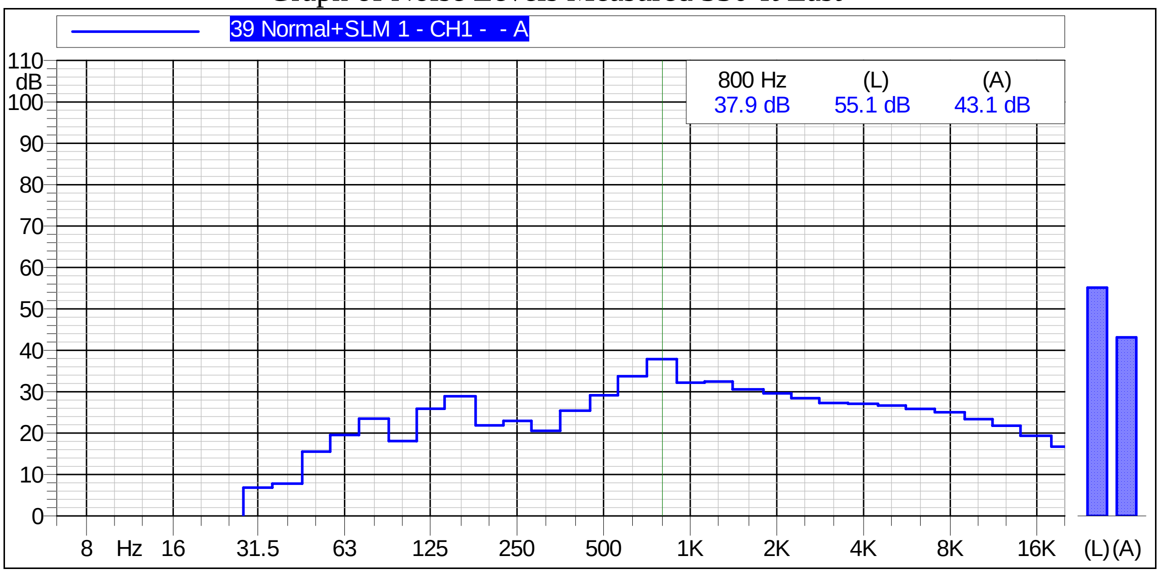


This figure shows that the Leq was 46 dBA and that the maximum sound pressure level of 38.8 dBA was measured at 2000 Hz. Pure tones do not appear on this graph. However, there are elevated levels at 80, 125, 250, 630 Hz. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people.

Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-14 shows a graph of spectral noise monitoring data collected at 330-ft East of the Facility.

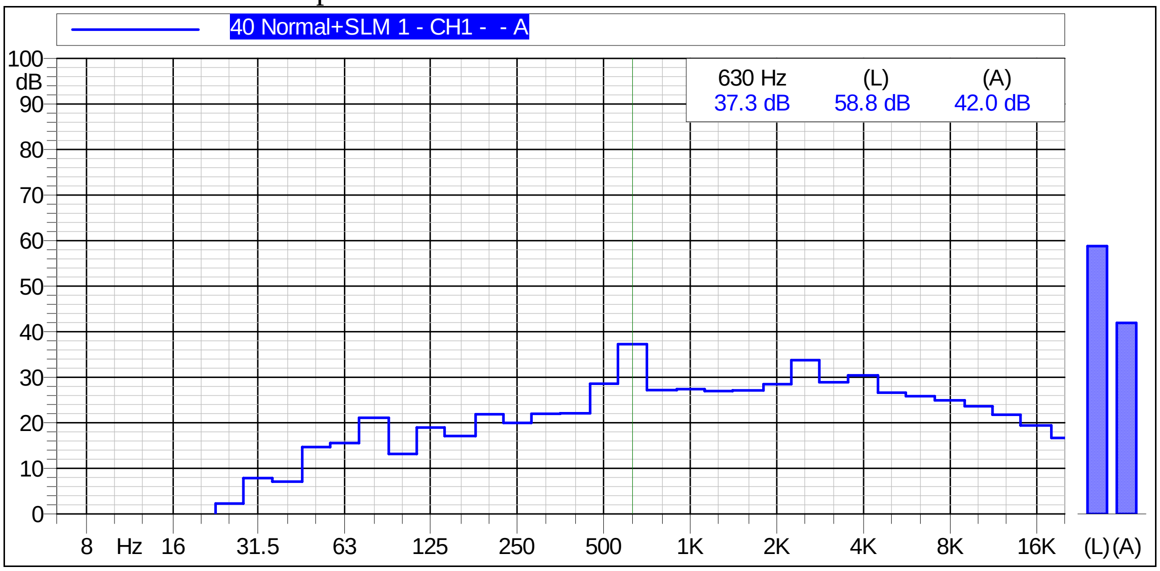
Figure A-14
Graph of Noise Levels Measured 330-ft East



This figure shows that the Leq was 43.1 dBA and that the maximum sound pressure level of 37.9 dBA was measured at 800 Hz. No pure tones appear on this graph. However there are peaks at 80, between 125 and 160, and at 800 Hz In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-15 shows a graph of spectral noise monitoring data collected at 660-ft East of the Facility.

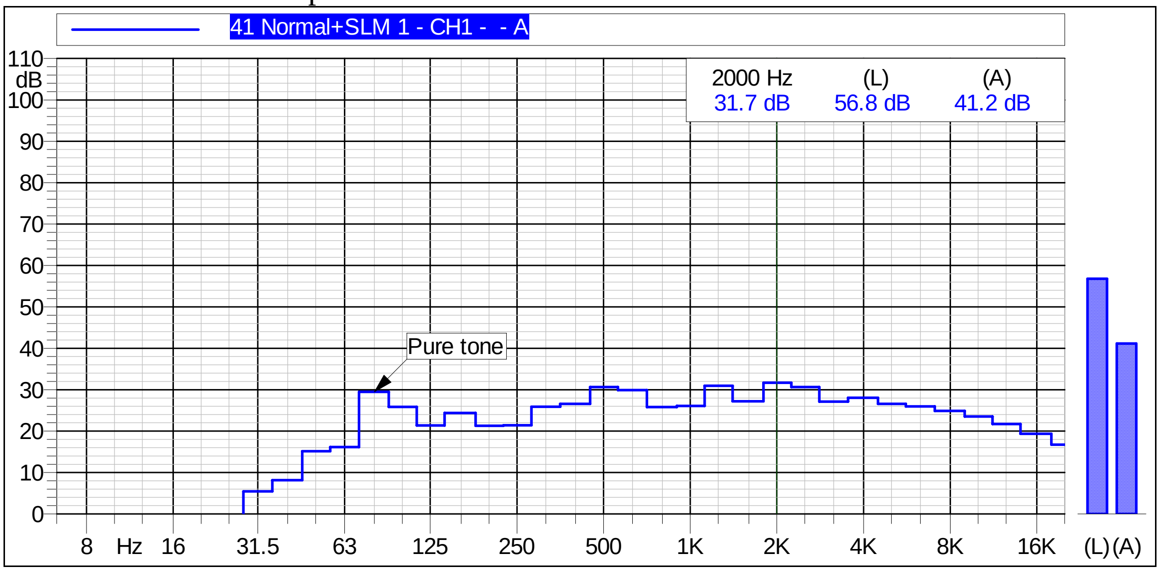
Figure A-15
Graph of Noise Levels Measured 660-ft East



This figure shows that the Leq was 42 dBA and that the maximum sound pressure level of 37.3 dBA was measured at 630 Hz. No pure tones appear on this graph. However elevated levels at 80, 630, and 2500 Hz octave band centers could reach pure tone levels under different operational and meteorological circumstances. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-16 shows a graph of spectral noise monitoring data collected at 1320-ft East of the Facility.

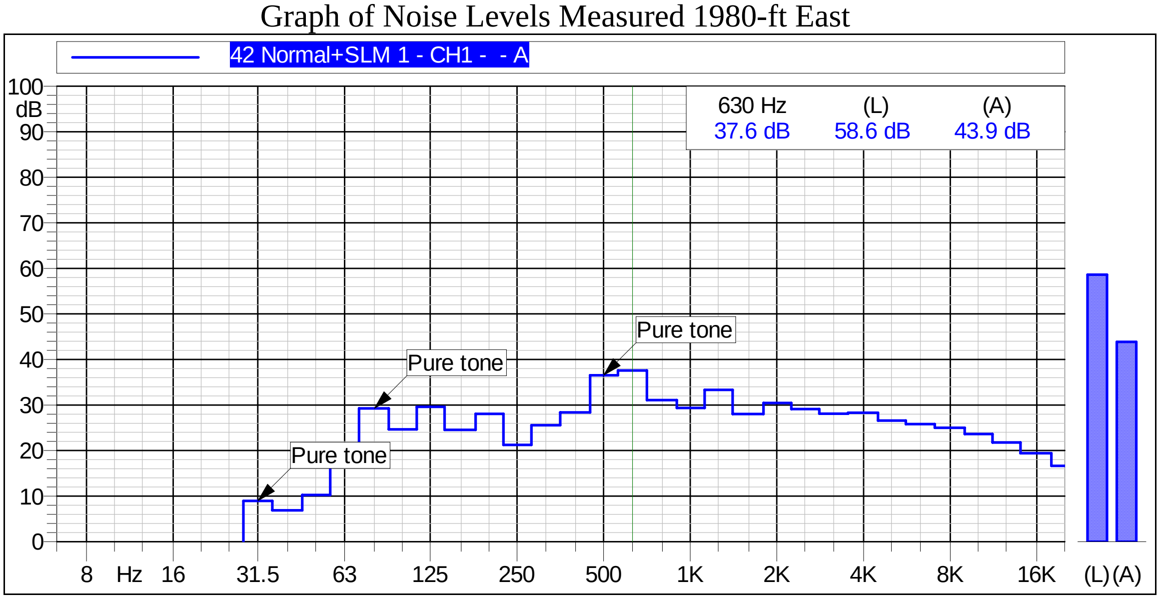
Figure A-16
Graph of Noise Levels Measured 1320-ft East



This figure shows that the Leq was 41.2 dBA and that the maximum sound pressure level of 31.7 BA was measured at 2000 Hz. A pure tone appears on this graph, at 80 Hz In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-17 shows a graph of spectral noise monitoring data collected at 1980-ft East of the Facility.

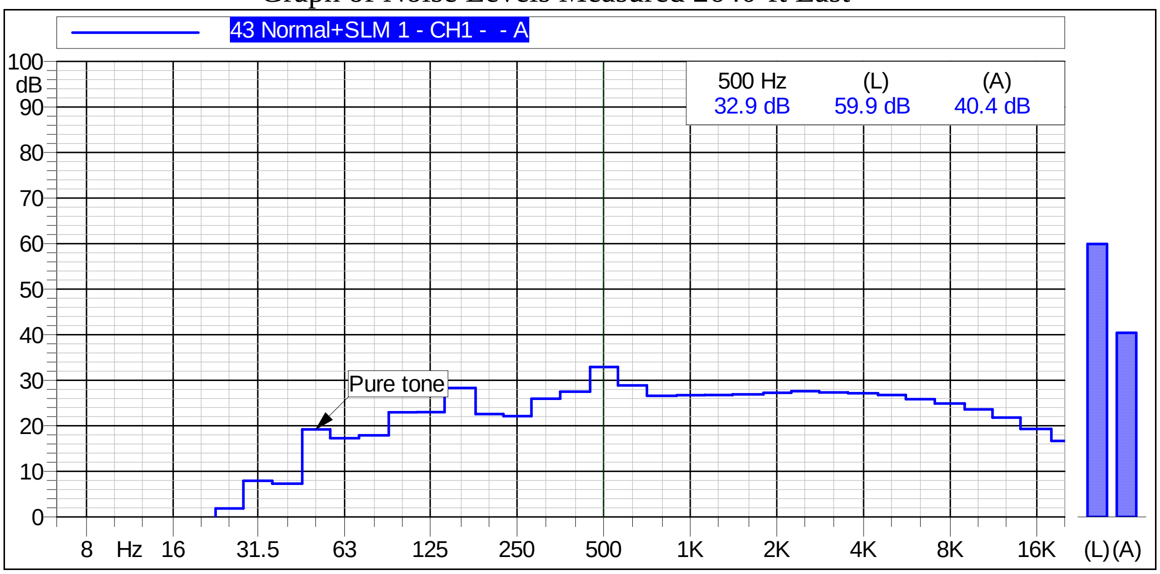
Figure A-17
Graph of Noise Levels Measured 1980-ft East



This figure shows that the Leq was 43.9 dBA and that the maximum sound pressure level of 37.6 dBA was measured at 630 Hz. Pure tones appear on this graph, at 31.5, 80, and 800 Hz There are also peaks at 125, 200, and 1250 Hz octave band centers. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-18 shows a graph of spectral noise monitoring data collected at 2630-ft East of the Facility.

Figure A-18
Graph of Noise Levels Measured 2640-ft East



This figure shows that the Leq was 40 dBA and that the maximum sound pressure level of 32.9 dBA was measured at 500 Hz. A pure tone appears on this graph at 50 Hz though there is a peak at the 160 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Noise Levels West of the Facility

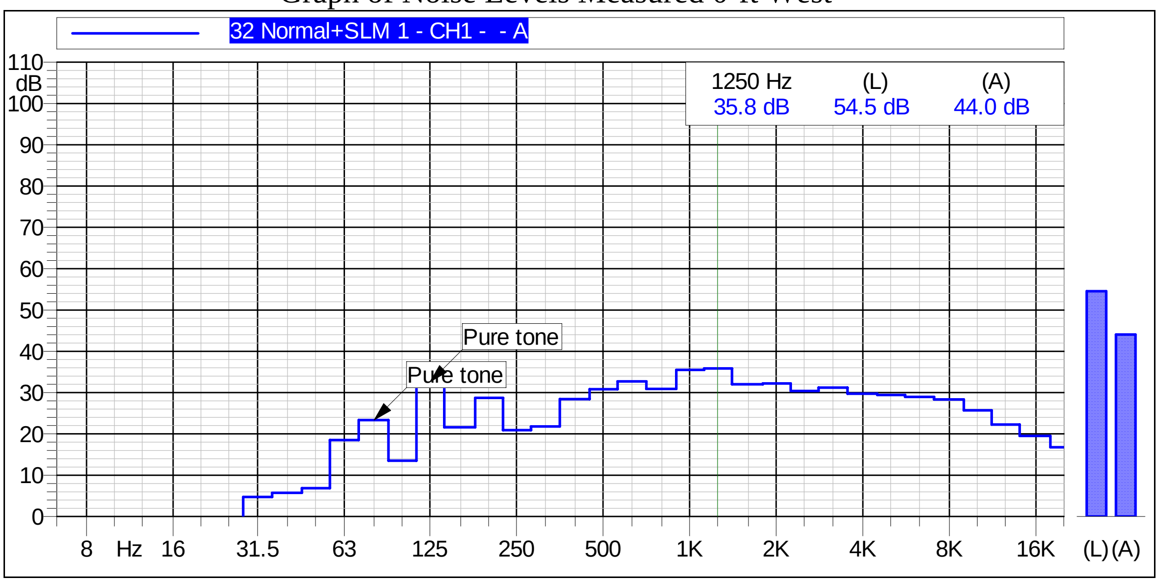
Table A-4 presents the Leq values measured at each of the six monitoring locations East of the Facility.

Table A-4
Spectral Data Measured West of the Facility

Monitoring Location ID	Leq (dBA)	Pure Tones?
0 feet West	44	Yes
330 feet West	41	Yes
660 feet West	41	Yes
1320 feet West	44	Yes
1980 feet West	40	Yes
2640 feet West	41	Yes

Figure A-19 shows a graph of spectral noise monitoring data collected at 0-ft West of the Facility.

Figure A-19
Graph of Noise Levels Measured 0-ft West

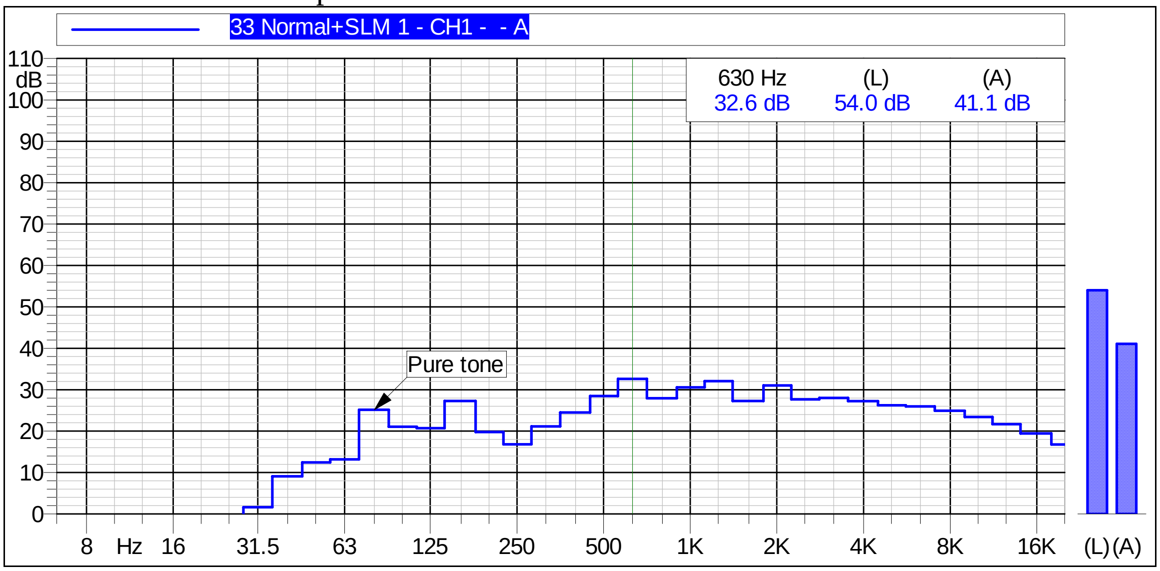


80 and 125 Hz

This figure shows that the Leq was 44 dBA and that the maximum sound pressure level of 35.8 dBA was measured at 1250 Hz. A pure tone appears on this graph, at 80 Hz and 125 Hz, though there is a peak at the 200 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-20 shows a graph of spectral noise monitoring data collected at 330-ft West of the Facility.

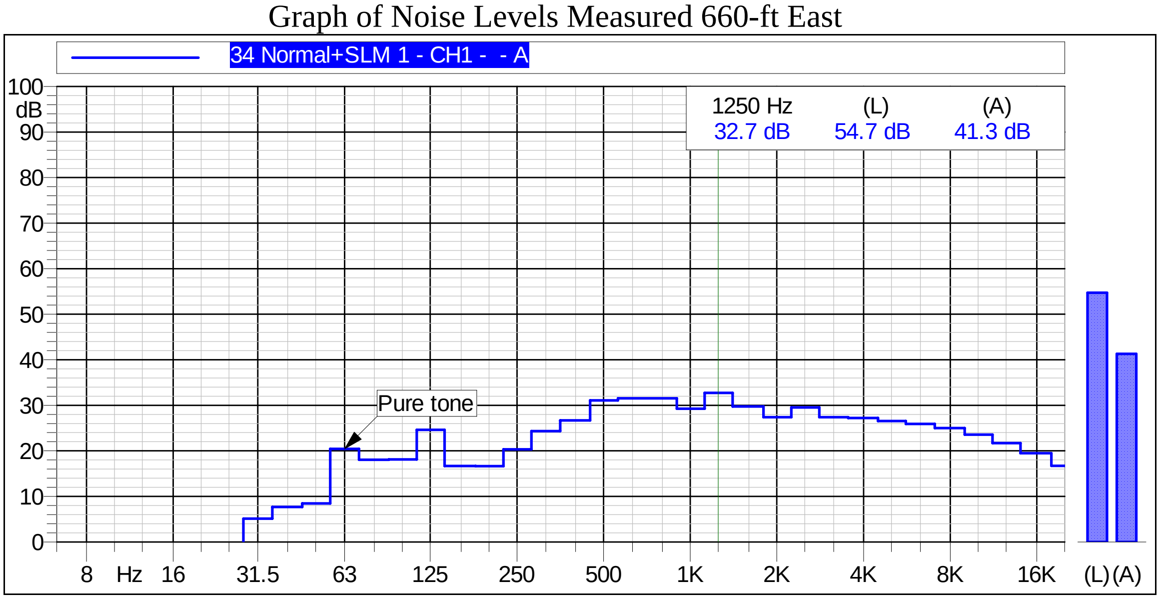
Figure A-20
Graph of Noise Levels Measured 330-ft East



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 32.6 dBA was measured at 630 Hz. A pure tone appears on this graph, at 80 Hz though there is a peak at the 160 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-21 shows a graph of spectral noise monitoring data collected at 660-ft West of the Facility.

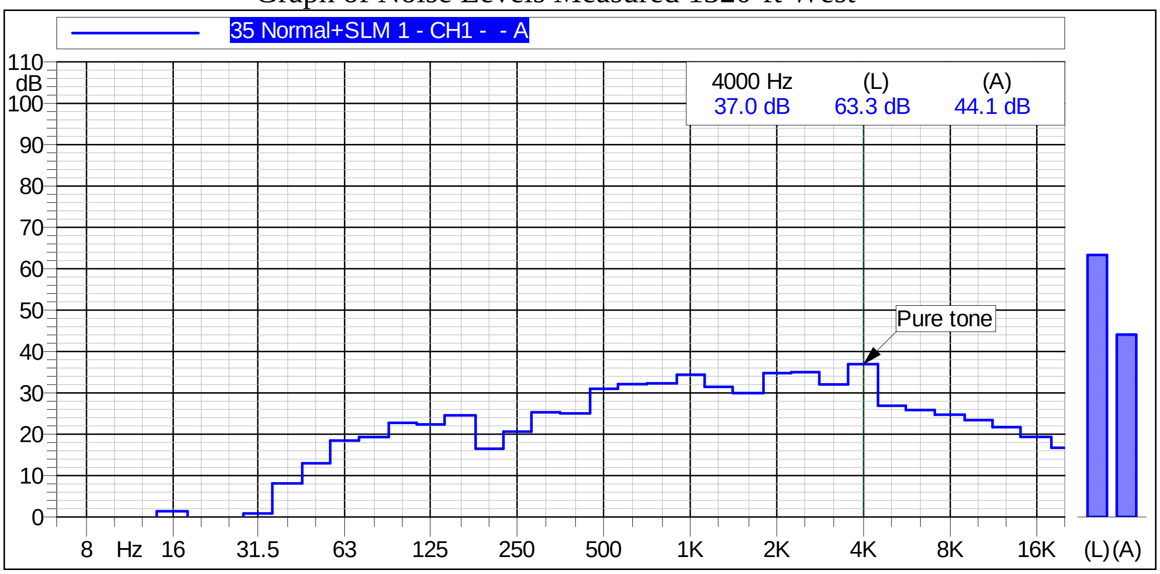
Figure A-21
Graph of Noise Levels Measured 660-ft East



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 32.7 dBA was measured at 1250 Hz. A pure tone appears on this graph, at 63 Hz though there is a peak at the 125 Hz octave band center. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-22 shows a graph of spectral noise monitoring data collected at 1320-ft East of the Facility.

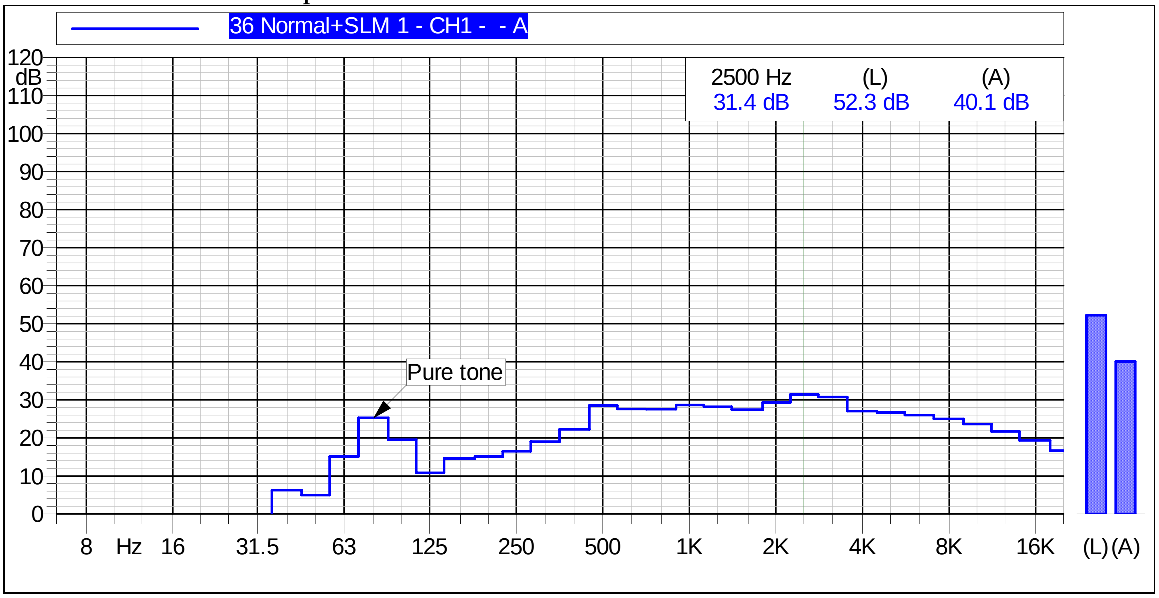
Figure A-22
Graph of Noise Levels Measured 1320-ft West



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 37 dBA was measured at 4000 Hz. A pure tone appears on this graph, at 4000 Hz. In the absence of background noises that can mask this tone, the tone may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-23 shows a graph of spectral noise monitoring data collected at 1980-ft West of the Facility.

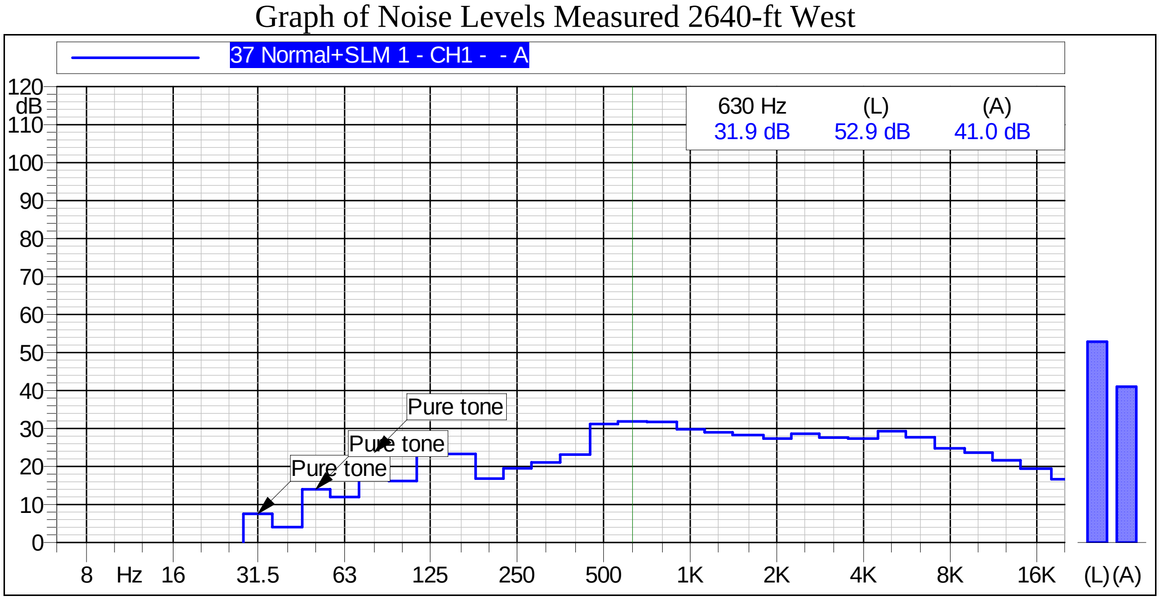
Figure A-23
Graph of Noise Levels Measured 1980-ft West



This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 31.4 dBA was measured at 2500 Hz. A pure tone appears on this graph at 80 Hz. In the absence of background noises that can mask this tone, the tone may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

Figure A-24 shows a graph of spectral noise monitoring data collected at 2640-ft West of the Facility.

Figure A-24
Graph of Noise Levels Measured 2640-ft West

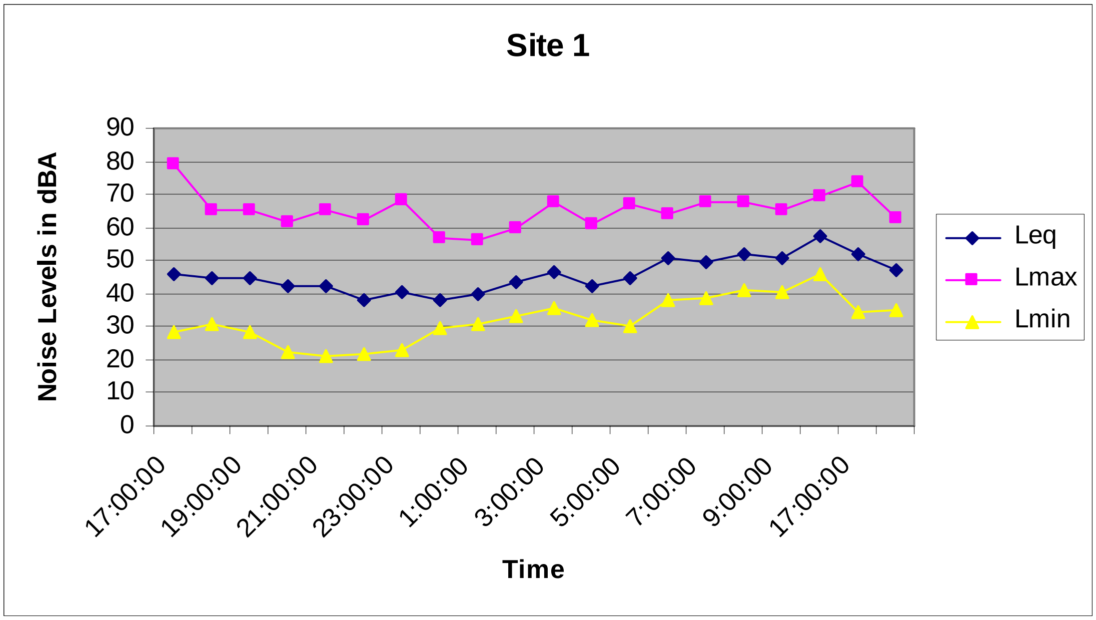


This figure shows that the Leq was 41 dBA and that the maximum sound pressure level of 31.9 dBA was measured at 630 Hz. Pure tones appear on this graph, at 31.5, 50, and 80 Hz though there are peaks at the 125 and 160 Hz octave band centers. In the absence of background noises that can mask these tones, the tones may be considered annoying to some people. Pure tones at levels below 30 dBA may not be audible to the average person, particularly at frequencies below 80 Hz.

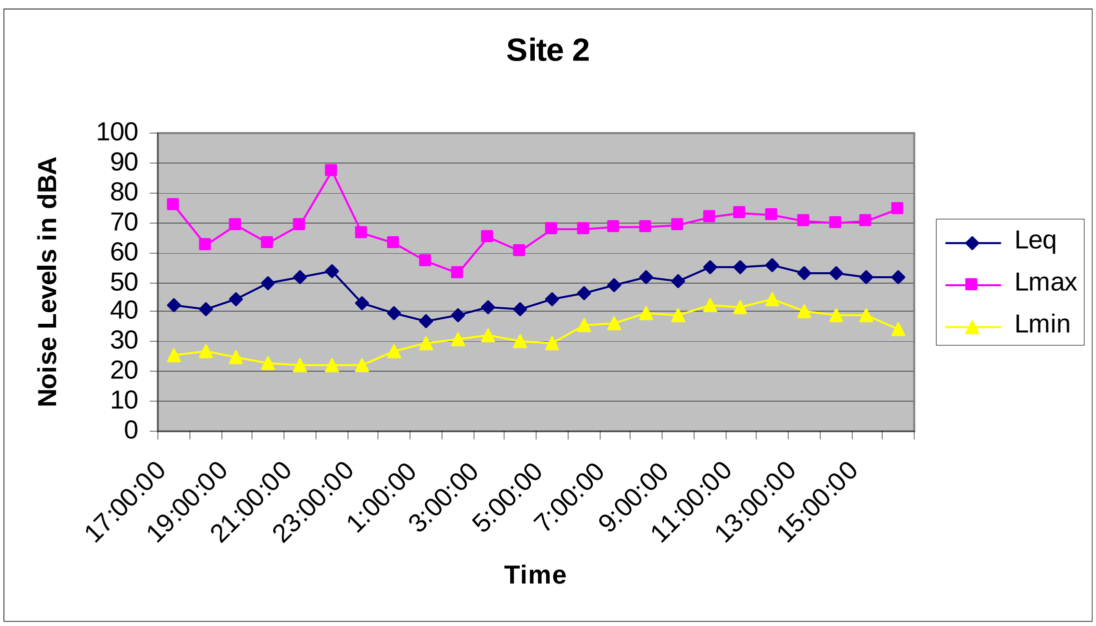
Appendix B
Detailed 24-Hour Noise Monitoring Data

SITE 1 (bin 4)							
Date	**Time**	**Leq**	**Lmax**	**Lmin**	**L(10)**	**L(50)**	**L(90)**
16May 07	17:00:00	46	79	29	48	41	35
16May 07	18:00:00	45	65	31	47	42	38
16May 07	19:00:00	44	65	28	47	41	36
16May 07	20:00:00	42	62	22	45	36	29
16May 07	21:00:00	42	66	21	43	32	25
16May 07	22:00:00	38	62	22	37	29	26
16May 07	23:00:00	41	68	23	39	30	26
17May 07	0:00:00	38	57	30	41	37	34
17May 07	1:00:00	40	56	31	43	38	36
17May 07	2:00:00	44	60	33	47	42	38
17May 07	3:00:00	47	68	36	50	45	41
17May 07	4:00:00	42	61	32	45	41	37
17May 07	5:00:00	45	67	30	47	43	38
17May 07	6:00:00	51	64	38	53	49	45
17May 07	7:00:00	49	68	39	52	48	44
17May 07	8:00:00	52	68	41	55	50	46
17May 07	9:00:00	51	65	41	54	49	45
17May 07	10:00:00	57	69	46	61	56	52
17May 07	17:00:00	52	74	35	55	50	44
17May 07	18:00:00	47	63	35	51	44	40
	max	57	79	46	61	56	52
	min	38	56	21	37	29	25

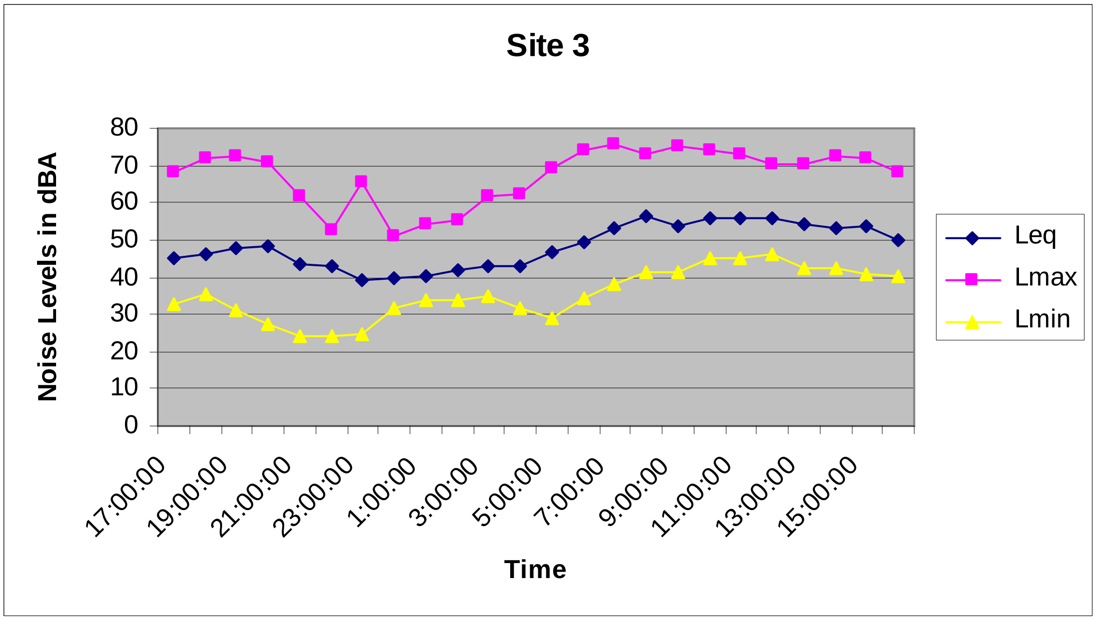
Note: although the identical configuration file was downloaded into each sound level meter, the sound level meter used at Location 1 did not store data between the hours of 11:00 a.m. and 16:00 p.m.. This data gap does not affect the calculated Ldn value, because that value is dominated by data in the hours between 22:00 p.m. and 7:00 a.m. that have a 10 dBA penalty applied to them.


Site 1
Noise Levels in dBA
90
80
70
60
50
40
30
20
10
0
17:00:00
19:00:00
21:00:00
23:00:00
1:00:00
3:00:00
5:00:00
7:00:00
9:00:00
17:00:00
Time
Leq
Lmax
Lmin

SITE 2 (bin 1)							
Date	Time	Leq	Lmax	Lmin	L(10)	L(50)	L(90)
16May 07	17:00:00	43	76	26	44	34	29
16May 07	18:00:00	41	63	27	44	34	31
16May 07	19:00:00	45	69	25	47	34	29
16May 07	20:00:00	50	63	23	55	42	27
16May 07	21:00:00	52	69	22	56	47	26
16May 07	22:00:00	54	87	22	39	27	24
16May 07	23:00:00	43	66	22	39	28	25
17May 07	0:00:00	40	63	27	39	34	31
17May 07	1:00:00	37	57	29	38	35	33
17May 07	2:00:00	39	53	31	41	37	35
17May 07	3:00:00	42	65	32	44	39	36
17May 07	4:00:00	41	61	31	43	38	35
17May 07	5:00:00	44	68	30	45	41	37
17May 07	6:00:00	46	68	36	48	44	40
17May 07	7:00:00	49	68	36	51	46	42
17May 07	8:00:00	52	69	39	55	48	44
17May 07	9:00:00	51	69	39	54	48	43
17May 07	10:00:00	55	72	42	59	52	47
17May 07	11:00:00	55	73	41	58	51	46
17May 07	12:00:00	56	72	44	59	53	48
17May 07	13:00:00	53	70	40	56	50	45
17May 07	14:00:00	53	70	39	57	50	45
17May 07	15:00:00	52	71	39	55	48	43
17May 07	16:00:00	52	74	34	55	47	41
	max	56	87	44	59	53	48
	min	37	53	22	38	27	24

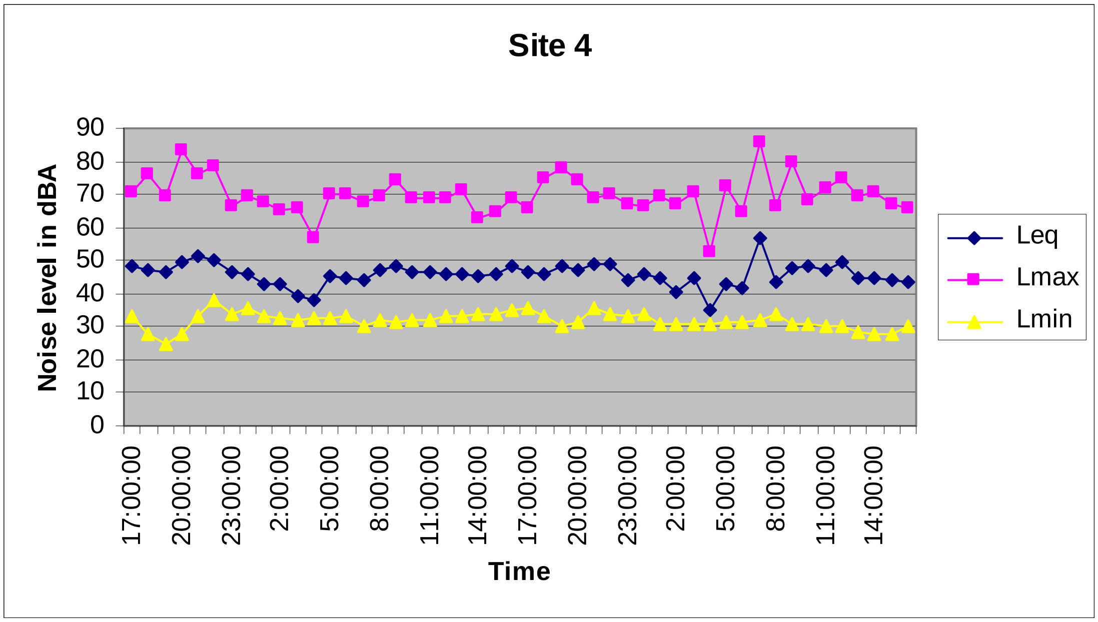


SITE 3 (bin 2)							
Date	**Time**	**Leq**	**Lmax**	**Lmin**	**L(10)**	**L(50)**	**L(90)**
16May 07	17:00:00	45	68	33	48	43	39
16May 07	18:00:00	46	72	36	47	43	41
16May 07	19:00:00	48	72	31	48	43	39
16May 07	20:00:00	48	71	27	50	45	35
16May 07	21:00:00	43	62	24	47	41	31
16May 07	22:00:00	43	52	24	48	37	29
16May 07	23:00:00	39	66	25	39	32	29
17May 07	0:00:00	40	51	32	42	38	36
17May 07	1:00:00	41	54	34	43	40	37
17May 07	2:00:00	42	55	34	44	41	38
17May 07	3:00:00	43	62	35	45	41	39
17May 07	4:00:00	43	62	32	46	40	37
17May 07	5:00:00	47	69	29	48	42	37
17May 07	6:00:00	49	74	35	51	45	41
17May 07	7:00:00	53	76	38	52	47	43
17May 07	8:00:00	57	73	41	60	52	47
17May 07	9:00:00	54	75	42	57	50	45
17May 07	10:00:00	56	74	45	59	53	49
17May 07	11:00:00	56	73	45	59	53	49
17May 07	12:00:00	56	71	46	59	54	50
17May 07	13:00:00	54	70	42	57	51	47
17May 07	14:00:00	53	73	42	56	50	46
17May 07	15:00:00	54	72	41	57	50	46
17May 07	16:00:00	50	68	40	53	48	44
	max	57	76	46	60	54	50
	min	39	51	24	39	32	29

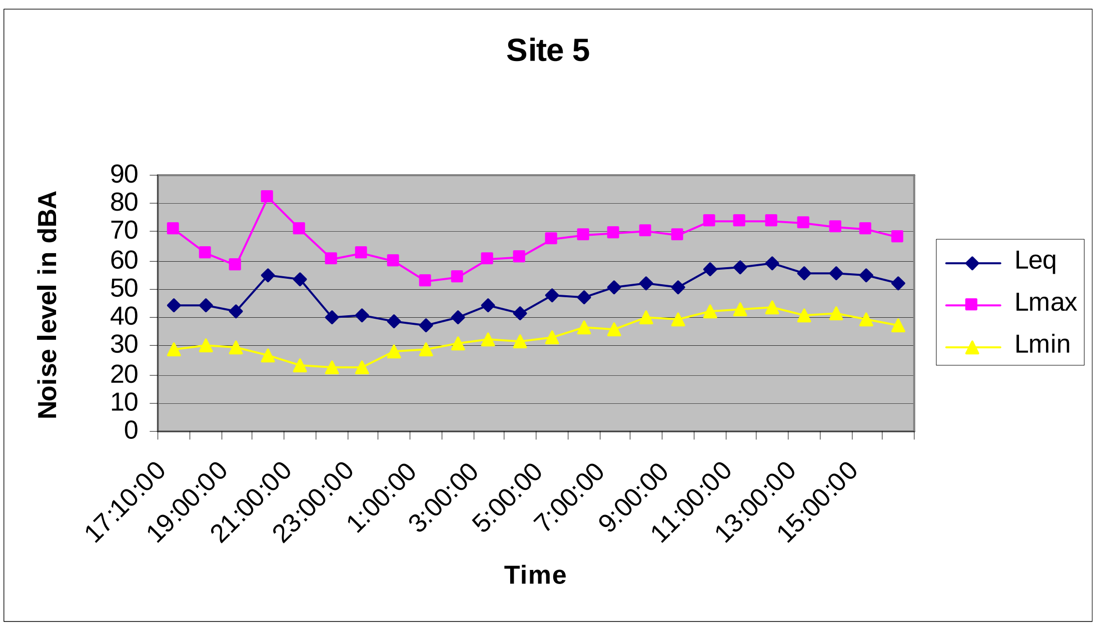


SITE 4 (13July_16.bin)							
Date	**Time**	**Leq**	**Lmax**	**Lmin**	**L(10)**	**L(50)**	**L(90)**
13Jul 07	17:00:00	48	70	33	47	40	37
13Jul 07	18:00:00	47	76	28	45	38	32
13Jul 07	19:00:00	46	69	25	46	33	30
13Jul 07	20:00:00	49	83	28	49	35	31
13Jul 07	21:00:00	51	76	33	52	48	41
13Jul 07	22:00:00	50	78	38	51	47	42
13Jul 07	23:00:00	47	66	34	49	42	37
14Jul 07	0:00:00	46	70	35	48	42	39
14Jul 07	1:00:00	43	68	33	43	40	36
14Jul 07	2:00:00	43	65	33	41	39	36
14Jul 07	3:00:00	39	66	32	40	37	34
14Jul 07	4:00:00	38	57	33	40	38	35
14Jul 07	5:00:00	46	70	33	41	38	36
14Jul 07	6:00:00	45	70	33	42	39	36
14Jul 07	7:00:00	44	68	30	42	38	34
14Jul 07	8:00:00	47	70	32	44	38	34
14Jul 07	9:00:00	48	74	32	43	37	34
14Jul 07	10:00:00	47	69	32	46	39	36
14Jul 07	11:00:00	47	69	32	46	40	36
14Jul 07	12:00:00	46	69	33	47	42	38
14Jul 07	13:00:00	46	71	33	47	41	37
14Jul 07	14:00:00	46	63	34	49	43	39
14Jul 07	15:00:00	46	65	34	48	42	38
14Jul 07	16:00:00	48	69	35	51	45	40
14Jul 07	17:00:00	47	66	36	50	45	40
14Jul 07	18:00:00	46	75	33	47	40	37
14Jul 07	19:00:00	48	78	30	48	38	34
14Jul 07	20:00:00	47	75	31	44	35	33
14Jul 07	21:00:00	49	69	36	49	44	41
14Jul 07	22:00:00	49	70	34	47	44	39
14Jul 07	23:00:00	44	67	33	46	43	36
15Jul 07	0:00:00	46	67	34	48	44	38
15Jul 07	1:00:00	44	70	31	46	39	34
15Jul 07	2:00:00	40	67	31	40	36	33
15Jul 07	3:00:00	44	70	31	41	35	33
15Jul 07	4:00:00	35	52	31	37	34	33
15Jul 07	5:00:00	43	73	31	39	36	34
15Jul 07	6:00:00	42	65	32	40	35	33
15Jul 07	7:00:00	57	86	32	54	43	36
15Jul 07	8:00:00	43	66	34	43	39	36
15Jul 07	9:00:00	48	80	31	47	40	37
15Jul 07	10:00:00	48	68	31	48	41	34
15Jul 07	11:00:00	47	72	30	45	38	34
15Jul 07	12:00:00	50	75	31	50	42	33
15Jul 07	13:00:00	45	70	28	42	33	30
15Jul 07	14:00:00	44	71	28	39	33	30

SITE 4 (13July_16.bin)							
Date	**Time**	**Leq**	**Lmax**	**Lmin**	**L(10)**	**L(50)**	**L(90)**
15Jul 07	15:00:00	44	67	28	41	34	30
15Jul 07	16:00:00	44	66	30	46	41	36
	max	57	86	38	54	48	42
	min	35	52	25	37	33	30



SITE 5 (bin 3)							
Date	**Time**	**Leq**	**Lmax**	**Lmin**	**L(10)**	**L(50)**	**L(90)**
16May 07	17:10:00	44	71	29	47	43	39
16May 07	18:00:00	44	62	30	47	43	38
16May 07	19:00:00	42	58	29	45	40	36
16May 07	20:00:00	55	83	26	57	44	34
16May 07	21:00:00	53	71	23	56	46	27
16May 07	22:00:00	40	61	22	37	28	25
16May 07	23:00:00	41	62	23	39	29	26
17May 07	0:00:00	39	60	28	38	34	31
17May 07	1:00:00	37	53	29	39	36	33
17May 07	2:00:00	40	54	31	44	38	35
17May 07	3:00:00	44	60	32	48	41	37
17May 07	4:00:00	42	62	32	44	39	36
17May 07	5:00:00	48	67	33	50	41	38
17May 07	6:00:00	47	69	37	49	45	41
17May 07	7:00:00	50	70	36	52	46	43
17May 07	8:00:00	52	70	40	55	48	45
17May 07	9:00:00	51	69	40	54	48	44
17May 07	10:00:00	57	74	42	61	55	49
17May 07	11:00:00	58	74	43	61	54	48
17May 07	12:00:00	59	74	44	63	56	51
17May 07	13:00:00	56	73	41	59	53	48
17May 07	14:00:00	55	71	41	59	53	47
17May 07	15:00:00	55	71	40	59	52	46
17May 07	16:00:00	52	69	37	56	49	44
17May 07	17:00:00	50	63	36	54	46	41
	max	59	83	44	63	56	51
	min	37	53	22	37	28	25



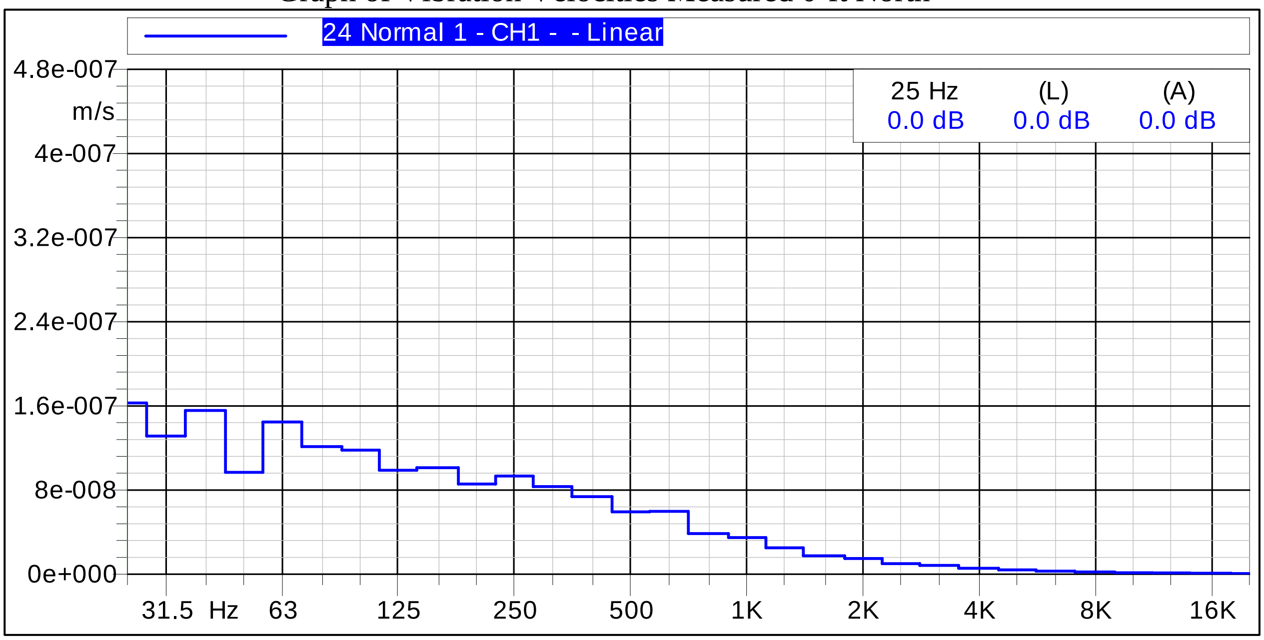
Appendix C
Detailed Vibration Monitoring Data

Table C-1
Vibration Velocities Measured North of the Facility

Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	6.42×10^{-6}	9.07×10^{-6}	NA
330 feet	1.28×10^{-5}	1.80×10^{-5}	31.5
660 feet	7.72×10^{-6}	1.09×10^{-5}	NA
1320 feet	1.31×10^{-5}	1.85×10^{-5}	31.5
1980 feet	1.10×10^{-5}	1.56×10^{-5}	31.5
2640 feet	8.94×10^{-6}	1.26×10^{-5}	31.5

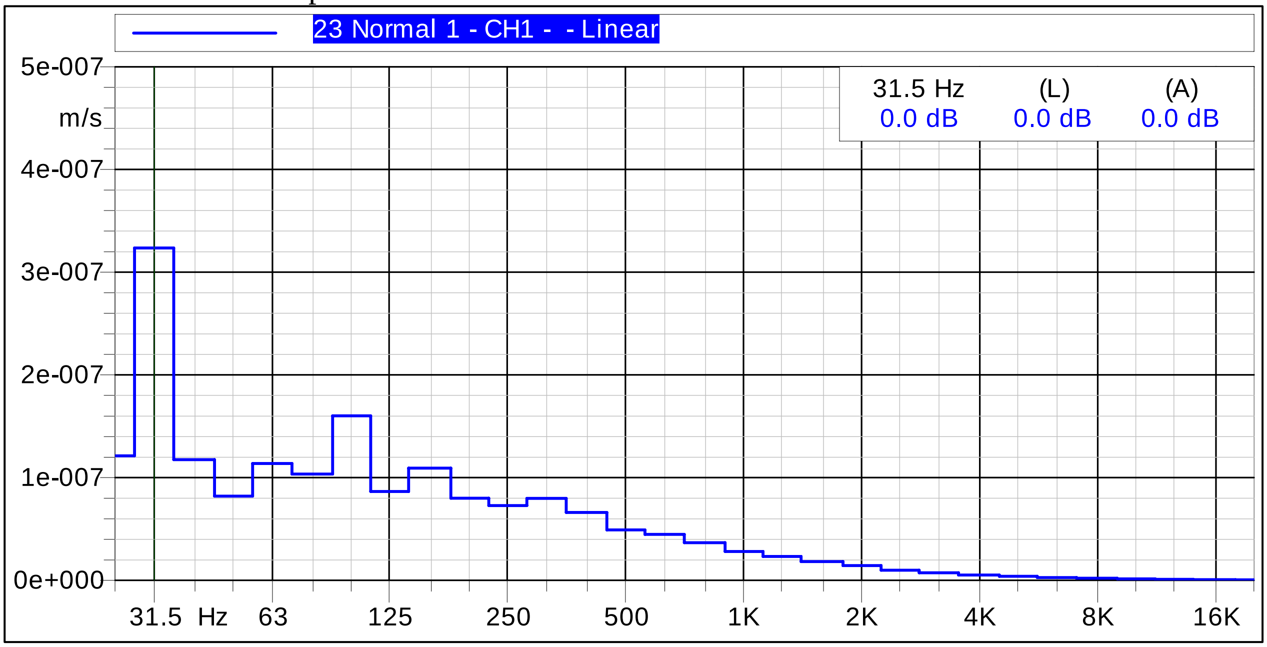
Following are graphs, of vibration velocities measured at each location. The units on the graphs are in meters per second because of limitations in the graphing software.

Figure C-1
Graph of Vibration Velocities Measured 0-ft North



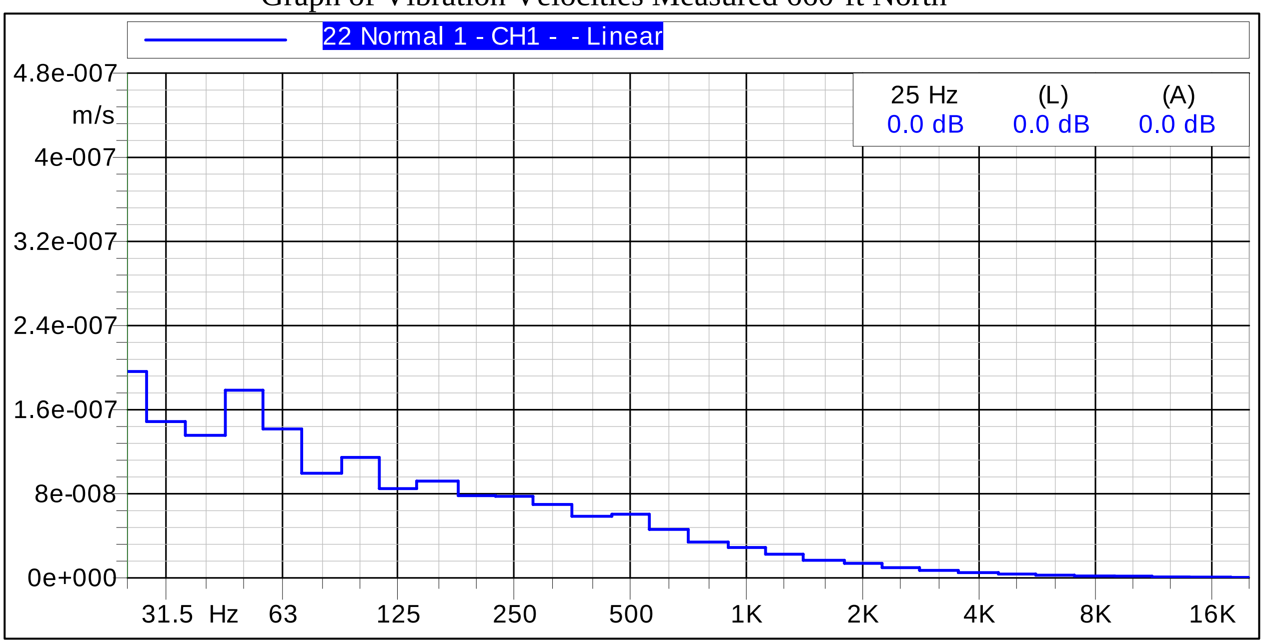
This figure shows that the maximum velocity occurred at 25 Hz. There are no frequency spikes that appear on this graph.

Figure C-2
Graph of Vibration Velocities Measured 330-ft North



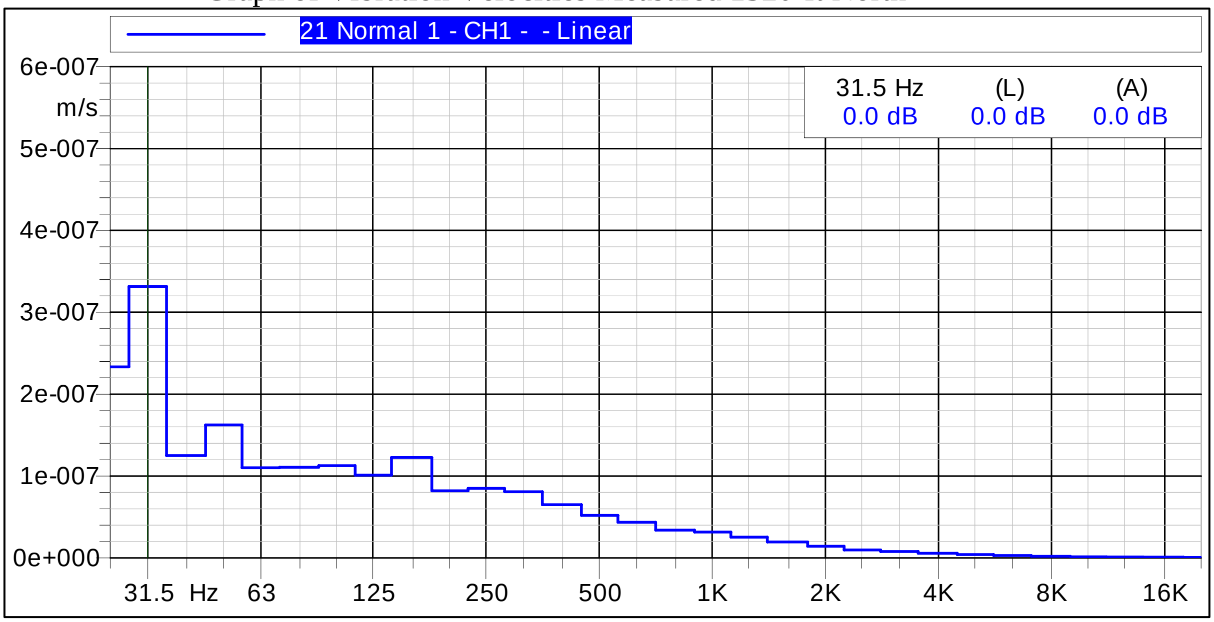
This figure shows that the maximum velocity occurred at 31.5 Hz. There is one large and one small frequency spikes that appear on this graph – the first at the octave band center of 31.5 Hz, the second at 100Hz.

Figure C-3
Graph of Vibration Velocities Measured 660-ft North



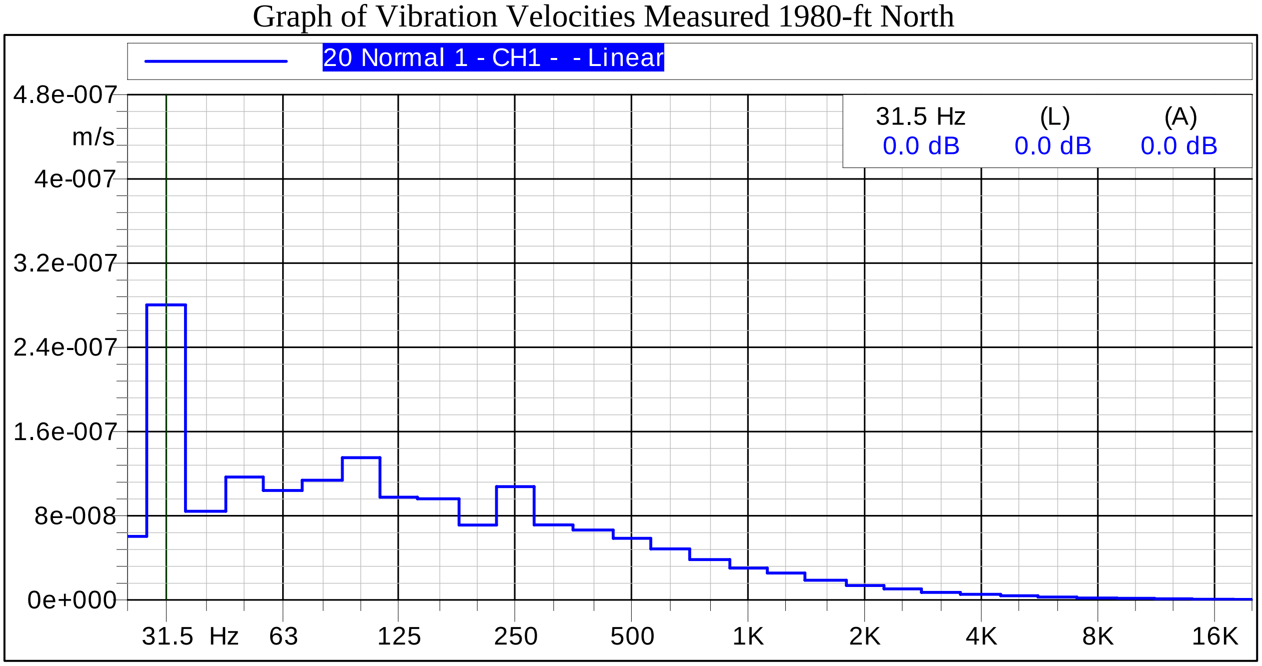
This figure shows that the maximum velocity occurred at 25 Hz. There are no frequency spikes that appear on this graph.

Figure C-4
Graph of Vibration Velocities Measured 1320-ft North



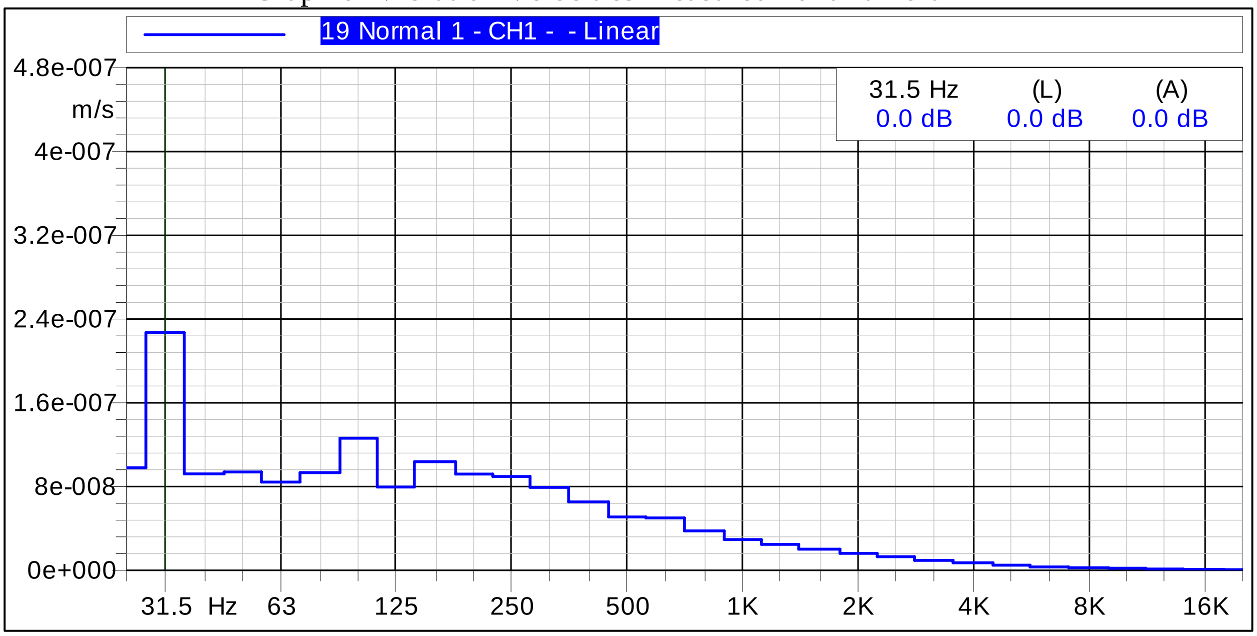
This figure shows that the maximum velocity occurred at 31.5 Hz. There is one frequency spike that appears on this graph – at the octave band center of 31.5 Hz.

Figure C-5
Graph of Vibration Velocities Measured 1980-ft North



This figure shows that the maximum velocity occurred at 31.5 Hz. There is one frequency spike that appears on this graph – at the octave band center of 31.5 Hz.

Figure C-6
Graph of Vibration Velocities Measured 2640-ft North



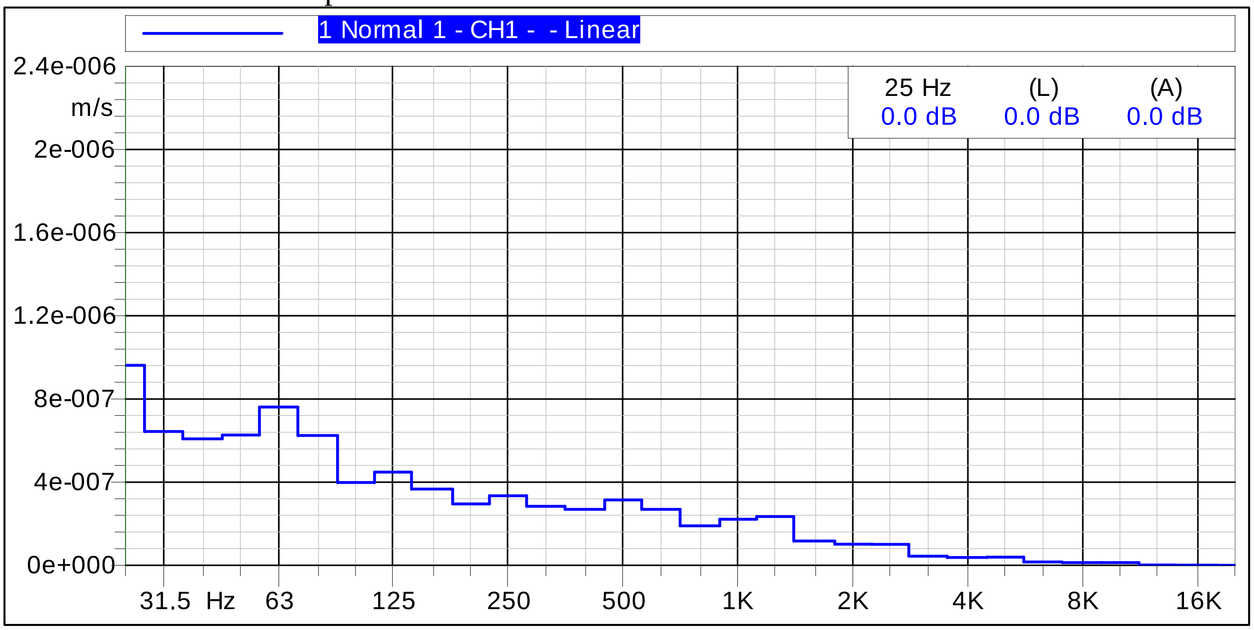
This figure shows that the maximum velocity occurred at 31.5 Hz. There is one large and one small frequency spikes that appear on this graph – the first at the octave band center of 31.5 Hz, the second at 100Hz.

Table C-2 summarizes vibration velocities measured South of the Facility.

Table C-2
Vibration Velocities Measured South of the Facility

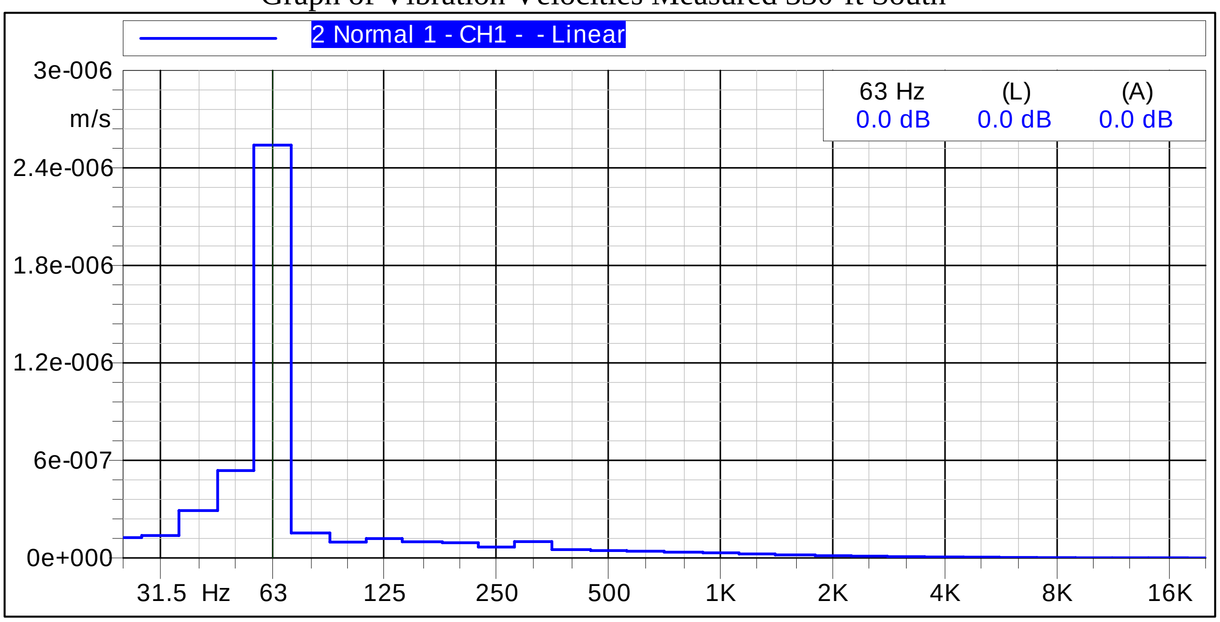
Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	3.79×10^{-5}	5.36×10^{-5}	25
330 feet	1.00×10^{-4}	1.41×10^{-4}	63
660 feet	9.06×10^{-6}	1.28×10^{-5}	63
1320 feet	6.93×10^{-6}	9.80×10^{-6}	63
1980 feet	1.44×10^{-5}	2.04×10^{-5}	31.5
2640 feet	8.39×10^{-6}	1.19×10^{-5}	31.5

Figure C-7
Graph of Vibration Velocities Measured 0-ft South



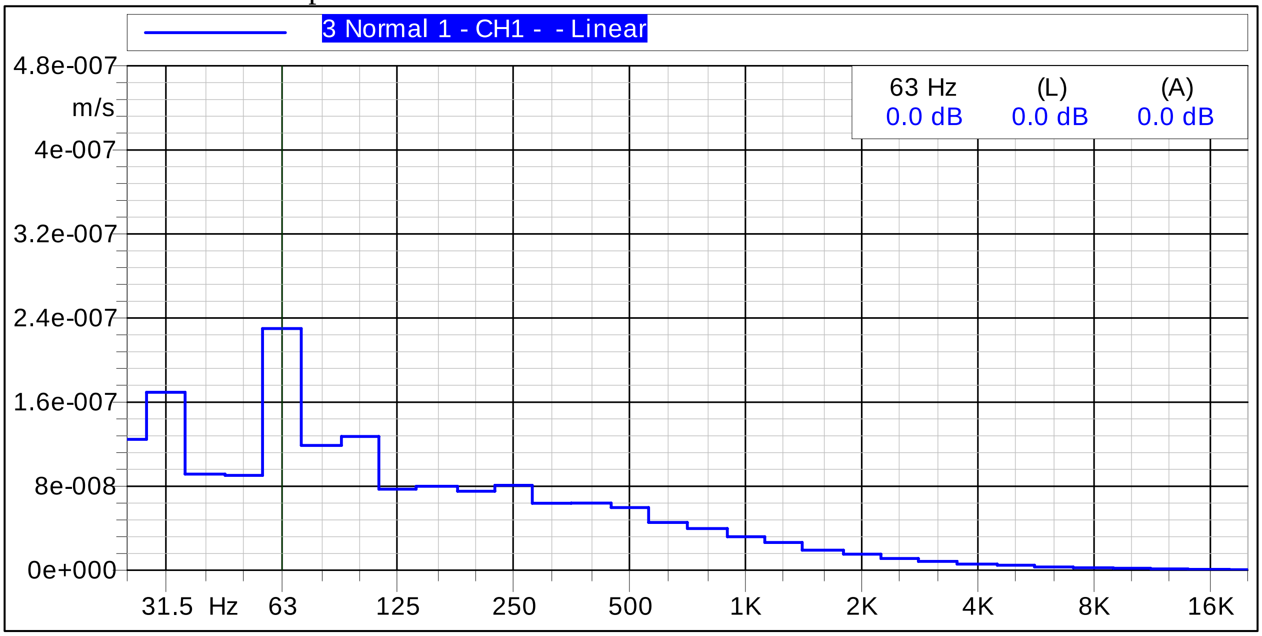
This figure shows that the maximum velocity occurred at 25 Hz. There is one frequency spike that appears on this graph – at 25 Hz.

Figure C-8
Graph of Vibration Velocities Measured 330-ft South



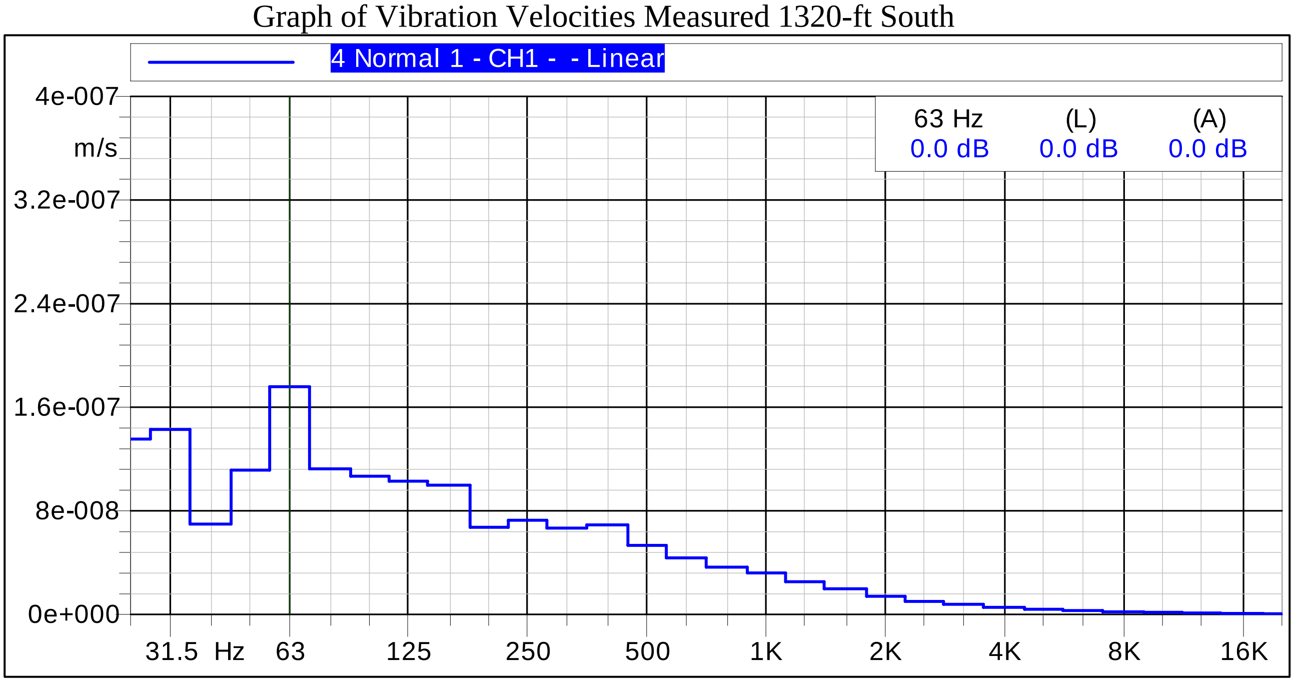
This figure shows that the maximum velocity occurred at 63 Hz. There is one frequency spike that appears on this graph – at the octave band center of 63 Hz.

Figure C-9
Graph of Vibration Velocities Measured 660-ft South



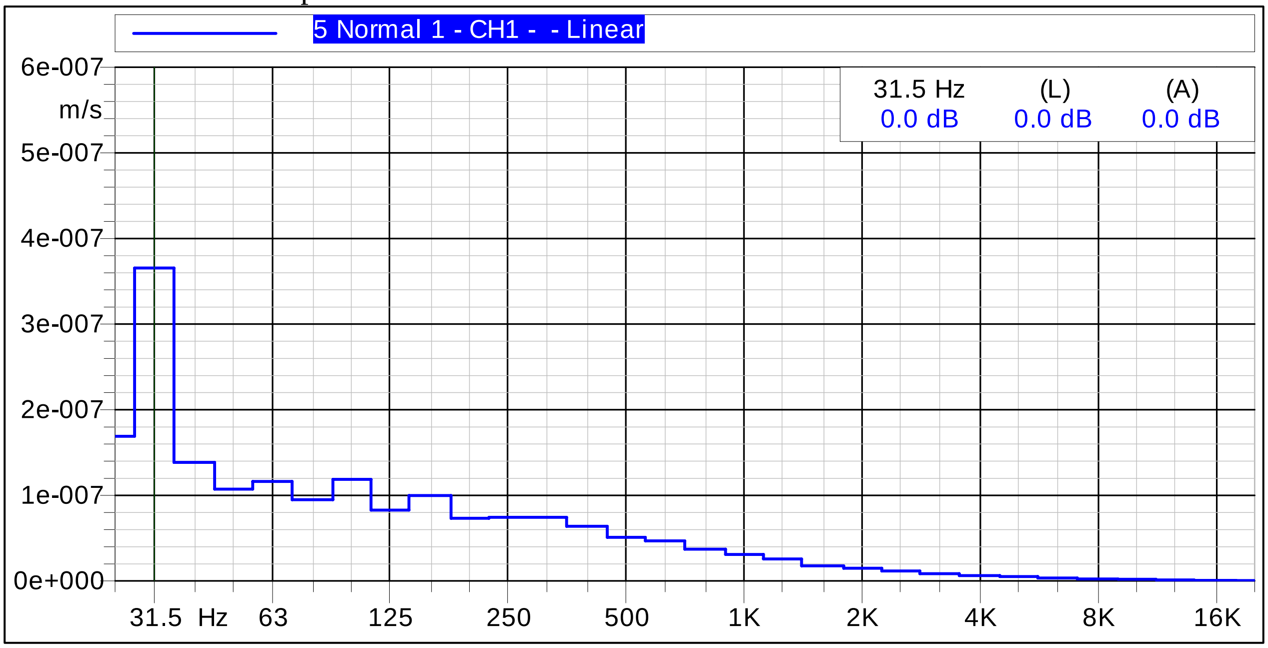
This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at the octave band center of 31.5Hz.

Figure C-10
Graph of Vibration Velocities Measured 1320-ft South



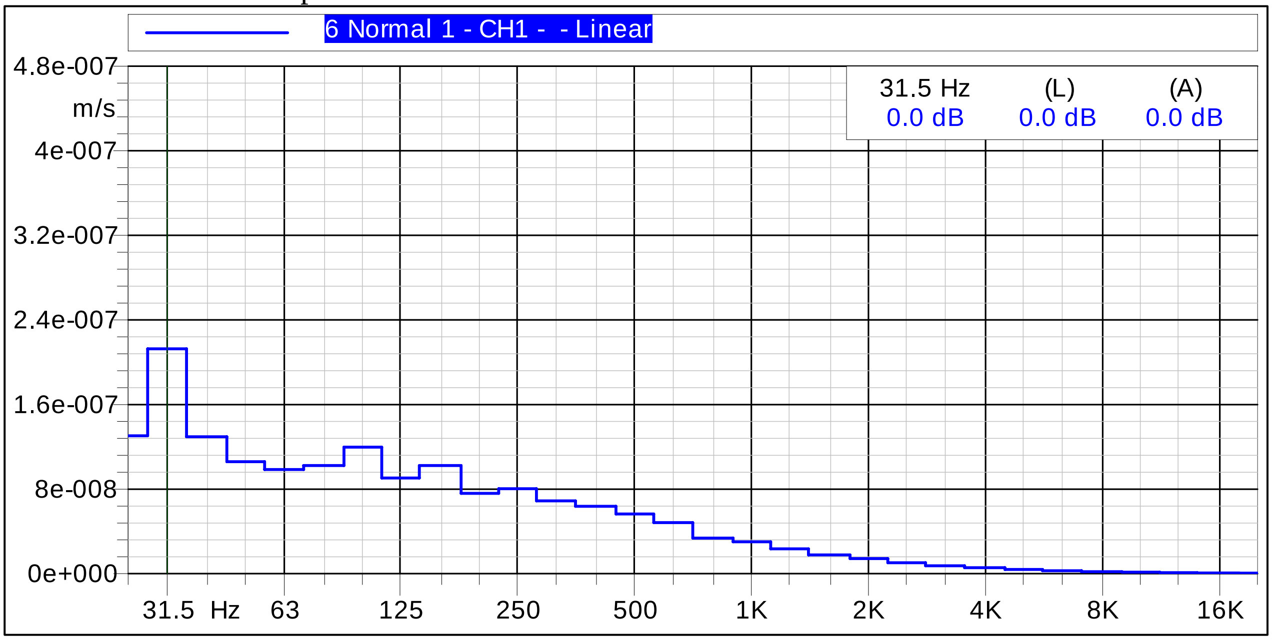
This figure shows that the maximum velocity occurred at 63 Hz. There is one frequency spike that appears on this graph – at the octave band center of 63 Hz.

Figure C-11
Graph of Vibration Velocities Measured 1980-ft South



This figure shows that the maximum velocity occurred at 31.5 Hz. There is one frequency spike that appears on this graph – at the octave band center of 31.5 Hz.

Figure C-12
Graph of Vibration Velocities Measured 1980-ft South



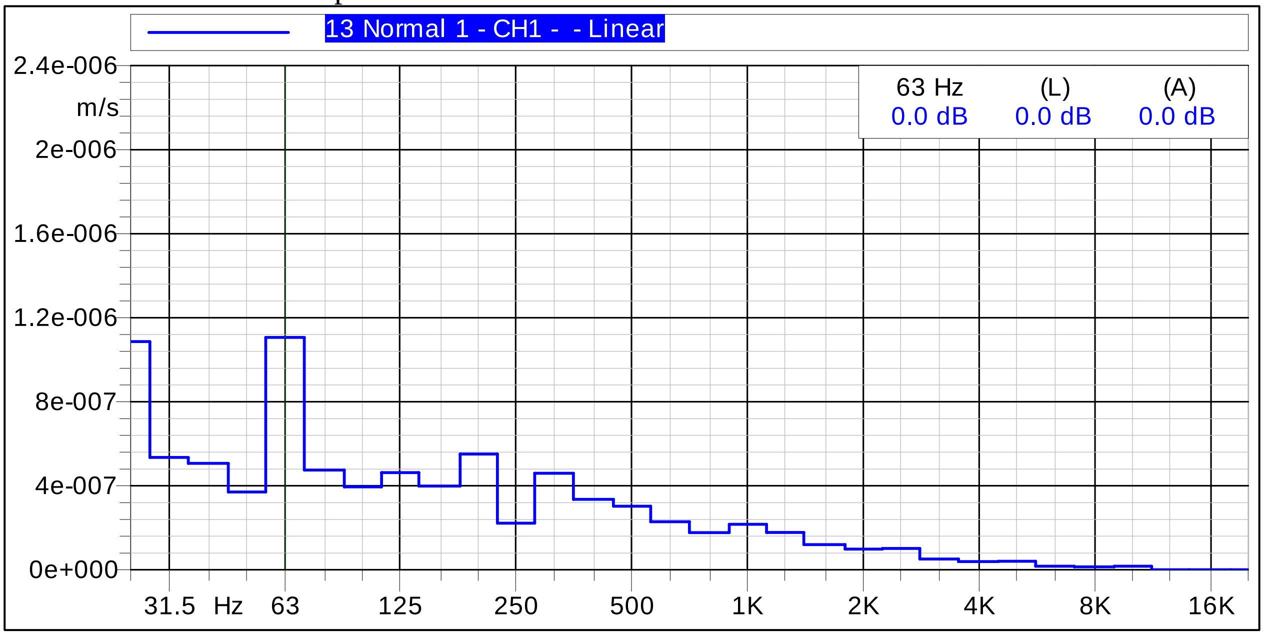
This figure shows that the maximum velocity occurred at 31.5 Hz. There is one frequency spike that appears on this graph – at the octave band center of 31.5 Hz.

Table C-3 summarizes vibration velocities measured South of the Facility.

Table C-3
Maximum Vibration Velocities Measured East of the Facility

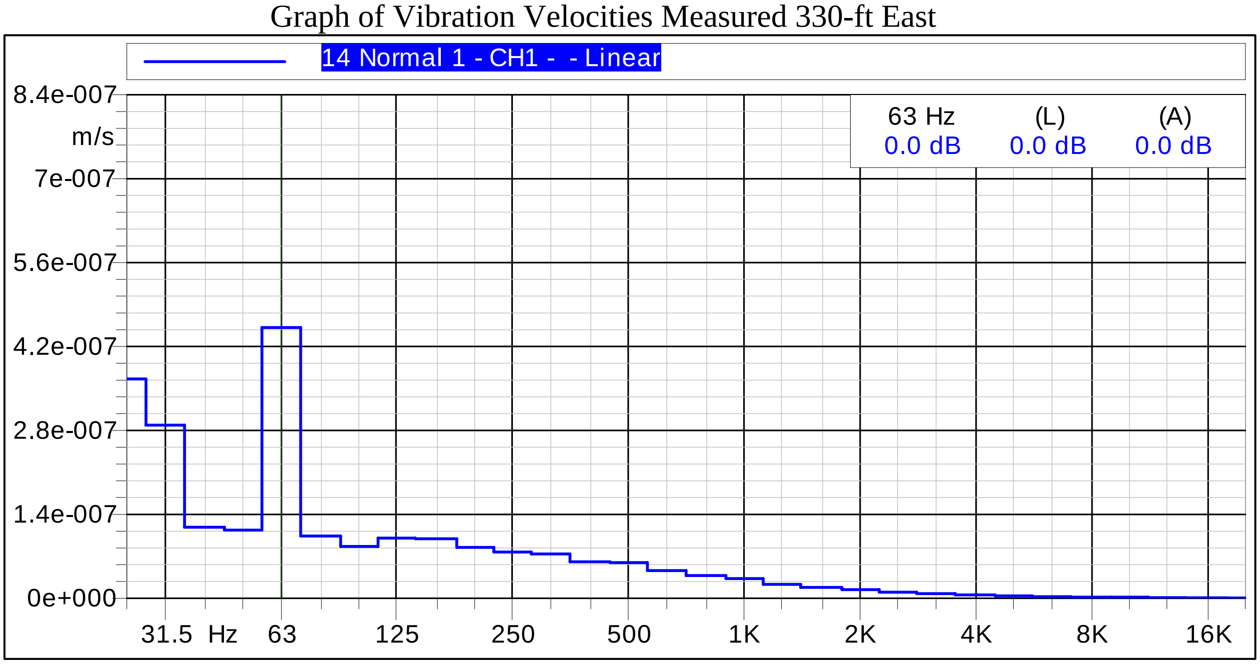
Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	4.37×10^{-5}	6.18×10^{-5}	25, 63
330 feet	1.78×10^{-5}	2.52×10^{-5}	25, 63
660 feet	No Data	No Data	NA
1320 feet	6.93×10^{-6}	9.80×10^{-6}	31.5
1980 feet	1.62×10^{-5}	2.29×10^{-5}	63
2640 feet	1.73×10^{-5}	2.44×10^{-5}	63
Recommended limit	0.011	0.008	NA

Figure C-13
Graph of Vibration Velocities Measured 0-ft East



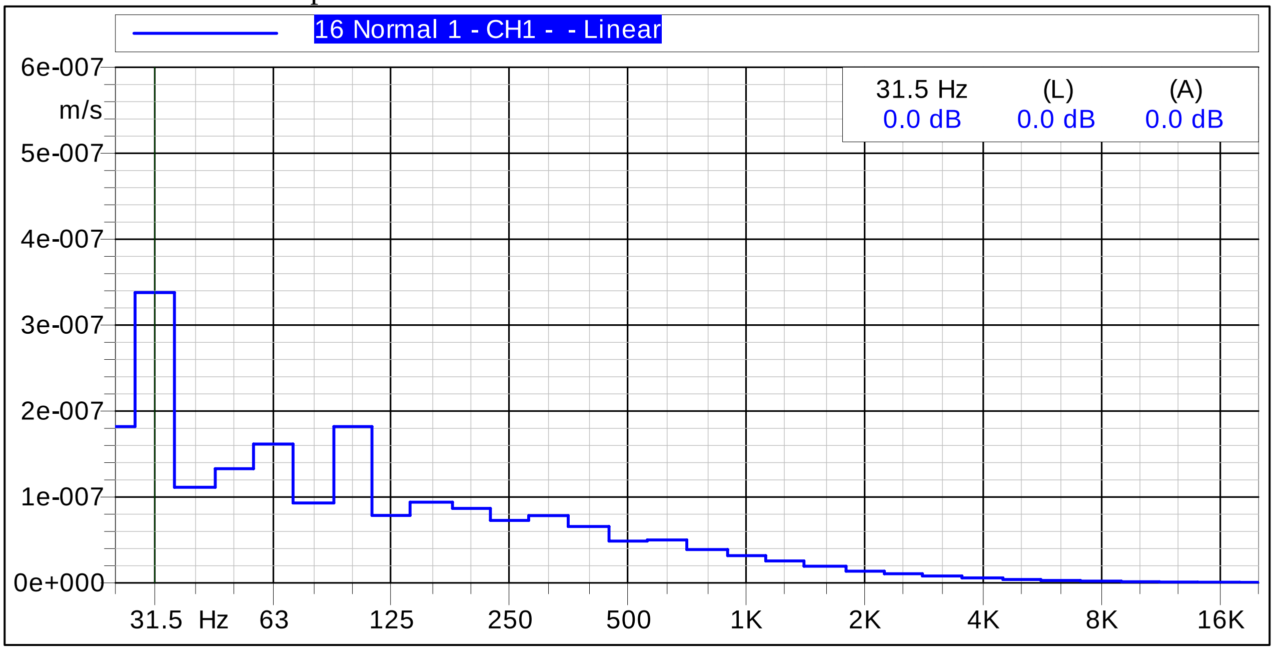
This figure shows that the maximum velocity occurred at 63 Hz. There are two large frequency spikes that appear on this graph – the first at the octave band center of 25 Hz, the second at the octave band center of 63Hz.

Figure C-14
Graph of Vibration Velocities Measured 330-ft East



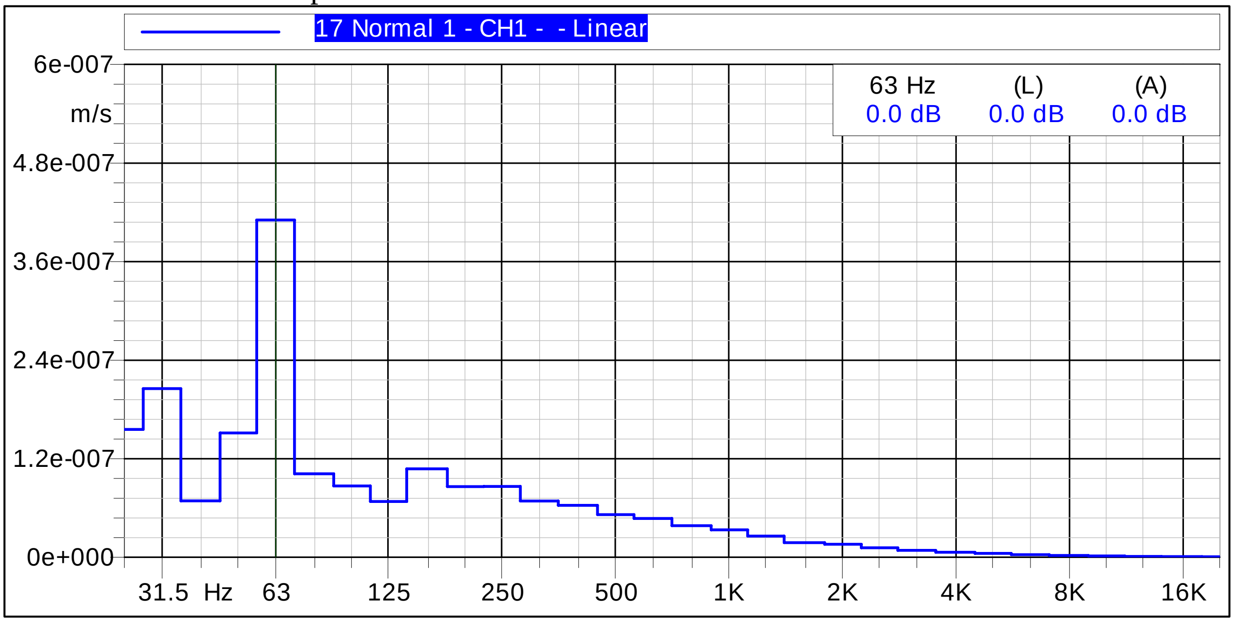
This figure shows that the maximum velocity occurred at 63 Hz. There are two large frequency spikes that appear on this graph – the first, a multi-frequency spike, centered at the octave band center of 25 Hz, the second at the octave band center of 63Hz.

Figure C-15
Graph of Vibration Velocities Measured 1320-ft East



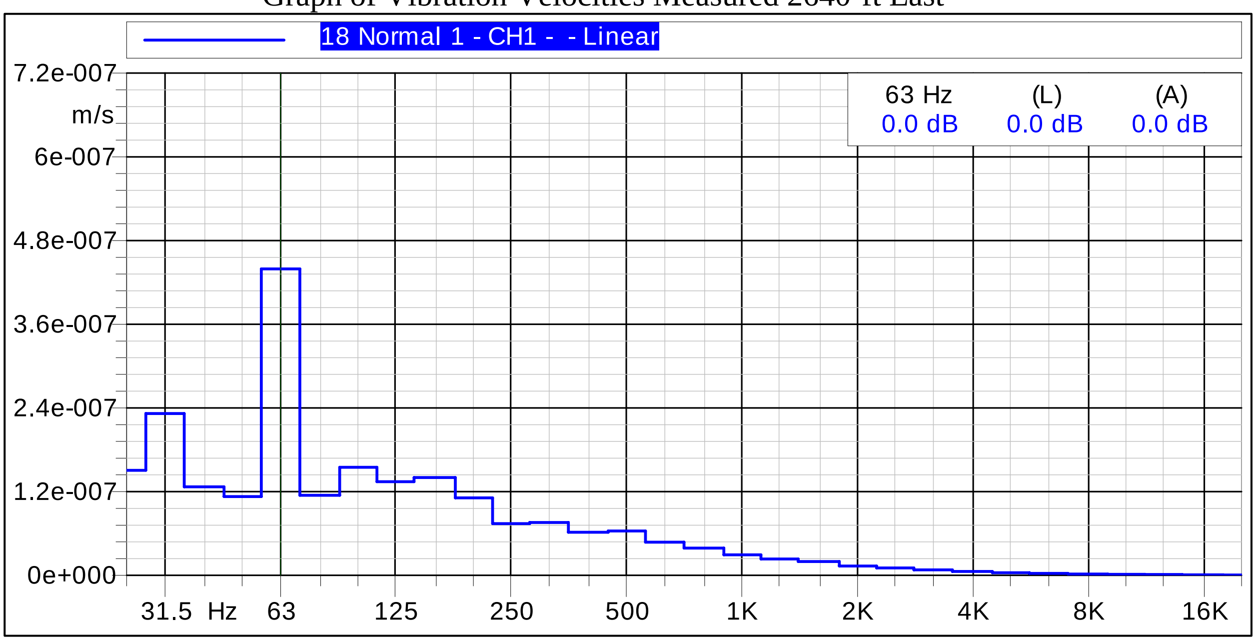
This figure shows that the maximum velocity occurred at 31.5 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 31.5 Hz, the second at 100 Hz.

Figure C-16
Graph of Vibration Velocities Measured 1980-ft East



This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at the octave band center of 31.5 Hz.

Figure C-17
Graph of Vibration Velocities Measured 2640-ft East



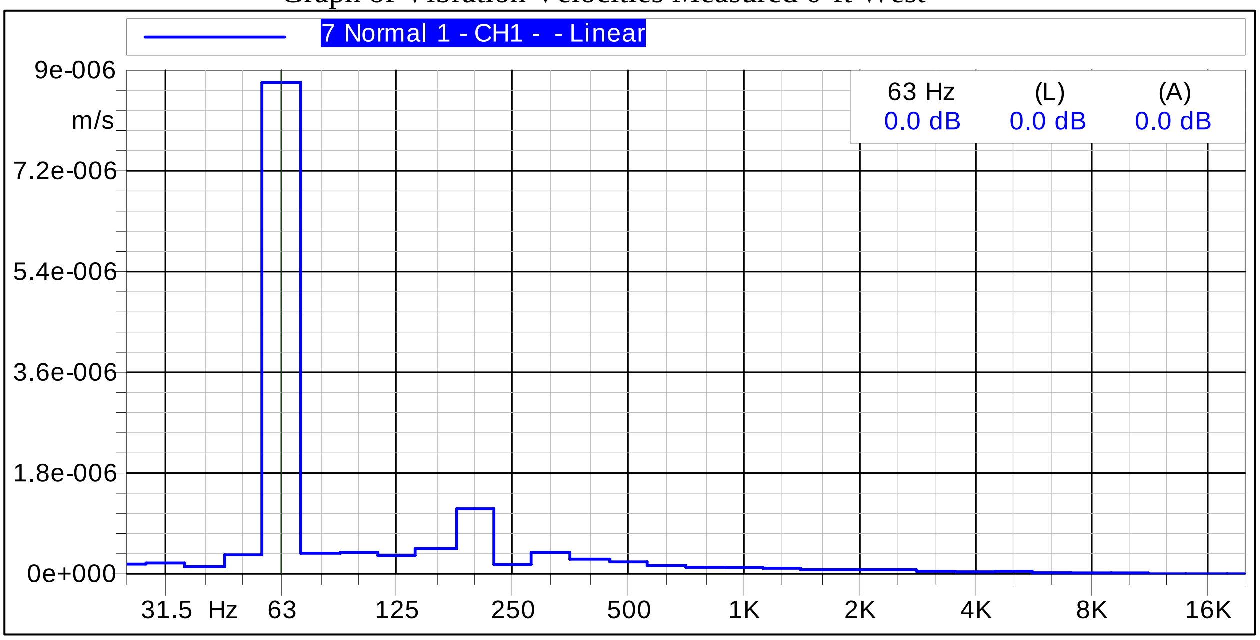
This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at the octave band center of 31.5 Hz.

Table C-4 summarizes vibration velocities measured West of the Facility.

Table C-4
Maximum Vibration Velocities Measured West of the Facility

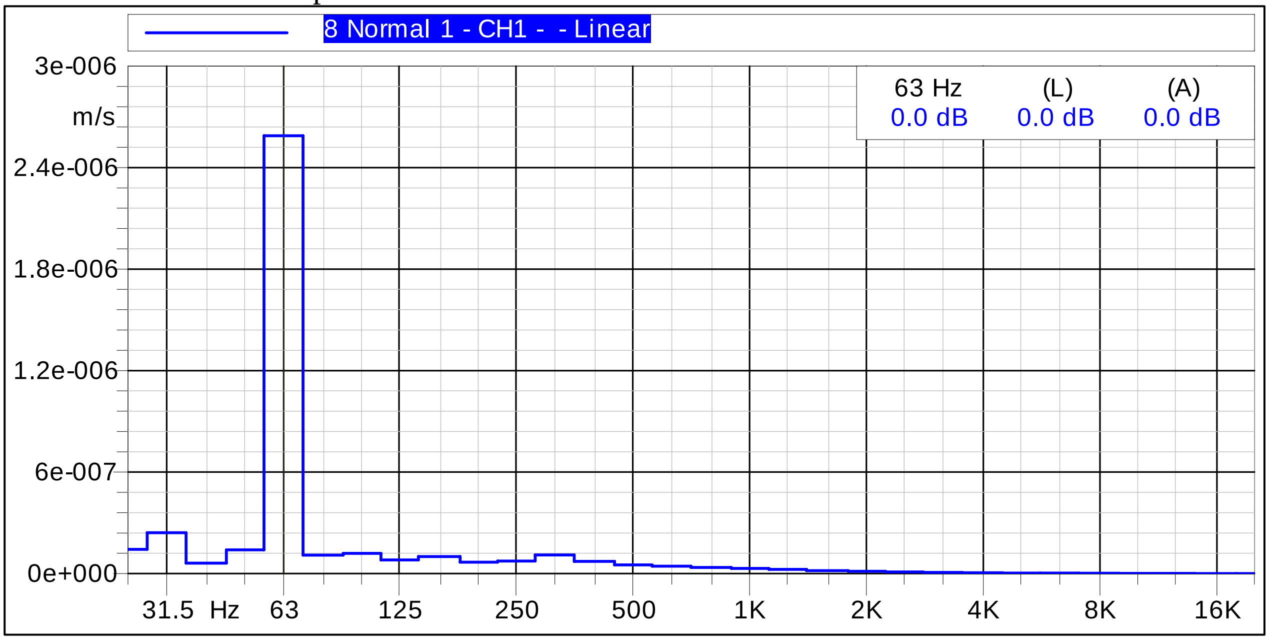
Monitoring Location ID	RMS (in/sec)	PPV (in/sec)	Spikes (Frequency)
0 feet	3.46×10^{-4}	4.89×10^{-4}	63
330 feet	1.02×10^{-4}	1.44×10^{-4}	63
660 feet	3.25×10^{-5}	4.60×10^{-5}	63
1320 feet	1.70×10^{-5}	2.40×10^{-5}	63
1980 feet	2.90×10^{-5}	4.10×10^{-5}	63
2640 feet	2.20×10^{-5}	3.11×10^{-5}	63
Recommended limit	0.011	0.008	NA

Figure C-18
Graph of Vibration Velocities Measured 0-ft West



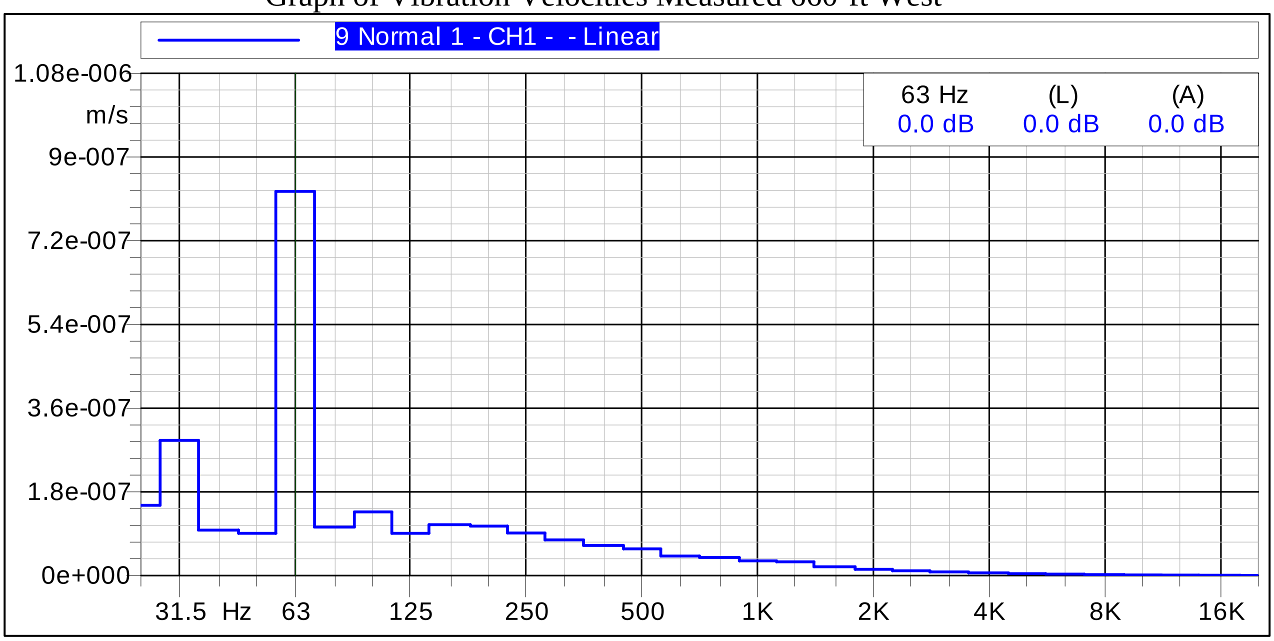
This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at 100 Hz.

Figure C-19
Graph of Vibration Velocities Measured 330-ft West



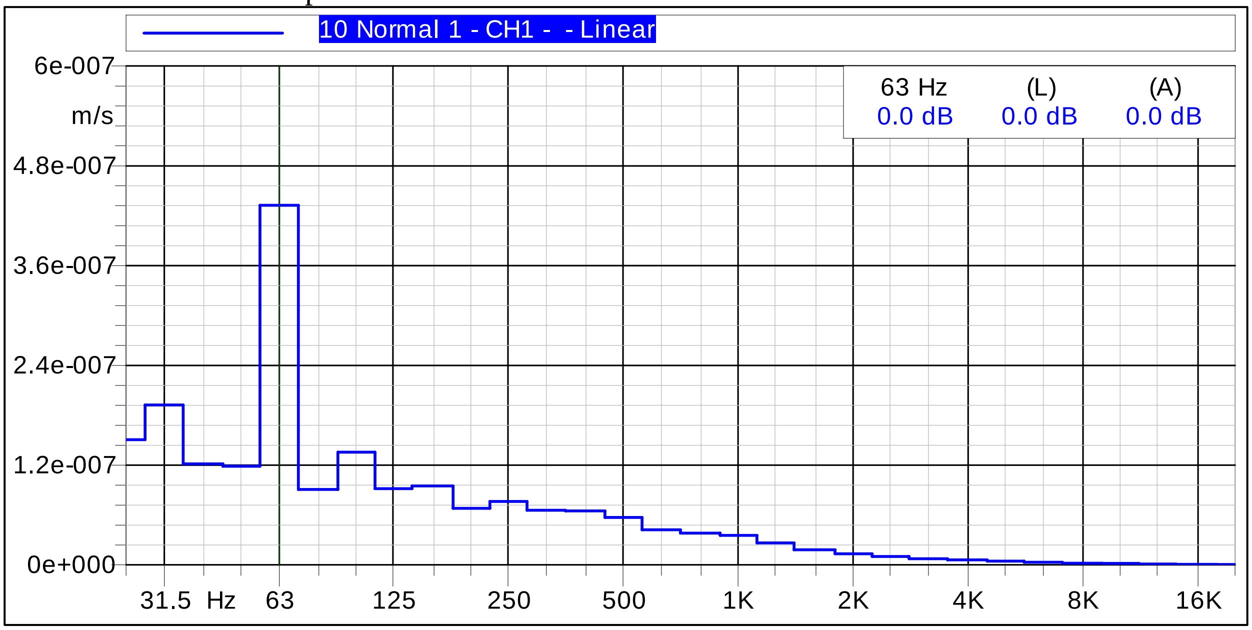
This figure shows that the maximum velocity occurred at 63Hz. There is one frequency spike that appears on this graph – at the octave band center of 63 Hz.

Figure C-20
Graph of Vibration Velocities Measured 660-ft West



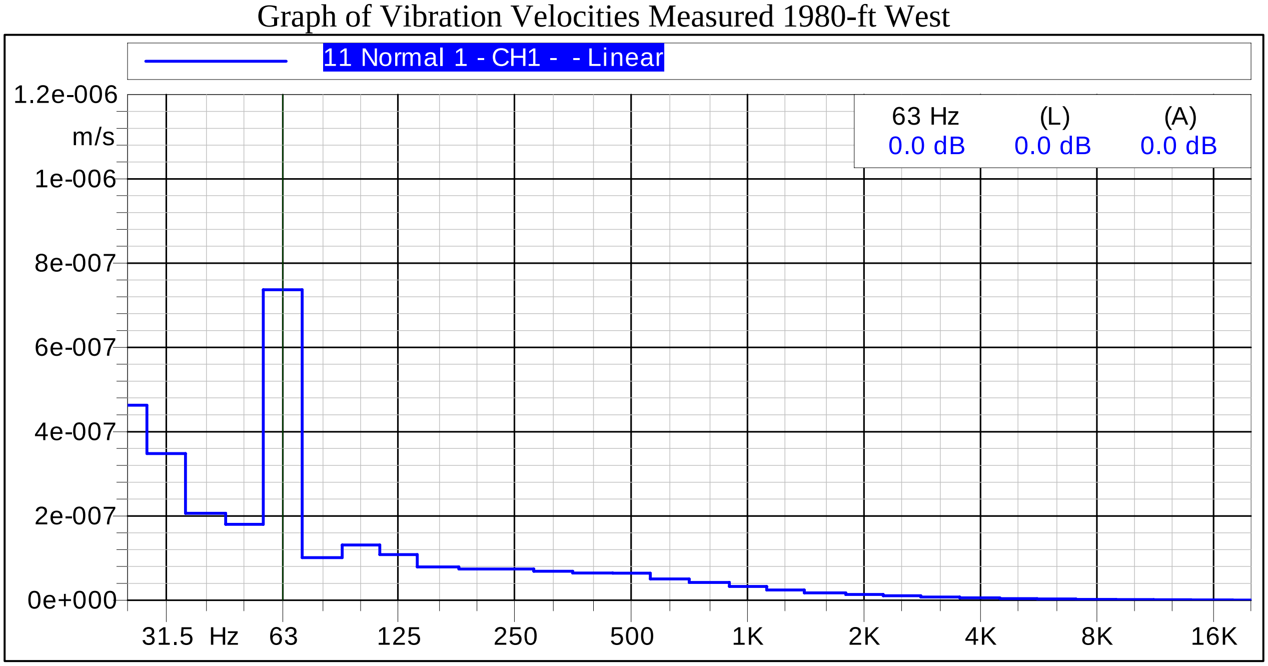
This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at the octave band center of 31.5 Hz.

Figure C-21
Graph of Vibration Velocities Measured 1320-ft West



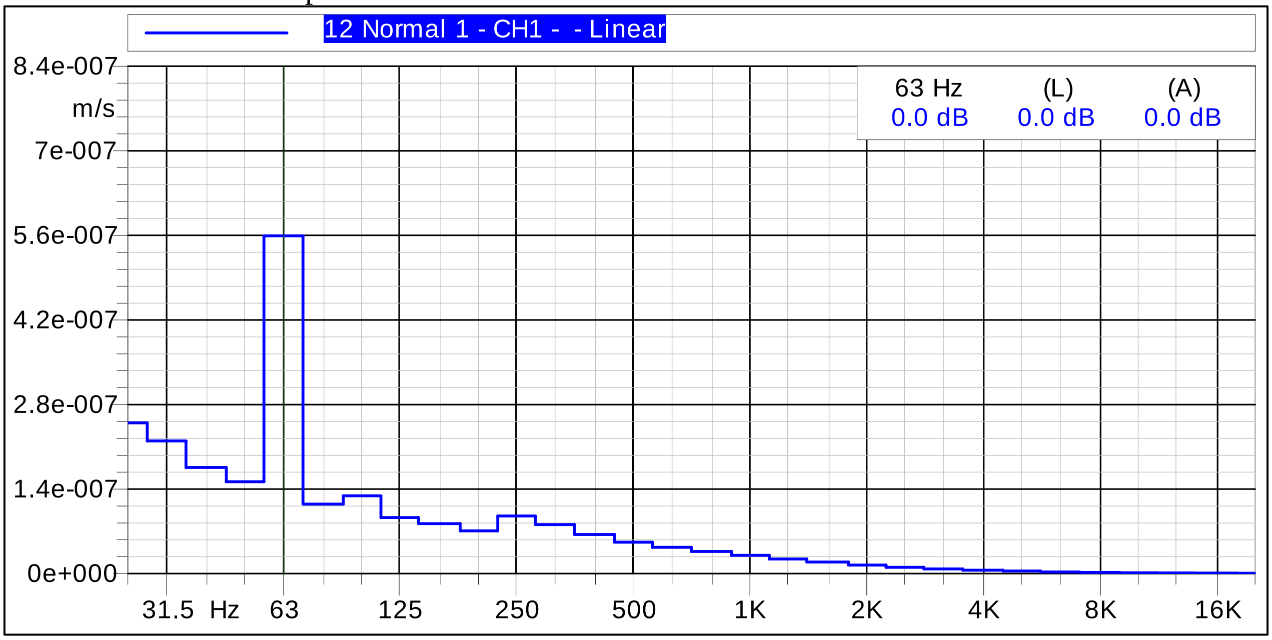
This figure shows that the maximum velocity occurred at 63 Hz. There is one large and one small frequency spike that appear on this graph – the first at the octave band center of 63 Hz, the second at the octave band center of 31.5 Hz.

Figure C-22
Graph of Vibration Velocities Measured 1980-ft West



This figure shows that the maximum velocity occurred at 63Hz. There is one frequency spike that appears on this graph – at the octave band center of 63 Hz.

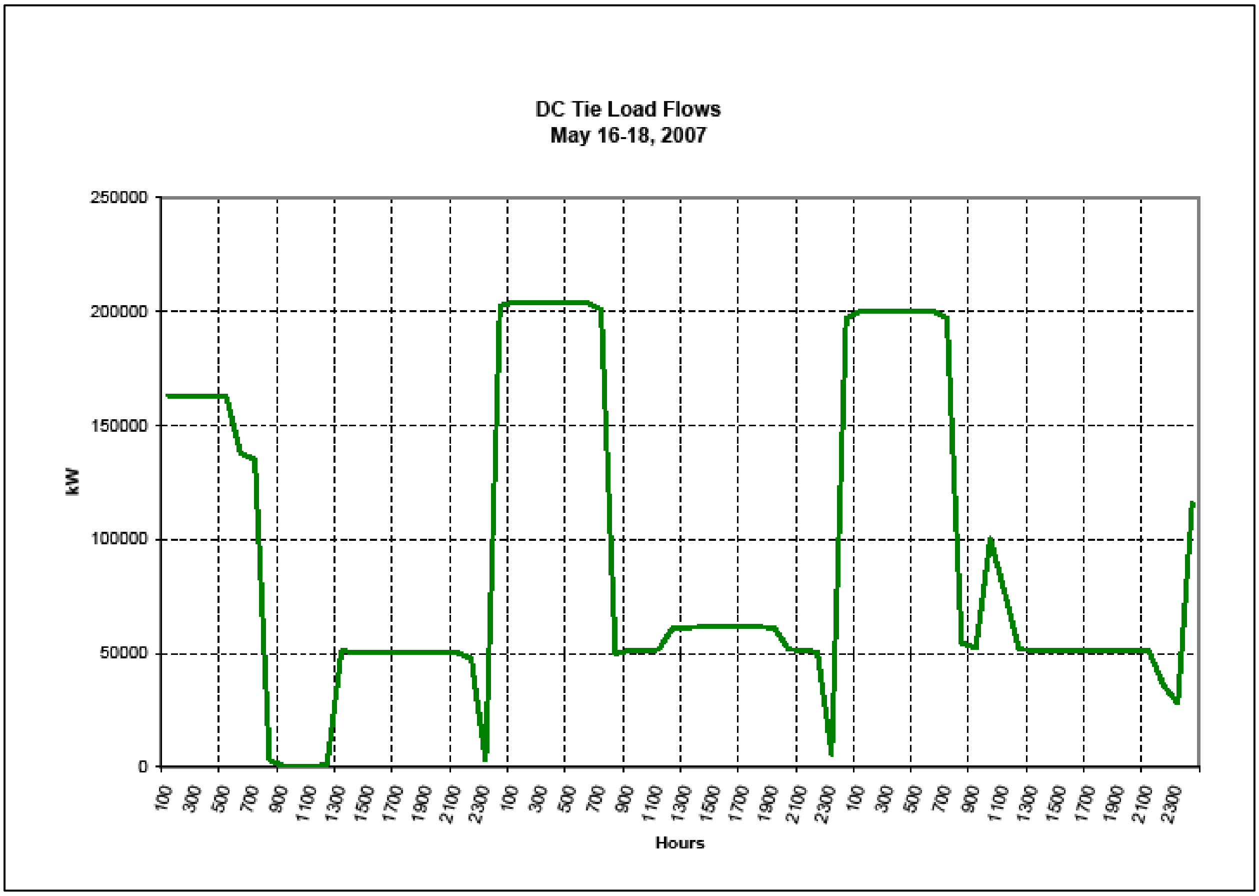
Figure C-23
Graph of Vibration Velocities Measured 2640-ft West



This figure shows that the maximum velocity occurred at 63Hz. There is one frequency spike that appears on this graph – at the octave band center of 63 Hz.

Appendix D
Facility Power Loads during Monitoring Events

Following are the power flows through the Facility during HDR's monitoring events – as provided by Black Hills Power.



Rapid City DC Tie Power Flow		
Friday, July 13, 2007		
Hour Ending	MW	
01:00	92	
02:00	101	
03:00	101	
04:00	101	
05:00	102	
06:00	101	
07:00	102	
08:00	121	
09:00	121	
10:00	120	
11:00	119	
12:00	119	
13:00	72	
14:00	71	
15:00	72	
16:00	71	
17:00	71	
18:00	72	
19:00	121	
20:00	121	
21:00	122	
22:00	122	
23:00	121	
00:00	102	

Power Flow - Rapid City DC Tie Substation				
Saturday, July 14, 5007			Sunday, July 15, 5007	
Hour Ending	MW		Hour Ending	MW
01:00	102		01:00	201
02:00	91		02:00	203
03:00	92		03:00	204
04:00	91		04:00	203
05:00	91		05:00	203
06:00	92		06:00	204
07:00	91		07:00	203
08:00	116		08:00	178
09:00	117		09:00	200
10:00	115		10:00	200
11:00	115		11:00	200
12:00	114		12:00	199
13:00	115		13:00	123
14:00	115		14:00	122
15:00	115		15:00	122
16:00	142		16:00	122
17:00	142		17:00	121
18:00	142		18:00	124
19:00	132		19:00	124
20:00	116		20:00	124
21:00	117		21:00	123
22:00	131		22:00	124
23:00	132		23:00	124
00:00	94		00:00	92