Noise and Ground-Borne Vibration Monitoring

Labrador City, Newfoundland

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PREPARED FOR:

Iron Ore Company of Canada

PREPARED BY:

ATCO Noise Management

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1.0 INTRODUCTION

From July 19 to July 20, 2007 ATCO Noise Management (ATCO) conducted a noise and vibration measurement study at the Iron Ore Company of Canada (IOC) Carol facility located in Labrador City, Newfoundland. Staff from ATCO measured noise and ground-borne vibration in the environment at five (5) locations exterior to the plant, when the facility was in continuous day to day operations. The collected data has been documented, analyzed and evaluated in this report. A discussion of methods to reduce the noise and vibration outside the facilities to the levels required by the Rio Tinto Environment Standard is outside the scope of this document. The information presented will be beneficial for monitoring noise and vibration levels and defining design goal requirements for future mitigation of any noise and/or vibration problems or complaint situations that may arise.

Appendix A includes definitions of the acoustic abbreviations used in this study.

1.1 Study Objectives

The key objective of this study is to establish, through methods of acoustical measurement and analysis, the levels of noise and vibration present in the vicinity of the IOC Carol facility and in Labrador City. This is accomplished by undertaking noise level and vibration acceleration level measurements at five (5) specified locations when the plant is in continuous day to day operations.

The data is then analyzed in order to produce a written report outlining the existing acoustic environment. This information gives IOC a record of noise and vibration information that is useful in evaluating the need to design remedial measures necessary to control a future exceedance of noise and vibration to meet environmental standards.

Specific dynamic behavior and machinery vibration analysis due to the individual operational components is outside the scope of this study.

2.0 MEASUREMENT PROCEDURES

2.1 Measurement Locations

Five measurement locations were selected for noise and vibration measurements. These locations were based chosen based on previous monitoring conducted at this site in 2004. Two of these locations are situated on the IOC property boundary, and three locations are residential and community receptor locations in Labrador City. Figure 1 shows each of the monitoring locations on an aerial view of Labrador City and the IOC facility.

Table 1 below contains the coordinates and acoustic environment description for each measurement location.

Table 1: Measurement Locations and Descriptions

Location	Description	Coordinates	Acoustic Environment (observed)
1	IOC Main Gate	N 52.95029 W 66.89981	Sound from IOC, vehicle traffic through IOC gate, hwy and local traffic
2	Intersection, Fermont Hwy & Smokey Mtn. Rd.	N 52.95214 W 66.91620	Hwy and Local Traffic, Sound from IOC in distance, natural sounds
3	IOC Contractor Gate	N 52.94901 W 66.89726	Sound from IOC, vehicle traffic through IOC gate, hwy and local traffic
4	Front Entrance, AP Lowe Elementary School	N 52.93854 W 66.91354	Local Traffic, Residential Activity, Mine and Trains are audible
5	Behind N&N Convenience Store, Tamarack Dr.	N 52.93614 W 66.92697	Local traffic and residential activity, ATV traffic, Carol mine and trains audible, Wabush mine activity is audible

The IOC facility was usually audible at each location when no nearby sources of sound were present. Observation indicates that it is the dominant source of background sound in this area, however some contribution from highway traffic and the Wabush mine facility is present as well.

2.2 Instrumentation and Setup

Sound level measurements were made using Bruel & Kjaer type 2250 sound level meters equipped with type 4189 microphones. These instruments comply with ANSI S1.4-1983, S1.4A-1985, and S1.43-1997, Type 1 specifications and have current laboratory certification. The instruments were equipped with windscreens and were field calibrated before and after measurements using a type 4231 calibrator which conforms to ANSI S1.40-1984 and also has current laboratory certification.

Vibration measurements were made with a Bruel & Kjaer type 2260 hand held analyzer equipped with an Endevco general purpose accelerometer. This analyzer is a precision instrument which has current laboratory calibration certification. The analyzer was field calibrated before and after each set of measurements using a Bruel & Kjaer type 4294 calibrator with current laboratory certification.

2.3 Weather Conditions

Wind, temperature, relative humidity and ground conditions can have a large effect on the propagation and measurement of sound. Weather conditions were variable during the monitoring period, with brief thunder showers occurring in the evening. For the majority of the survey period, wind speed, temperature and relative humidity were within limits recommended by ANSI standards. Appendix B shows the local temperature and humidity levels during the measurement period. Portions of the period during which weather conditions were unsuitable for measurement of environmental sound are excluded from analysis.

3.0 FACILITY OPERATIONS

Noise and vibration measurements were conducted at the five environmental monitoring locations with the facility in normal day to day operations. Although measurement during shut down conditions was also scheduled, unfavorable weather and scheduling issues prevented a sufficient sample period for background noise and vibration measurements. Since background ambient noise levels tend to increase over time, recent measurements should be used to document any changes in the overall acoustic environment. ATCO recommends that a study of background noise and vibration levels be conducted at the next available opportunity.

4.0 NOISE AND VIBRATION ASSESSMENT GUIDELINES

4.1 Rio Tinto Environmental Standards

For IOC facility operations, noise is governed by the "Rio Tinto Environment Standard – Environmental Management System". The intent of this Noise and Vibration guideline is to ensure that noise and vibration impact on the surrounding environment and communities is not adverse. The following citations are from "Section 1.0 – Planning":

1. *Develop, document and maintain knowledge of the baseline, and for existing operations, background noise and vibration levels.*
2. *Employ change management procedures and predictive modeling of near and far field noise and vibration levels as part of the pre-feasibility and feasibility study for:*

- *New developments;*
- *Significant expansions;*
- *Changes to existing activities and facilities.*

The first step of the planning program is to determine the baseline noise and vibration levels in the surrounding environment and community locations. This baseline data is required to assess the noise and vibration impact from the facility operations. "Minimizing the noise and vibration impact on the environment" is a qualitative measure. In the following sections, quantitative approaches are used to compare the measured sound and vibration level to applicable standards.

4.2 General Standards Related to Noise and Vibration Impact Assessment

Humans hear audible sound in the frequency range of approximately 20Hz to 20,000Hz. This the audible range of human hearing. Sounds produced in frequencies lower than 20Hz are called infra-sound. In general, the lower the frequency, the higher the amplitude or magnitude of energy required to generate sound pressure waves. Sound at frequencies higher than 20,000Hz is called ultrasound and carries a relatively smaller amount of energy. These types of sounds are attenuated easily and are not commonly an environmental noise issue. Air-borne vibrations are measured as pressure ratios (i.e., dB). Ground-borne (solid-borne) vibrations are measured as forces and expressed as acceleration, velocity or displacement.

Human hearing does not respond to all frequencies in the audible range in the same way. Our ears are less sensitive to lower and higher ranges compared to those frequencies in the middle of the audible range, particularly those between 31.5Hz and 8000Hz. For the purpose of this investigation, two concepts are being introduced that are commonly used to quantify human annoyance due to noise and human perception to vibration. These concepts are described in the following sections of this report.

In general, community noise criteria are commonly expressed in terms of L_{eq} (see definitions in Appendix A) and statistical exceedance levels L_n. We included these terms in our measurement report in addition to including noise levels in Octave and One-Third Octave bands to describe the spectral energy density of the sound.

Ground-borne vibration criteria is expressed in terms of acceleration, a vector quantity that specifies rate of change of velocity; the acceleration levels are presented in units of m/s^2 and related to human tolerance to vibration in the frequency range of approximately 1 Hz to 80 Hz.

The following is a summary of the current most widely used guidelines for the control of low- frequency noise (LFN) and noise annoyance.

ANSI S12.2 Criteria for Sound Induced Vibration in Lightweight Structures

ANSI S12.2 recommends the use of criteria for vibration in lightweight structures in the LFN octave band center frequency for 16, 31.5, 63Hz bands. The noise criteria curves (NC and NCB Curves) in the Octave Bands (Beranek); and the indoor room criteria curves (RC) in the Octave Bands recommended by ASHRAE 1995; and ANSI 12.2 restrict LFN to “moderately noticeable” on Region B and LFN should not exceed the “clearly noticeable” on Region A.

Human Perception to Ground-Borne (Structure-Borne) Vibration

ANSI 3.18 has been established to estimate human perception and tolerance to vibration levels in the environment. Human perception of vibration occurs when an individual physically senses the vibration or the individual hears noise generated by vibrating building components. Tolerance is dependant on the requirements of the occupied space. In residential spaces, the perceptible threshold is usually described as the limit for vibration. This study investigates the perception of ground borne vibration as well as vibration induced in lightweight structures by low frequency noise.

4.3 Representative Regulatory Noise Criteria

Although IOC is not obligated to comply with the regulatory criteria presented in this section, these standards are representative example of the criteria used to assess airborne environmental noise levels in Canadian communities.

4.3.1 Ministry of the Environment of Ontario NPC-205, NPC-232

The Ministry of the Environment for the Province of Ontario has a comprehensive set of noise standards. The criteria are defined in the MOE publication NPC-205 "Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban)" and NPC-232 "Sound Level Limits for Stationary Sources in Class 3 Areas (Rural)". The recommended limits are based on the one-hour L_{eq} sound level in dBA and vary by time of day. For each daytime period, the limit is based on the higher of two levels: ambient sound level obtained from an acoustical environment in the absence of a stationary noise source, and an L_{eq} value given by the MOE. Any tonal, transient, impulsive and unwanted qualities for a stationary source are penalized by 5dB in accordance with NPC-104 "Sound Level Adjustments".

Table 2: Minimum Values of One Hour L_{eq} or L_{LM} by Time of Day

	One Hour L_{eq} (dBA) or L_{LM} (dBAI)		
Time of Day	**Class 1 Area**	**Class 2 Area**	**Class 3 Area**
0700 - 1900	50	50	45
1900 - 2300	47	45	40
2300 - 0700	45	45	40

Class 1 areas are defined as "an area with an acoustical environment typical of a major population centre, where the background noise is dominated by the urban hum."

Class 2 areas are defined as "an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 areas, and in which a low ambient sound level, normally occurring only between 23:00 and 07:00 hours in Class 1 areas, will typically be realized as early as 19:00 hours."

Class 3 areas are defined as "a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic."

4.3.2 Ministry of Environment of Quebec Directive 98-01

Since February 1998, the Ministry of Environment (MENV) of Quebec uses the Directive 98-01 to define the requirements for regulated plants that produce noise. There are two approaches used under these regulations.

The first one is related to the maximum level allowed based on the zoning category.

Zoning Category	Night (dBA)	Day (dBA)
1	40	45
2	45	50
3	50	55
4	70	70

Zoning 1: Residential housing (single or double), schools and hospitals. Dwellings in an agriculturally zoned area.
Zoning 2: Residential houses (multiple unit), mobile homes, campgrounds.
Zoning 3: Commercially zoned areas, parks.
Zoning 4: Industrial or agriculturally zoned areas. If there is an existing dwelling in an industrial zone, established by municipal by-law in force at the moment of its construction, criteria are 50 dBA during the night and 55 dBA during the day.

The second approach is based on the Leq_{1h}. If the ambient Leq is higher than the criteria for the zoning category, the noise source can produce a noise level lower than or equal to the existing ambient noise level Leq_{1h}.

5.0 RESULTS

5.1 Sound Level Measurements During Minesite Operation

Sound levels measured at each of the 5 receptor locations are shown in Table 3 below. The $L_{eq\ 1min}$ history of the sound monitoring survey is shown graphically in Figures 2-6. Samples of the highest and lowest daytime and nighttime background sound levels, measured at each location are shown in Figures 7-16. The sample measurements are shown graphically in Octave Bands with ANSI 12.2 criteria in Figures 27-36.

Table 3: Hourly Leq (dBA) Sound Levels Measured at Labrador City Noise and Vibration Monitoring Locations

Time	Location (See Figure 1 and Table 1)				
	1	2	3	4	5
11:00 AM	54	64		59	47
12:00 PM	53	63	58	58	49
1:00 PM	55	63	57	57	42
2:00 PM	57	64	61	60	45
3:00 PM	59	64	62	61	64
4:00 PM	56	63	58	60	45
5:00 PM	56	63	57	59	45
6:00 PM	59	64	59	59	44
7:00 PM	55	63	56	60	48
8:00 PM	54	61	53	60	47
9:00 PM	56	58	53	58	45
10:00 PM	57	56	55	56	44
11:00 PM	57	54	59	53	43
12:00 AM	56	51	54	65	47
1:00 AM	53	54	51	51	50
2:00 AM	50	47	49	48	51
3:00 AM	54	49	52	48	42
4:00 AM	57	57	54	51	41
5:00 AM	54	62	56	57	48
6:00 AM	59	64	67	59	48
7:00 AM	53	63	58	57	51
8:00 AM	53	62	56	55	49
9:00 AM	51	62	59	58	52
10:00 AM				57	48

5.2 Ground-borne Vibration Level Measurements

Vibration acceleration level measurements were taken at the 5 monitoring locations to determine the baseline levels during day-time and nighttime periods. Acceleration measurements at the three offsite locations during day-time and nighttime periods are shown graphically in Figures 17-26. Measurements were taken in acceleration (m/s^2) with an FFT analyzer and levels are shown from 2.9 – 80 Hz for comparison with ANSI 3.18-1979 criteria. No continuous perceptible vibration was observed at any of the five locations. Occasional perceptible events caused by vehicle traffic nearby were the only ground-borne vibration observed at these sites. At location 1, a notable increase in ground-borne vibration is shown at approximately 60 Hz; however the levels measured remain below the perceptible threshold.

6.0 ASSESMENT

6.1 Comparison with Previous Measurements

Comparison of recently measured sound levels with levels measured in previous surveys is a good way to identify significant changes in noise and vibration emission from IOC, however minor changes may not be readily identifiable due to variations in environmental factors affecting noise and vibration transmission. If a noise or vibration level caused by IOC operation is found to be undesirably high then care must be taken to monitor the phenomenon under representative conditions to ensure a valid comparison and assessment in future studies. Equivalent continuous L_{eq} 1_{hr} sound levels measured in 2004 are shown compared with measurements taken in July 2007 in Table 4 below.

Table 4: Comparison of Measured L_{eq} 1_{hr} sound levels, dBA

	Location				
Daytime	**1**	**2**	**3**	**4**	**5**
2004	58	47	75	60	45
2007	53-59	62-64	53-62	55-61	42-64
Nighttime					
2004	43	44	47	53	40
2007	50-59	47-64	49-67	48-65	41-51

*The 2007 measurements cover a larger duration than the 2004 survey, the range of sound levels over the entire dataset is shown in Table 4, compared with spot measurements taken in 2004.

Acceleration measurements (see Figures 17-26) show that ground-borne vibration is predominantly below perceptible levels at all locations. Observations indicate that the only measured vibration events above the perceptible threshold outlined in ANSI S3.18 are caused by nearby vehicle traffic. This result is consistent with findings from 2004 measurements.

6.2 Acceptability of IOC Noise Emissions With Respect to Relevant Standards

6.1.1 Rio Tinto Environmental Standards

"Rio Tinto Environment Standard – Environmental Management System" advocates documenting and maintaining a knowledge base of background noise and vibration measurements. This study serves to accomplish this objective. The sound and vibration levels documented here can be used in planning activities for facility expansion or modification of existing equipment to accommodate regulatory requirements and community expectations.

6.1.2 ANSI S12.2 Criteria for Vibration in Lightweight Structures

The ANSI 12.2 criteria for noise induced vibration in buildings is shown in Figures 27-31 compared to the highest and lowest hourly equivalent continuous sound levels, measured during plant operation. These figures show that at locations 1, 3, and 4 sound levels can occasionally enter region B where low frequency noise may induce vibration in lightweight structures. This phenomenon occurs consistently at locations 1 and 3 which are the IOC site gates. At location 4, the measured sound levels reach region B sporadically due to intermittent sources of sound extraneous to IOC operations.

6.1.3 Ministry of the Environment of Ontario NPC-205, NPC-232

Noise monitoring locations 2, 4, and 5 can be compared to the limits specified by the Ontario MOE noise criteria. These locations are class 2 areas according to the definitions provided and would be obligated to meet $L_{eq\ 1hr}$ 50 dBA daytime and 45 dBA nighttime.

At location 2, the $L_{eq\ 1hr}$ sound level is typically above the limits described above. At this location, the L_{eq} sound level is strongly influenced by traffic noise on Fermont Hwy. The L_{90} sound level (shown in Figure 3) is representative of the sound level without influence from intermittent sounds from passing vehicles. The L_{90} sound level is usually within the allowable limits, indicating that the background sound level during IOC operations meets the MOE noise criteria for stationary noise sources.

At location 4, the $L_{eq\ 1hr}$ sound level is typically above the limits described above. At this location, the L_{eq} sound level is strongly influenced by local traffic and activity. The L_{90} sound level (shown in Figure 5) is representative of the sound level without influence from intermittent sounds from passing vehicles. The L_{90} sound level is usually at the allowable limits, indicating that the background sound level during IOC operations meets the MOE noise criteria for stationary noise sources.

At location 5, the $L_{eq\ 1hr}$ sound level is within the limits described above. At this location, the L_{eq} sound level is occasionally influenced by local traffic and activity and exceeds the allowable limits; however these periods are not sustained and are not representative of normal background noise during IOC operations.

6.1.4 Ministry of the Environment of Ontario NPC-205, NPC-232

In this section measured $L_{eq\ 1hr}$ sound levels are compared with the permissible levels included in Directive 98-01. Where measured $L_{eq\ 1hr}$ sound levels exceed the permissible levels in Directive 98-01, statistical exceedance levels L_{10} and L_{90}, shown in Figures 2-6, are used determine if the measurement is representative of continuous background sound including IOC operations or of intermittent sounds such as traffic or activity near the monitoring location.

At location 1, which is a commercial / industrial land use the $L_{eq\ 1hr}$ sound level is 53-59 dBA during the daytime and 50-59 dBA during the nighttime. Zoning Category 4 is applicable which specifies 70 dBA daytime and 70 dBA nighttime, indicating that this location is within the allowable limits specified above during IOC operations.

At location 2, which is near recreational and commercial land uses, the $L_{eq\ 1hr}$ sound level is 62-64 dBA during the daytime and 47-64 dBA during the nighttime. Zoning Category 3 is applicable which specifies 55 dBA daytime and 50 dBA nighttime. Excluding the strong influence from intermittent traffic on Fermont Hwy., the L_{90} sound level, shown in Figure 3, indicates that the background sound level is within the limits specified above during IOC operations.

At location 3, which is a commercial / industrial land use the $L_{eq\ 1hr}$ sound level is 53-62 dBA during the daytime and 49-67 dBA during the nighttime. Zoning Category 4 is applicable which specifies 70 dBA daytime and 70 dBA nighttime, indicating that this location is within the allowable limits specified above during IOC operations.

At location 4, which is a school the $L_{eq\ 1hr}$ sound level is 55-61 dBA during the daytime and 48-65 dBA during the nighttime. Zoning Category 1 is applicable which specifies 45 dBA daytime and 40 dBA nighttime. Analysis of the sound levels in Figure 5, shows that the L_{eq} sound level is strongly influenced by intermittent sounds such as traffic and that the continuous background nighttime sound level is approximately 44 dBA. This is above the specified limit for this land use and may be partially due to IOC operations.

At location 5, which is near residential land use the $L_{eq\ 1hr}$ sound level is 42-64 dBA during the daytime and 41-51 dBA during the nighttime. Zoning Category 2 is applicable which specifies 50 dBA daytime and 45 dBA nighttime. The Leq 1hr sound levels and data from Figure 6 shows that the background sound level is within the specified limits during IOC operations at this location.

7.0 CONCLUSIONS

Assessment of noise and acceleration measurements using relevant standards, example noise regulations, and comparison with previous data shows that the sound levels present during IOC operations are consistent with previous findings and are within generally acceptable levels. Stationary noise sources at the IOC facility are audible at the monitoring locations in Labrador City during their operation, as well as trains. The acoustic environment in Labrador City is often dominated by local traffic and sound from other activity near residential receptors; however IOC operations are clearly audible in the background. No evidence of continuous perceptible ground-borne vibration or low-frequency noise induced vibration was found at any of the receptor locations.

8.0 DISCLAIMERS

Our "Sound Monitoring Survey" is based on the locations supplied by IOC and on the present site conditions and parameters listed in this report only. We cannot and do not warrant any different parameters and conditions that may exist but which were not represented in this study.

Third Party:

This "Sound Monitoring Survey", which is reported in the preceding pages, has been prepared in response to a specific request for service from the Client to whom it is addressed. The information contained in this "Sound Monitoring Survey" is not intended for the use of, nor is it intended to be relied upon, by any person, firm, or corporation other than the Client to whom it is addressed. We deny any liability whatsoever to other parties who may obtain access to the information contained in this "Sound Monitoring Survey" for any damages or injury suffered by such third parties arising from the use of this "Sound Monitoring Survey" by them without the express prior written permission from ATCO and its Client who has commissioned this "Sound Monitoring Survey".

ATCO Noise Management Ltd.

Prepared by:
Chris Giesbrecht, B.Sc.,
Acoustic Engineer E.I.T.

Reviewed by:
Ashley Gibson, P.Eng. AMIOA
Supervisor, Acoustical Engineering

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ANSI S12.8-1987, Methods for Determination of Insertion Loss of Outdoor Noise Barrier;

ANSI S12.23-1989, Method for the Designation of Sound Power Emitted by Machinery and Equipment;

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EPA Report No.55019-74-004, 1974, Information on Levels of Environment Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety, U.S.Environmental Protection Agency, Washington, D.C., pg D-17;

The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) Room Criterion, 1999.

NASA Guideline TM-83288 The National Aeronautical Space Association criterion for Perceptibility of Vibration in housing Structural Elements and Hearing Threshold.

FIGURES

Figure 1: Aerial view of Labrador City showing noise and vibration monitoring locations

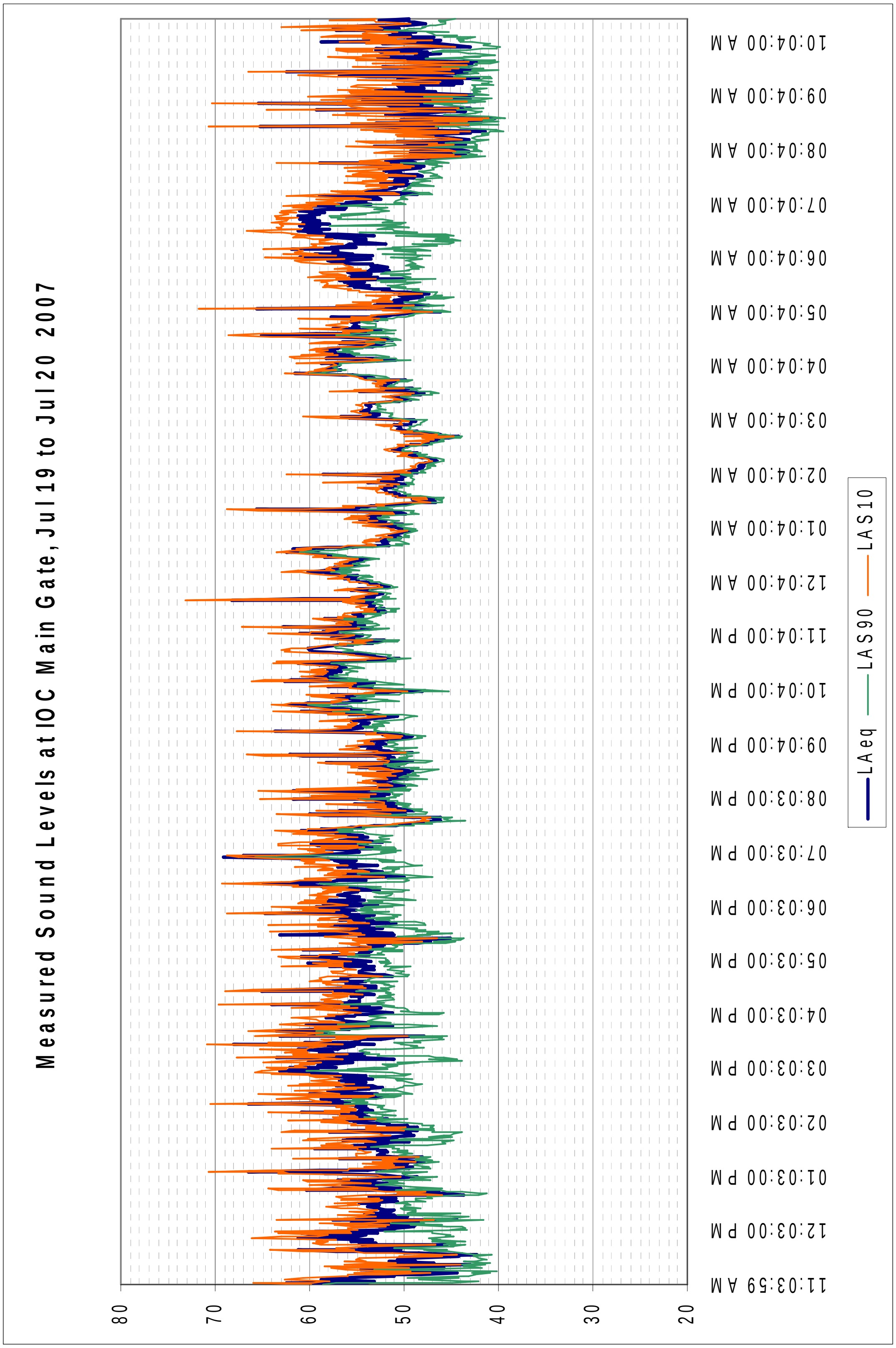

Figure 2: Logged Sound Level Measurement at Location 1

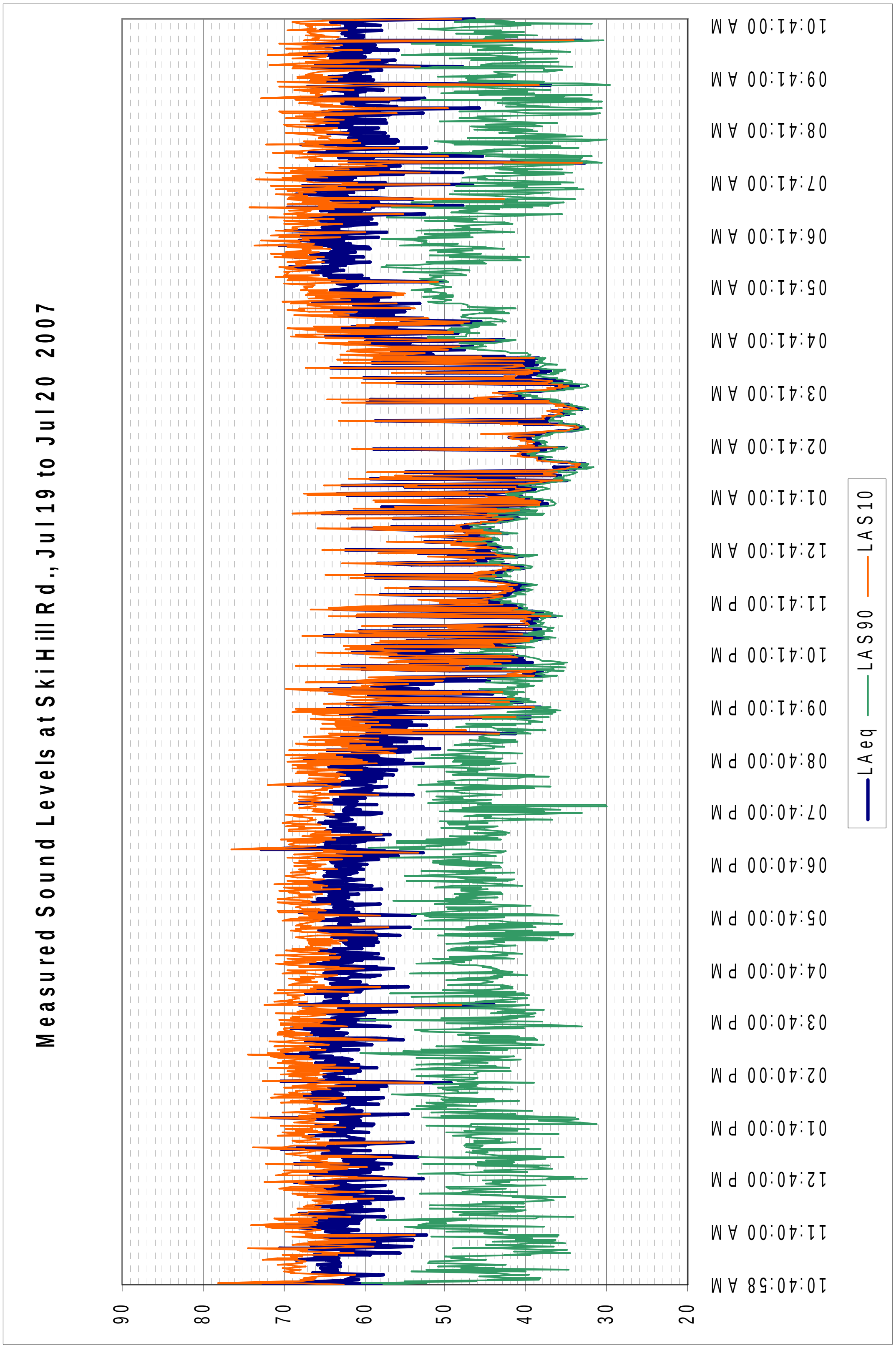

Figure 3: Logged Sound Level Measurement at Location 2

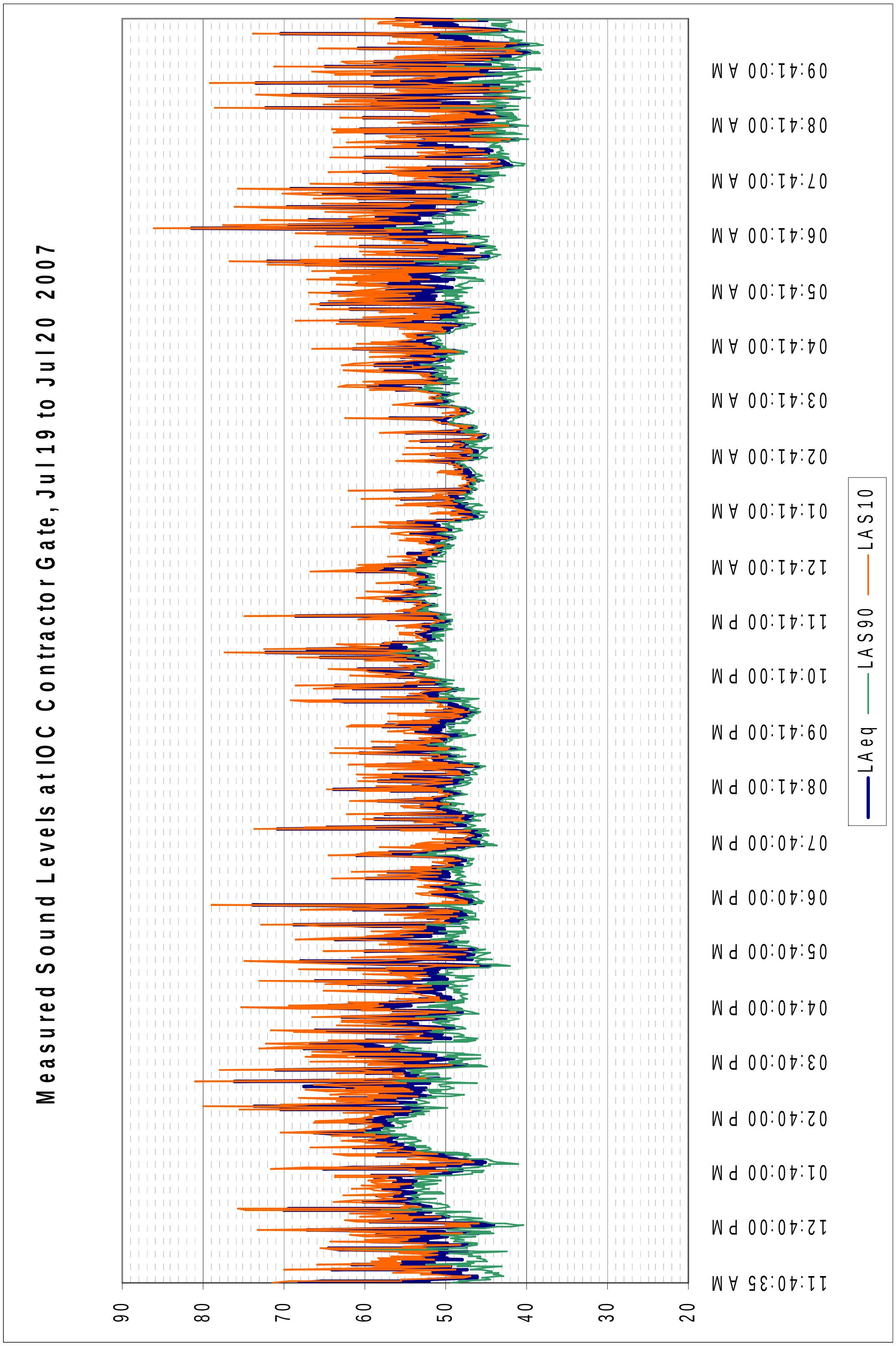

Figure 4: Logged Sound Level Measurement at Location 3

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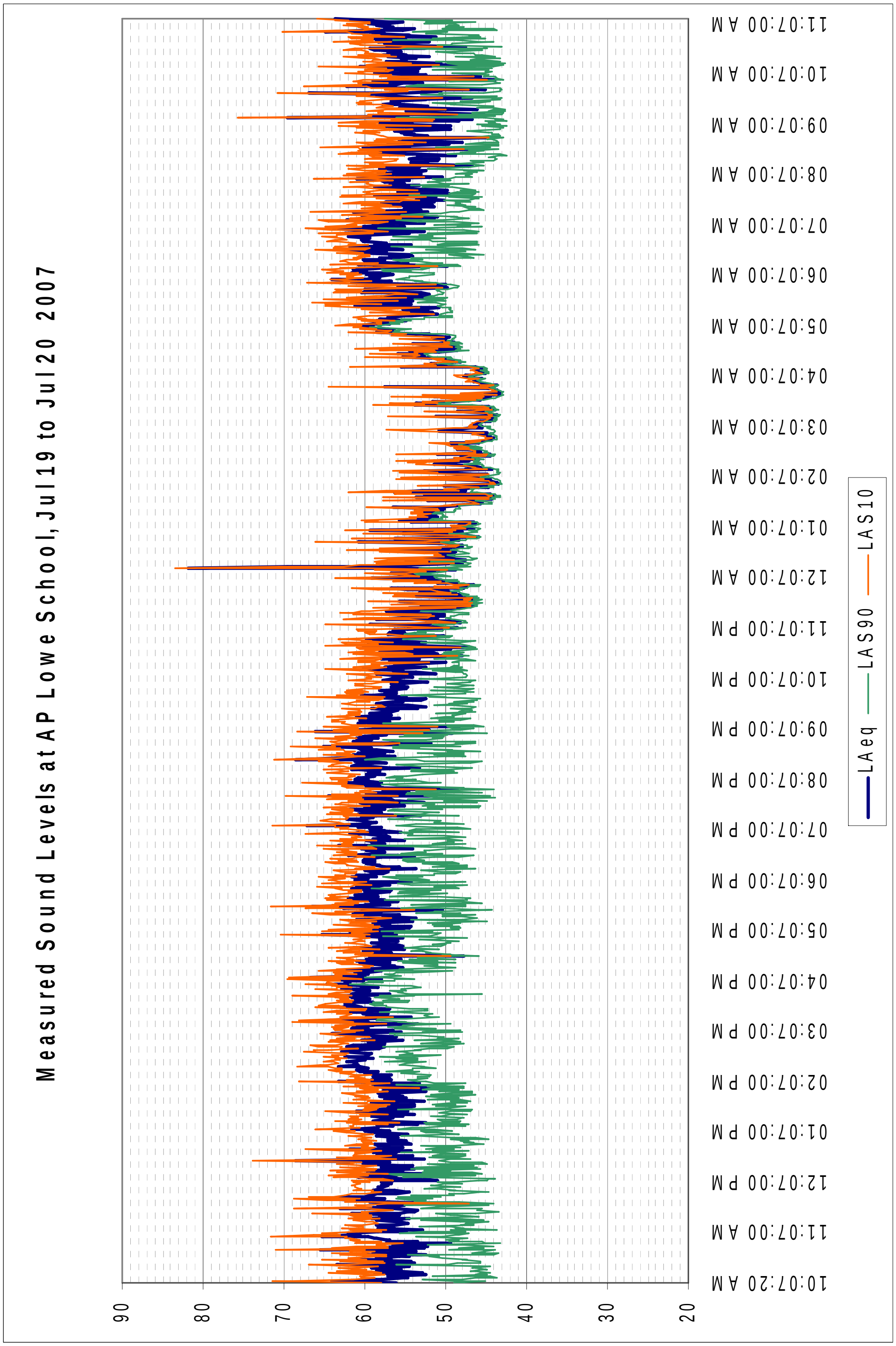


Figure 5: Logged Sound Level Measurement at Location 4

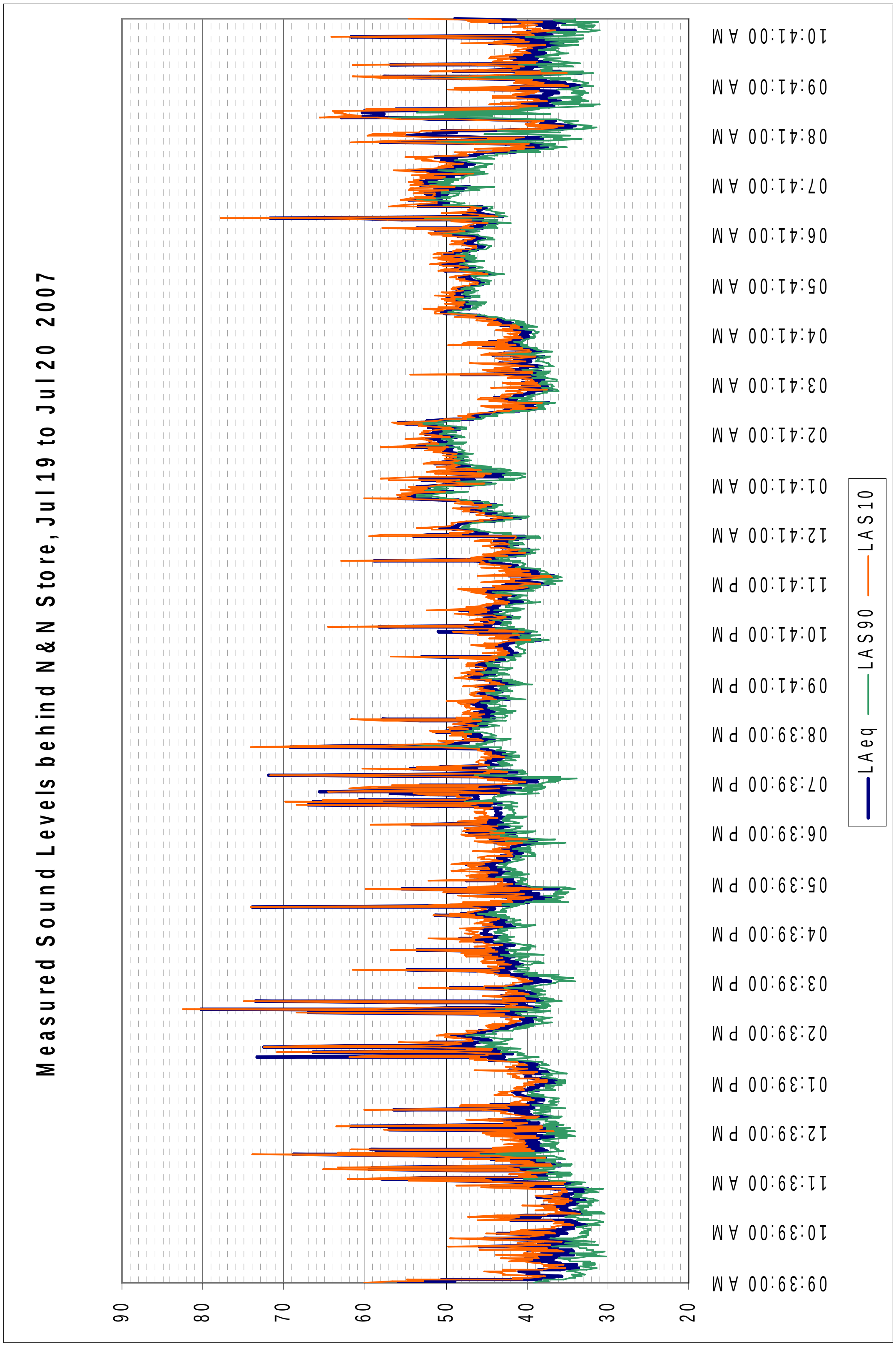


Figure 6: Logged Sound Level Measurement at Location 5

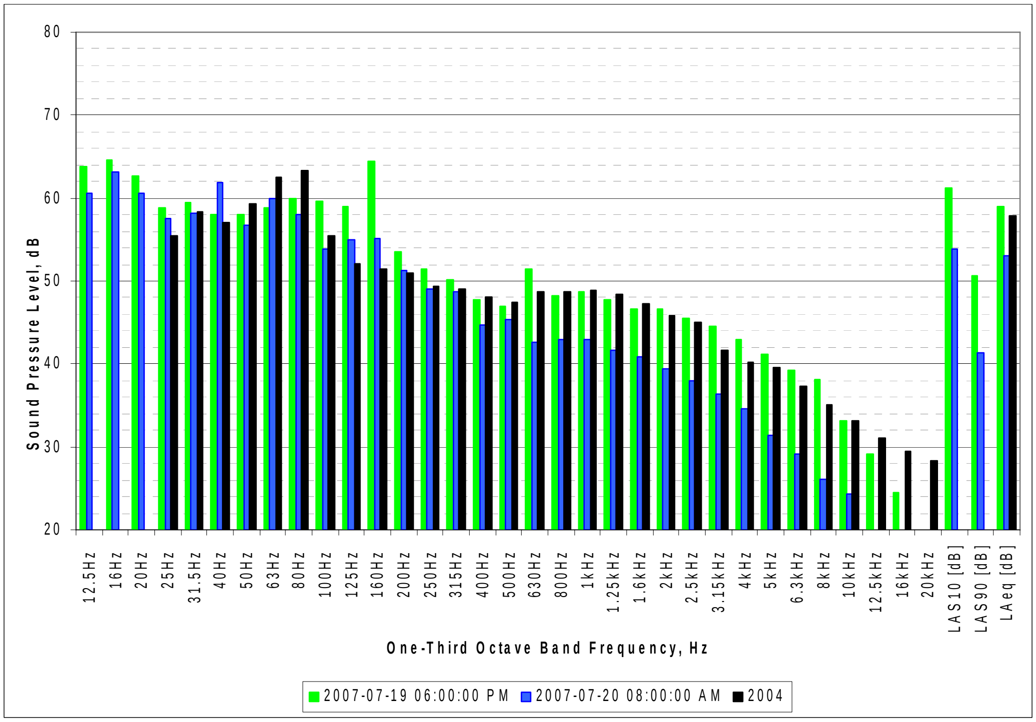


Figure 7: Highest and Lowest Daytime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 1 (IOC Main Gate)

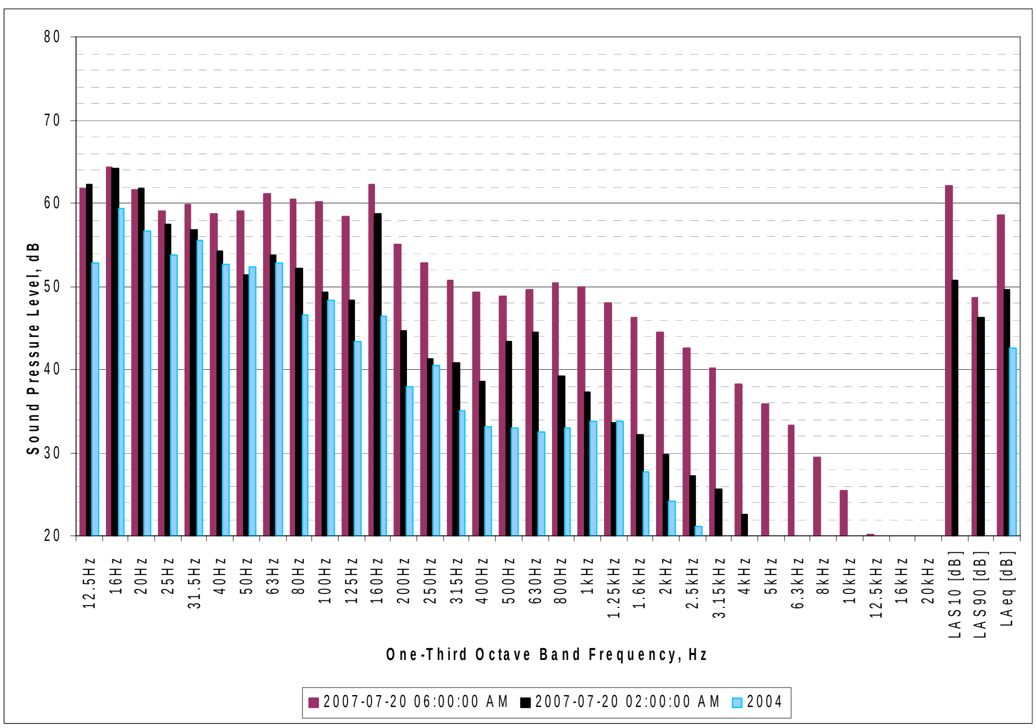


Figure 8: Highest and Lowest Nighttime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 1 (IOC Main Gate)

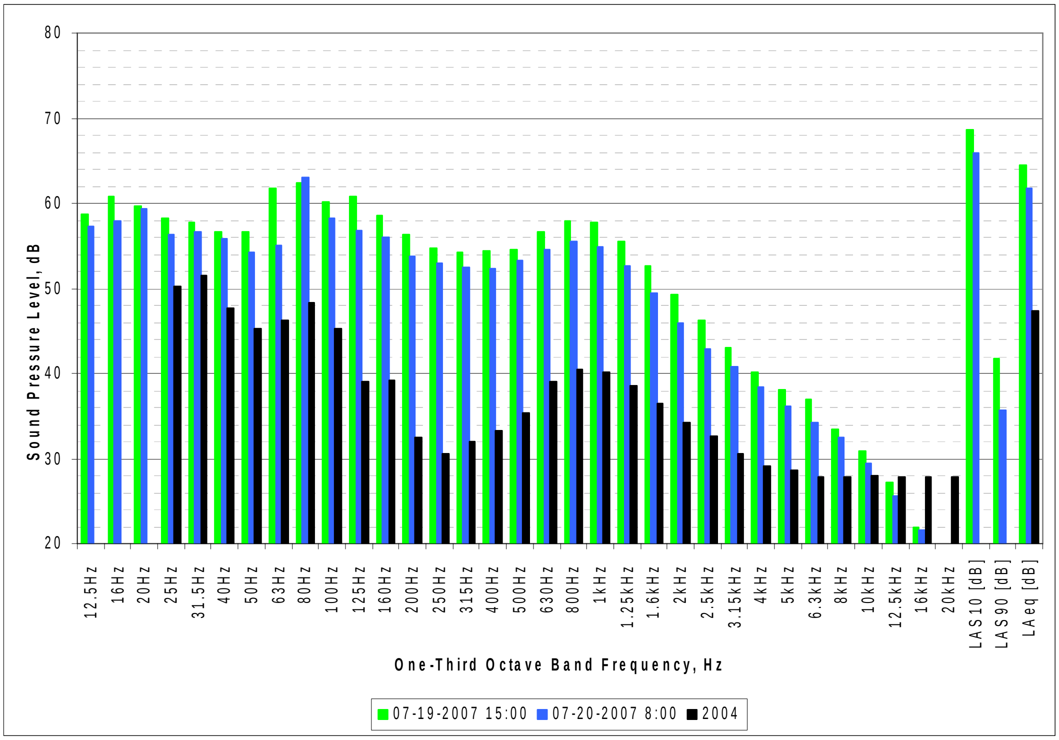


Figure 9: Highest and Lowest Daytime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 2 (Ski Hill Rd. & Fermont Hwy)

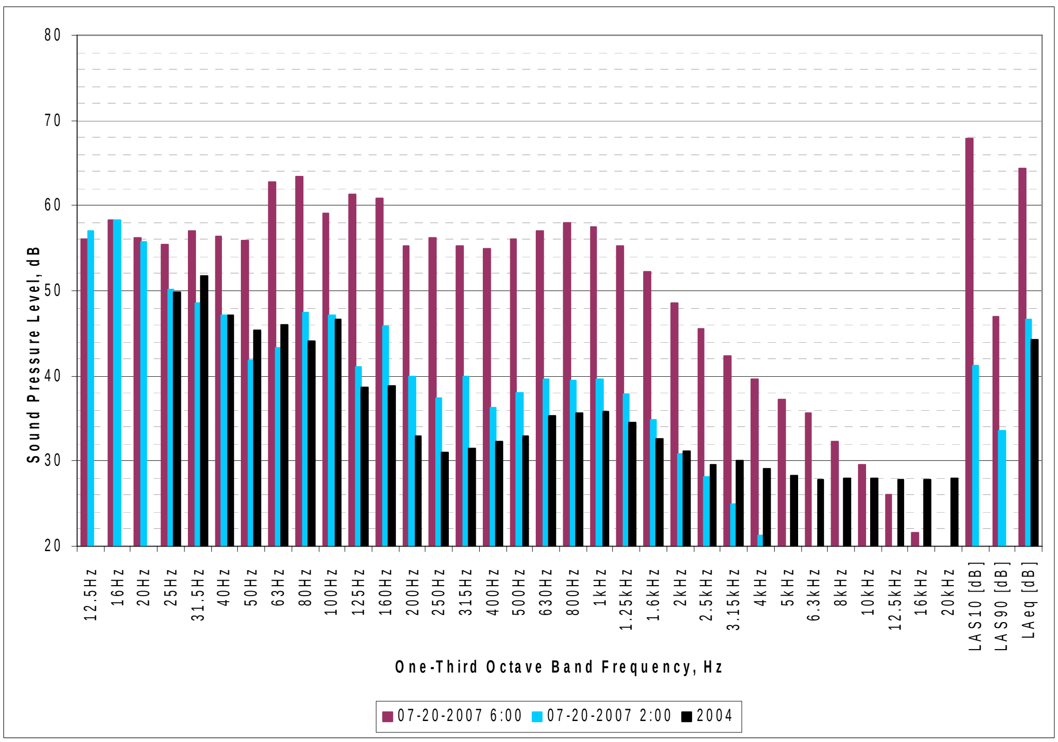


Figure 10: Highest and Lowest Nighttime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 2 (Ski Hill Rd. & Fermont Hwy)

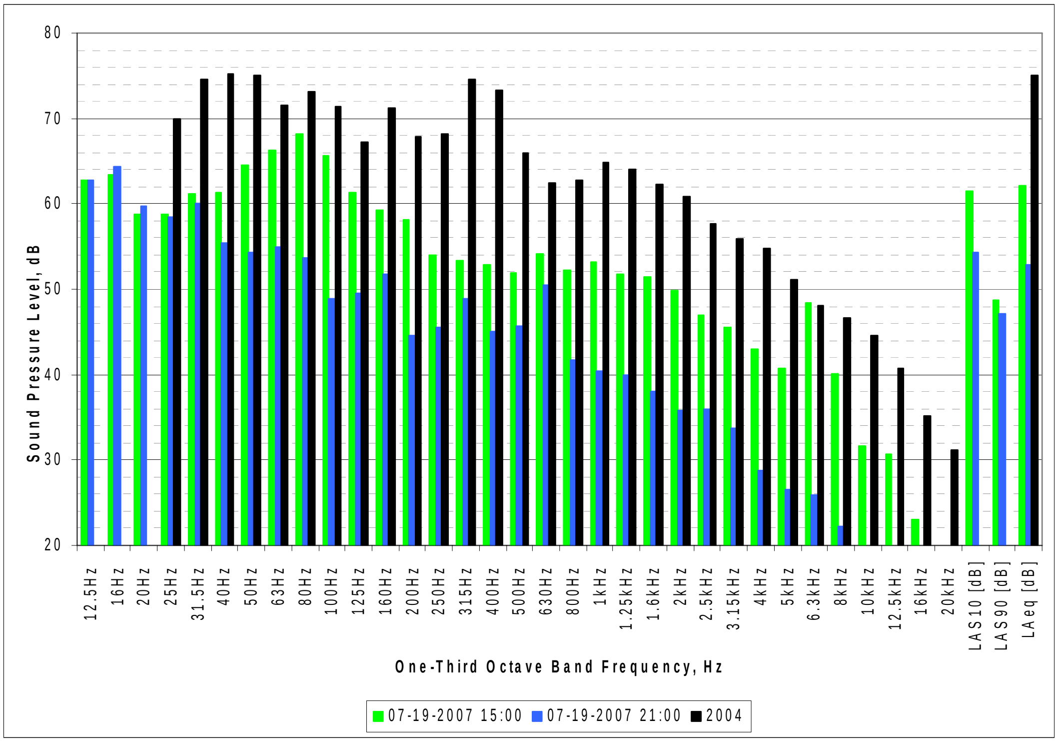


Figure 11: Highest and Lowest Daytime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 3 (IOC Contractor Gate)

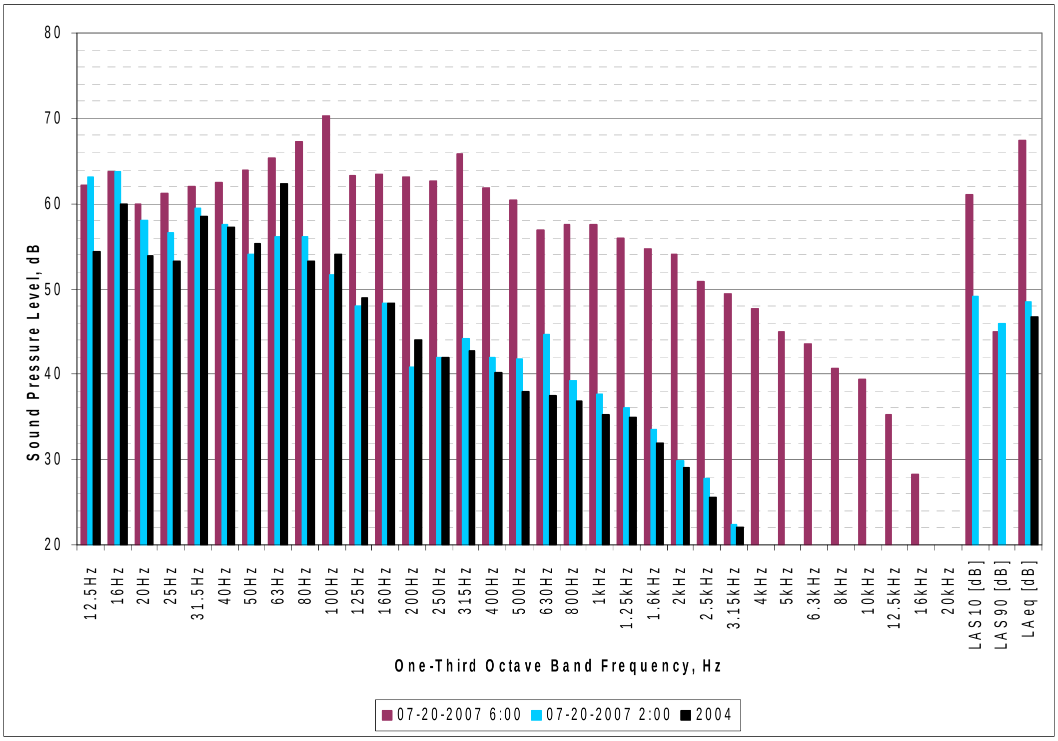


Figure 12: Highest and Lowest Nighttime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 3 (IOC Contractor Gate)

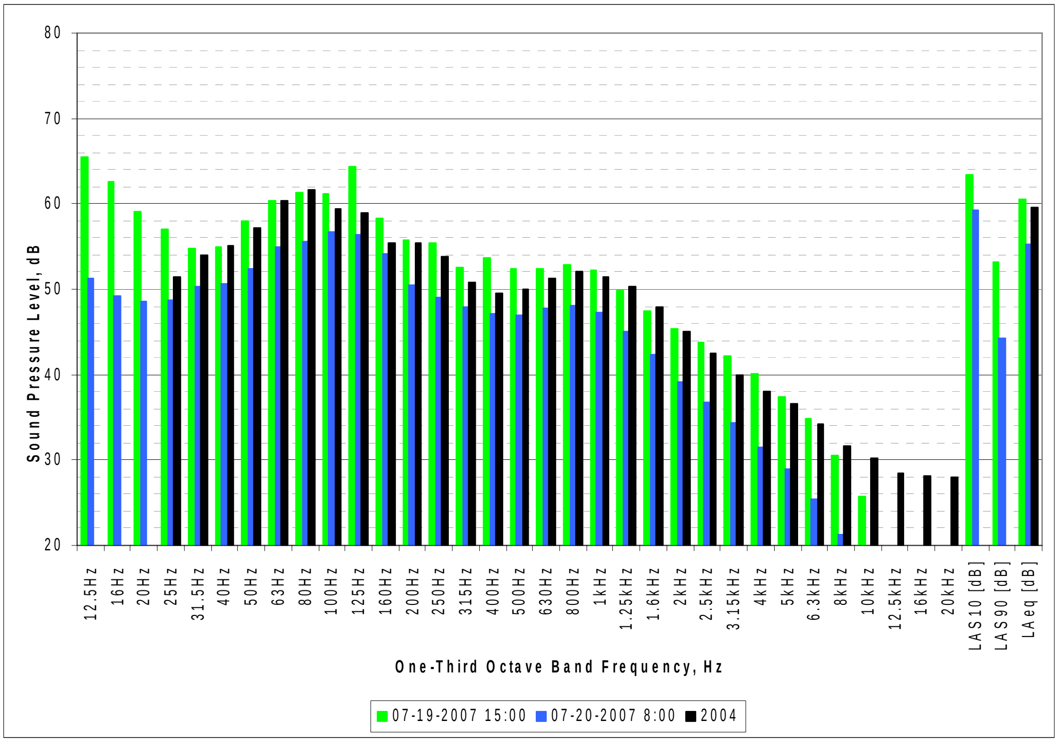


Figure 13: Highest and Lowest Daytime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 4 (A.P. Lowe School)

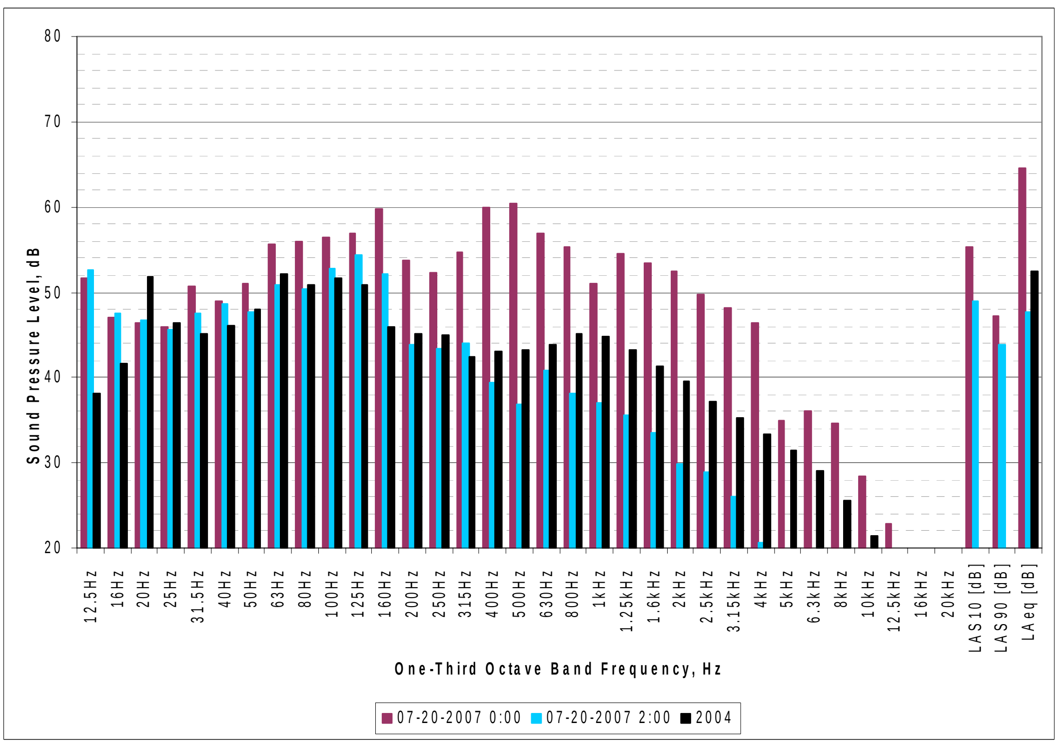


Figure 14: Highest and Lowest Nighttime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 4 (A.P. Lowe School)

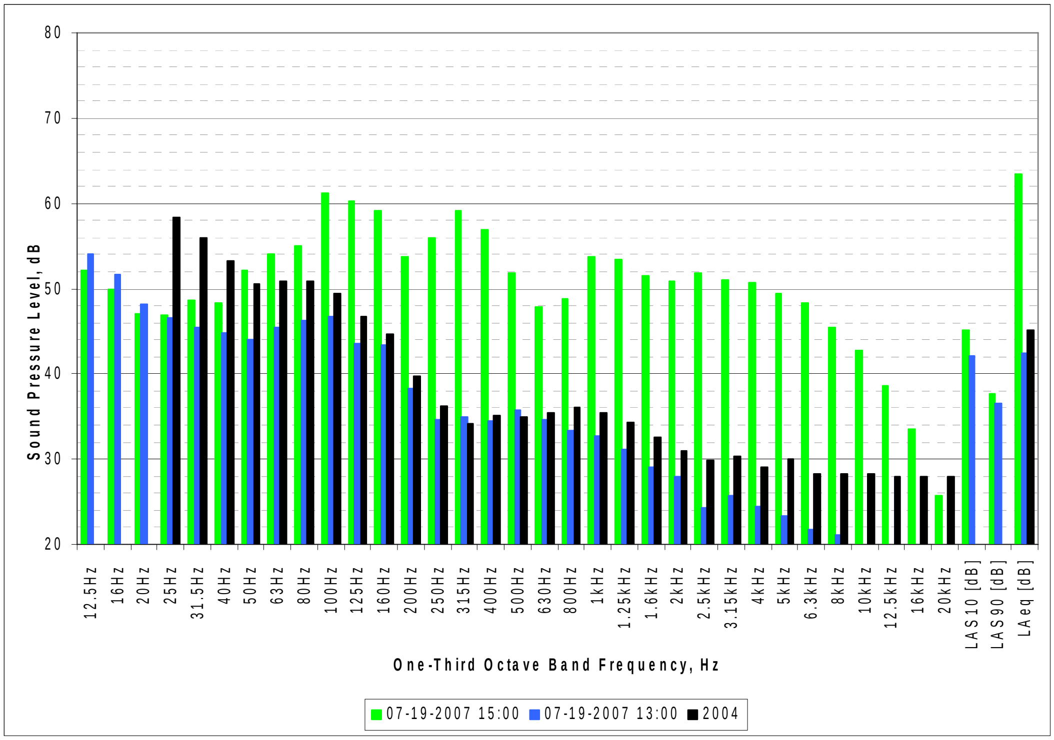


Figure 15: Highest and Lowest Daytime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 5 (Behind N&N Store @ Tamarack Dr.)

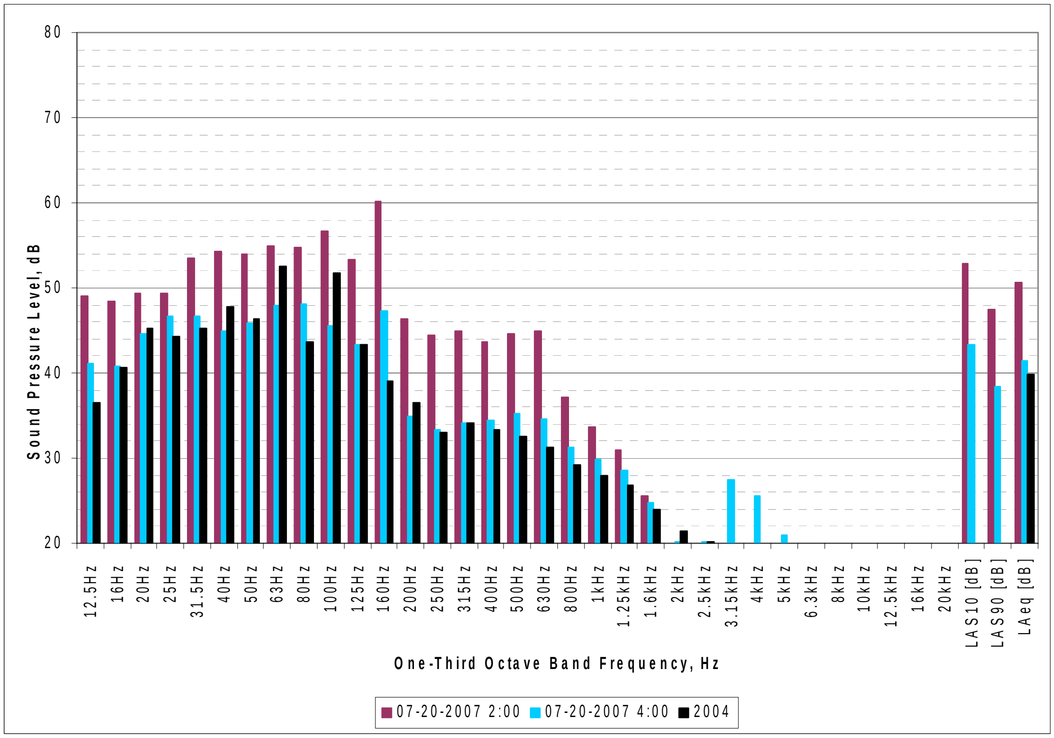


Figure 16: Highest and Lowest Nighttime Sound Levels ($L_{eq\ 1hr}$) Measured at Location 5 (Behind N&N Store @ Tamarack Dr.)

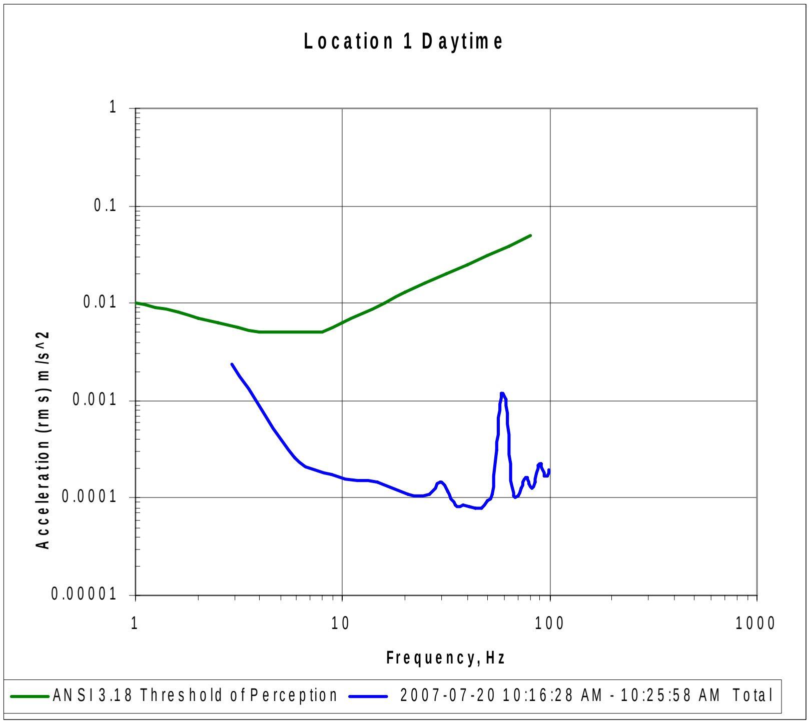


Figure 17: Daytime Vibration Measurement at Location 1 with ANSI vibration perception threshold criteria

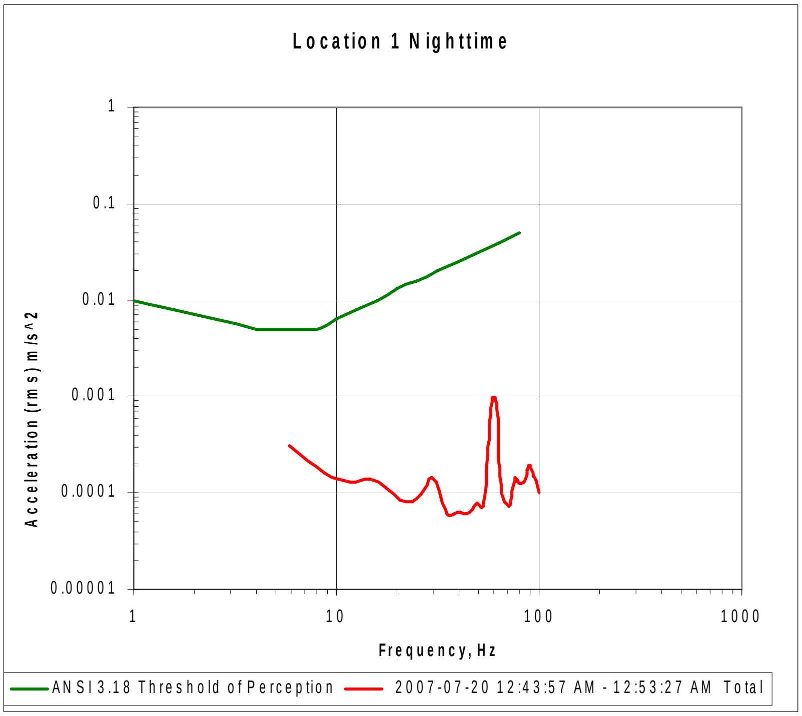


Figure 18: Nighttime Vibration Measurement at Location 1 with ANSI vibration perception threshold criteria

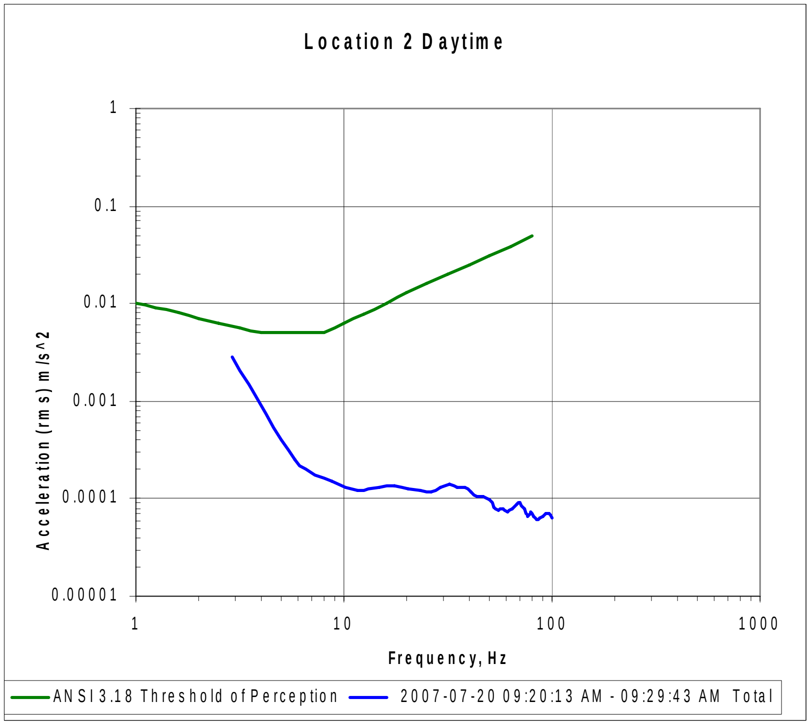


Figure 19: Daytime Vibration Measurement at Location 2 with ANSI vibration perception threshold criteria

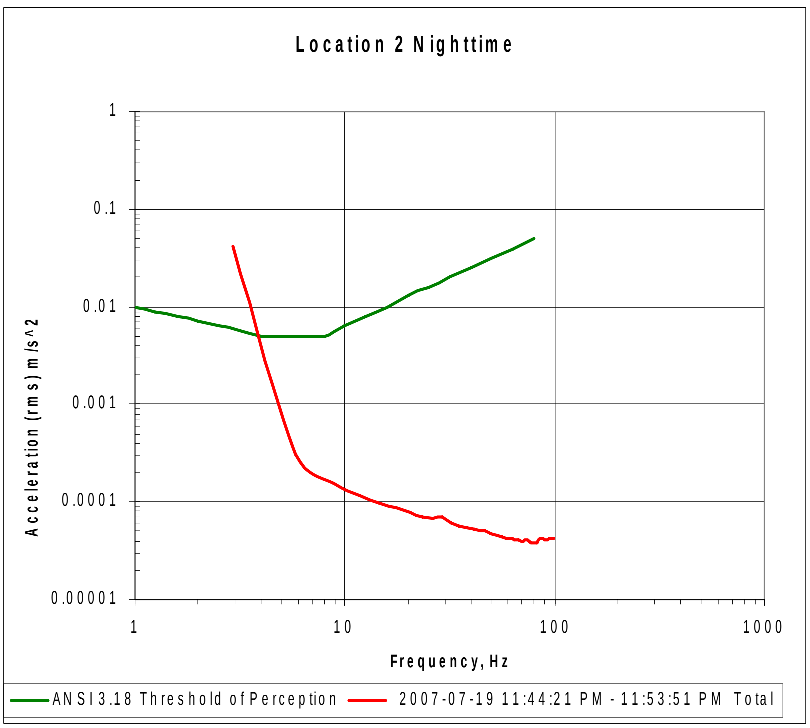


Figure 20: Nighttime Vibration Measurement at Location 2 with ANSI vibration perception threshold criteria

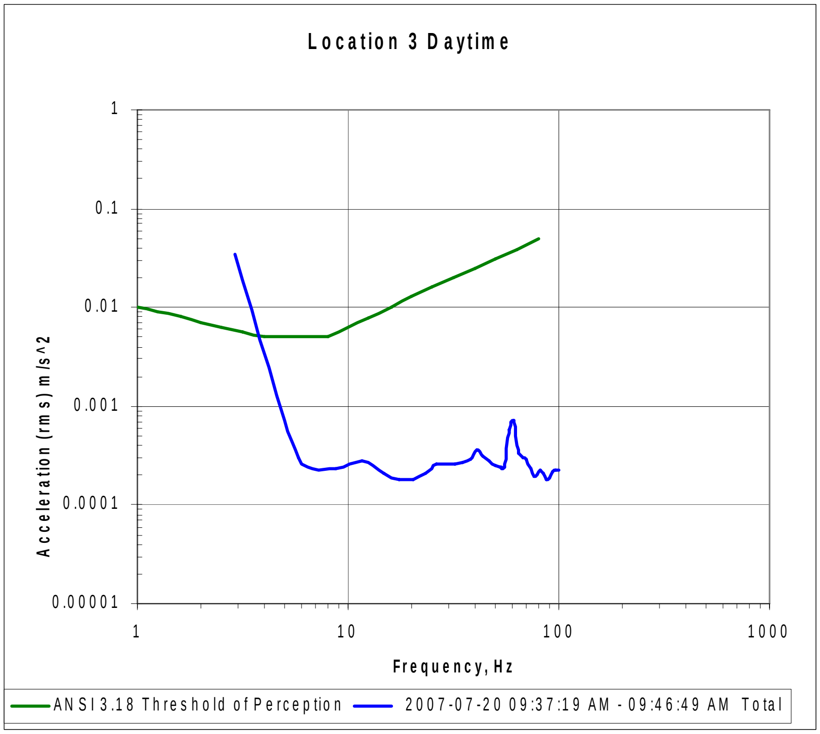


Figure 21: Daytime Vibration Measurement at Location 3 with ANSI vibration perception threshold criteria

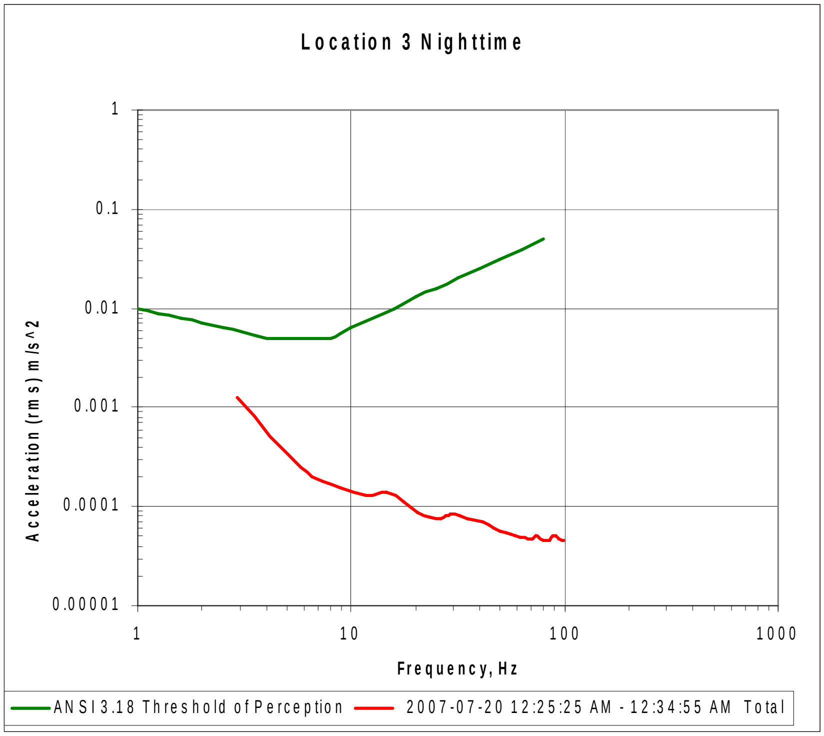


Figure 22: Nighttime Vibration Measurement at Location 3 with ANSI vibration perception threshold criteria

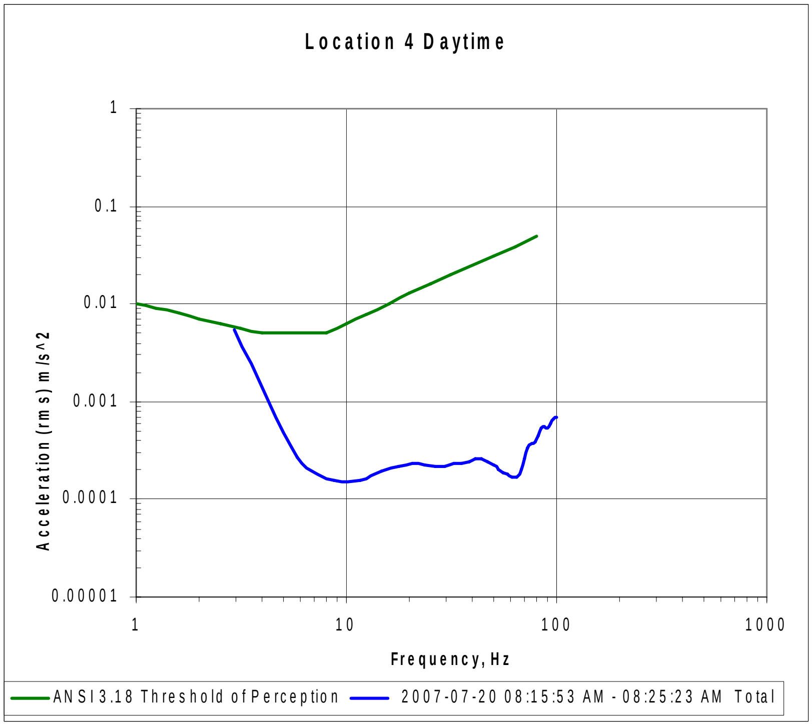


Figure 23: Daytime Vibration Measurement at Location 4 with ANSI vibration perception threshold criteria

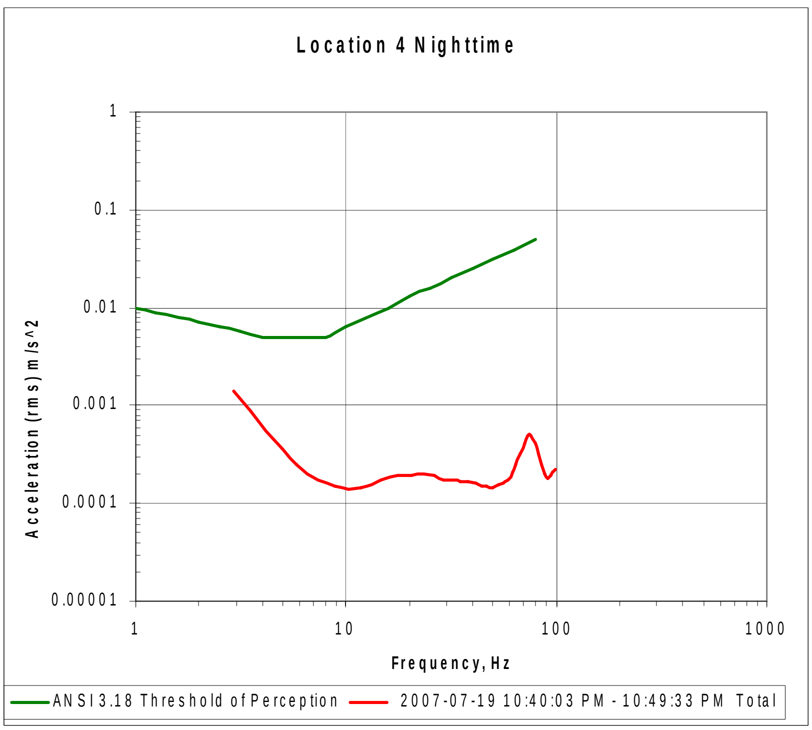


Figure 24: Nighttime Vibration Measurement at Location 4 with ANSI vibration perception threshold criteria

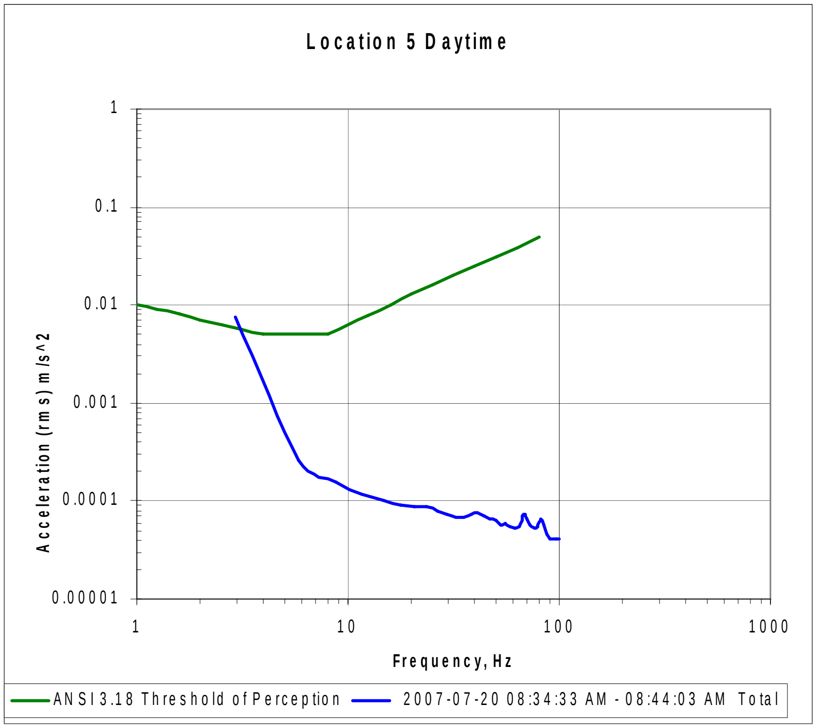


Figure 25: Daytime Vibration Measurement at Location 5 with ANSI vibration perception threshold criteria

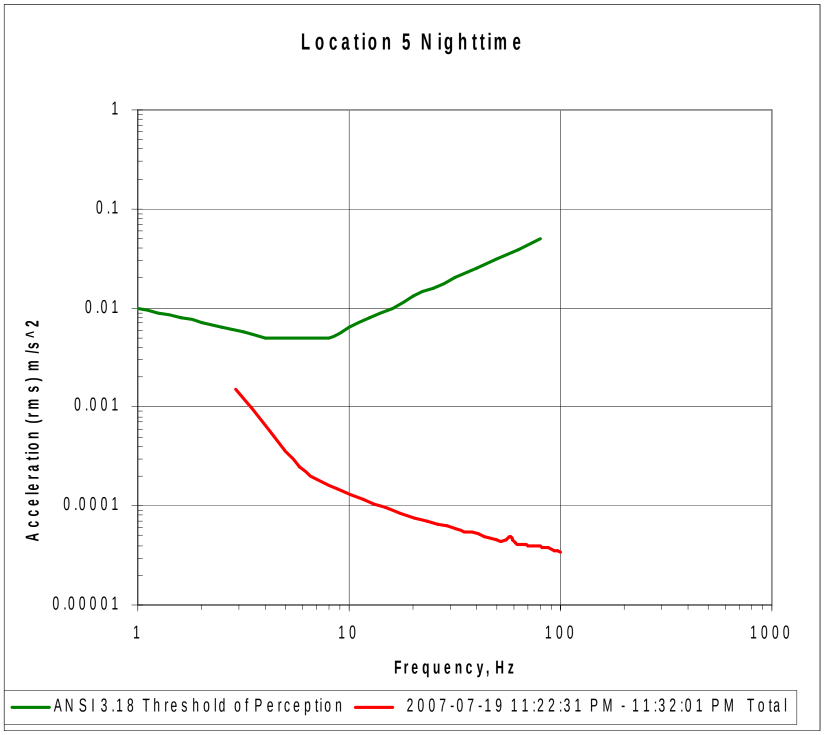


Figure 26: Nighttime Vibration Measurement at Location 5 with ANSI vibration perception threshold criteria

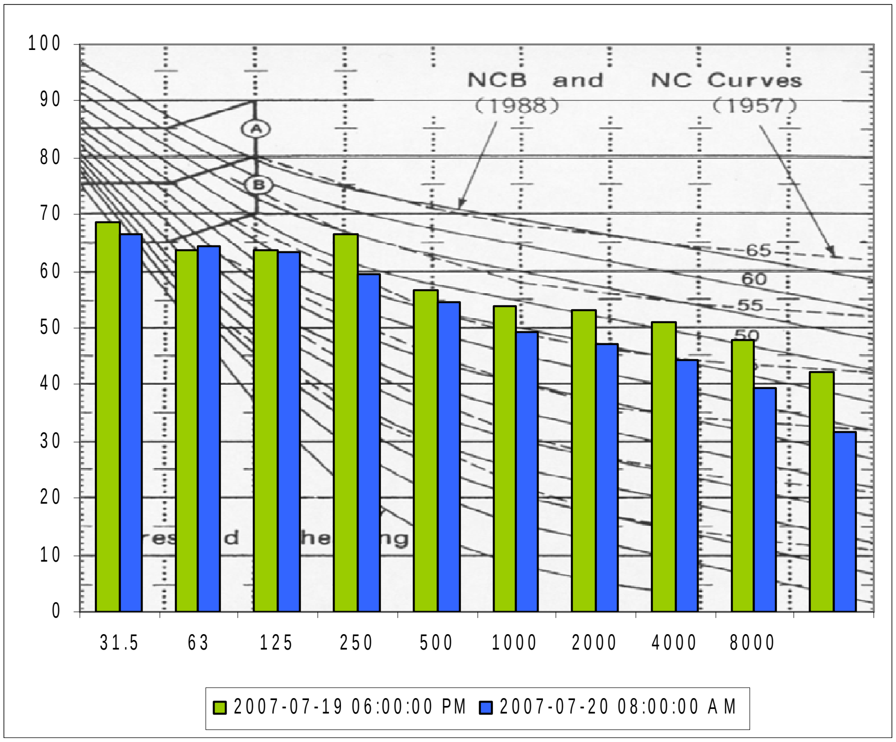


Figure 27: Measured Daytime Sound Levels at Location 1 w.r.t. ANSI criteria for low-frequency noise-induced vibration

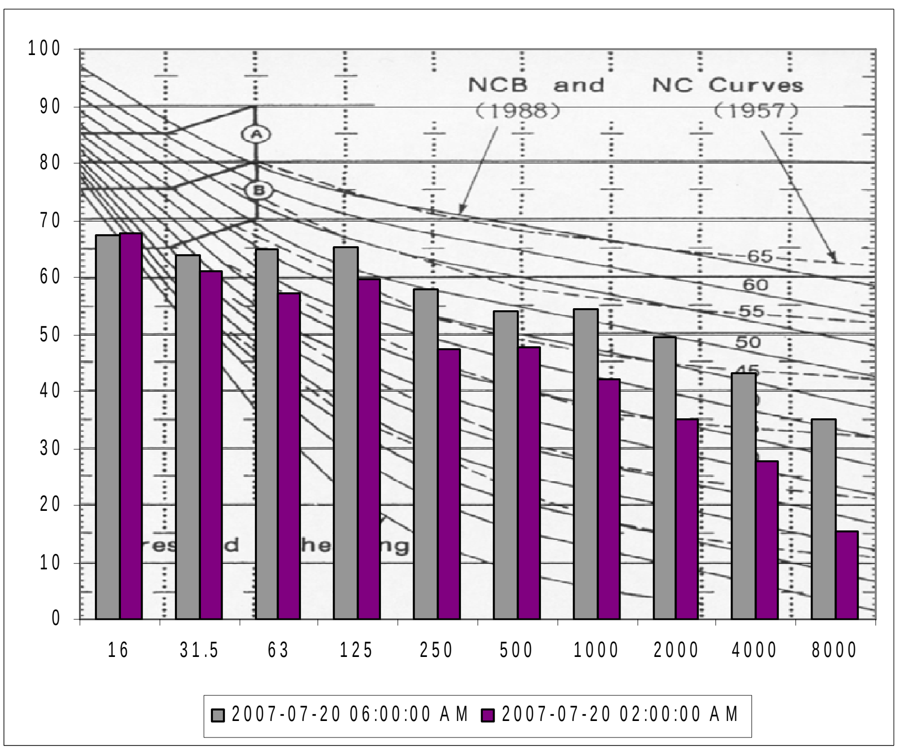


Figure 28: Measured Nighttime Sound Levels at Location 1 w.r.t. ANSI criteria for low-frequency noise-induced vibration

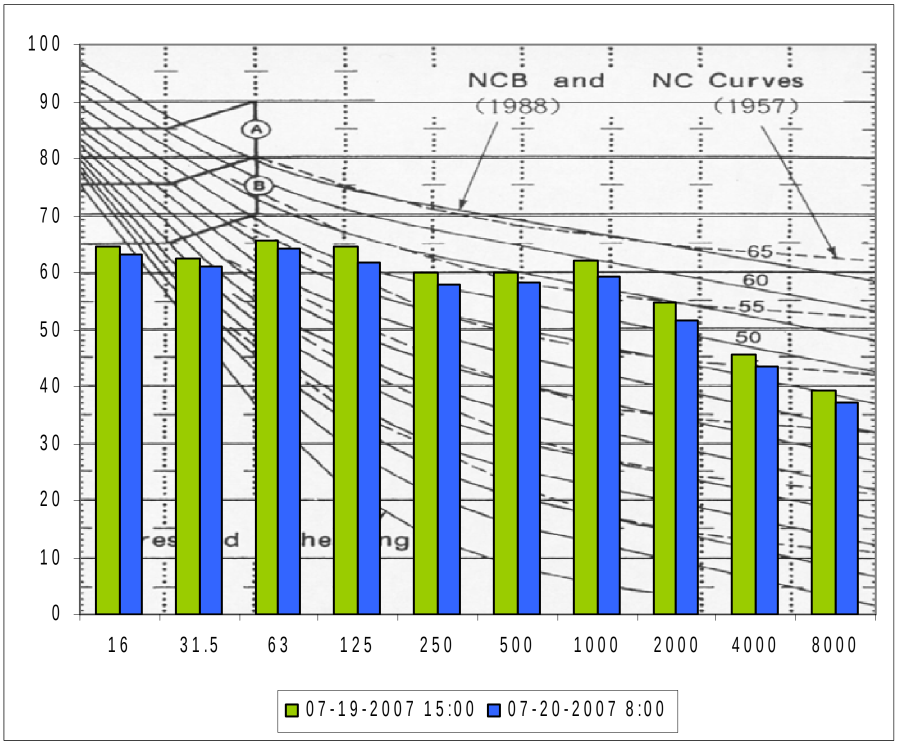


Figure 29: Measured Daytime Sound Levels at Location 2 w.r.t. ANSI criteria for low-frequency noise-induced vibration

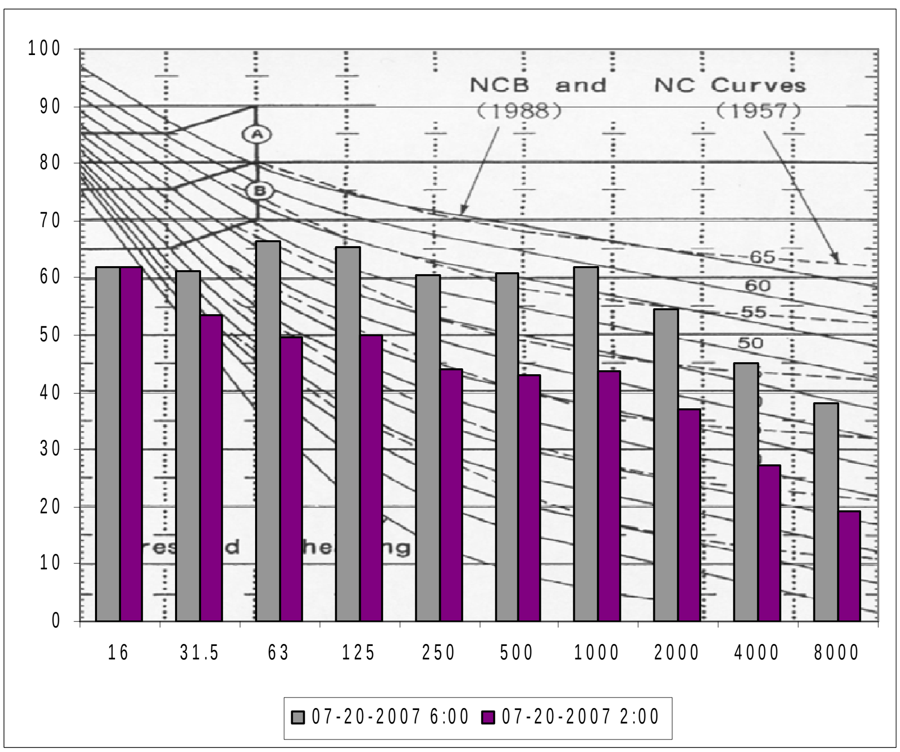


Figure 30: Measured Nighttime Sound Levels at Location 2 w.r.t. ANSI criteria for low-frequency noise-induced vibration

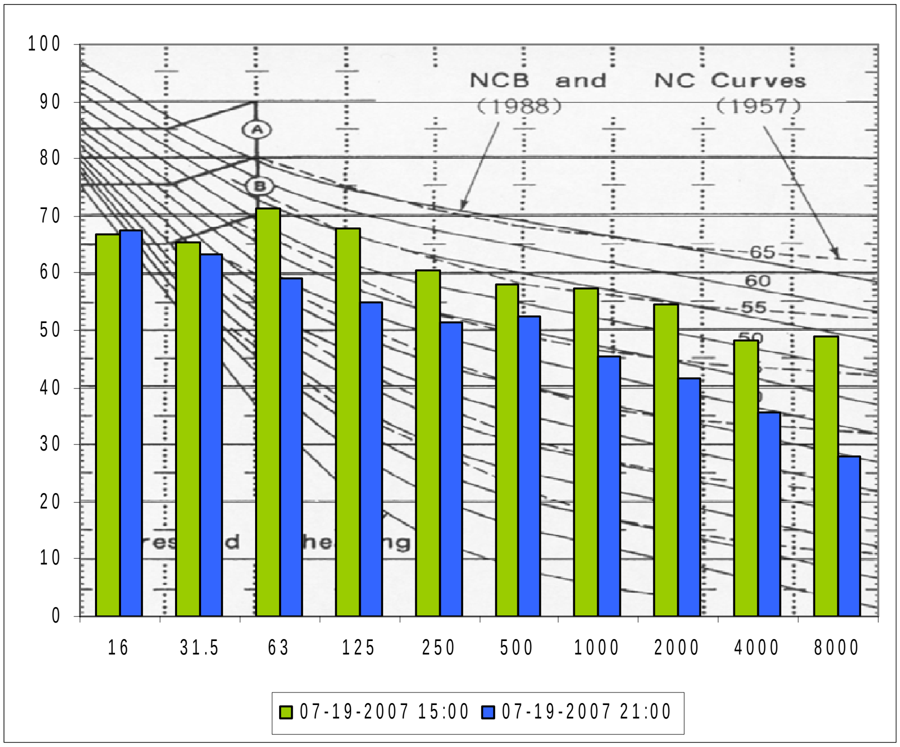


Figure 31: Measured Daytime Sound Levels at Location 3 w.r.t. ANSI criteria for low-frequency noise-induced vibration

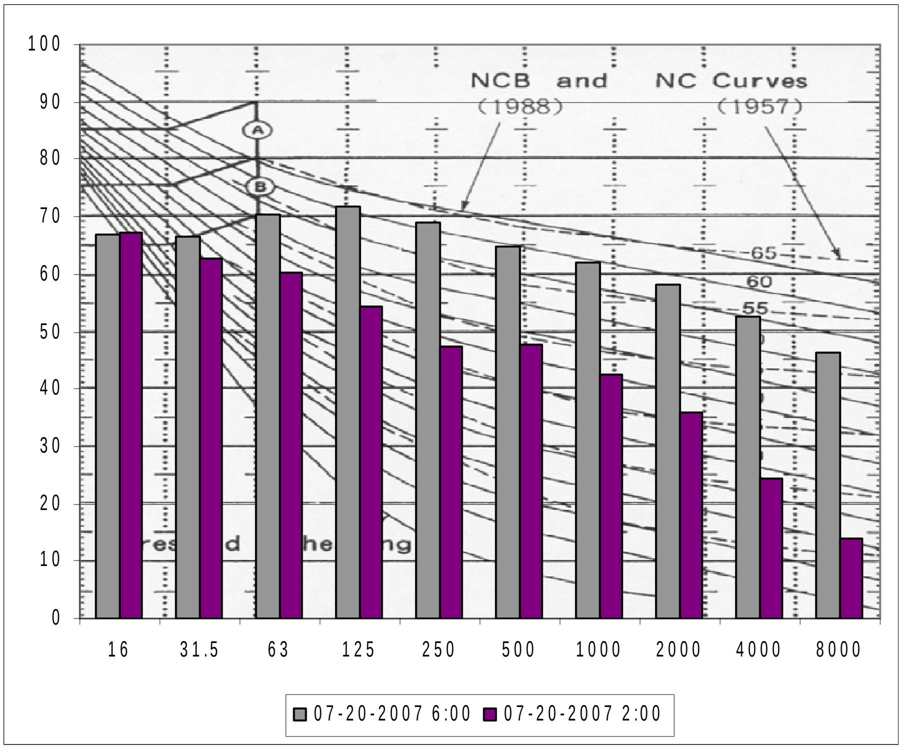


Figure 32: Measured Nighttime Sound Levels at Location 3 w.r.t. ANSI criteria for low-frequency noise-induced vibration

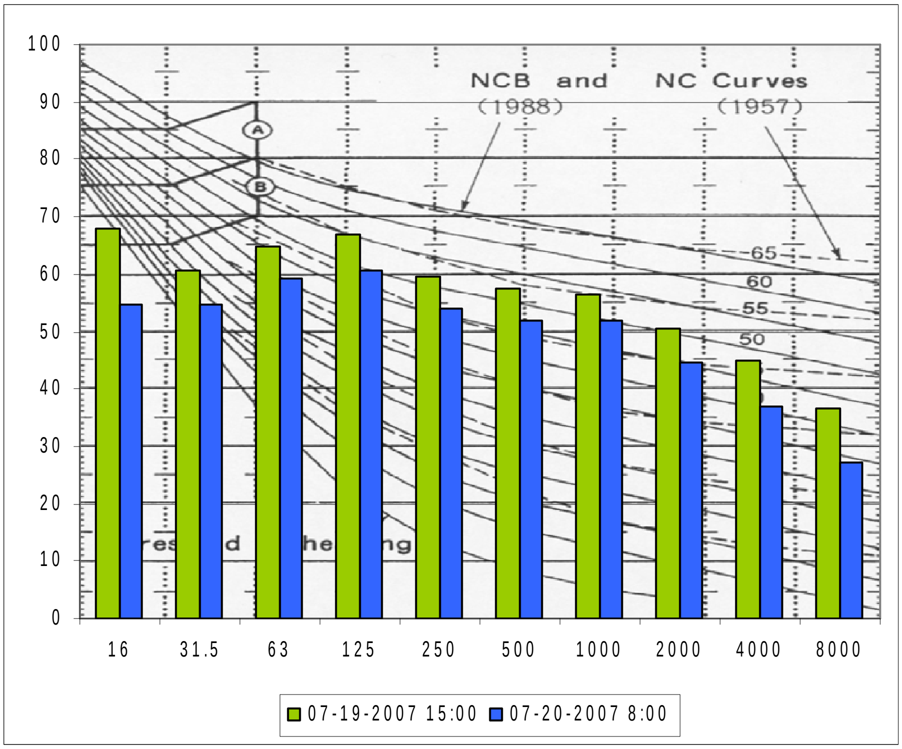


Figure 33: Measured Daytime Sound Levels at Location 4 w.r.t. ANSI criteria for low-frequency noise-induced vibration

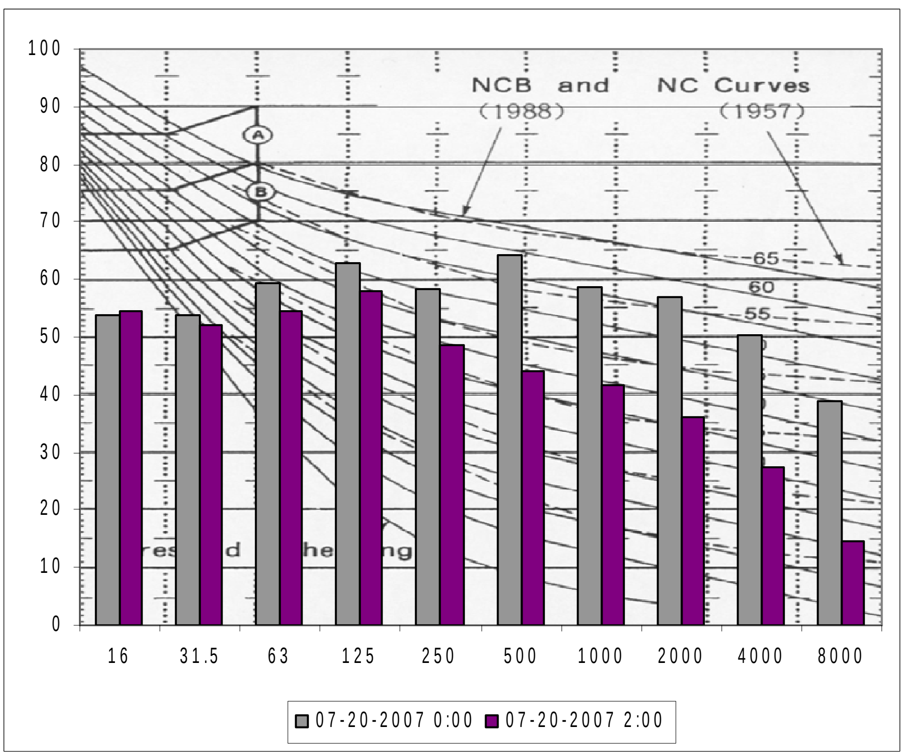


Figure 34: Measured Nighttime Sound Levels at Location 4 w.r.t. ANSI criteria for low-frequency noise-induced vibration

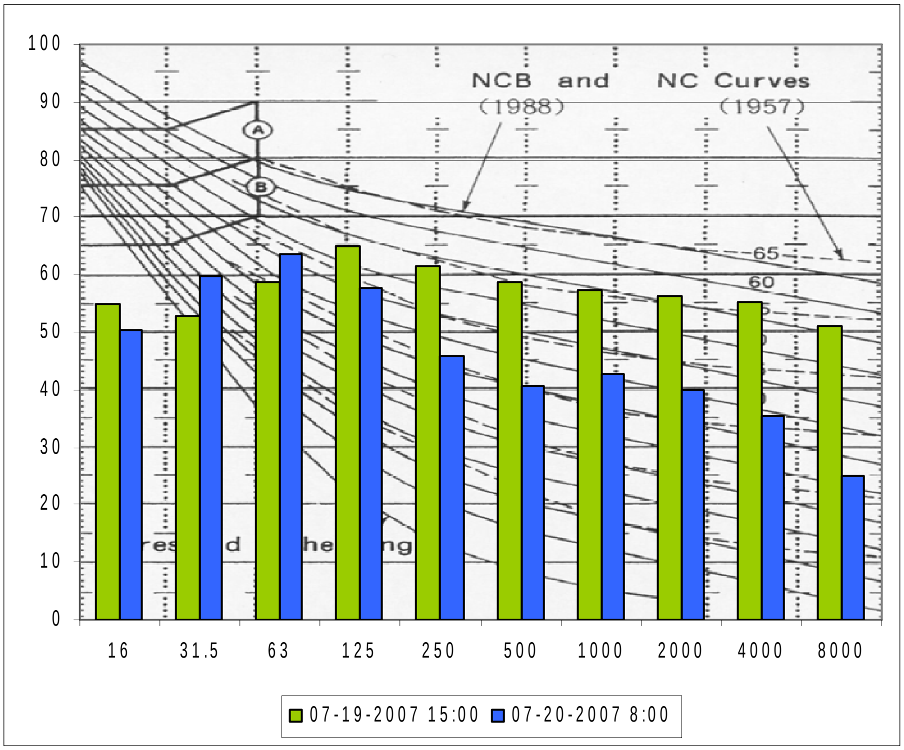


Figure 35: Measured Daytime Sound Levels at Location 5 w.r.t. ANSI criteria for low-frequency noise-induced vibration

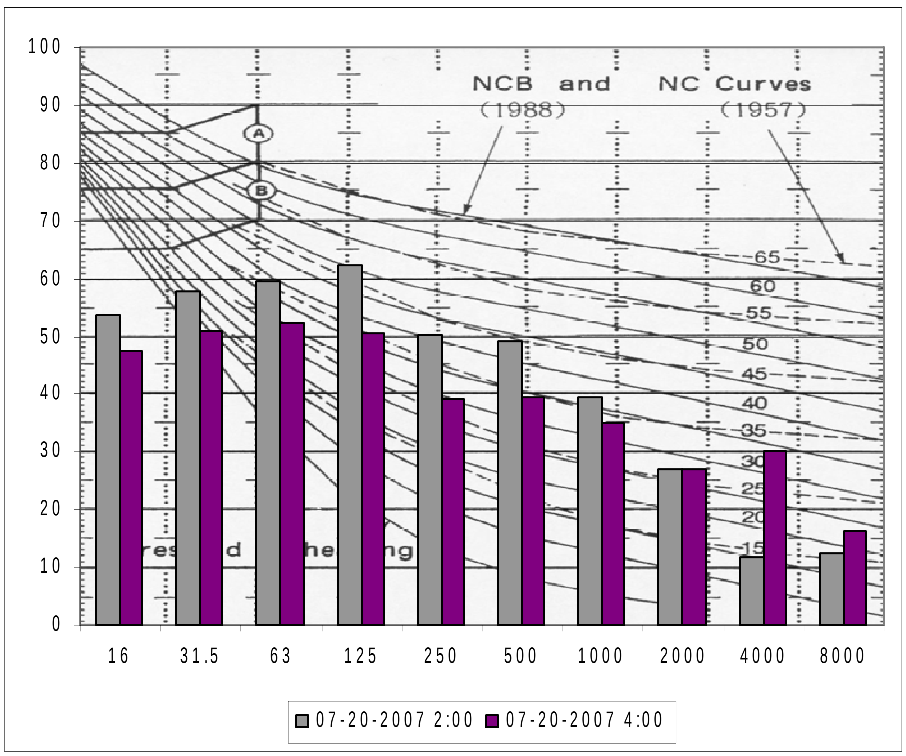


Figure 36: Measured Nighttime Sound Levels at Location 5 w.r.t. ANSI criteria for low-frequency noise-induced vibration

APPENDIX A

Guide and Abbreviations

APPENDIX A: SOUND LEVEL TERMINOLOGY

Frequency - the number of cycles per unit interval of time. *Units Hz (Hertz).*

Bel (B) - a unit of measure for LEVEL or LEVEL DIFFERENCE (A.G. Bell *1847-1922*). If a quantity is increased by a factor 10^n, its level goes up by *n* bels.

Decibel (dB) - the standard unit of measure, in acoustics, for level or level difference. The decibel scale is based on the ratio $10^{1/10}$; multiplying a power-like quantity (such as sound power or mean square) by this factor increases its level by 1 decibel. If a power-like quantity is increased by a factor $10^{n/10}$, its level goes up by *n* decibels. *Unit symbol for dB.*

Sound Pressure (Pa) - the difference between the instantaneous pressure at a fixed point in a sound field, and the pressure at the same point with the sound absent. *Units Pa (Pascal).*

Sound Pressure Level (SPL, L_p) - or sound pressure-squared level, at a given point the quantity L_p defined by $L_p = 10 \text{ Log}_{10}(P_{rms}/P_{ref})^2 = 20 \text{ Log}_{10}(P_{rms}/P_{ref})$. Here P_{rms} is the ROOT MEAN SQUARE sound pressure, and P_{ref} is the reference rms sound pressure. *Units dB re* $(20\mu Pa)^2$.

A-weighted Sound Pressure Level (SPL, L_{pA}, L_A) - the LEVEL of sound pressure signal to which A-WEIGHTING has been applied. *Units dB re* $(20\mu Pa)^2$.

Sound Power – the rate of acoustic energy flow across a specified surface, or emitted by a specified sound source. *Units W (Watt).*

Sound Power Level (PWL, L_w) - the level of SOUND POWER expressed in decibels relative to a stated reference value. The quantity L_w is defined by $L_w = 10 \text{ Log}_{10}(W/W_{ref})$. Here W_{ref} is the reference sound power. *Units dB re* $1_{P}W$.

A-weighted Sound Power Level (PWL, L_{wA}) - the level of sound power to which A-WEIGHTING has been applied. *Units dB re* $(20\mu Pa)^2$.

A-weighting - a frequency-weighting procedure, in which the power or energy spectrum of a signal is progressively attenuated towards the high and low ends of the human audible range. Frequency components around 1 kHz - 5 kHz are hardly affected, but the attenuation is large at low frequencies (i.e., 70 dB at 10 Hz).

Percentile Sound Levels, L_N - since the noise levels in a community vary with time in a more or less random manner, the descriptors of these time varying noise levels may be defined in statistical terms. The statistical descriptors are referred to as the percentile sound levels, L_N; with L_N defined as the level exceeded N% of the time. The descriptors often used are:

> **L_0, Highest Level** - this is the highest noise level, also known as L_{max}.
>
> **L_1, Level of Highly Intrusive Sounds –** the level exceeded 1% of the time, is a measure of the highly intrusive sounds.
>
> **L_{10}, Level of Intrusive Sounds -** The level exceeded 10% of the time, and is used to indicate the average level of the intrusive sounds.
>
> **L_{50}, Median Level -** The level exceeded 50% of the time or the median level. A useful measure of the average noise conditions on a site.
>
> **L_{90}, Background Level –** The level exceeded 90% of the time. It provides a good indication of the steady background noise level on a site.

L_{eq}, Equivalent Sound Level - the prime descriptor used in assessing most types of sounds heard in a community. The L_{eq} is an average of sounds measured over time. It is strongly influenced by occasional loud, intrusive noises. Because it is able to account for such noises, for example, the L_{eq} is the best descriptor for the intermittent sound levels from construction activities.

L_{DN}, The Day-Night Sound Level, derived by applying a 10 dB "penalty" to noise levels that occur at night, between 10 p.m. and 7 a.m., thus accounting for increased sensitivity to noise during nighttime hours.

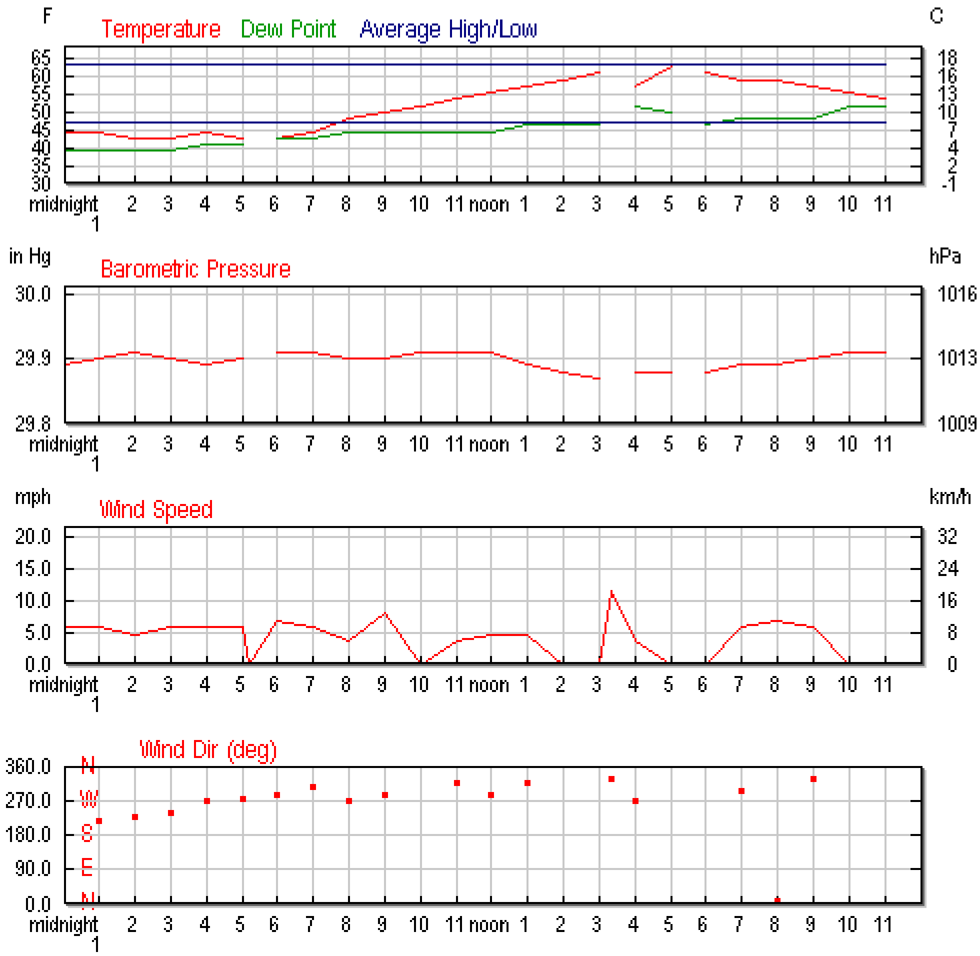
Ambient sound level - means background sound level. It is the sound level that is present in the acoustic environment of a defined area. Aircraft flyover and rail noise may be excluded in some jurisdictions.

Reference: Dictionary of Acoustics, Christopher L Morfey, Institute of Sound and Vibration Research, University of Southampton, Southampton, UK –Academic Press, 2001.

APPENDIX B

Meteorological Conditions

Labrador City Newfoundland, July 19, 2007



Labrador City Newfoundland, July 20, 2007