APPENDIX F

Noise Study

Noise and Vibration Assessments
Traffic Noise Predictions
and
Sound Attenuation Barrier Specification
17th Street Planning and Design
Edmonton, Alberta
Revision 0

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Executive Summary

Patching Associates Acoustical Engineering Ltd. (PAAE) was retained by McElhanney Consulting Services Ltd. (Edmonton) to conduct a noise and vibration analysis and barrier design study for the proposed widening of 17th Street between Whitemud Drive (in Edmonton) and Knightsbridge Road (in the County of Strathcona). Both the City's and the County's traffic noise policies address the potential noise impact on residential development only, and do not specify any limits on traffic noise in commercial and industrial areas. The only residential area along the subject road is the Maple Ridge Community in Edmonton, Alberta, and so this study focused on the future noise and current vibration levels affecting this area.

It is planned to widen and upgrade 17th Street, which is a truck route carrying significant industrial traffic. This will likely lead to increased traffic volumes on this road. The Edmonton and Strathcona traffic noise criteria are both based on the average noise exposure, which is based on the noise from the total traffic volumes. Measurements were taken of the current traffic noise near one residence and in the park at the centre of the community, to assess the current traffic noise and the effectiveness of the current fencing as noise barriers.

Available vibration standards, relevant to residential developments, deal with the maximum levels of vibration which are experienced, with some consideration of the number of events, but are not usually based on the cumulative exposure levels. As the upgraded road will slightly closer to the houses than the current road, the future vibration levels are expected to be slightly, but not significantly higher than what was measured.

The purpose of the study of future noise levels is to predict the level of traffic noise that will be received at residences adjacent to the proposed upgraded roadway and to determine the height of sound attenuation barrier required to comply with the Edmonton Urban Traffic Noise Policy (C506) target noise level of 60 dBA Leq (24 Hour). Noise predictions for road traffic were developed using the Federal Highway Administration's Traffic Noise Model computer program **TNM 2.5** based on conservative traffic volume projections, road profiles and topography provided by McElhanney Consulting Services Ltd. (Edmonton).

The predicted Leq (24 Hour) noise levels with the existing fence attenuation for the developments in the study area range from 56 to 69 dBA for the 17th Street upgraded road design.

The analysis predicts that additional attenuation will be required to meet the Edmonton Urban Traffic Noise Policy (C506) target noise level of 60 dBA Leq (24 Hour). Several sections of barrier wall ranging from 1.8 metres to 2.2 metres high are warranted at the same locations as the existing fences, and the coordinates for the end points are specified within the report:

- 1.8 metres for sections on the west property line locations of the Crystal Crescent residences
- 2.0 to 2.2 metres for sections on the west property line locations of the Oak Wood residences

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Introduction

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One of the purposes of this study is to predict the level of traffic noise that would be received at residences adjacent to the proposed upgraded roadway and to determine the height of attenuation required to comply with the Edmonton Urban Traffic Noise Policy (C506) target noise level of 60 dBA Leq (24 Hour). Noise predictions for road traffic were developed using the Federal Highway Administration's Traffic Noise Model computer program based on traffic volume conservative projections, road and land profiles provided by McElhanney Consulting Services Ltd. (Edmonton).

Noise Criteria

Sound is typically measured using the A-weighting scale and is commonly expressed as an Leq value. The A-weighted equivalent-continuous sound level is the noise descriptor used in the City of Edmonton noise attenuation guidelines. This index is an energy average of the varying sound level over a specified period. The use of this index permits the description of a varying sound level environment as a single number. As the Leq is an "average" level, the measured sound level may exceed the criterion level, provided the duration is limited. The Leq value considers both the sound level and the length of time that the sound level occurs. Appendix A provides a detailed explanation of other units and descriptors.

The City of Edmonton specifies that a basic noise abatement threshold level of 65 dBA Leq (24 Hours) or as low as technically, administratively, and economically practical, with an objective of achieving a Design Noise Level (DNL) of 60 dBA Leq (24hours), may be received in a resident's yard at a location three meters from the rear of the residence at an elevation of approximately 1.5 meters. A 20-year time horizon for traffic volume projections (AAWDT volumes) is used to predict future noise levels adjacent to new developments and new or upgraded transportation facilities.

For this study, the Edmonton Urban Traffic Noise Policy (C506, adopted 2004) was used by PAAE to examine the impact of traffic noise to the adjacent Community. Other noise sources were not considered in this evaluation.

Noise levels will be predicted with the traffic volumes supplied for the proposed 17th Street widening The noise levels will be predicted to a point 3 metres inside the adjacent properties, at a height of 1.5 metres above the ground surface, as per the Policy.

A copy of the Edmonton Urban Traffic Noise Policy (C506) document is found in Appendix B.

Vibration Criteria

There are several criteria related to human perception and reaction to traffic-related vibration. Human reaction to vibration is very frequency dependant, as is human hearing, but is much more sensitive to vibration at low frequencies than hearing is.

Using the criteria adopted by the US Federal Transit Administration (FTA) for urban transportation sources, ground vibration levels are evaluated in terms of the vibration velocity. This parameter correlates well with human sensitivity, as well as the potential for any structure damage. Humans find vibration levels of living quarters completely intolerable at levels many orders of magnitude lower than those which will cause any structural or cosmetic damage.

The FTA criteria are shown in Appendix F. For 17th Street, as there is currently, and will presumable in the future be, heavy industrial traffic the criterion chosen is a maximum vertical vibration velocity of 72 dB referenced to 1 microinch per second – as this is not weighted for human hearing, the A-weighting scale is not used for this part of the evaluation.

Measurement of Existing Traffic Noise Levels

Overnight continuous noise measurements were conducted at the residence at 27 Crystal Lane and the park in the middle of the Maple Ridge community, from the afternoon of July 23 to the afternoon of July 24, 2012. The microphone near the residence was located 2 metres to the northwest from the residence, at a distance of 33 metres from the near edge of the road – there was significant noise from the industries to the west, but traffic noise was dominant

The sound monitoring surveys at a residence and park were conducted with a Brüel & Kjær Model 2250 Precision Sound Level Meters equipped with Brüel & Kjær Model 4189 microphones. The microphones were mounted with windscreens to reduce the potential for wind-induced noise at the microphone. The meters were configured to sample the noise and record the levels in terms of one-minute equivalent-continuous (L_{eq}) level, as well as statistical sound levels for each interval.

For both sets of readings, noises which were contributed by the presence of PAAE staff, and from other source which could be clearly identified as non-traffic sources such as a weather event or industrial noise, have been isolated from the assessment of the traffic noise. The remaining noise is indicated as the 'Residual' level.

The sound level meters were calibrated at the beginning and confirmed at the end of the surveys with a Brüel & Kjær Model 4231 Sound Level Calibrator. The meter at the residential receiver was configured to record the sound for the whole measurement period. These sound recordings were used to help identify the source of different noises in order to assist with isolation analysis to eliminate noise sources (other than the traffic noise) from the data set.

Table 1 shows a summary of the major equipment used for this survey and the calibration dates for this equipment.

Table 1 - Instrumentation Summary

Equipment	Manufacturer	Instrument Model / SN	Microphone Model / SN	Last Calibration	Calibration Valid
Sound Meter 2250 Unit 1 *Residence*	Bruel & Kjaer	2250/2473172	4189/2458606	14-Aug-12	Yes
Sound Meter 2250 Unit 3 *Park*	Bruel & Kjaer	2250/2671998	4189/2656149	21-Jan-11	Yes
Calibrator 4231 Unit 1	Bruel & Kjaer	4231/2175822	N/A	10-Aug-12	Yes

Table 2 shows the 24 hours measurement results for the residence. See Appendix C for graphs of the overall sound level results for the residence. The overall L_{eq} level at this location was 55.9 dBA – this level is below the City's design noise level of 60 dBA, and well below the threshold for barrier retrofit.

Table 2 – Results of Measurements at Residence at 27 Crystal Lane

Date	Time	Measured Sound Level		Residual Sound Level	
		Leq (dBA)	Hours	Leq (dBA)	Hours
Jul. 23, 2012	07:00 - 21:59	**73**	6.6	**55**	5.2
Jul. 23, 2012 - Jul. 24, 2012	22:00 - 06:59	**53**	9.0	**53**	9.0
Jul. 24, 2012	07:00 - 21:59	**74**	8.5	**58**	8.4

For the nighttime periods the average residual sound levels at the microphone near the residence range from 53 dBA to 58 dBA.

Table 3 shows the 24 hour measurement results for the park. See Appendix D for graphs of the overall sound level results for the park. The overall L_{eq} noise level at this location was 58.2 dBA. As the location in the park is approximately the same distance from the road as at the residence, this indicates that the existing fence provides approximately 2 dBA noise attenuation.

For the nighttime periods the average residual sound levels range from 56 dBA to 60 dBA.

Table 3 – Results of 24hrs Measurements at Park

Date	Time	Measured		Residual	
		Leq	Hours	Leq	Hours
Jul. 23, 2012	07:00 - 21:59	**74**	7.8	**56.7**	6.9
Jul. 23- Jul. 24, 2012	22:00 - 06:59	**57**	9.0	**56.7**	9.0
Jul. 24, 2012	07:00 - 21:59	**61**	6.2	**60.8**	5.8

Assumptions for Noise Barrier Design

17th Street and the immediately adjacent residences to the proposed roadwork were modeled using FHWA TNM 2.5 with elevations according to drawings obtained from McElhanney.

Traffic data provided by McElhanney gave the traffic volumes based on conservative estimates, which is 25,000 vehicles per day. It was assumed the total traffic volume in the SB and NB directions are the same. The classifications of truck percentages were given as 18% on 17th Street in this area. The ratios of medium trucks (e.g. buses and single unit trucks) to heavy trucks on each road were modeled as 1:1.

Vehicles were modeled as traveling at a design speed of 70 kph on 17th Street.

Environmental conditions used in the model were 20 degrees Celsius with 50% relative humidity.

Future Noise Level Predictions

Predictions can be made for the noise levels that will be generated by traffic at given receiver points based on the traffic volumes, speeds and land topography. Appendix C presents drawings showing the relative positions of the receiver, barrier and roadway locations.

Tables 4 and 5 show the anticipated noise levels for the upgraded 17th Street with existing and upgraded noise attenuation features. The bolded and italicized entries indicate receivers where the DNL is exceeded.

The results presented in Table 1 shows that most of the receivers in the Maple Ridge Community could expect to receive levels that are greater than the DNL, with the existing fence attenuation.

Table 5 shows the barrier heights required at each station number to achieve the PAAE Upgraded Attenuation results tabulated in Tables 1. The PAAE upgraded barriers were modeled along the property line along the west edge of the Maple Ridge community, which are also the locations of the existing fence. (See Appendix E for drawings and tables showing stationing and locations of modeled objects.)

Table 4 - Anticipated L_{eq} (24 Hour) Traffic Noise Levels for Receivers Located in the Maple Ridge Community

Receiver Location	Receiver Name	No Fence (dBA)	Existing Fence Attenuation (dBA)	PAAE Upgraded Attenuation (dBA)
Crystal Crescent NW Edmonton	R01	56	53	53
	R02	57	54	54
	R03	59	56	56
	R04	**67**	**64**	59
	R05	**67**	**64**	60
	R06	**67**	**64**	**60**
	R07	**67**	**64**	60
	R08	**67**	**64**	60
	R09	**67**	**64**	60
	R10	**67**	**64**	60
	R11	**67**	**64**	59
	R12	**67**	**64**	59
	R13	59	56	57
	R14	57	54	55
Oak Wood Road Edmonton	R15	**69**	**66**	60
	R16	**69**	**66**	60
	R17	**69**	**66**	60
	R18	**69**	**66**	60
	R19	**69**	**66**	60
	R20	**69**	**66**	59
	R21	**69**	**66**	60
	R22	**69**	**66**	60
	R23	**69**	**66**	60
	R24	**69**	**66**	60
	R25	**69**	**66**	60

Table 5 – Barrier Heights Needed to Achieve DNL

Start		End		Barrier Height (m)	Barrier Top Elevation (m)	Barrier Base Elevation (m)
X	Y	X	Y			
Crystal Crescent Barrier						
41968.00	5929742.00	41955.20	5929742.00	1.80	703.11	701.31
41955.20	5929742.00	41936.70	5929742.00	1.80	702.76	700.96
41936.70	5929742.00	41916.60	5929742.00	1.80	702.39	700.59
41916.60	5929742.00	41891.90	5929742.00	1.80	701.88	700.08
41891.90	5929742.00	41891.90	5929729.80	1.80	701.57	699.77
41891.90	5929729.80	41892.40	5929711.50	1.80	701.80	700.00
41892.40	5929711.50	41892.40	5929694.40	1.80	701.82	700.02
41892.40	5929694.40	41892.60	5929678.60	1.80	701.89	700.09
41892.60	5929678.60	41892.00	5929665.80	1.80	701.98	700.18
41892.00	5929665.80	41892.30	5929650.50	1.80	702.05	700.25
41892.30	5929650.50	41892.00	5929633.50	1.80	702.18	700.38
41892.00	5929633.50	41892.00	5929610.30	1.80	702.35	700.55
41892.00	5929610.30	41892.20	5929585.90	1.80	702.43	700.63
41892.20	5929585.90	41901.10	5929585.90	1.80	703.08	701.28
41901.10	5929585.90	41921.00	5929585.90	1.80	703.22	701.42
41921.00	5929585.90	41941.30	5929585.90	1.80	703.33	701.53
41941.30	5929585.90	41955.20	5929585.90	1.80	703.65	701.85
41955.20	5929585.90	41971.40	5929585.90	1.80	703.82	702.02
Oak Wood Road Barrier						
41890.50	5930361.90	41883.30	5930352.80	2.00	702.50	700.50
41883.30	5930352.80	41877.40	5930347.30	2.00	702.65	700.65
41877.40	5930347.30	41877.60	5930336.30	2.00	703.01	701.01
41877.60	5930336.30	41877.70	5930324.10	2.20	703.70	701.50
41877.70	5930324.10	41877.90	5930311.30	2.00	703.50	701.50
41877.90	5930311.30	41878.00	5930299.10	2.00	703.78	701.78
41878.00	5930299.10	41878.20	5930286.30	2.00	704.00	702.00
41878.20	5930286.30	41878.50	5930274.10	2.00	704.00	702.00
41878.50	5930274.10	41878.50	5930262.00	2.00	704.00	702.00
41878.50	5930262.00	41878.80	5930249.80	2.00	704.00	702.00
41878.80	5930249.80	41879.00	5930237.00	2.00	704.00	702.00
41879.00	5930237.00	41879.10	5930224.20	2.00	704.00	702.00
41879.10	5930224.20	41879.20	5930216.20	2.00	704.00	702.00
41879.20	5930216.20	41883.90	5930211.40	2.00	704.00	702.00

Figures 1 and 2 present a pictorial representation of the study area. (See Appendix E for larger image.)

Figure 1 – Barrier Design Study for the Proposed 17th Street Widening (Crystal Crescent Residences)

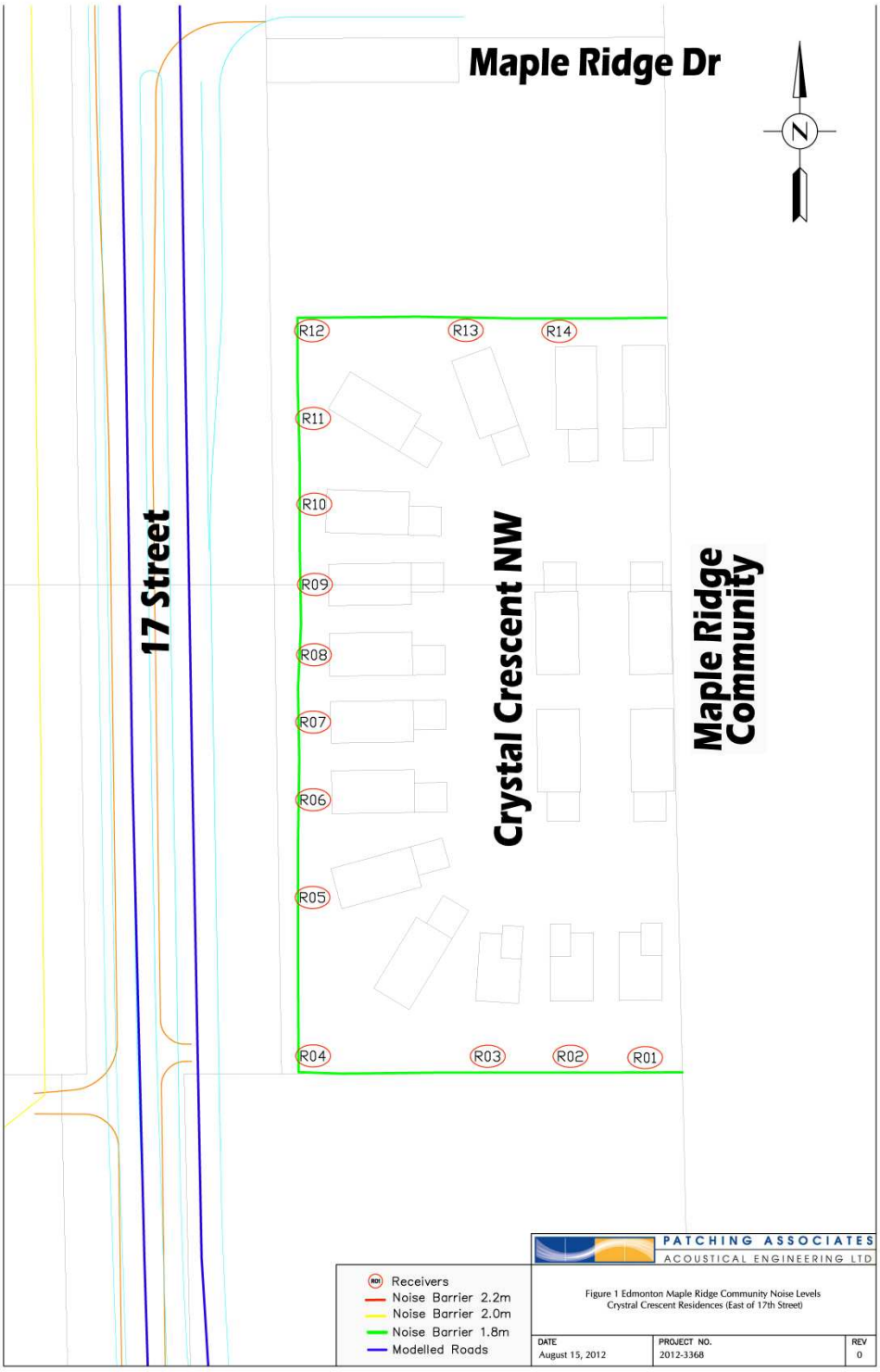
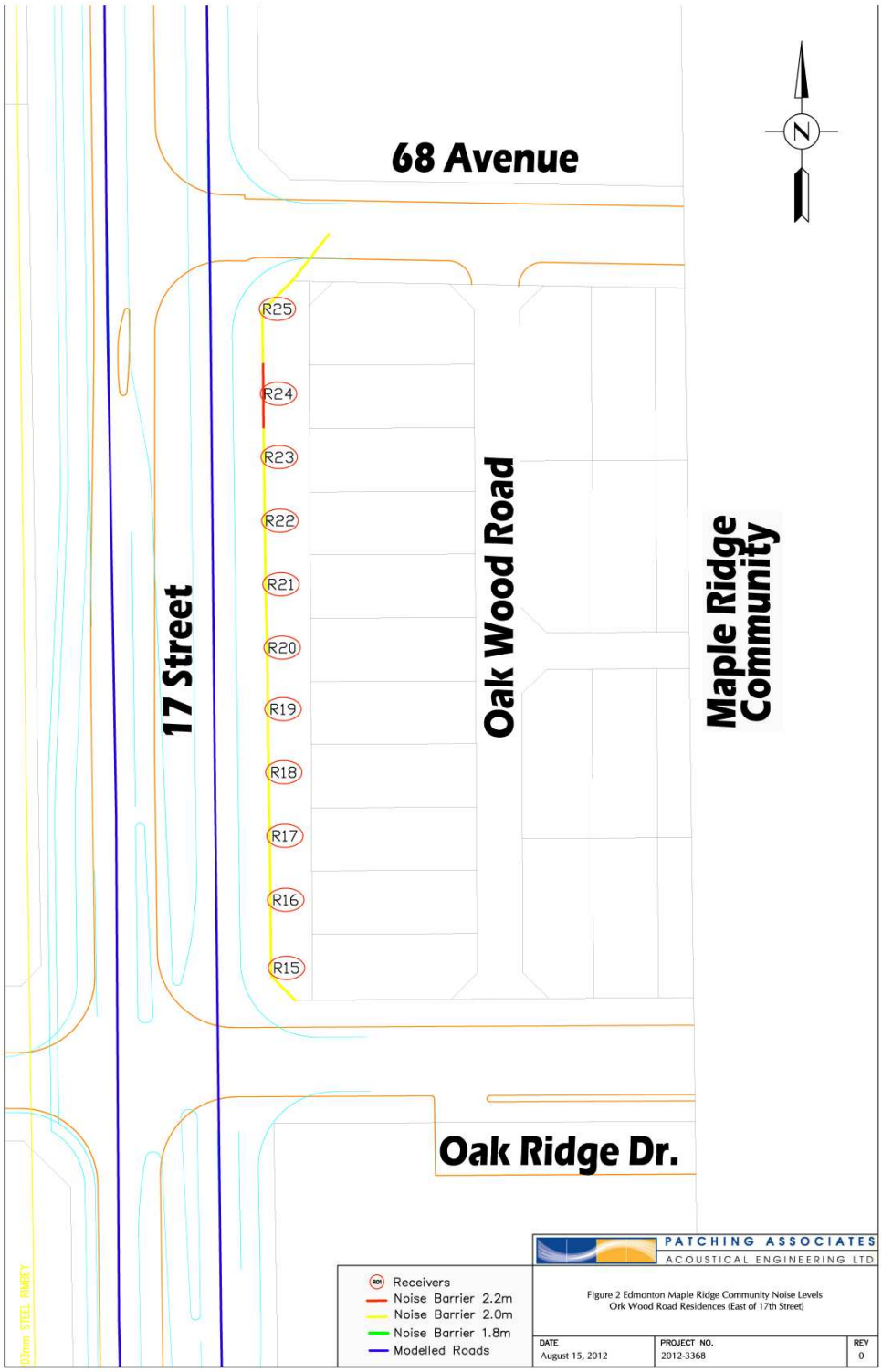


Figure 2 – Barrier Design Study for the Proposed 17th Street Widening (Oak Wood Road Residences)



Discussion and Conclusions On Future Noise Levels and Barrier Specification

The predicted Leq (24 Hour) noise levels with the existing fence attenuation for the developments in the study area range from 56 to 69 dBA for the 17th Street upgraded road design.

The analysis predicts that additional attenuation will be required to meet the Edmonton Urban Traffic Noise Policy (C506) target noise level of 60 dBA Leq (24 Hour). Several sections of barrier wall ranging from 1.8 metres to 2.2 metres high are warranted, to be located at the same locations of the existing fences, with the coordinates for the end points specified within the report:

- 1.8 metres for sections on the west property line locations of Crystal Crescent residences
- 2.0 to 2.2 metres for sections on the west property line locations of Oak Wood residences

Vibration Assessment

Human reaction to vibrations is based more on the maximum levels of the vibration, rather than an overall average as it typically used to assess airborne noise.

On August 28, 2012, a vibration monitor was set up in the park in the Maple Ridge Community. The system consisted of a highly sensitive accelerometer (Brüel and Kjaer type 8306), connected to a Brüel and Kjaer type 2260 precision sound level meter using a direct coupling adapter. The accelerometer was mounted on a platform fastened to the ground using nails, which provides this mount with a resonant frequency above 2 kiloHertz. The monitor was located 32 metres from the near edge of the nearest lane of traffic on 17th Street, and 50 metres south from the edge of 68th Avenue.

From the 1/3 octave measured levels, the maximum vibration velocity was calculated in a deciBel form, using a reference velocity level of 1 microinch per second (abbreviated as 1 μin/sec). A deciBel scale was used, as this logarithmic scale allowed for assessment of vibration of very widely differing levels.

Readings of the acceleration levels were taken in one-second samples in 1/3 octaves for an approximately two hour period in the middle of the day, while there was considerable traffic along 17th Street. Notes were taken of the types and apparent speeds of the traffic – the observed vehicles included heavily loaded trucks travelling at speed, as well as passenger cars and empty trucks. There were also large trucks turning into and out of the industrial area to the west.

A graph of the maximum one-second velocity levels is shown in appendix G.

According to the FTA criterion of 72 dB (ref 1 μin/sec) for frequent events near residences, the current vibration levels exceed this threshold, and were higher than this threshold 19 times in a 2 hour period.

The nearest lane of the upgraded road will move about 5 metres closer to the residences. Although vibration propagation is extremely sensitive to sub-surface conditions, it may be assumed that the maximum levels decrease by approximately 6 dB per doubling of distance (based on energy spreading from a point source). This would increase the levels by about 1.5 dB, which is generally considered an imperceptible change. However, this level is still above the recommended level for residences subjected to frequent (more than 70 per day) events.

As the nearest residences are built as trailers, the nature of the coupling of the residences to the ground is unknown. The way a building is coupled to the ground has a major effect on the transmission of vibrations into the building. This factor make it very difficult to assess what the interior vibration levels would be, and they may be less than what is measured by an instrument directly coupled to the ground.

If anything, the vibration levels at the residences should be only marginally higher than what is currently experienced.

Overall Conclusions

A new noise barrier will be warranted to reduce the future levels from the upgraded and expanded 17th Street at the residences in the Maple Ridge community, in order to meet the City of Edmonton noise policy.

As there are no residences along this section of 17th Street within the County of Strathcona, no analysis was conducted for this portion of the road.

Vibration levels are currently at levels above the recommended levels for frequent events at residences. With the road shifting 5 metres closer to the residences, a marginal increase in vibration levels is expected. The increase is not expected to be perceptible, although the individual events will be perceptible as they are today.

APPENDIX A

Explanation of Technical Details Regarding Sound Measurement and Analysis

Technical Details

Sound is the phenomena of vibrations transmitted through air, or other medium such as water or a building structure. The range of pressure amplitudes, intensities, and frequencies of the sound energy is very wide, and many specialized fields have developed using different ranges of these variables, such as room acoustics and medical ultrasound.

Due to the wide range of intensities, which are perceived as sound, standard engineering units become inconvenient. Sound levels are commonly measured on a logarithmic scale, with the level (in decibels, or dB) being proportional to ten times the common logarithm of the sound energy or intensity. Normal human hearing covers a range of about twelve to fourteen orders of magnitude in energy, from the threshold of hearing to the threshold of pain. On the decibel scale, the threshold of hearing is set as zero, written as 0 dB, while the threshold of pain varies between 120 to 140 dB. The most usual measure of sound is the sound pressure level (SPL), with 0 dB SPL set at 2.0×10^{-5} N/m^2 (also written 20 μPa), which corresponds to a sound intensity of 10^{-12} Watts/m^2 (or 1 picoWatt/m^2, written 1 pW/m^2).

Normal human hearing spans a frequency range from about 20 Hertz (Hz, or cycles per second) to about 20,000 Hz (written 20 KHz). However, the sensitivity of human hearing is not the same at all frequencies. To accommodate the variation in sensitivity, various frequency-weighting scales have been developed. The most common is the A-weighting scale, which is based on the sensitivity of human hearing at moderate levels; this scale reflects the low sensitivity to sounds of very high or very low frequencies. Sound levels measured on the A-weighted scale are written in A-weighted decibels, commonly shown as dBA or dB(A).

When sound is measured using the A-weighting scale, the reading is often called the "Noise level", to confirm that human sensitivity and reactions are being addressed. A table of some common noise sources and their associated noise levels are shown in Table A1.
When the A-weighting scale is not used, the measurement is said to have a "linear" weighting, or to be unweighted, and may be called a "linear" level. As the linear reading is an accurate measurement of the physical (sound) pressure, the term "Sound Pressure Level", or SPL, is usually (but not universally) reserved for unweighted measurements.

Noise is usually defined as "unwanted sound", which indicates that it is not just the physical sound that is important, but also the human reaction to the sound that leads to the perception of sound as noise. It implies a judgment of the quality or quantity of sound experienced. As a human reaction to sound is involved, noise levels are usually given in A-weighted decibels (dBA). An alternate definition of noise is "sound made by somebody else", which emphasizes that the ability to control the level of the sound alters the perception of noise.

Table A1- Noise Levels of Familiar Sources

Source Or Environment	Noise Level (dBA)
High Pressure Steam Venting To Atmosphere (3m)	121
Steam Boiler (2m)	90-95
Drilling Rig (10m)	80-90
Pneumatic Drill (15m)	85
Pump Jack (10m)	68-72
Truck (15m)	65-70
Business Office	65
Conversational Speech (1m)	60
Light Auto Traffic (30m)	50
Living Room	40
Library	35
Soft Whisper (5m)	20-35

The single number A-weighted level is often inadequate for engineering purposes, although it does supply a good estimate of people's reaction to a noise environment. As noise sources, control measures, and materials differ in the frequency dependence of their noise responses or production, sound is measured with a narrower frequency bandwidth; the specific methodology varies with the application. For most wok, the acoustic frequency range is divided into frequency bands where the center frequency of each band is twice the frequency of the next lower band; these are called "Octave" bands, as their frequency relation is called an "Octave" in music, where the field of acoustics has its roots. For more detailed work, the octave bands, and certain standard octave and 1/3 octave bands have been specified by international agreements.

Where the noise at the receiver is steady, it is easy to assess the noise level. However, both the production of noise at the source and the transmission of noise can vary with time; most noise levels are not constant, either because of the motion of the noise source (as in traffic noise), because the noise source itself varies, or because the transmission of sound to the receiver location is not steady as over long distances. This is almost always the case for environmental noise studies. Several single number descriptors have been developed and are used to assess noise in these conditions.

The most common is the measurement of the "equivalent continuous" sound level, or L_{eq}, which is the level of a hypothetical source of a constant level which would give the same total sound energy as is measured during the sampling period. This is the "energy" average noise level. Typical sampling periods are one hour, nighttime (9 hours) or one day (24 hours); the sampling period used must be reported when using this unit.

The greatest value of the L_{eq} is that the contributions of different sources to the total noise level can be assessed, or in a case where a new noise source is to be added to an existing environment, the total noise level from new and old sources can be easily calculated. It is also sensitive to short term high noise levels.

Statistical noise levels are sometimes used to assess an unsteady noise environment. They indicate the levels that are exceeded a fixed percentage of the measurement time period measured. For example, the 10%-ile level, written L_{10}, is the levels exceeded 10% of the time; this level is a good measure of frequent noisy occurrences such as steady road traffic. The 90% level, L_{90}, is the level exceeded 90% of the time, and is the background level, or noise floor. A steady noise source will modify the background level, while an intermittent noise source such as road or rail traffic will affect the short-term levels only.

One disadvantage with the L_{eq} measure, when used alone, is that nearby loud sources (e.g. dogs barking, or birds singing) can confuse the assessment of the situation when it is the noise from a distant plant that is the concern. For this reason, the equivalent level and the statistical levels can be used together to better understand the noise environment. One such indication is the difference between the L_{eq} and the L_{90} levels. A large difference between the L_{eq} and L_{90}, greater than 10 dB, indicates the intrusion of short-term noise events on the general background level. A small difference, less than 5 dB, indicates a very steady noise environment. If the L_{eq} value exceeds the L_{10} value this indicates the presence of significant short-term loud events.

APPENDIX B

Edmonton Urban Traffic Noise Policy (C506)

CITY POLICY

POLICY NUMBER: C506

REFERENCE:
City Council 14 09 04
City of Edmonton Urban Traffic Noise Policy Study (1983)

ADOPTED BY:
City Council

SUPERSEDES:
Repealed Policy C411

PREPARED BY: Transportation and Streets Department **DATE:** 2004-06-15

TITLE: URBAN TRAFFIC NOISE POLICY

Policy Statement:

Mitigating the impact of traffic noise in the urban environment is governed by the following criteria:

The City of Edmonton will seek to ensure that no new residential development less than three storeys will be allowed adjacent to transportation facilities (arterial roadways, light rail transit, and future high speed transit) unless the developer proves to the satisfaction of the City that the projected noise level in outdoor amenity areas will not exceed 60 dBA Leq_{24}. Construction of any noise attenuation measures necessary to achieve this threshold will be funded and undertaken by the developer of the adjacent property, unless specific site characteristics, such as topography or existing land uses, necessitate the consideration of relief from the requirement. Under these circumstances, the attenuated noise level in outdoor amenity areas should be the lowest level technically and economically practicable with an objective of up to 65 dBA Leq_{24}.

The City of Edmonton will seek to ensure that no new residential development of three storeys or greater will be allowed adjacent to transportation facilities (arterial roadways, light rail transit, and future high speed transit) unless the developer proves to the satisfaction of the City that the projected noise level in outdoor amenity areas will not exceed 60 dBA Leq_{24}. Construction of any noise attenuation measures necessary to achieve this threshold will be funded and undertaken by the developer of the adjacent property, unless specific site characteristics, such as topography or existing land uses, necessitate the consideration of relief from the requirement. Under these circumstances, the attenuated noise level in outdoor amenity areas should be the lowest level technically and economically practicable with an objective of up to 65 dBA Leq_{24}. Relief from this requirement may be considered if the residential development does not include any outdoor amenity space.

For residential development without outdoor amenity areas or for residential development of three storeys or more, where the incident sound level at the façade of any dwelling unit exceeds 60 dBA Leq_{24}, the developer is to endeavour to achieve a projected interior noise level, after applying attenuation measures, of 45 dBA Leq_{24} or less. Funding and construction of noise attenuation measures, where appropriate, is provided by the developer of the adjacent property.

The City of Edmonton will seek to achieve a projected attenuated noise level below 65 dBA Leq_{24} or as low as technically, administratively, and economically practical, with an objective of achieving a noise level of 60 dBA Leq_{24}, where any urban transportation facility (major arterial roadway, light rail transit, or future high speed transit) is proposed to be built or upgraded through or adjacent to a developed residential area. Funding for noise attenuation, where appropriate, and subject to availability, is considered in the cost of the project.

Existing residential sites backing onto a transportation facility with measured noise levels of 65 dBA Leq_{24} or above in the rear outdoor amenity area will be considered for noise attenuation by the City of Edmonton, subject to the availability of funds and the endorsement of adjacent property owners. The City will also consider identified “problem” sites with measured noise levels in the discretionary range between 60 dBA Leq_{24} and 65 dBA Leq_{24} as potentially eligible for future noise attenuation.

CITY POLICY

POLICY NUMBER: C506

REFERENCE:
City of Edmonton Urban Traffic Noise Policy Study (1983)

ADOPTED BY:
City Council

SUPERSEDES:

PREPARED BY:	Transportation and Streets Department	**DATE:**	2004-06-15
TITLE:	URBAN TRAFFIC NOISE POLICY		

The purpose of this policy is to:

1. Seek to ensure that the negative impacts associated with the ongoing exposure to excessive traffic noise is mitigated in the City of Edmonton.
2. Assign the responsibility for traffic noise mitigation to the developers of new residential land uses as appropriate.
3. Assign the responsibility for traffic noise mitigation to the City of Edmonton where major transportation facilities are proposed or upgraded, subject to funding availability.
4. Govern the application of the City of Edmonton's "retrofit noise attenuation program", subject to funding availability.

CITY PROCEDURE

		POLICY NUMBER:	C506
AUTHORITY:	City Manager	**EFFECTIVE DATE:**	2004-06-15
TITLE:	URBAN TRAFFIC NOISE POLICY		

1. INTRODUCTION

Urban traffic noise is the "background" noise generated by traffic on major transportation facilities. Vehicle-related noise sources of short duration or limited locational influence, including loud stereos, mufflers, and engine retarder brakes, are not addressed by the Urban Traffic Noise Policy and Procedures.

Noise is measured in decibels. The decibel scale starts at 0, which represents the faintest sound that can be heard by a human with acute hearing. The scale progresses logarithmically; in other words, a sound level of 60 dB is perceived as twice as loud as that of 50 dB. The unit of measurement is denoted as dB.

Arterial roadways, expressways, freeways, light rail transit corridors, and future "high speed transit" corridors are considered major transportation facilities. Rail noise generated by Federally-regulated facilities is not within the jurisdiction of the City of Edmonton's Urban Traffic Noise Policy and Procedures.

The outdoor amenity area is defined as the area immediately adjacent to the housing unit, provided and designed for active or passive recreation and enjoyment of the occupants of a residential development, which may be for private or communal use and owned individually or in common.

2. PROCEDURES

2.01 The City of Edmonton Urban Traffic Noise Policy and Procedures are applied only to residential land uses adjacent to major transportation facilities (arterial roadways, light rail transit, and future high speed transit facilities).

2.02 The City of Edmonton Urban Traffic Noise Policy and Procedures are applied only to the "background" noise generated by traffic on major transportation facilities.

2.03 Noise measurements are undertaken in the rear "amenity" area for residential properties backing onto major transportation facilities. Whenever possible, the City will take noise measurements 3 metres from the rear of the residence at an elevation of approximately 1.5 metres.

2.04 Noise levels are measured in dBA Leq_{24}.

2.05 A 20-year time horizon for traffic volume projections (AAWDT volumes) is used to predict future noise levels adjacent to new developments and new or upgraded transportation facilities.

2.06 Where noise levels are projected to be above 60 dBA Leq_{24} in outdoor amenity areas, after the implementation of noise attenuation measures, the City will endeavour to have the developer inform prospective purchasers or renters of residential dwelling units which are affected by excessive noise, by posting a sign in the affected building or by letter that reads: "Purchasers are advised that despite the inclusion of noise attenuation features with the development area and/or within the individual building unit(s), noise levels may continue to be of concern, occasionally interfering with some activities of the dwelling occupants."

2.07 Noise measurements will be undertaken to establish priorities for retrofit noise attenuation.

CITY PROCEDURE

		POLICY NUMBER:	C506
AUTHORITY:	City Manager	**EFFECTIVE DATE:**	2004-06-15
TITLE:	URBAN TRAFFIC NOISE POLICY		

2.08 The City of Edmonton will undertake a survey of affected property owners to determine support for the installation of any noise attenuation measures proposed under the City's retrofit noise attenuation program. Affected property owners are those who are immediately adjacent to the proposed noise attenuation measure (berm and/or noise wall), in an area encompassing the entire length of the proposed noise attenuation device. Endorsement of the proposed project will be considered sufficient if 60% or more of property owners indicate support (targetting a 100% response rate).

2.09 In the case of an existing residential area, where noise mitigation measures are appropriate and supported, the City will seek to involve community stakeholders in the selection of suitable materials and the design of the structure.

2.10 Residential property owners with existing dwelling units with measured noise levels less than 65 dBA Leq_{24}, who do not fall within the noise attenuation responsibilities of the City, are encouraged to improve the sound environment of their property through acoustically designed building improvements, at their own expense.

2.11 Reports will be provided periodically to City Council on the status of traffic noise attenuation in the City (including a current listing of noise level measurements).

2.12 The City of Edmonton will continue to use a series of brochures and Traffic Noise Bulletins to communicate the City's Urban Traffic Noise Policy and Procedures, programs, and abatement measures that may be employed by individual home owners to improve their indoor sound environment.

2.13 The City of Edmonton will continue to use the Transportation Association of Canada (TAC) methodology to estimate noise levels where measurements are not available and to predict future noise levels based on anticipated traffic volumes. The results of other recognized noise predication models may be accepted with appropriate documentation provided by acoustical consultants in the submission of noise impact studies.

2.14 The appropriate departments within the City will continue to consult with respect to the land use planning implications of traffic noise, as appropriate, at the Area Structure Plan, Neighbourhood Structure Plan, Subdivision, and Development Application stages of the planning process.

APPENDIX C

Measurement Results Graphs of 1 Minute Sound Data

Residence at 27 Crystal Lane

Figure C.1

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Yard at 27 Crystal Lane

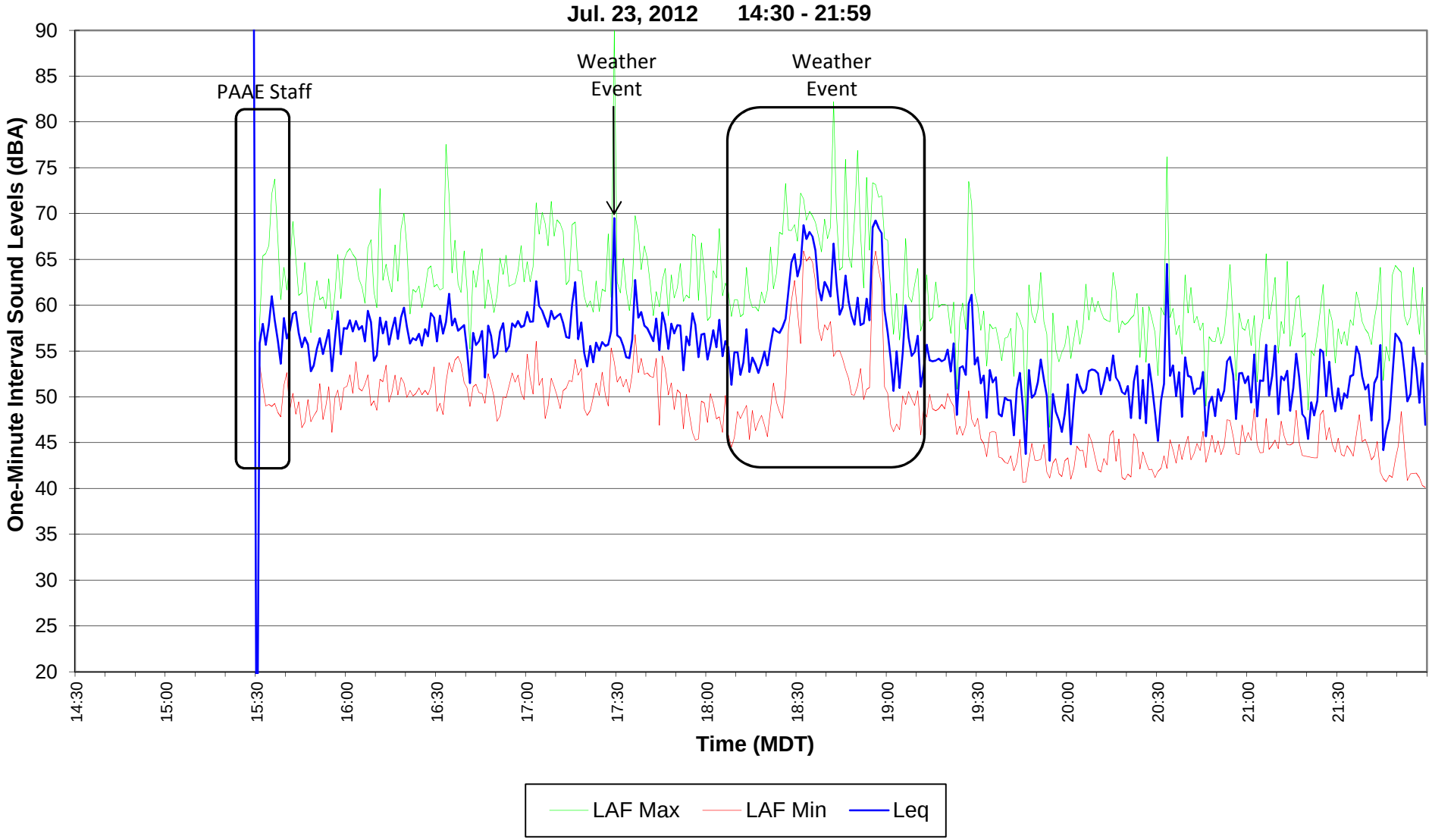


Figure C.2

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Yard at 27 Crystal Lane

Jul. 23, 2012 - Jul. 24, 2012 22:00 - 06:59

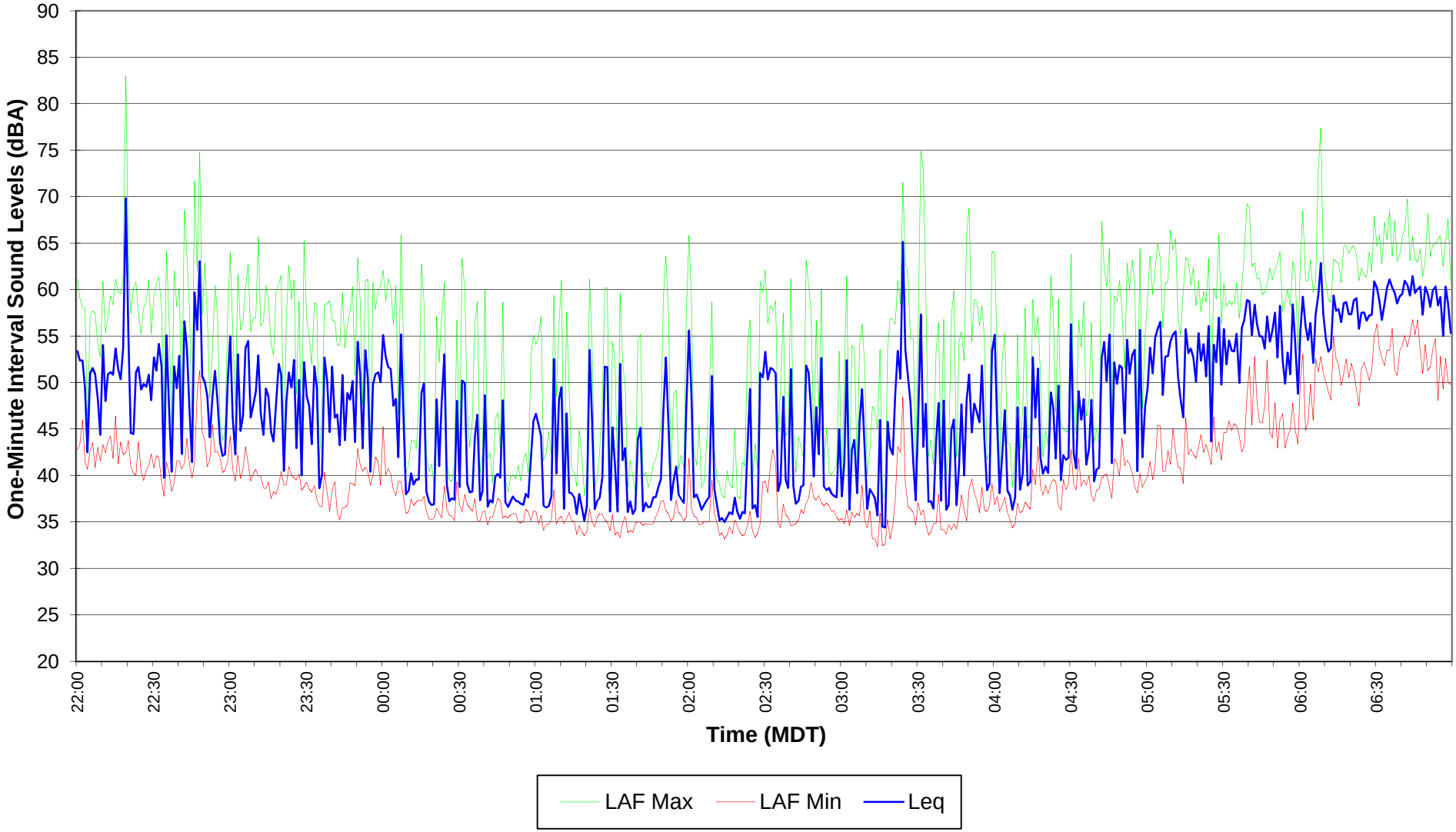


Figure C.3

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Yard at 27 Crystal Lane

Jul. 24, 2012 07:00 - 14:29

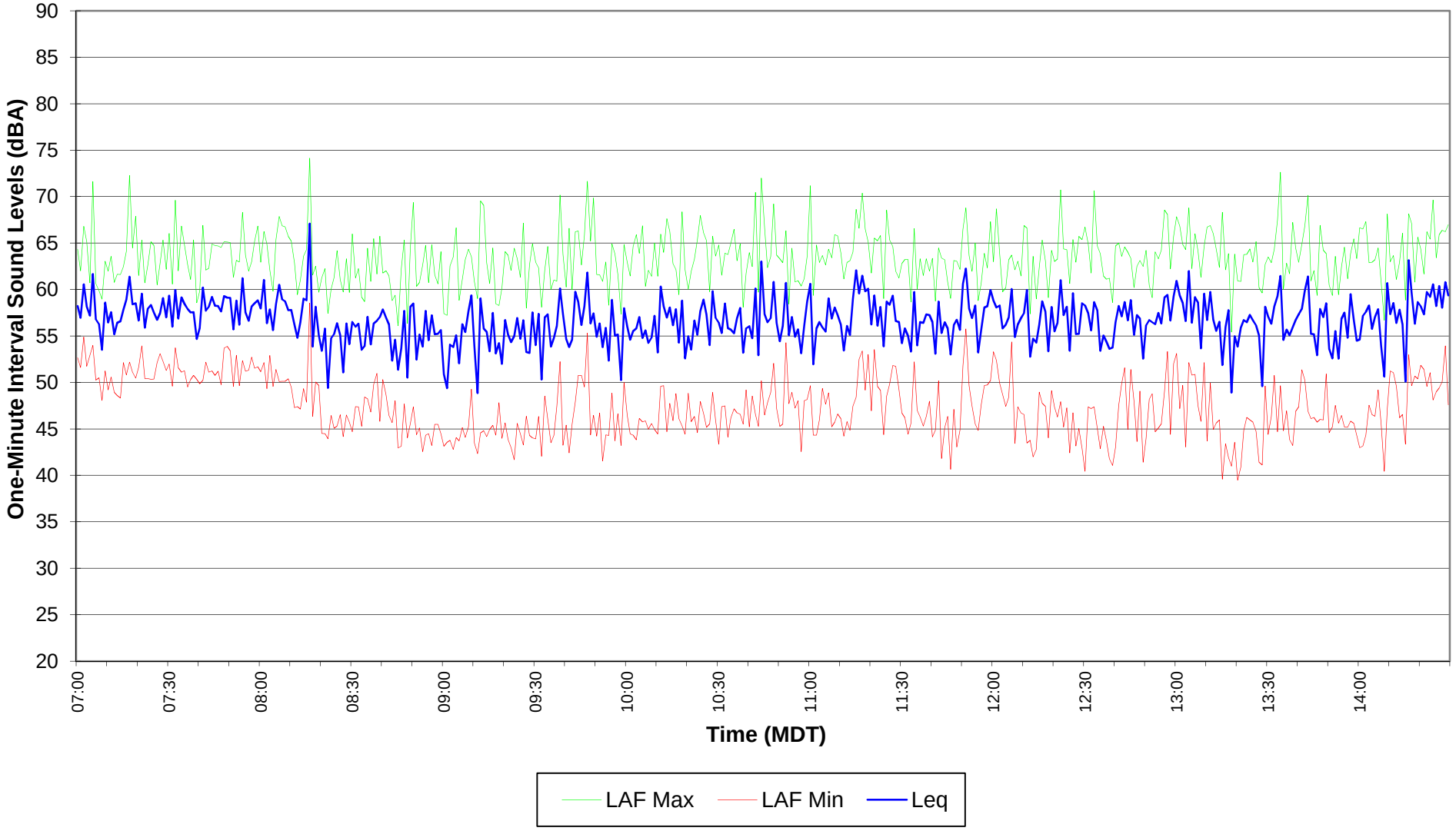
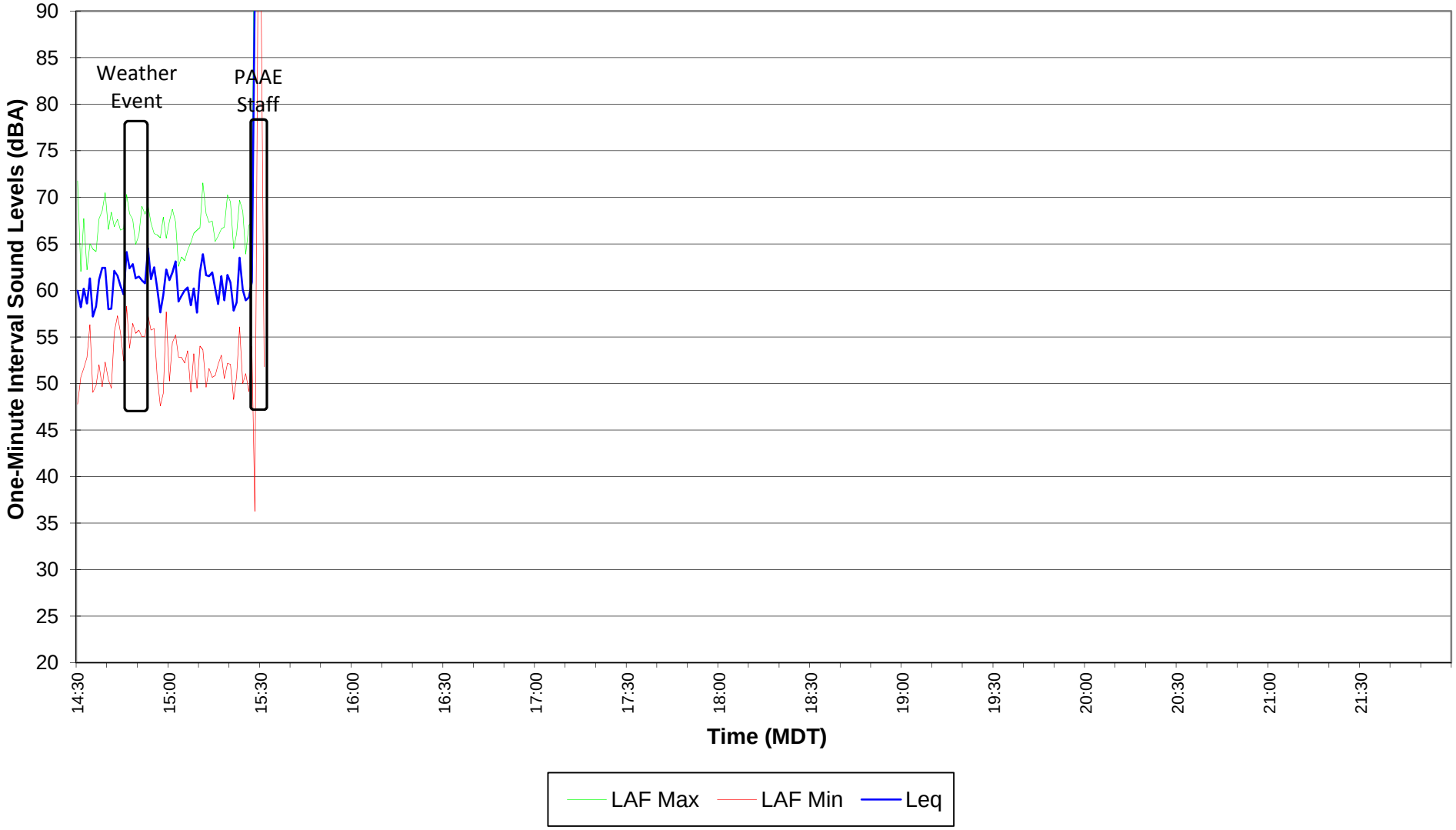


Figure C.4

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Yard at 27 Crystal Lane

Jul. 24, 2012 14:30 - 21:59



APPENDIX D

Measurement Results Graphs of 1 Minute Sound Data

In Park

Figure D.1

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Park 30 metres from 17th Street

Jul. 23, 2012 07:00 - 14:29

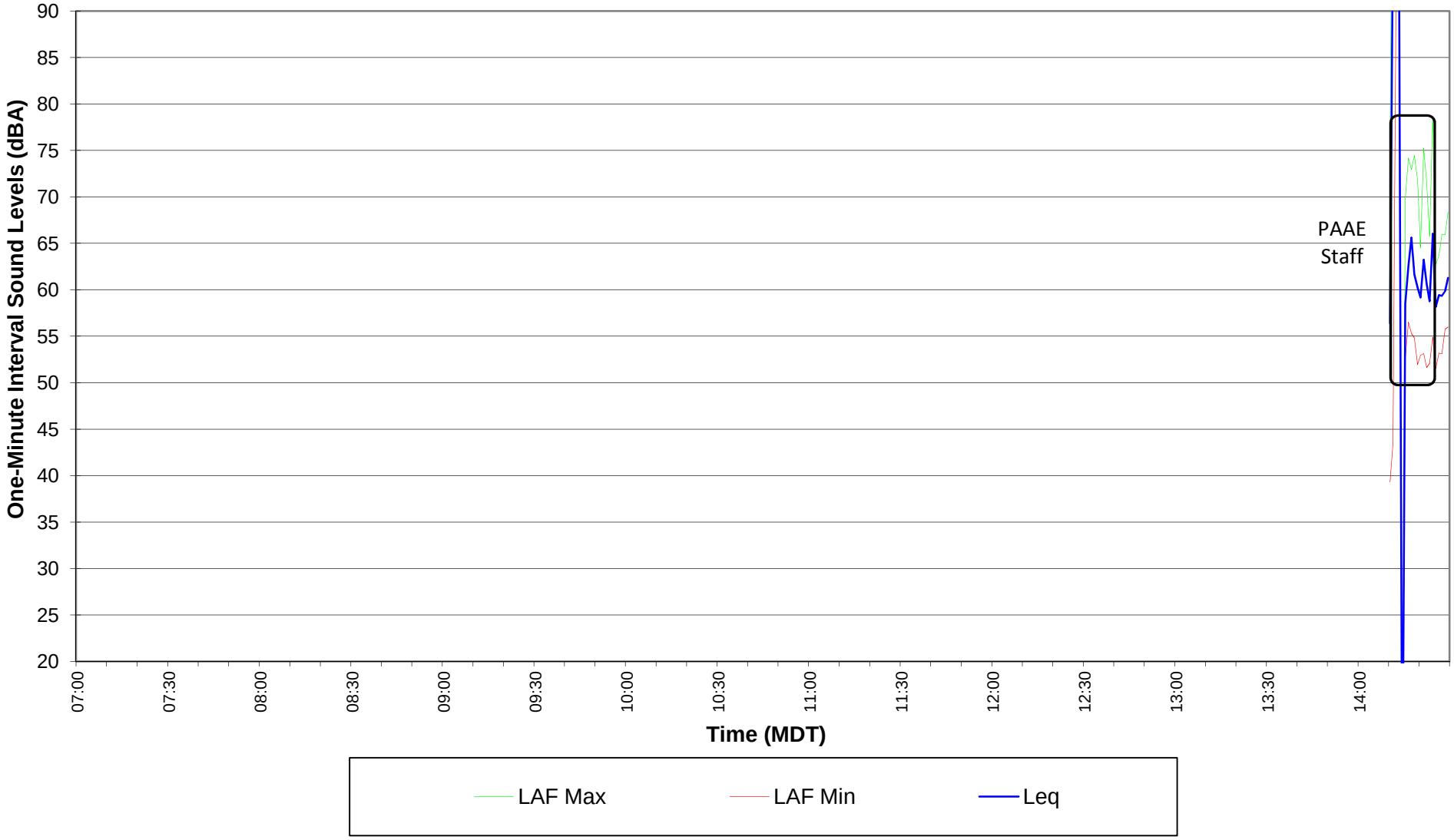


Figure D.2

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Park 30 metres from 17th Street

Jul. 23, 2012 14:30 - 21:59

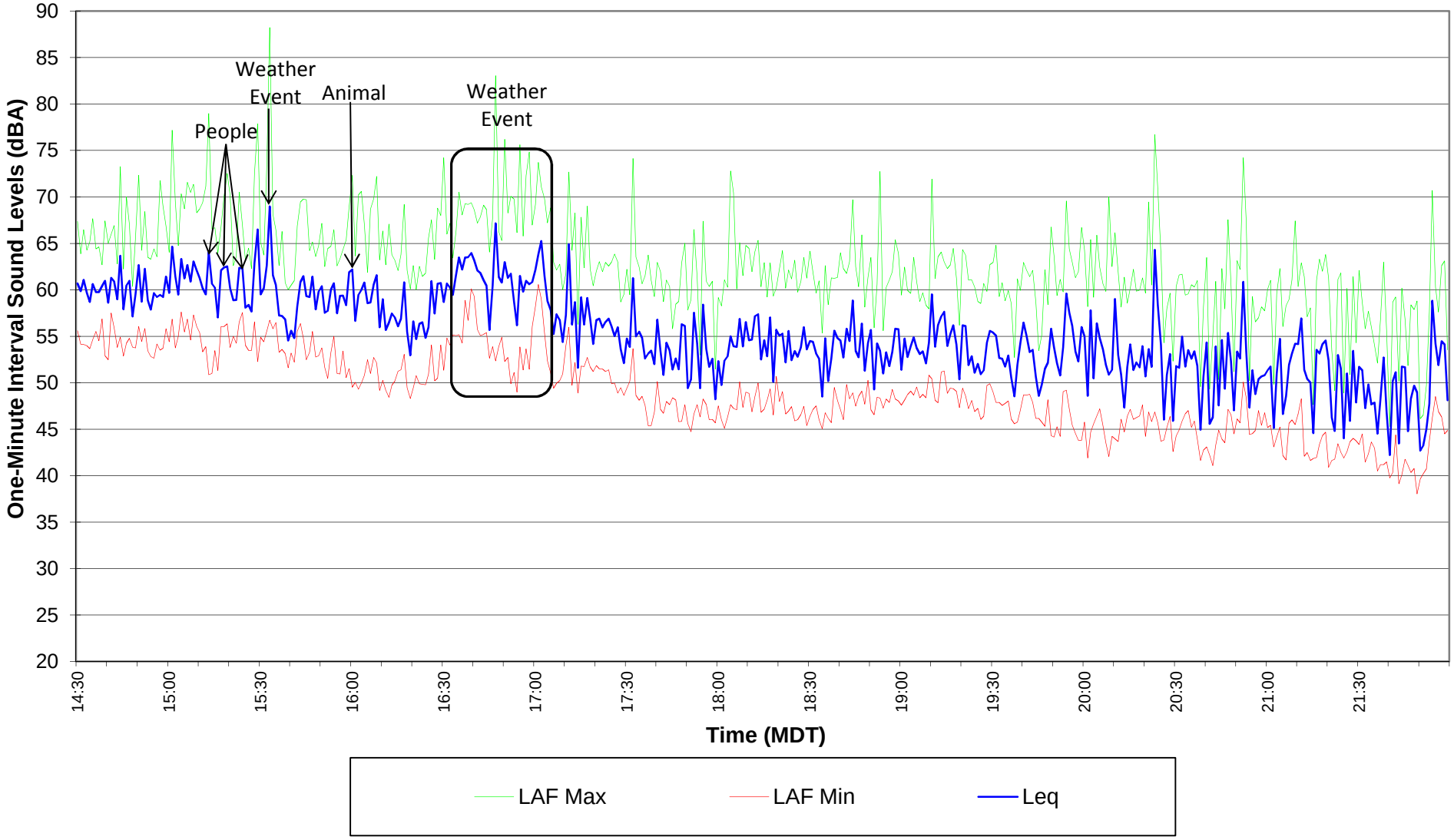


Figure D.3

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Park 30 metres from 17th Street

Jul. 23, 2012 - Jul. 24, 2012 22:00 - 06:59

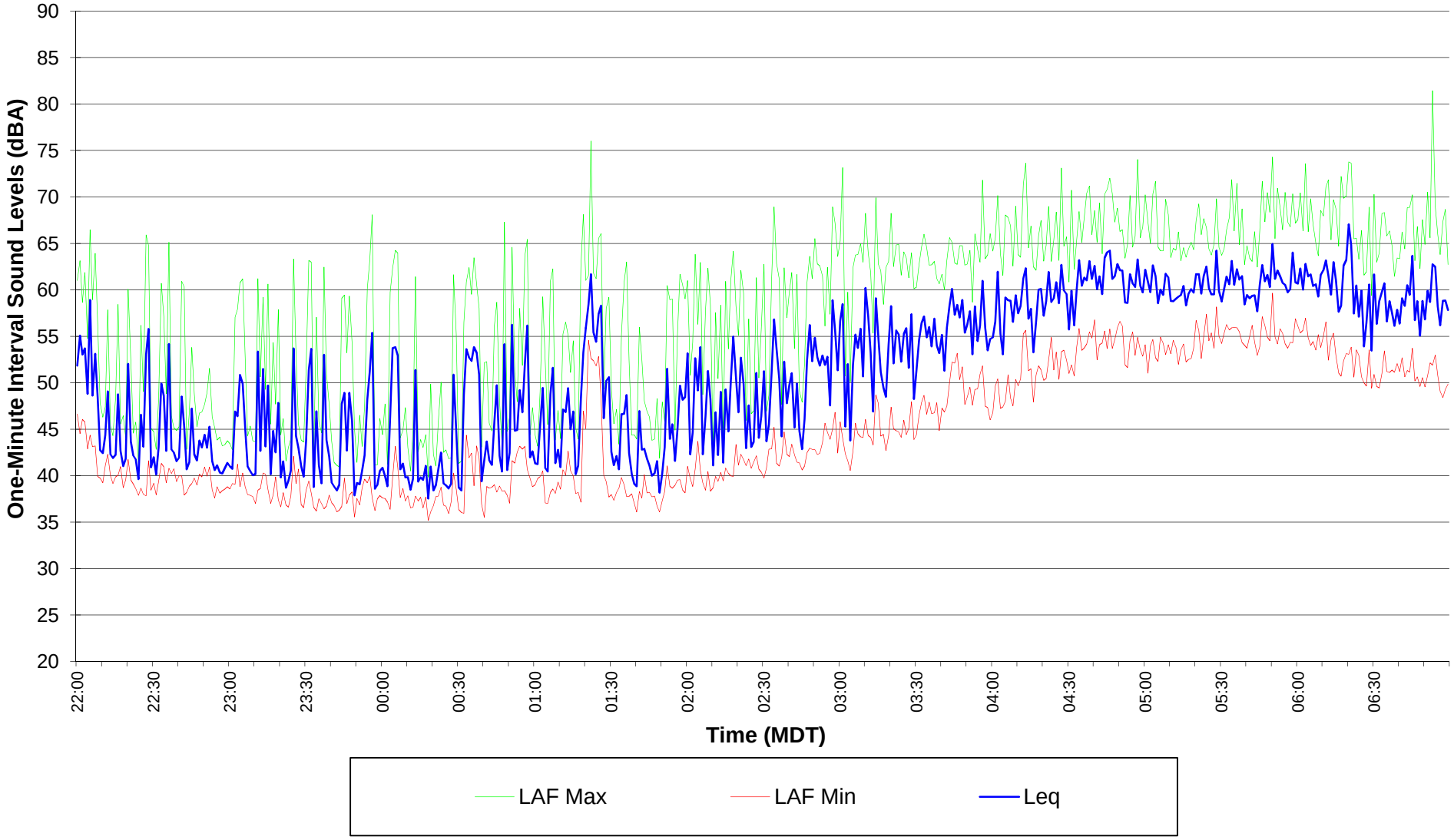
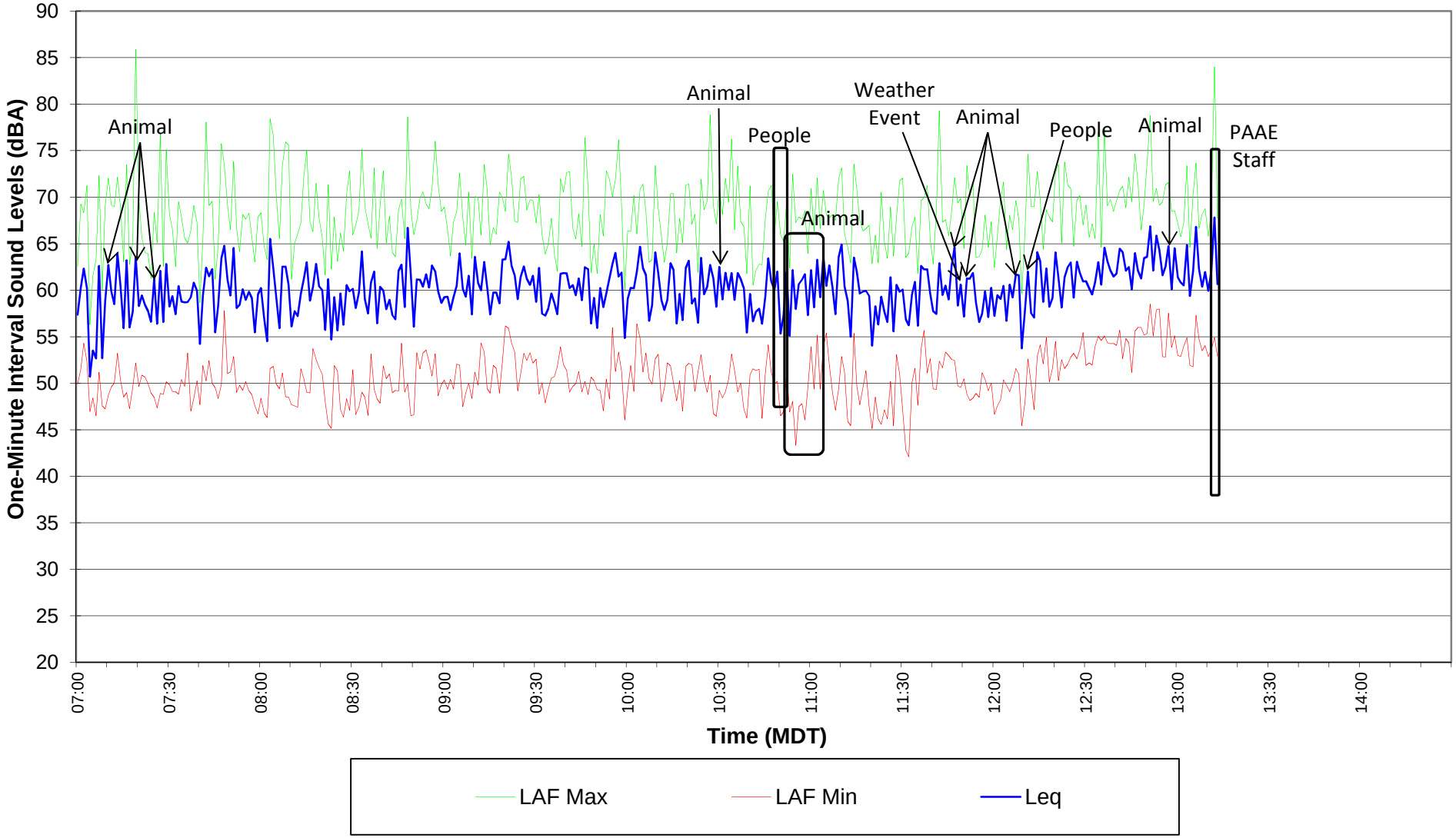


Figure D.4

3368 McElhanney City of Edmonton 17 Street Planning and Design

Noise Survey In Park 30 metres from 17th Street

Jul. 24, 2012 07:00 - 14:29



APPENDIX E

Site Plans
Receiver, Barrier, Roadway Point Locations and Traffic

Maple Ridge Dr

N

R12 R13 R14

R11

R10

R09

R08

R07

R06

R05

R04 R03 R02 R01

17 Street

Crystal Crescent NW

Maple Ridge Community

R01 Receivers

Noise Barrier 2.2m

Noise Barrier 2.0m

Noise Barrier 1.8m

Modelled Roads

PATCHING ASSOCIATES
ACOUSTICAL ENGINEERING LTD

Figure 1 Edmonton Maple Ridge Community Noise Levels
Crystral Crescent Residences (East of 17th Street)

DATE	PROJECT NO.	REV
August 15, 2012	2012-3368	0

68 Avenue

17 Street

Oak Wood Road

Maple Ridge Community

Oak Ridge Dr.

R25
R24
R23
R22
R21
R20
R19
R18
R17
R16
R15

203mm STEEL RIMBEY

N

R01 Receivers
Noise Barrier 2.2m
Noise Barrier 2.0m
Noise Barrier 1.8m
Modelled Roads

PATCHING ASSOCIATES
ACOUSTICAL ENGINEERING LTD

Figure 2 Edmonton Maple Ridge Community Noise Levels
Ork Wood Road Residences (East of 17th Street)

DATE	PROJECT NO.	REV
August 15, 2012	2012-3368	0

PAAE 15 August 2012
SS TNM 2.5

INPUT: RECEIVERS
PROJECT/CONTRACT: 2012-3368
RUN: Edmonton 17th Street NIA

Receiver Name	No.	#DUs	Coordinates (ground) X	Y	Z	Height above Ground	Input Sound Levels and Criteria: Existing LAeq1h	Impact Criteria LAeq1h	Impact Criteria Sub'l	NR Goal	Active in Calc.
			m	m	m	m	dBA	dBA	dB	dB	
R01	1	1	41,963.3	5,929,589.0	701.86	1.50	0.00	60	10.0	8.0	Y
R02	2	1	41,948.3	5,929,589.0	701.65	1.50	0.00	60	10.0	8.0	Y
R03	3	1	41,931.2	5,929,589.0	701.48	1.50	0.00	60	10.0	8.0	Y
R04	4	1	41,895.1	5,929,589.0	700.99	1.50	0.00	60	10.0	8.0	Y
R05	5	1	41,895.0	5,929,622.0	700.57	1.50	0.00	60	10.0	8.0	Y
R06	6	1	41,895.2	5,929,642.0	700.53	1.50	0.00	60	10.0	8.0	Y
R07	7	1	41,895.2	5,929,658.0	700.37	1.50	0.00	60	10.0	8.0	Y
R08	8	1	41,895.3	5,929,672.0	700.27	1.50	0.00	60	10.0	8.0	Y
R09	9	1	41,895.5	5,929,686.5	700.17	1.50	0.00	60	10.0	8.0	Y
R10	10	1	41,895.4	5,929,703.0	700.12	1.50	0.00	60	10.0	8.0	Y
R11	11	1	41,895.2	5,929,721.0	700.03	1.50	0.00	60	10.0	8.0	Y
R12	12	1	41,894.9	5,929,739.0	699.90	1.50	0.00	60	10.0	8.0	Y
R13	13	1	41,926.6	5,929,739.0	700.41	1.50	0.00	60	10.0	8.0	Y
R14	14	1	41,945.9	5,929,739.0	700.81	1.50	0.00	60	10.0	8.0	Y
R15	15	1	41,882.2	5,930,217.5	701.79	1.50	0.00	60	10.0	8.0	Y
R16	16	1	41,882.0	5,930,230.5	701.93	1.50	0.00	60	10.0	8.0	Y
R17	17	1	41,881.9	5,930,243.0	701.88	1.50	0.00	60	10.0	8.0	Y
R18	18	1	41,881.7	5,930,256.0	701.86	1.50	0.00	60	10.0	8.0	Y
R19	19	1	41,881.5	5,930,268.0	701.84	1.50	0.00	60	10.0	8.0	Y
R20	20	1	41,881.4	5,930,280.0	701.81	1.50	0.00	60	10.0	8.0	Y
R21	21	1	41,881.1	5,930,293.0	701.82	1.50	0.00	60	10.0	8.0	Y
R22	22	1	41,880.9	5,930,305.0	701.81	1.50	0.00	60	10.0	8.0	Y

R23	23	1	41,880.8	5,930,318.0	701.50	1.50	0.00	60	10.0	8.0	Y
R24	24	1	41,880.6	5,930,330.0	701.50	1.50	0.00	60	10.0	8.0	Y
R25	25	1	41,880.4	5,930,347.5	701.01	1.50	0.00	60	10.0	8.0	Y

PAAE	15 August 2012
SS	TNM 2.5
INPUT: BARRIERS	
PROJECT/CONTRACT:	2012-3368
RUN:	Edmonton 17th Street NIA

Barrier									Points										
Name	Type	Height		If Wall	If Berm			Add'tnl	Name	No.	Coordinates (bottom)			Height	Segment				
		Min	Max	$ per	$ per	Top	Run:Rise	$ per			X	Y	Z	at	Seg Ht Perturbs			On	Important
				Unit	Unit	Width		Unit						Point	Incre-	#Up	#Dn	Struct?	Reflec-
				Area	Vol.			Length							ment				tions?
		m	m	$/sq m	$/cu m	m	m:m	$/m			m	m	m	m	m				
Crystal Crescent Barrier	W	0.00	30.48	0.00				0.00	point1	1	41,968.0	5,929,742.0	701.31	1.80	0.20	5	0		
									point2	2	41,955.2	5,929,742.0	700.96	1.80	0.20	5	0		
									point3	3	41,936.7	5,929,742.0	700.59	1.80	0.20	5	0		
									point4	4	41,916.6	5,929,742.0	700.08	1.80	0.20	5	0		
									point5	5	41,891.9	5,929,742.0	699.77	1.80	0.20	5	0		
									point6	6	41,891.9	5,929,730.0	700.00	1.80	0.20	5	0		
									point7	7	41,892.4	5,929,711.5	700.02	1.80	0.20	5	0		
									point8	8	41,892.4	5,929,694.5	700.09	1.80	0.20	5	0		
									point9	9	41,892.6	5,929,678.5	700.18	1.80	0.20	5	0		
									point10	10	41,892.0	5,929,666.0	700.25	1.80	0.20	5	0		
									point11	11	41,892.3	5,929,650.5	700.38	1.80	0.20	5	0		
									point12	12	41,892.0	5,929,633.5	700.55	1.80	0.20	5	0		
									point13	13	41,892.0	5,929,610.5	700.63	1.80	0.20	5	0		
									point14	14	41,892.1	5,929,586.0	701.28	1.80	0.20	5	0		
									point15	15	41,901.1	5,929,586.0	701.42	1.80	0.20	5	0		
									point16	16	41,921.0	5,929,586.0	701.53	1.80	0.20	5	0		
									point17	17	41,941.3	5,929,586.0	701.85	1.80	0.20	5	0		
									point18	18	41,955.2	5,929,586.0	702.02	1.80	0.20	5	0		
									point19	19	41,971.4	5,929,586.0	702.13	1.80					
Ork Wood Road Barrier	W	0.00	30.48	0.00				0.00	point34	34	41,890.5	5,930,362.0	700.50	1.80	0.20	5	0		
									point35	35	41,883.3	5,930,353.0	700.65	1.80	0.20	5	0		
									point36	36	41,877.4	5,930,347.5	701.01	1.80	0.20	5	0		
									point37	37	41,877.6	5,930,336.5	701.50	1.80	0.20	5	0		
									point38	38	41,877.7	5,930,324.0	701.50	1.80	0.20	5	0		
									point39	39	41,877.9	5,930,311.5	701.78	1.80	0.20	5	0		
									point40	40	41,878.0	5,930,299.0	702.00	1.80	0.20	5	0		
									point41	41	41,878.2	5,930,286.5	702.00	1.80	0.20	5	0		
									point42	42	41,878.5	5,930,274.0	702.00	1.80	0.20	5	0		
									point43	43	41,878.5	5,930,262.0	702.00	1.80	0.20	5	0		
									point44	44	41,878.8	5,930,250.0	702.00	1.80	0.20	5	0		
									point45	45	41,879.0	5,930,237.0	702.00	1.80	0.20	5	0		
									point46	46	41,879.1	5,930,224.0	702.00	1.80	0.20	5	0		
									point47	47	41,879.2	5,930,216.0	702.00	1.80	0.20	5	0		
									point48	48	41,883.9	5,930,211.5	701.00	1.80					

PAAE	15 August 2012
SS	TNM 2.5
INPUT: ROADWAYS	Average pavement type shall be used unless
PROJECT/CONTRACT:	2012-3368 a State highway agency substantiates the use
RUN:	Edmonton 17th Street NIA of a different type with the approval of FHWA

Roadway		Points					Flow Control			Segment	
Name	Width	Name	No.	Coordinates (pavement) X	Y	Z	Control Device	Speed Constraint	Percent Vehicles Affected	Pvmt Type	On Struct?
	m			m	m	m		km/h	%		
17th St NB	7.3	point37	37	41,912.4	5,928,038.5	709.00				Average	
		point36	36	41,909.4	5,928,148.5	707.00				Average	
		point35	35	41,907.4	5,928,248.5	705.50				Average	
		point34	34	41,906.3	5,928,348.5	704.50				Average	
		point33	33	41,902.6	5,928,448.5	704.00				Average	
		point32	32	41,898.7	5,928,548.5	703.84				Average	
		point31	31	41,896.3	5,928,648.5	702.47				Average	
		point30	30	41,894.2	5,928,748.5	702.00				Average	
		point29	29	41,891.8	5,928,848.5	701.06				Average	
		point28	28	41,889.9	5,928,948.5	701.17				Average	
		point27	27	41,893.7	5,929,048.0	701.50				Average	
		point26	26	41,892.6	5,929,148.0	702.00				Average	
		point25	25	41,888.1	5,929,249.0	703.94				Average	
		point24	24	41,885.0	5,929,349.0	704.49				Average	
		point23	23	41,878.3	5,929,448.0	702.66				Average	
		point22	22	41,872.1	5,929,548.0	701.05				Average	
		point21	21	41,870.2	5,929,648.0	699.61				Average	
		point20	20	41,868.5	5,929,748.5	698.00				Average	
		point19	19	41,866.9	5,929,848.0	696.67				Average	
		point18	18	41,866.6	5,929,898.0	696.50				Average	
		point17	17	41,868.6	5,929,948.0	697.00				Average	
		point16	16	41,870.9	5,929,998.5	698.45				Average	
		point15	15	41,870.9	5,930,048.0	700.00				Average	
		point14	14	41,869.3	5,930,148.0	700.31				Average	
		point13	13	41,868.2	5,930,248.0	701.30				Average	

		point12	12	41,867.2	5,930,348.0	700.50				Average	
		point11	11	41,866.1	5,930,448.0	700.15				Average	
		point10	10	41,864.3	5,930,548.0	699.50				Average	
		point9	9	41,863.2	5,930,648.0	699.00				Average	
		point8	8	41,861.8	5,930,748.0	697.50				Average	
		point7	7	41,860.3	5,930,848.0	696.50				Average	
		point6	6	41,859.2	5,930,948.0	696.00				Average	
		point5	5	41,857.8	5,931,047.5	695.07				Average	
		point4	4	41,856.5	5,931,147.5	694.21				Average	
		point3	3	41,855.1	5,931,248.5	694.68				Average	
		point2	2	41,854.0	5,931,347.5	694.38				Average	
		point1	1	41,853.8	5,931,376.5	693.73					
17th St SB	7.3	point72	72	41,833.7	5,931,375.5	693.50				Average	
		point71	71	41,834.1	5,931,348.5	694.00				Average	
		point70	70	41,835.4	5,931,247.5	694.42				Average	
		point69	69	41,836.8	5,931,147.5	694.50				Average	
		point68	68	41,838.1	5,931,047.5	695.50				Average	
		point67	67	41,839.2	5,930,948.0	696.50				Average	
		point66	66	41,840.6	5,930,848.0	697.50				Average	
		point65	65	41,841.9	5,930,748.0	698.50				Average	
		point64	64	41,843.1	5,930,648.5	699.50				Average	
		point63	63	41,844.8	5,930,548.5	700.00				Average	
		point62	62	41,845.9	5,930,448.0	700.50				Average	
		point61	61	41,846.9	5,930,347.5	700.50				Average	
		point60	60	41,848.6	5,930,248.0	701.00				Average	
		point59	59	41,849.2	5,930,148.0	700.88				Average	
		point58	58	41,851.1	5,930,048.0	699.50				Average	
		point57	57	41,852.6	5,929,948.0	698.00				Average	
		point56	56	41,854.4	5,929,848.0	697.58				Average	
		point55	55	41,856.3	5,929,748.0	699.00				Average	
		point54	54	41,857.8	5,929,648.0	700.31				Average	
		point53	53	41,860.3	5,929,548.0	701.73				Average	
		point52	52	41,863.4	5,929,448.0	703.00				Average	
		point51	51	41,866.2	5,929,348.0	704.00				Average	
		point50	50	41,868.3	5,929,248.0	703.70				Average	
		point49	49	41,869.0	5,929,148.0	702.50				Average	
		point48	48	41,871.1	5,929,048.0	702.38				Average	
		point47	47	41,873.8	5,928,948.5	702.42				Average	
		point46	46	41,875.4	5,928,848.5	702.43				Average	

		point45	45	41,878.1	5,928,747.5	703.00				Average	
		point44	44	41,880.6	5,928,647.5	704.50				Average	
		point43	43	41,883.0	5,928,548.5	704.50				Average	
		point42	42	41,882.2	5,928,448.5	704.50				Average	
		point41	41	41,883.3	5,928,348.5	705.32				Average	
		point40	40	41,884.1	5,928,248.5	705.62				Average	
		point39	39	41,885.2	5,928,148.5	706.50				Average	
		point38	38	41,886.2	5,928,048.5	707.09					

PAAE 15 August 2012
SS TNM 2.5

INPUT: TRAFFIC FOR LAeq1h Volumes
PROJECT/CONTRACT: 2012-3368
RUN: Edmonton 17th Street NIA

Roadway	Points		Segment									
Name	Name	No.	Autos		MTrucks		HTrucks		Buses		Motorcycles	
			V	S	V	S	V	S	V	S	V	S
			veh/hr	km/h	veh/hr	km/h	veh/hr	km/h	veh/hr	km/h	veh/hr	km/h
17th St NB	point37	37	427	70	47	70	47	70	0	0	0	0
	point36	36	427	70	47	70	47	70	0	0	0	0
	point35	35	427	70	47	70	47	70	0	0	0	0
	point34	34	427	70	47	70	47	70	0	0	0	0
	point33	33	427	70	47	70	47	70	0	0	0	0
	point32	32	427	70	47	70	47	70	0	0	0	0
	point31	31	427	70	47	70	47	70	0	0	0	0
	point30	30	427	70	47	70	47	70	0	0	0	0
	point29	29	427	70	47	70	47	70	0	0	0	0
	point28	28	427	70	47	70	47	70	0	0	0	0
	point27	27	427	70	47	70	47	70	0	0	0	0
	point26	26	427	70	47	70	47	70	0	0	0	0
	point25	25	427	70	47	70	47	70	0	0	0	0
	point24	24	427	70	47	70	47	70	0	0	0	0
	point23	23	427	70	47	70	47	70	0	0	0	0
	point22	22	427	70	47	70	47	70	0	0	0	0
	point21	21	427	70	47	70	47	70	0	0	0	0
	point20	20	427	70	47	70	47	70	0	0	0	0
	point19	19	427	70	47	70	47	70	0	0	0	0
	point18	18	427	70	47	70	47	70	0	0	0	0
	point17	17	427	70	47	70	47	70	0	0	0	0
	point16	16	427	70	47	70	47	70	0	0	0	0
	point15	15	427	70	47	70	47	70	0	0	0	0

	point14	14	427	70	47	70	47	70	0	0	0	0
	point13	13	427	70	47	70	47	70	0	0	0	0
	point12	12	427	70	47	70	47	70	0	0	0	0
	point11	11	427	70	47	70	47	70	0	0	0	0
	point10	10	427	70	47	70	47	70	0	0	0	0
	point9	9	427	70	47	70	47	70	0	0	0	0
	point8	8	427	70	47	70	47	70	0	0	0	0
	point7	7	427	70	47	70	47	70	0	0	0	0
	point6	6	427	70	47	70	47	70	0	0	0	0
	point5	5	427	70	47	70	47	70	0	0	0	0
	point4	4	427	70	47	70	47	70	0	0	0	0
	point3	3	427	70	47	70	47	70	0	0	0	0
	point2	2	427	70	47	70	47	70	0	0	0	0
	point1	1										
17th St SB	point72	72	427	70	47	70	47	70	0	0	0	0
	point71	71	427	70	47	70	47	70	0	0	0	0
	point70	70	427	70	47	70	47	70	0	0	0	0
	point69	69	427	70	47	70	47	70	0	0	0	0
	point68	68	427	70	47	70	47	70	0	0	0	0
	point67	67	427	70	47	70	47	70	0	0	0	0
	point66	66	427	70	47	70	47	70	0	0	0	0
	point65	65	427	70	47	70	47	70	0	0	0	0
	point64	64	427	70	47	70	47	70	0	0	0	0
	point63	63	427	70	47	70	47	70	0	0	0	0
	point62	62	427	70	47	70	47	70	0	0	0	0
	point61	61	427	70	47	70	47	70	0	0	0	0
	point60	60	427	70	47	70	47	70	0	0	0	0
	point59	59	427	70	47	70	47	70	0	0	0	0
	point58	58	427	70	47	70	47	70	0	0	0	0
	point57	57	427	70	47	70	47	70	0	0	0	0
	point56	56	427	70	47	70	47	70	0	0	0	0
	point55	55	427	70	47	70	47	70	0	0	0	0
	point54	54	427	70	47	70	47	70	0	0	0	0
	point53	53	427	70	47	70	47	70	0	0	0	0
	point52	52	427	70	47	70	47	70	0	0	0	0
	point51	51	427	70	47	70	47	70	0	0	0	0

	point50	50	427	70	47	70	47	70	0	0	0	0
	point49	49	427	70	47	70	47	70	0	0	0	0
	point48	48	427	70	47	70	47	70	0	0	0	0
	point47	47	427	70	47	70	47	70	0	0	0	0
	point46	46	427	70	47	70	47	70	0	0	0	0
	point45	45	427	70	47	70	47	70	0	0	0	0
	point44	44	427	70	47	70	47	70	0	0	0	0
	point43	43	427	70	47	70	47	70	0	0	0	0
	point42	42	427	70	47	70	47	70	0	0	0	0
	point41	41	427	70	47	70	47	70	0	0	0	0
	point40	40	427	70	47	70	47	70	0	0	0	0
	point39	39	427	70	47	70	47	70	0	0	0	0
	point38	38										

APPENDIX F

Vibration Criteria

(per US Federal Transit Administration Guidelines)

Table 8-1 Ground-Borne Vibration and Noise Impact Criteria

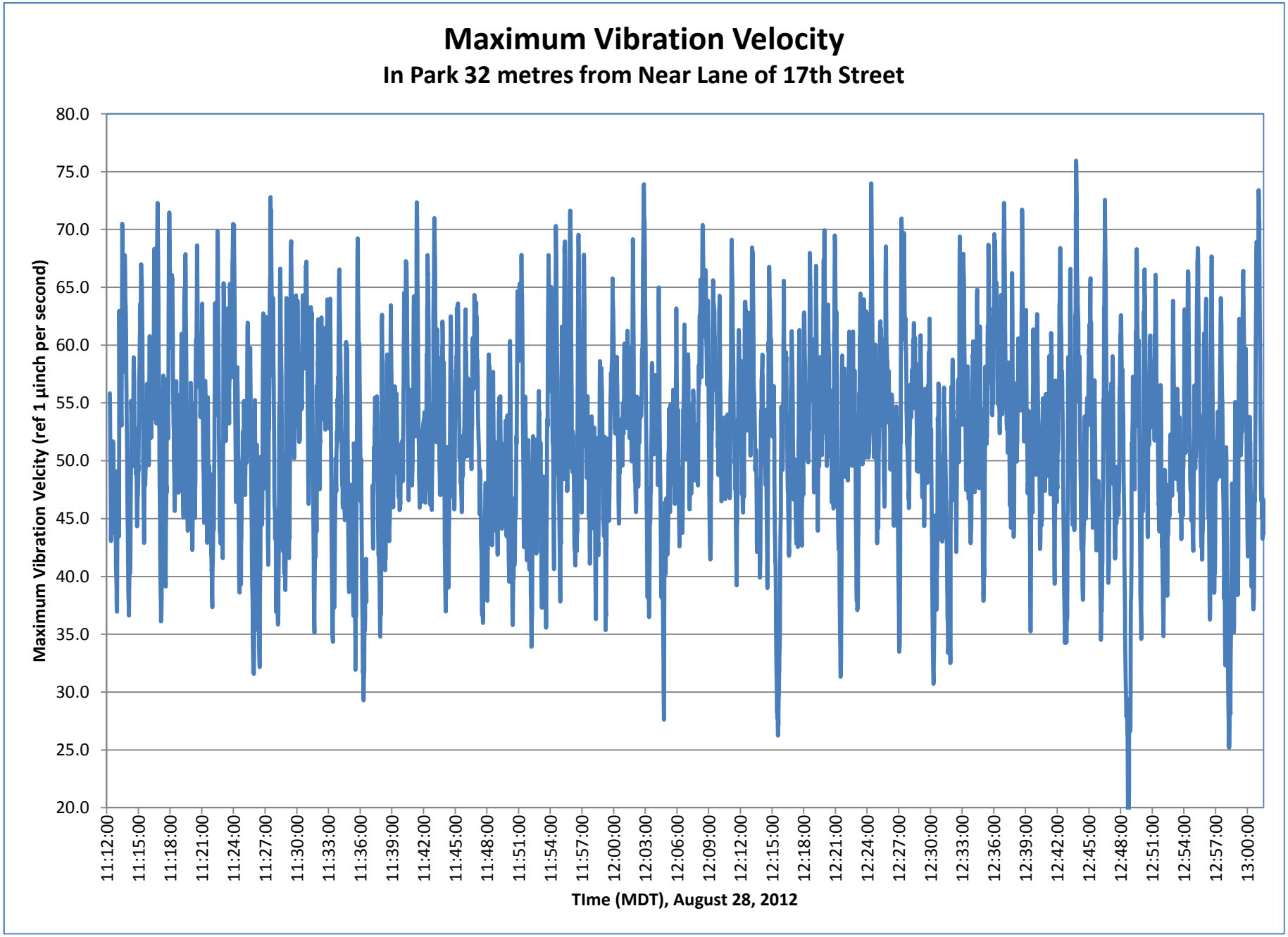
Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro inch/sec)		Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)	
	Frequent[1] Events	Infrequent[2] Events	Frequent[1] Events	Infrequent[2] Events
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB[3]	65 VdB[3]	[4]	[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	80 VdB	35 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	83 VdB	40 dBA	48 dBA

Notes:

1. "Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
2. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
4. Vibration-sensitive equipment is not sensitive to ground-borne noise.

APPENDIX G

Measured Maximum Vibration Levels


Maximum Vibration Velocity
In Park 32 metres from Near Lane of 17th Street
Maximum Vibration Velcity (ref 1 µinch per second)
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
11:12:00
11:15:00
11:18:00
11:21:00
11:24:00
11:27:00
11:30:00
11:33:00
11:36:00
11:39:00
11:42:00
11:45:00
11:48:00
11:51:00
11:54:00
11:57:00
12:00:00
12:03:00
12:06:00
12:09:00
12:12:00
12:15:00
12:18:00
12:21:00
12:24:00
12:27:00
12:30:00
12:33:00
12:36:00
12:39:00
12:42:00
12:45:00
12:48:00
12:51:00
12:54:00
12:57:00
13:00:00
TIme (MDT), August 28, 2012