CITY OF
VANCOUVER

CITY CLERK'S DEPARTMENT
Access to Information

File No.: 04-1000-20-2017-525

January 24, 2018

s.22(1) [redacted]

Dear s.22(1) [redacted]

Re: **Request for Access to Records under the Freedom of Information and Protection of Privacy Act (the "Act")**

I am responding to your request of December 18, 2017 for:

> **Wakefield Acoustics prepared a report, " Vancouver Arterial Road Noise Study" for the City of Vancouver on April 23, 2015 according to their website: http://wakefieldacoustics.com/projects/community-noise/vancouver-arterial-road-noise-study/. Request is for the copy of the said report.**

All responsive records are attached.

Please note: we were informed by our Engineering Staff that the report referenced on the Wakefield Acoustics website on April 25, 2015 was submitted in 2005. This is the record attached. The City does not have a more recent study from Wakefield Acoustics on this topic.

Under section 52 of the Act you may ask the Information & Privacy Commissioner to review any matter related to the City's response to your request. The Act allows you 30 business days from the date you receive this notice to request a review by writing to: Office of the Information & Privacy Commissioner, info@oipc.bc.ca or by phoning 250-387-5629.

If you request a review, please provide the Commissioner's office with: 1) the request number assigned to your request (#04-1000-20-2017-525); 2) a copy of this letter; 3) a copy of your original request for information sent to the City of Vancouver; and 4) detailed reasons or grounds on which you are seeking the review.

Please do not hesitate to contact the Freedom of Information Office at foi@vancouver.ca if you have any questions.

Yours truly,

Barbara J. Van Fraassen, BA
Director, Access to Information & Privacy

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Encl.

:ma

DRAFT
TRAFFIC NOISE LEVELS AND TRAFFIC NOISE COMPOSITION ON ARTERIAL ROADS STUDY
SUMMARY OF UNMANNED NOISE MONITORING

Submitted to:

City of Vancouver
453 West 12th Avenue
Vancouver, British Columbia
V5Y 1V4

Submitted by:

Wakefield Acoustics Ltd.
301 – 2250 Oak Bay Avenue
Victoria, British Columbia
V8R 1G5

March 30, 2005

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1.0 INTRODUCTION

This report, Deliverable 1 of Contract PS04083 for the City of Vancouver, provides a summary of the results of the arterial road noise monitoring program recently performed by ***Wakefield Acoustics Ltd.*** It explains the methodology utilized in the monitoring program, as well as the results obtained. Charts have been included to show the results of the noise monitoring for each of the sites.

2.0 METHODOLOGY

2.1 Arterial Road Noise Monitoring Program

To establish the existing noise environments at representative locations within the city, continuous 24-hour monitoring has generally been employed, giving daily average community noise metrics such as the $L_{eq}(24)$ and L_{dn}[1]. Monitoring was conducted at locations that were approved by the client. Monitoring was generally performed on weekdays rather than weekends because residents experience weekday traffic more often than weekend traffic and it is also considered to establish the noisiest conditions. However, one site was repeated on a weekend to make a comparison.

Twenty-four hour continuous baseline noise monitoring was conducted at thirty-one residential locations (sites) throughout the city, while shorter-term noise monitoring (2-3 hours) was conducted at three other sites. Furthermore, 23-hour *manned* monitoring was conducted at another five locations, giving a total of thirty-nine sites. The manned monitoring consisted of manually logging noisy events throughout the day and night in order to correlate them with the measured data.

The distribution of the sites throughout the city is graphically shown in Figure 2.1. The red dots represent sites where 23 to 24-hour monitoring was performed, while blue dots represent short-term sites. Monitoring was also performed at a quiet residential site, well-removed from arterial traffic (the approximate location shown as a green dot), to provide a comparison with the louder arterial road sites.

[1] These and other metrics are explained in Appendix A

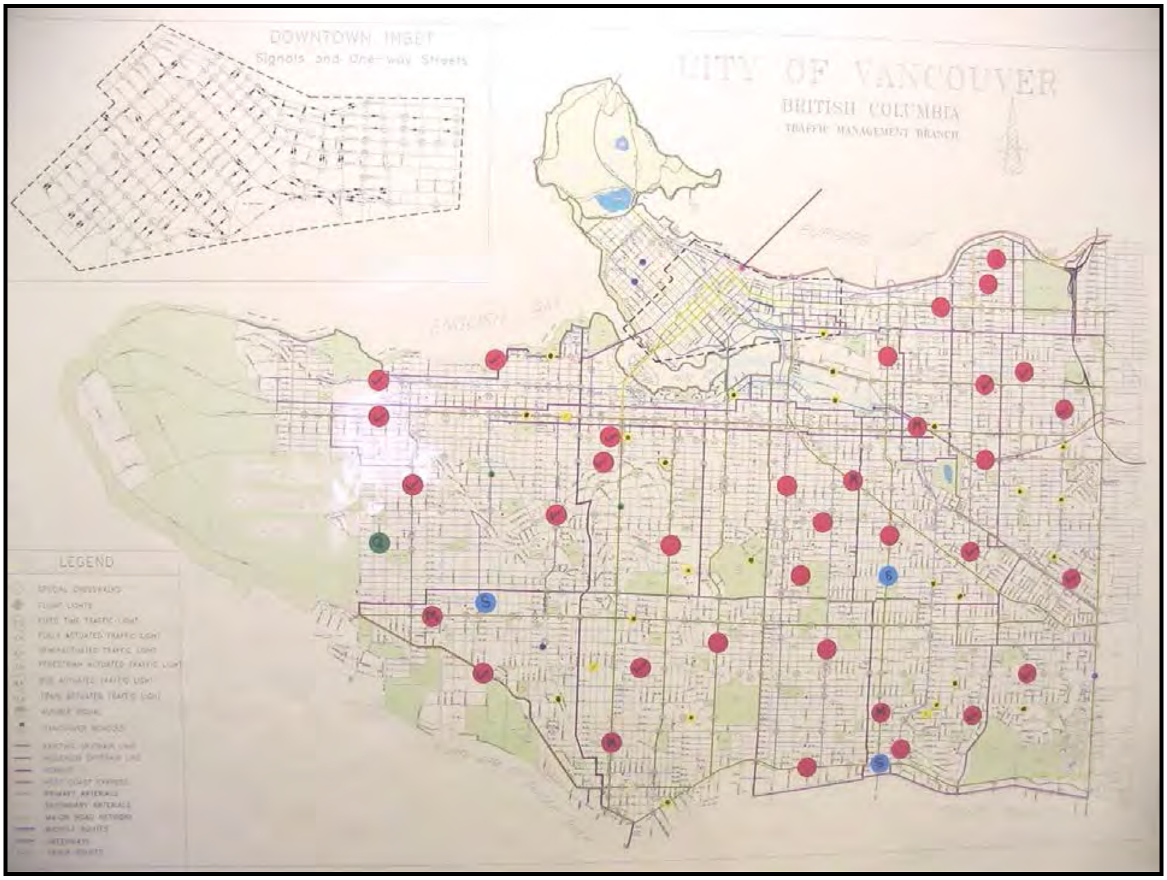


Figure 2.1 - Noise Monitoring Site Locations

2.2 Quality Control / Quality Assurance

The continuous noise monitoring was conducted using four Larson-Davis Model 820 and 812 Community Noise Analyzers, with one instrument set-up per site. These digital instruments comply with ANSI S1.4 [1983] standards for Type 1 Sound Level Meters and are capable of sampling the ambient sound level many times per second and storing the resulting sound level data for subsequent analysis and display. The instruments were set to collect a complete statistical description of the noise environment every 60 minutes. For each such interval, these instruments store the Equivalent Sound Level, or L_{eq} – this being a single-number descriptor of the average sound energy level over any selected time period and expressed in units of A-weighted decibels, or dBA. The statistical levels L_5, L_{10}, L_{50} and L_{90}, which represent the sound exceeded for a certain percentage of time, were also stored. In addition, the L_{eq} and maximum sound level, or L_{max}, were sampled at one minute intervals. Histograms were also recorded to show the distribution of the measured levels.

The instruments and field calibrator (Larson Davis Type CA200 Acoustic Calibrator) were last calibrated in February 2004 by a certified Calibration Laboratory. The sound level meters were field-calibrated before and after each monitoring period using the LD CA200. The microphones were mounted on poles approximately 1.7 m above ground level in positions where overall community noise exposures were considered to be representative of the residential facades facing the arterial road. The level of surety of the baseline measurements performed is ±0.5 dBA for the instrumentation and generally ±1.0 dBA for day-to-day variation, including meteorological conditions and traffic volume and speed variations.

3.0 RESULTS

The noise monitoring program was conducted from February 7 – 23, 2005. Weather conditions were sunny or partly overcast for all sites, with a light breeze or negligible wind. Temperatures generally neared the freezing point overnight and were around 10° Celsius at midday. An overview of the noise monitoring results is provided in Tables 3.2 to 3.3 while detailed noise data is shown graphically in Appendices B, C and D. Tables 3.2 to 3.3 provide the location, address, type of road, distance from the road's near curb to the microphone and residential façade, monitoring durations and daily average noise exposures obtained at each site, expressed in terms of L_{eq} and L_{dn}. The types of road, as defined in the City's RFP, are shown in Table 3.1 below, with shorthand notation. Short-term sites have been labelled with the prefix "S", while the five manned monitoring sites have been labelled with the prefix "M". Due to data loss, histogram charts are not available for two sites (Sites 22 and 23) and the 1-minute Noise Intervals chart is not available for one site (Site 22).

Table 3.1 – Types/Categories of Roads

Type of Road	
P	Primary Road
S	Secondary Road
C	Collector Road
M	Minor Road
Category	
1	Major Truck, 25,000+ VPD, Some Transit
2	Major Truck, 15,000 VPD, Some Transit
3	Non-Truck, 25,000+ VPD, No Transit
4	Non-Truck, 25,000+ VPD, Some Transit
5	Non-Truck, 15,000 VPD, Some Transit
6	Other

Since it is preferred to express noise exposures at the setback of a residences façade, some of these noise levels will be adjusted (for submission with Deliverable 3) to more accurately describe the noise environment. It can be seen from the tables that sites 10, 23, 24 and S3 have large differences between the setback to the microphone and setback to the residential façade. However, while the differences to the road's curb may be near 50% for these cases, the more appropriate difference in setback distance is relative to the acoustic centre of the road, which is near the centerline of the road, and would thus result in a smaller percentage difference.

The L_{dn}, which applies a 10 dBA penalty to night-time noise (22:00 to 07:00), will be higher in magnitude than the $L_{eq}(24)$ depending on how much noise occurred through the night. The average difference between the L_{dn} and $L_{eq}(24)$ was 3.6 dBA, which is approximately 1 dBA lower than is normally experienced on major highways. Figure 3.1 below shows a histogram of the $L_{eq}(24)$ levels obtained for the 35 long-term monitoring sites, both manned and unmanned, excluding the $L_{eq}(24)$ 47.5 dBA quiet residential site.

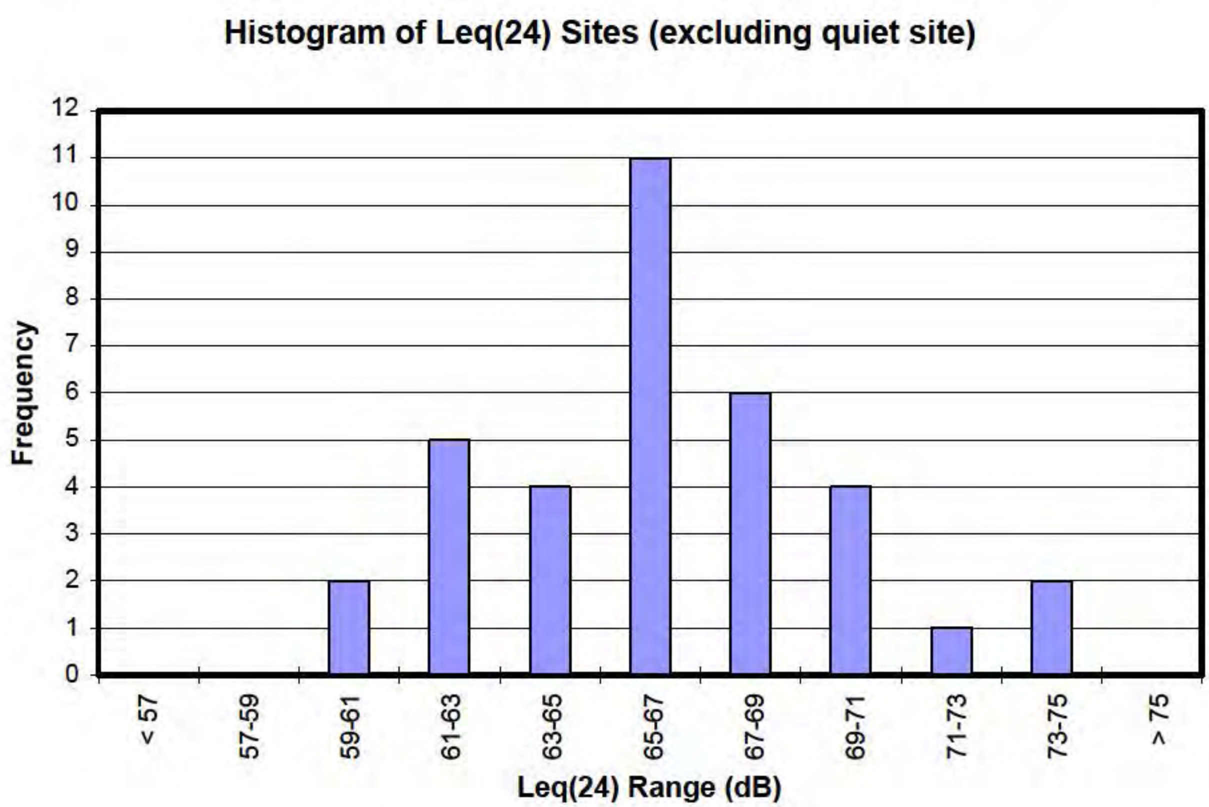


Figure 3.1 – $L_{eq}(24)$ Histogram Chart

The histogram shows that 11 of the 35 sites (31%) had L_{eq}(24)'s of 65 to 67 dBA. The distribution looks fairly normal, and would have a more normal distribution if the levels were adjusted to estimate façade noise levels rather than microphone noise levels since there were some sites where microphone setbacks were quite different from façade setbacks (for example, Site 24 would be adjusted to 71.4 dBA from 74.4 dBA).

3.1 Repeatability of 24-hour Baseline Sound monitoring Results

To address the ability of a single 24-hour monitoring session to define the baseline noise environment at a given site, 24-hour baseline sound monitoring was repeated at 1406 East 28th Avenue (on Knight Street; Site 24) and 3034 Grandview Highway South (Site 28). The L_{eq}(24) at Site 24 was 74.4 dBA on Friday, February 18 and 72.8 dBA on Saturday, February 19. This weekday to weekend variation of 1.6 dBA is larger than would be expected on a weekday to weekday comparison and supports the general finding that traffic noise levels are somewhat higher on weekdays due largely to the commercial truck component of the noise. However, such differences in noise would not be perceptible to the average resident.

The L_{eq}(24) at Site 28 was 68.3 dBA on Monday to Tuesday, February 21-22, and 68.5 dBA on Tuesday to Wednesday, February 22-23. This weekday to weekday variation is imperceptibly small and is normal for a high traffic volume road.

Therefore, it can be estimated that typical day-to-day variations in L_{eq}(24) are approximately 0.5 to 1.5 dBA for all locations where arterial traffic is the dominant noise source. Variations in average daily noise exposures of these magnitudes are not readily perceptible.

3.2 Analysis of Short-Term Monitoring Sites Results

Site S1 was the short-term site on the Mackenzie bus loop. The corresponding 1-minute intervals figure in Appendix C shows that a bus drove by every 15 minutes, with an L_{max} of about 75 dBA.

Site S2 was the short-term site near the Knight Street bridge deck joint, on the west side of the road. While the 15-minute intervals figure in Appendix B and 1-second intervals figure in Appendix C show that the noise exposure was very high at this site, the measured noise energy was due to the traffic pass-by's and not the deck joint noise. The deck joint noise was noticeable, but this was because it was impulsive and tonally different than the traffic tire and engine noise from traffic; it did not affect the A-weighted L_{max} noise levels. If a subjective penalty was applied to these noise events to account for the impulsiveness and tonality, which increase the subjective annoyance of noise, it should then be reflected in the overall noise levels.

Site S3 was the short-term site on the "OGA" section of Knight Street, near 37^{th} Avenue. The 60-minute intervals figure in Appendix B compares Site S3 with Site 24 during the same time period and with a similar setback from the road, and shows that the noise exposure was almost identical at each site ($L_{eq}(3)$ 74.0 dBA at Site 24 and $L_{eq}(3)$ 73.9 dBA at Site S3). This suggests that the section of "quiet" pavement currently has no acoustical benefit. Upon close inspection of the pavement, it did not appear to be similar to other local OGA pavements.

4.0 CONCLUSIONS AND DISCUSSION

To put these measured noise exposures into perspective, the Canada Mortgage and Housing Board (CMHC) guidelines for community noise recommend an $L_{eq}(24)$ of less than 55 dBA outdoors for dwellings and outdoor recreational areas. In addition to this recommendation, the Health Canada guidelines for environmental noise control comment on the severity of different noise exposures above $L_{eq}(24)$ 55 dBA (Table 4.1).

Table 4.1 - Applying Recommended Sound Level Limits to Residential Land Use Developments

Source; Health Canada National Guidelines for Environmental Noise Control

Excess above Recommended Sound Level Limit (dBA)	Change in Subjective Loudness	Magnitude of Noise Problem
No excess [$\leq L_{eq}(24)$ 54][1]	----	No expected noise problem
1 to 5 inclusive [$L_{eq}(24)$ 55 to 59]	Noticeably Louder[2]	Slight Noise Problem
6 to 10 inclusive [$L_{eq}(24)$ 60 to 64]	Almost twice as loud	Definite noise problem
11 to 15 inclusive [$L_{eq}(24)$ 65 to 69]	Almost three times louder	Serious noise problem
16 and over [$\geq L_{eq}(24)$ 70]	Almost four times as loud	Very serious noise problem

1. For convenience, the corresponding noise level ranges for "Suburban outdoor areas" have been added to this table.
2. 1 to 2 dBA increases in level of a given noise are not in fact readily noticeable.

It is therefore concluded that unmanned traffic noise levels were adequately measured at the recommended locations for the purpose of this project. The charts contained in the Appendices give an exhaustive report of the data obtained in the field.

APPENDIX A – COMMUNITY NOISE FUNDAMENTALS AND DESCRIPTORS

Noise Fundamentals

What is Sound and How is it Made?

Vibrating surfaces such as engine housings, drumheads or loudspeakers and rapidly moving fluids such as in jet engine exhausts, produce minute fluctuations in atmospheric, or air, pressure. These pressure fluctuations spread out from the source in the form of expanding pressure waves in the air, much as a water wave on a pond spreads out from the point where a pebble has been dropped – their intensity steadily decreasing with distance from the source. Our ears, acting like microphones, sense these air pressure fluctuations and our brain interprets them as sound.

The Sound Pressure Level or "Decibel" Scale

The ear is capable of sensing sound, or "hearing", over an enormous range of intensities - from the faintest rustling of leaves to the roar of a nearby jet aircraft. The jet may produce sound that is one million times more intense than the rustling of leaves. Therefore, similar to the "Richter" scale which compresses the entire range of earthquake magnitudes into a 1 to 10 scale, the "Sound Pressure Level" or "Decibel" scale was developed to represent the even greater range of audible sound intensities within a compressed, or "logarithmic", scale. Within this scale, a Sound Pressure Level (SPL) of 0 decibels (dB) represents the threshold of hearing in the ear's most sensitive frequency range, while the thresholds of tickling or painful sensations in the ear occur at 120 to 130 dB. The accompanying poster shows the Sound Pressure Levels, or more commonly "sound levels", typically created by a variety of common sources in the community. Roughly speaking, each 10 dB increase in sound level corresponds to a "doubling of subjective loudness".

How is Sound Measured?

Sound is measured with instruments called "Sound Level Meters" which consist of a microphone in conjunction with an electronic amplifier, a display meter and commonly today, a digital memory for logging sound level data over time. These meters are calibrated before each use.

The Frequency or "Pitch" Sensitivity of the Ear - "A"-weighted Decibels

The normal range of sound frequencies audible to the young, healthy ear is from 20 cycles per second, or Hertz (Hz.) to about 20,000 Hz. The ear is much more sensitive to mid and higher frequencies (particularly the 500 to 4000 Hz, range) than to lower frequencies. To approximate the ear's frequency sensitivity, Sound Level Meters contain electronic weighting networks, the most widely used and appropriate for typical measurements in the community being the "A-weighting". Sound levels measured with this weighting in effect are called "A-weighted sound levels" and their unit of measurement is the "A-weighted decibel, or dBA".

What is Noise?

Noise is commonly referred to as "unwanted sound", because it interferes with human activities and/or creates annoyance. The judging of sound as noise is then, to a substantial degree, a personal or subjective matter since it depends on the situation, the activities engaged in as well as individual attitudes and sensitivity.

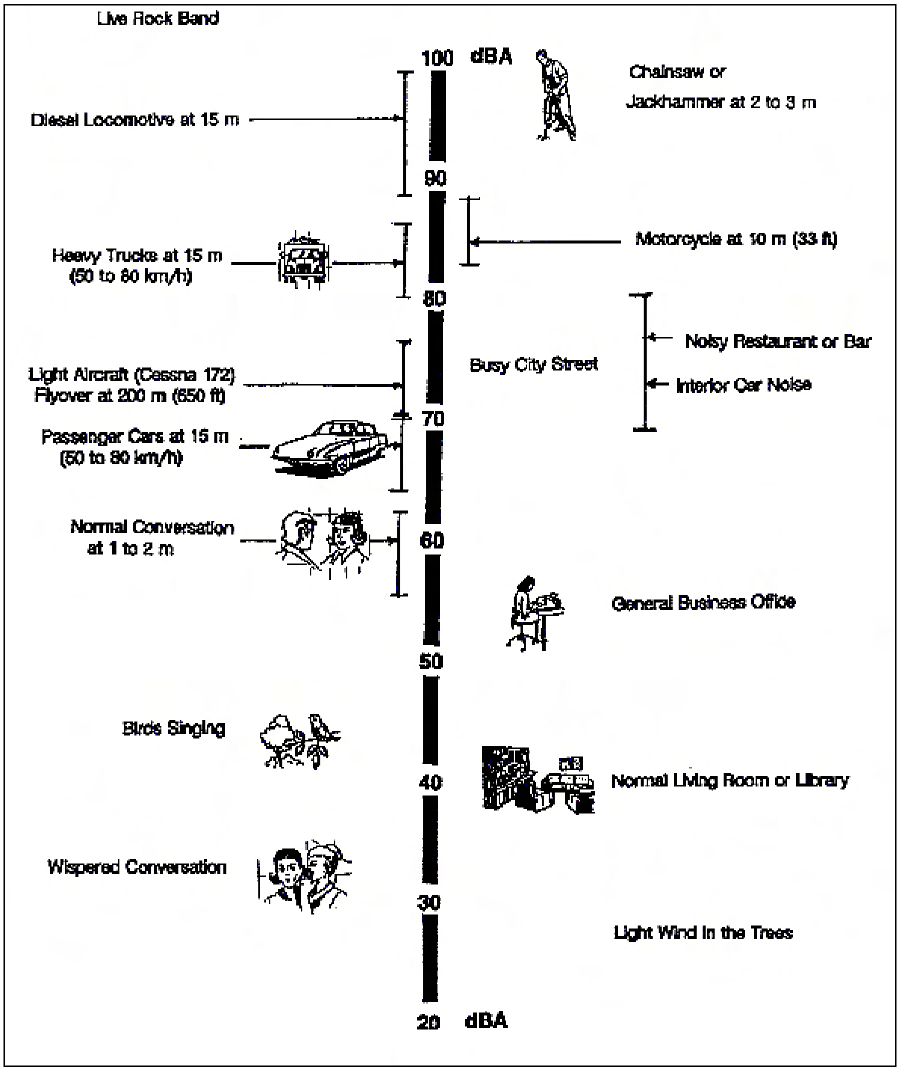


Figure A.1: Levels of Common Noises in the Community (dBA)

How is Sound Energy Lost?

Geometric spreading is the reduction in the intensity of sound waves as they move away from the source due to the spreading of their energy over progressively larger and larger areas.

Atmospheric absorption is the extraction of energy from sound waves as they pass through the atmosphere due to a variety of phenomena.

Ground effect attenuation is the reduction in sound intensity at a distance from the source caused by destructive interference between direct and ground-reflected sound waves and occurs where sound waves travel close to acoustically soft ground.

Principal Community Noise Level Descriptors

The principal descriptor of the baseline community noise environment provided by the monitoring is the 24-hour Equivalent Sound Level, or $L_{eq}(24)$. This is a widely-utilized, single-number descriptor of the average sound energy exposure over a 24-hour day and is employed in the B.C. Ministry of Transportation's noise impact mitigation policy as well as other community noise guidelines. The L_{eq} is that steady sound level which, over a given time period, would result in the same overall sound energy exposure as would the actual time-varying community noise level.

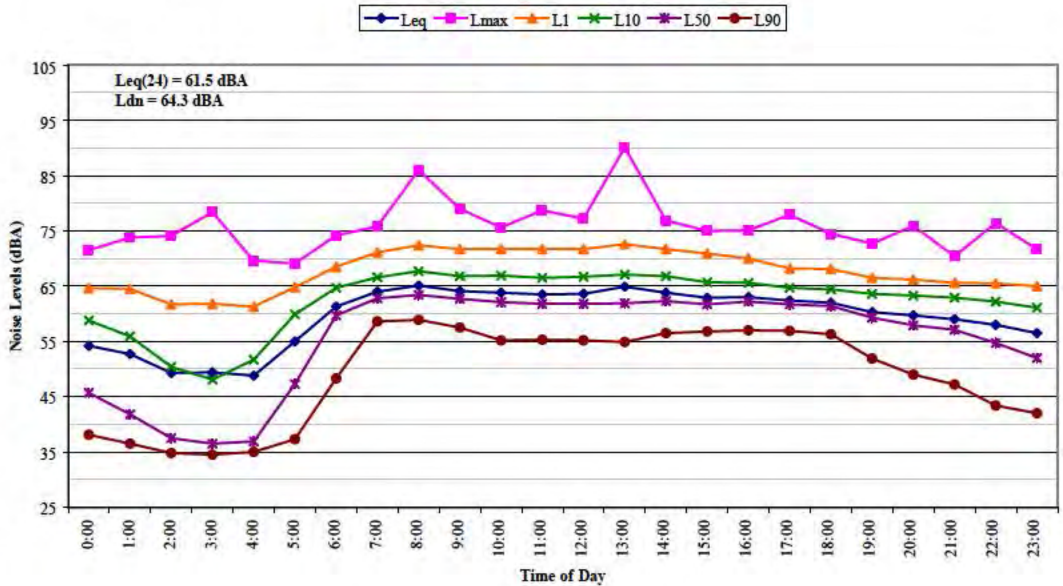
A variant of the $L_{eq}(24)$ is the Day-Night Average Noise Level, or L_{dn}. Like the $L_{eq}(24)$, the L_{dn} is an energy-averaged descriptor of daily noise exposure and is expressed in dBA. However, in computing L_{dn}, all noise levels occurring between 22:00 and 07:00 hours are increased by 10 dBA to reflect the greater sensitivity of residential communities to noise at night. Where noise environments are dominated by highway/road traffic noise (which tends to be substantially lower at night than during the day), these two daily-average noise descriptors yield fairly similar results. However, should industry, railway operations or other noisy activities be prominent and continue during the nighttime, the L_{dn} tends to be significantly higher than the $L_{eq}(24)$. For this reason, L_{dn} is an appropriate noise descriptor where significant nighttime noise is expected and is used in other guidelines.

Other noise descriptors or quantifiers include the maximum sound level, or L_{max}, and exceedance levels, or L_n. The L_{max} is the highest sound pressure level measured over a defined time interval. The exceedance levels are those noise levels that were exceeded for a given percentage "n" of the monitoring time. For example, the L_{50} is that noise level exceeded 50% of the time, i.e. the median level, while the L_{90} is that noise level exceeded 90% of the time and hence may be considered the background noise level. In all cases, these noise levels are expressed in units of A-weighted decibels, or dBA. The "A-weighting" refers to the electronic weighting network built into most sound measuring devices (sound level meters) which simulate the frequency (or pitch) sensitivity of the human ear. Noise levels measured with this network in place are then expressed in A-weighted decibels, or "dBA".

APPENDIX B – MONITORING SITE RESULTS, 1-HOUR INTERVALS

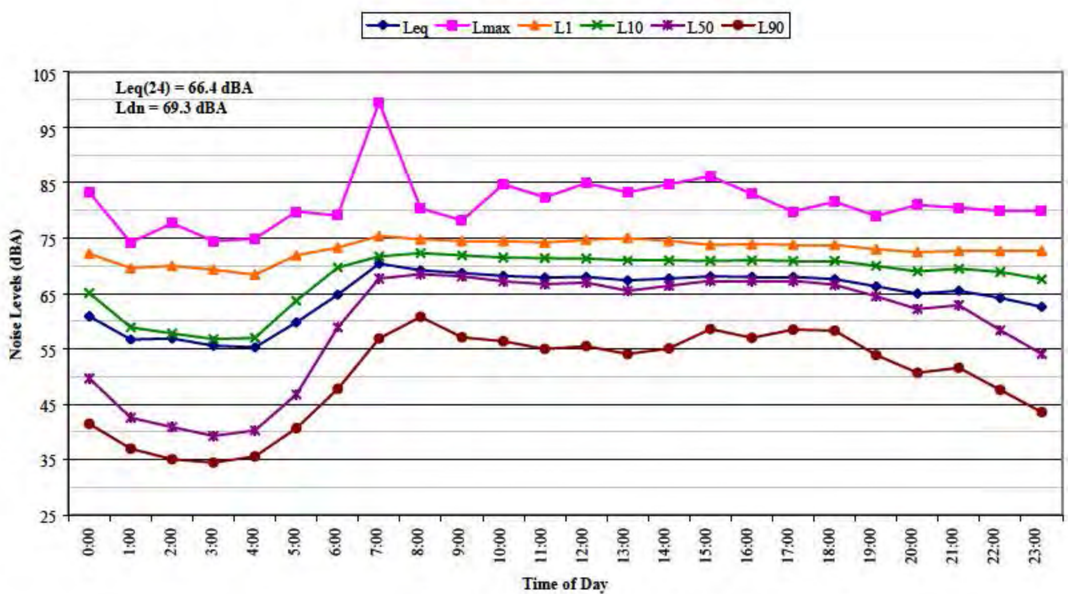
Vancouver Arterial Road Study - Noise Monitoring

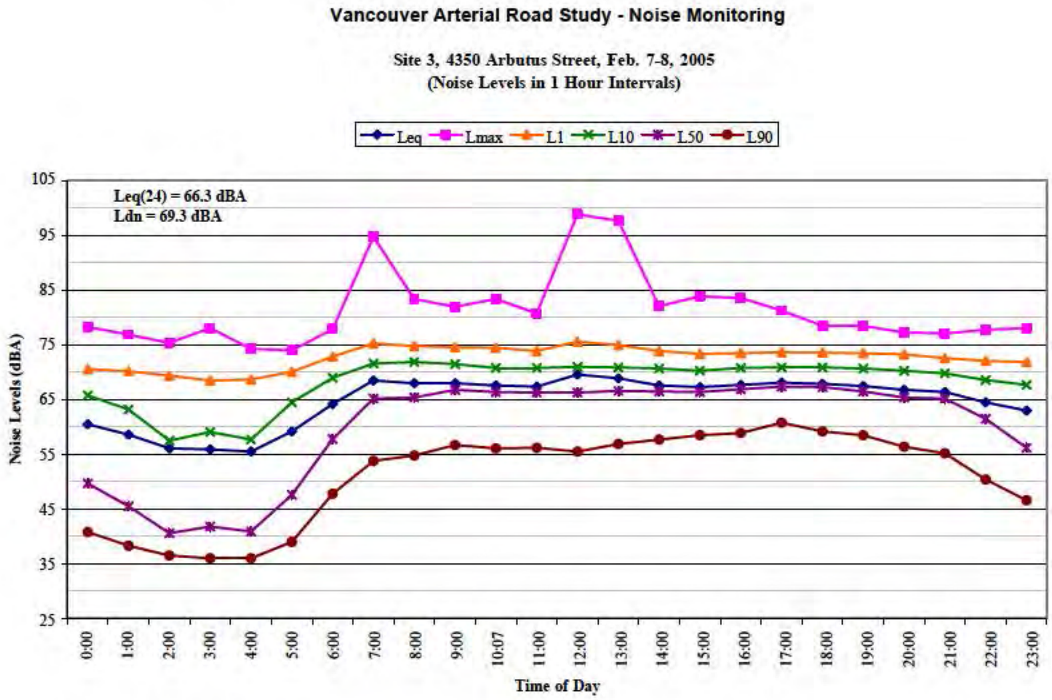
Site 1, 2328 S.W. Marine Drive, Feb. 7-8, 2005
(Noise Levels in 1 Hour Intervals)



Vancouver Arterial Road Study - Noise Monitoring

Site 2, 6525 W 49th Avenue, Feb. 7-8, 2005
(Noise Levels in 1 Hour Intervals)




Vancouver Arterial Road Study - Noise Monitoring
Site 3, 4350 Arbutus Street, Feb. 7-8, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 66.3 dBA
Ldn = 69.3 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:07
11:00
12:00
13:00
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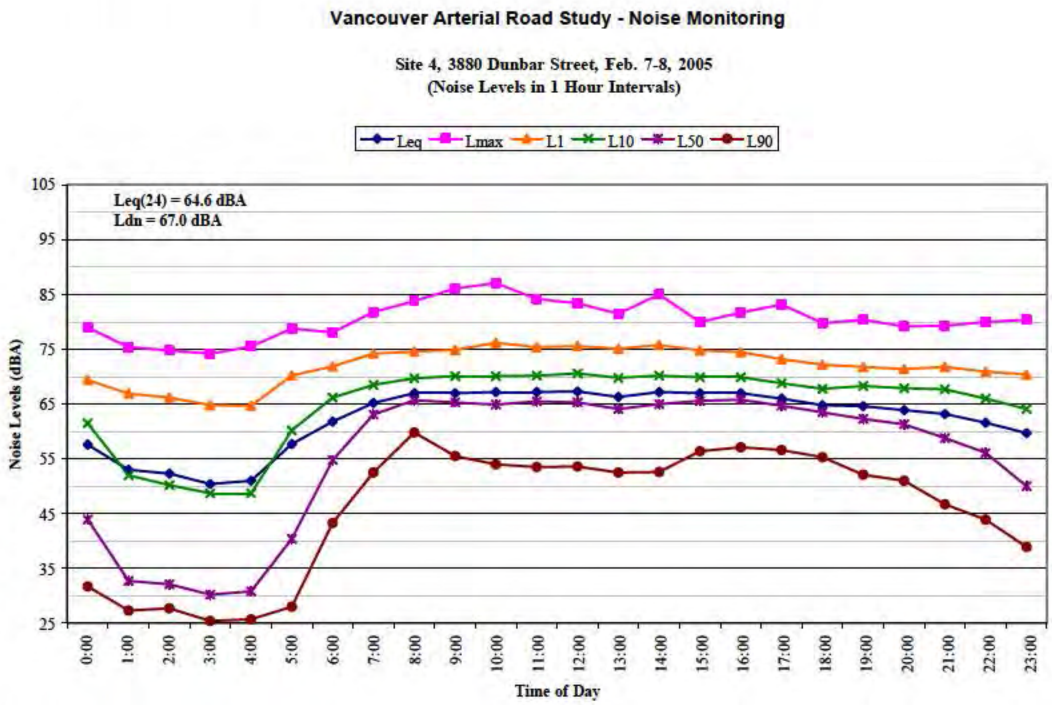
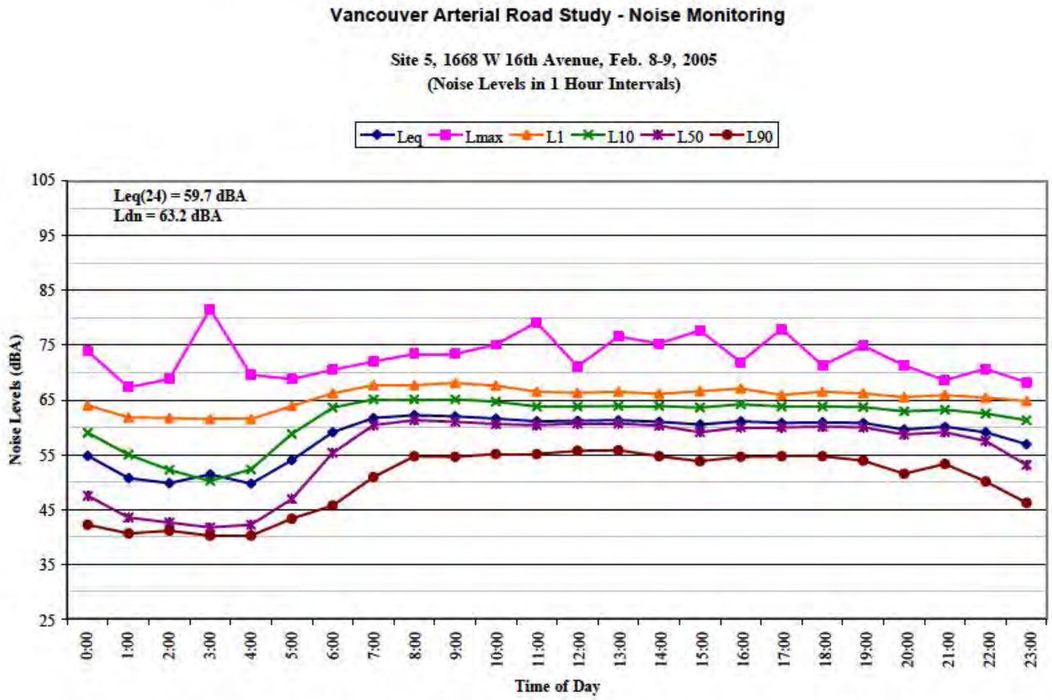
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 4, 3880 Dunbar Street, Feb. 7-8, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 64.6 dBA
Ldn = 67.0 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 5, 1668 W 16th Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 59.7 dBA
Ldn = 63.2 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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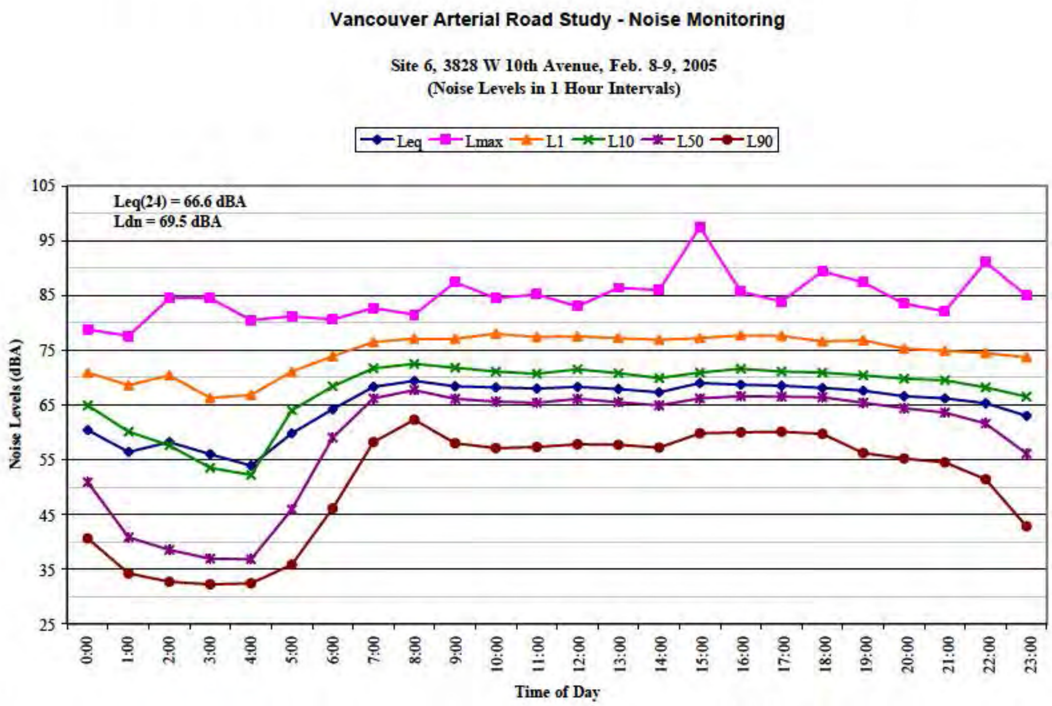
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 6, 3828 W 10th Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 66.6 dBA
Ldn = 69.5 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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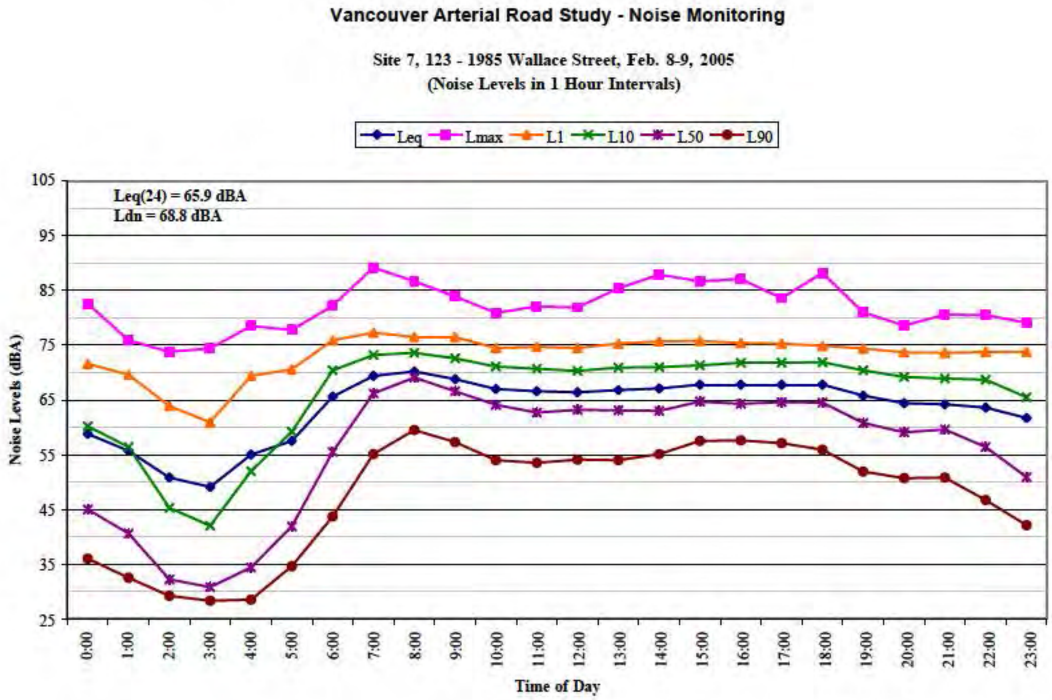
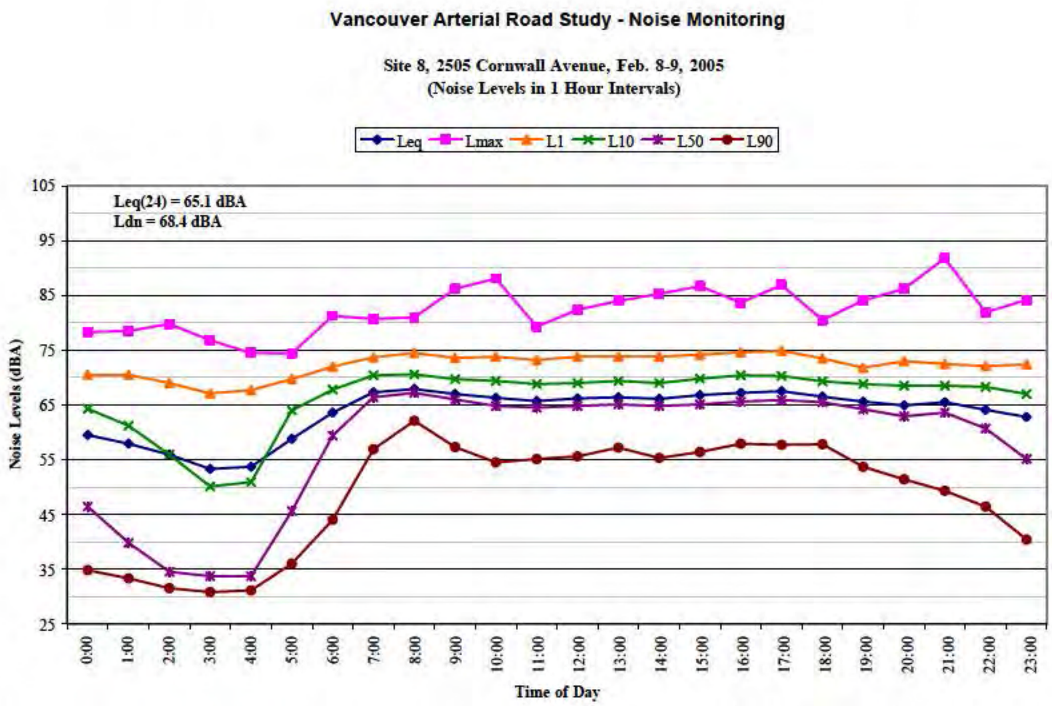
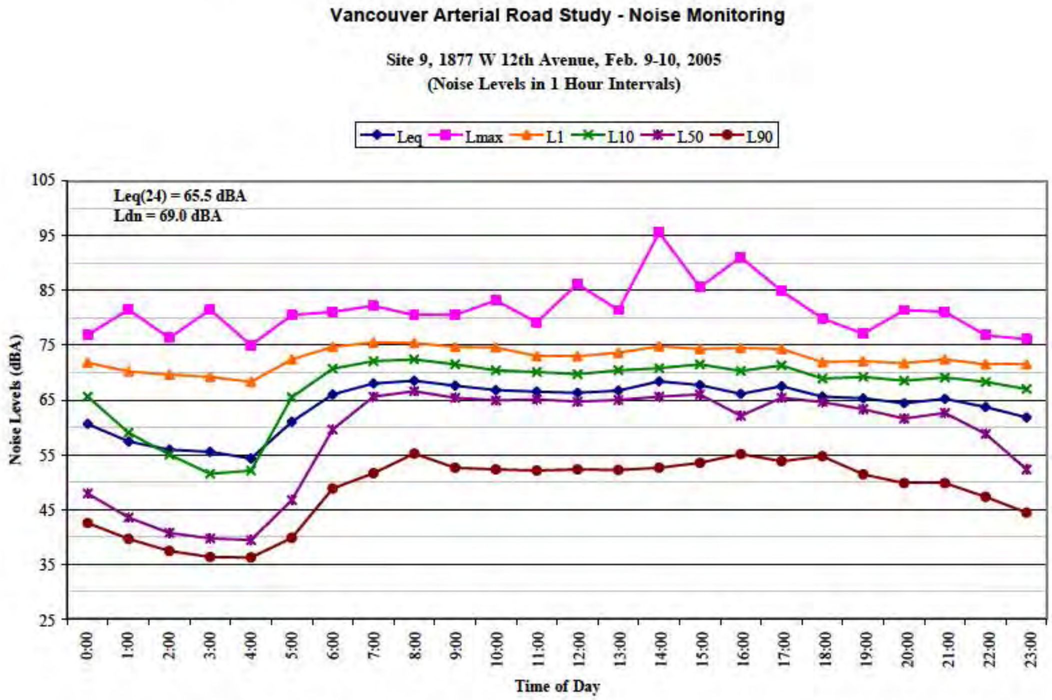
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 7, 123 - 1985 Wallace Street, Feb. 8-9, 2005
(Noise Levels in 1 Hour Intervals)
Leq Lmax L1 L10 L50 L90
Leq(24) = 65.9 dBA
Ldn = 68.8 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 8, 2505 Cornwall Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Hour Intervals)
Leq Lmax L1 L10 L50 L90
Leq(24) = 65.1 dBA
Ldn = 68.4 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 9, 1877 W 12th Avenue, Feb. 9-10, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 65.5 dBA
Ldn = 69.0 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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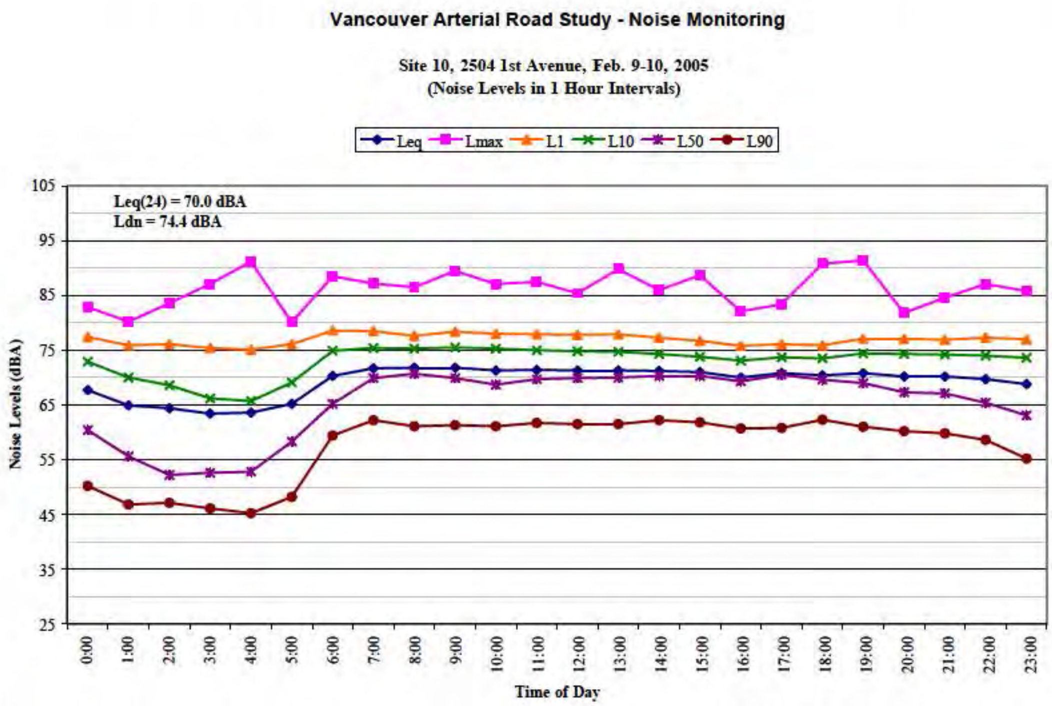
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 10, 2504 1st Avenue, Feb. 9-10, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 70.0 dBA
Ldn = 74.4 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
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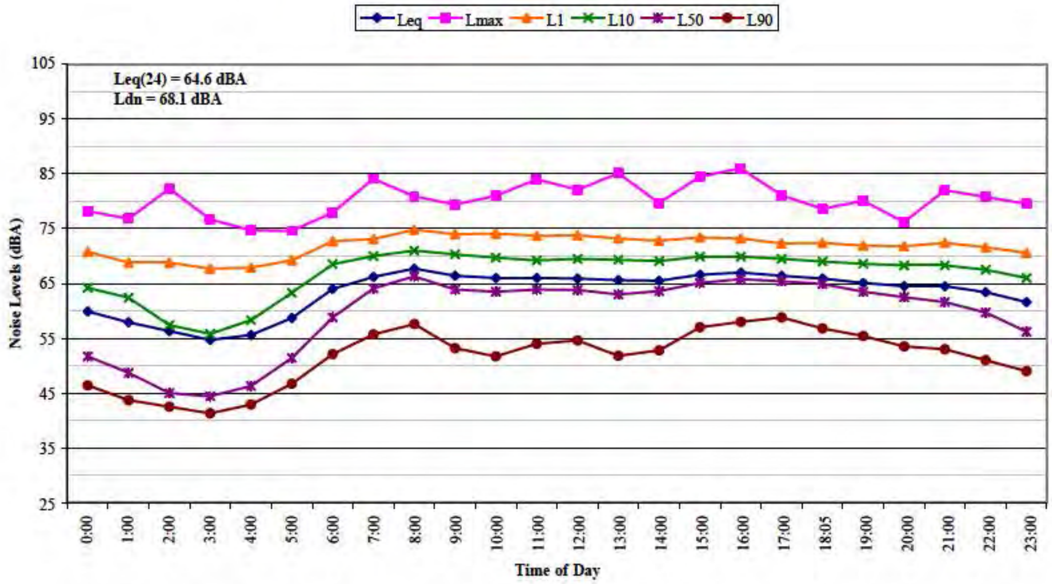
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

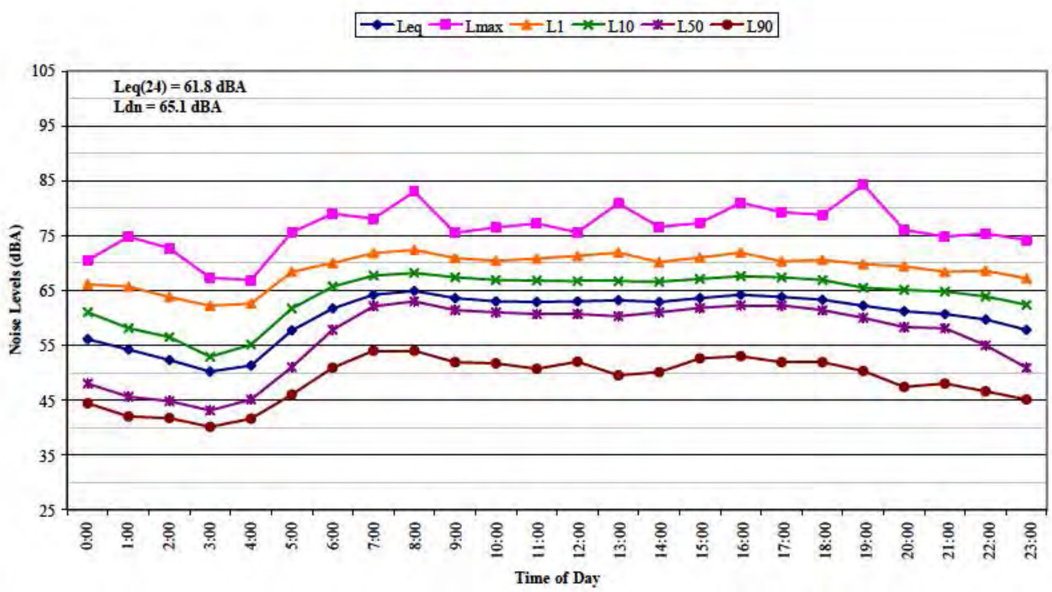
Vancouver Arterial Road Study - Noise Monitoring

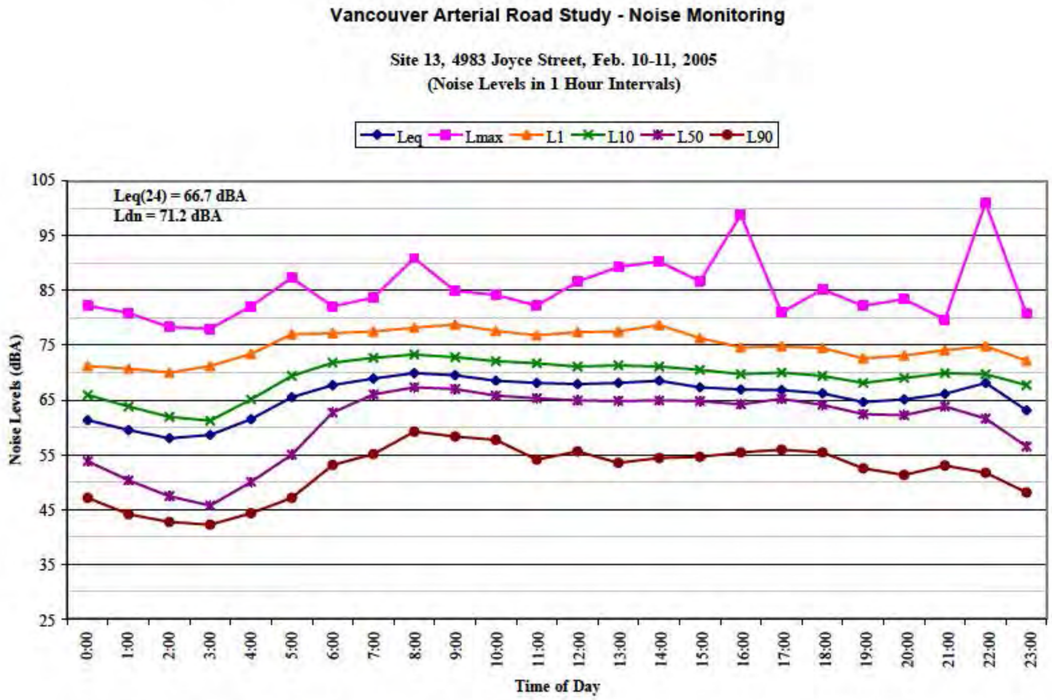
Site 11, 1137 Renfrew Street, Feb. 9-10, 2005
(Noise Levels in 1 Hour Intervals)

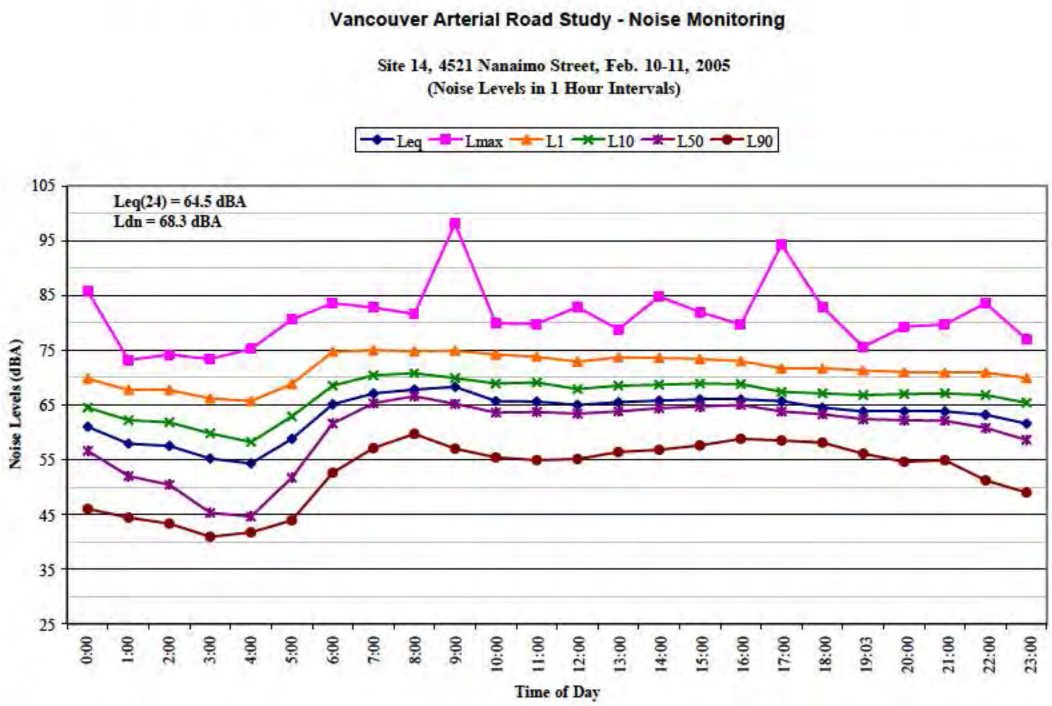


Vancouver Arterial Road Study - Noise Monitoring

Site 12, 2358 Rupert Street, Feb. 9-10, 2005
(Noise Levels in 1 Hour Intervals)

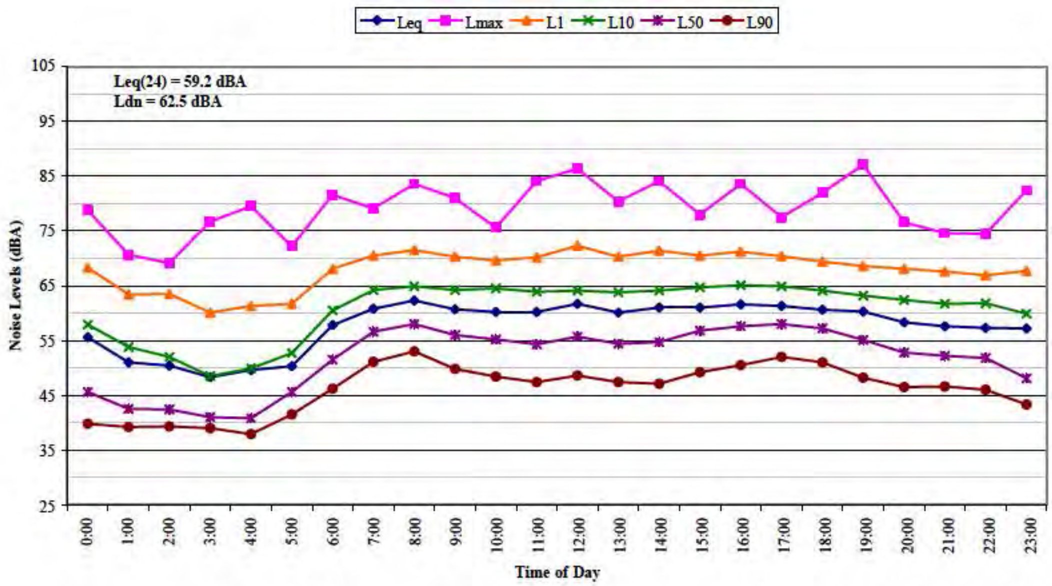



Vancouver Arterial Road Study - Noise Monitoring
Site 13, 4983 Joyce Street, Feb. 10-11, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 66.7 dBA
Ldn = 71.2 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 14, 4521 Nanaimo Street, Feb. 10-11, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 64.5 dBA
Ldn = 68.3 dBA
Noise Levels (dBA)
Time of Day

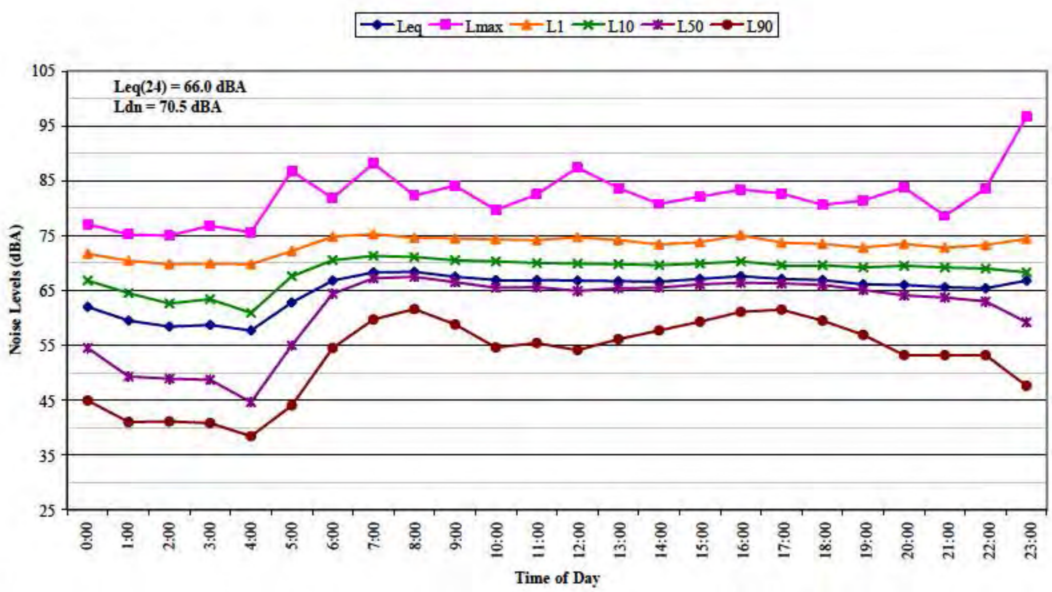
Vancouver Arterial Road Study - Noise Monitoring

Site 15, 7057 Elliot Street, Feb. 10-11, 2005
(Noise Levels in 1 Hour Intervals)



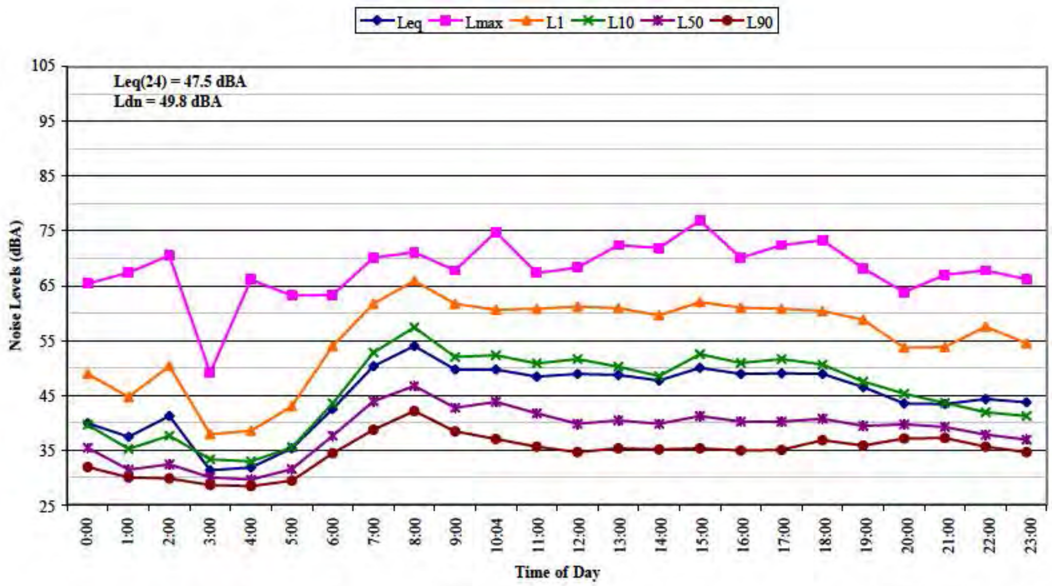
Vancouver Arterial Road Study - Noise Monitoring

Site 16, 6749 Kerr Street, Feb. 10-11, 2005
(Noise Levels in 1 Hour Intervals)



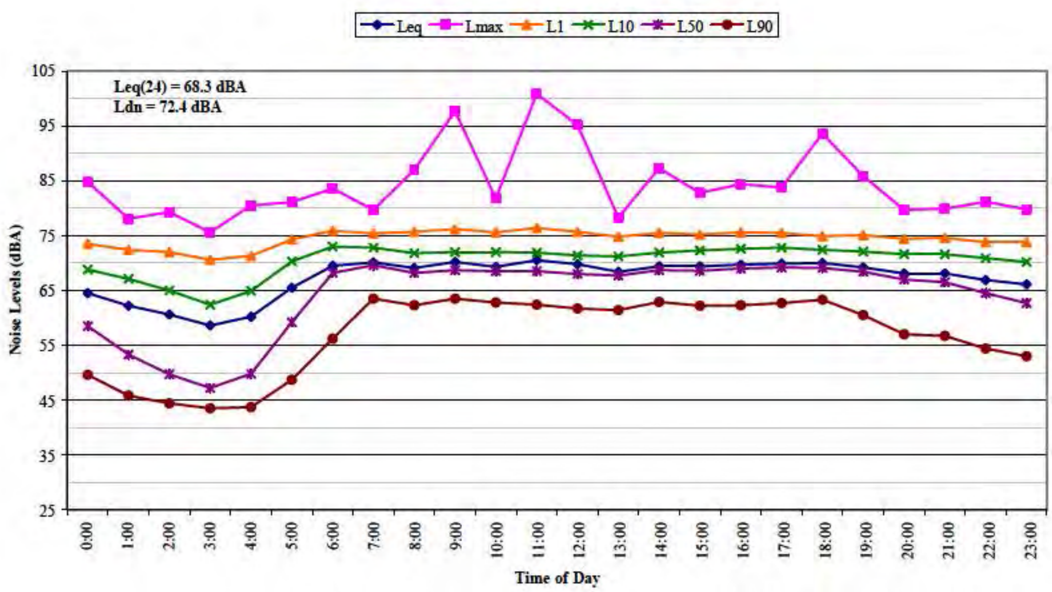
Vancouver Arterial Road Study Noise Monitoring

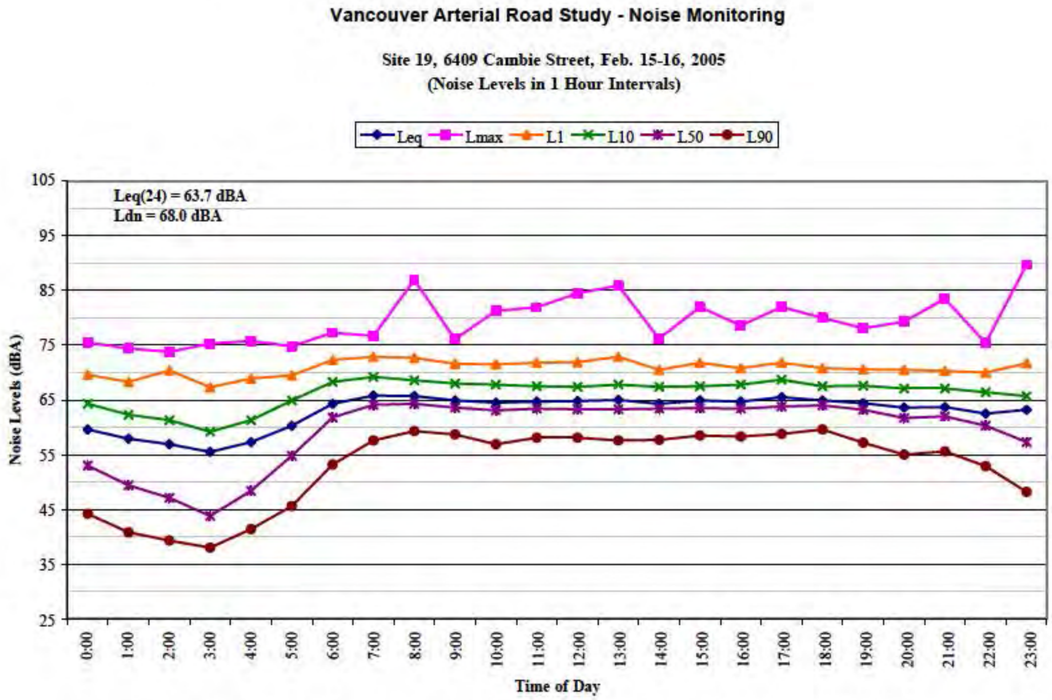
Site 17, 3956 W 34th Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Hour Intervals)

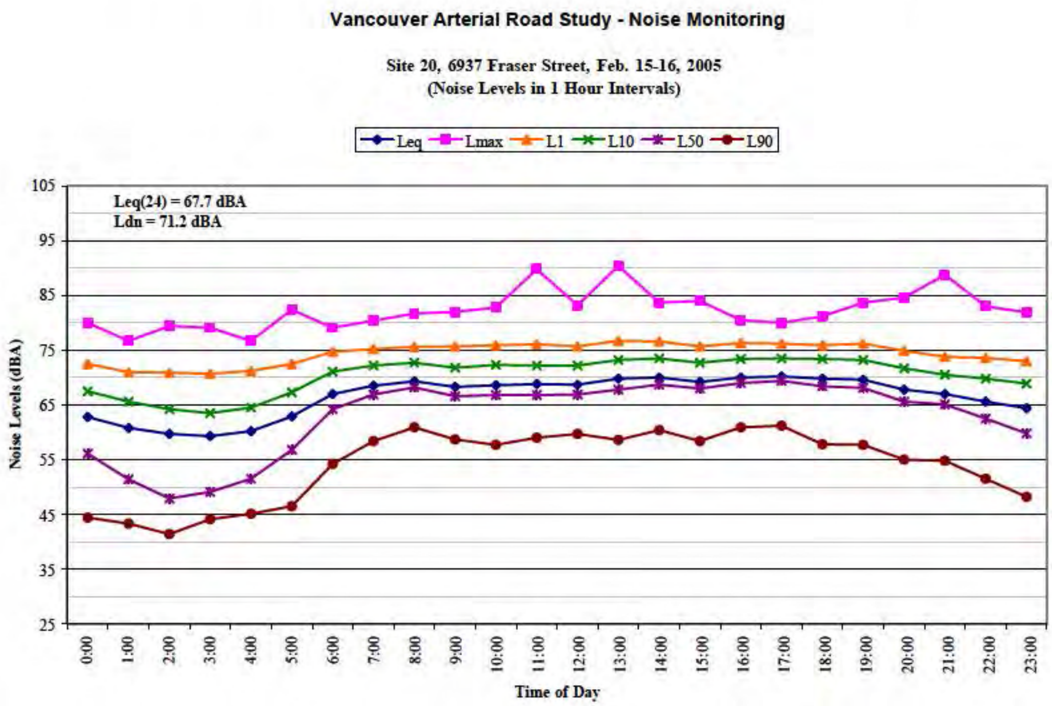


Vancouver Arterial Road Study Noise Monitoring

Site 18, 1019 Nanton Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Hour Intervals)

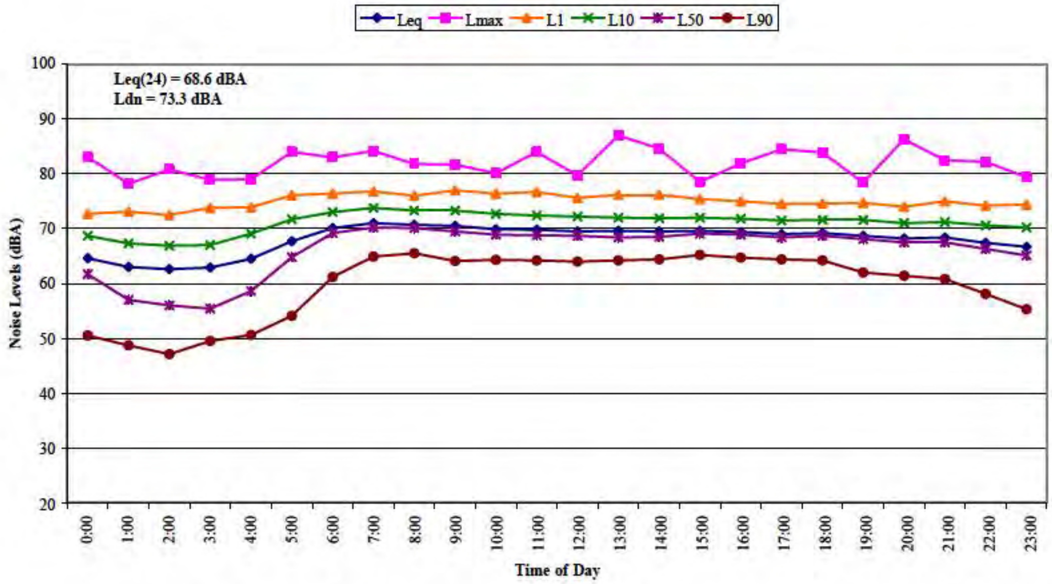



Vancouver Arterial Road Study - Noise Monitoring
Site 19, 6409 Cambie Street, Feb. 15-16, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 63.7 dBA
Ldn = 68.0 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 20, 6937 Fraser Street, Feb. 15-16, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 67.7 dBA
Ldn = 71.2 dBA
Noise Levels (dBA)
Time of Day

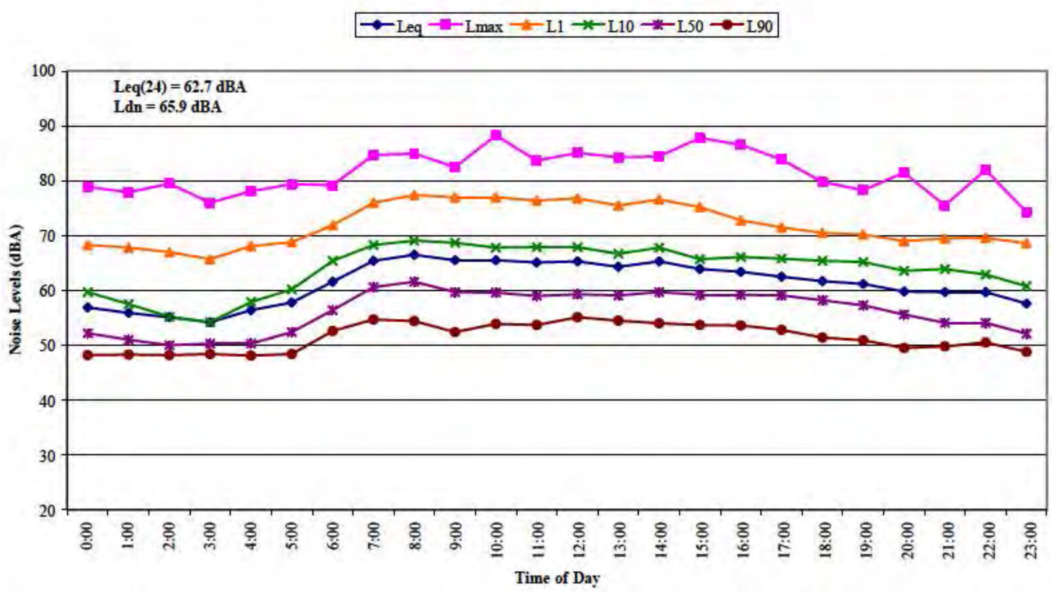
Vancouver Arterial Road Study - Noise Monitoring

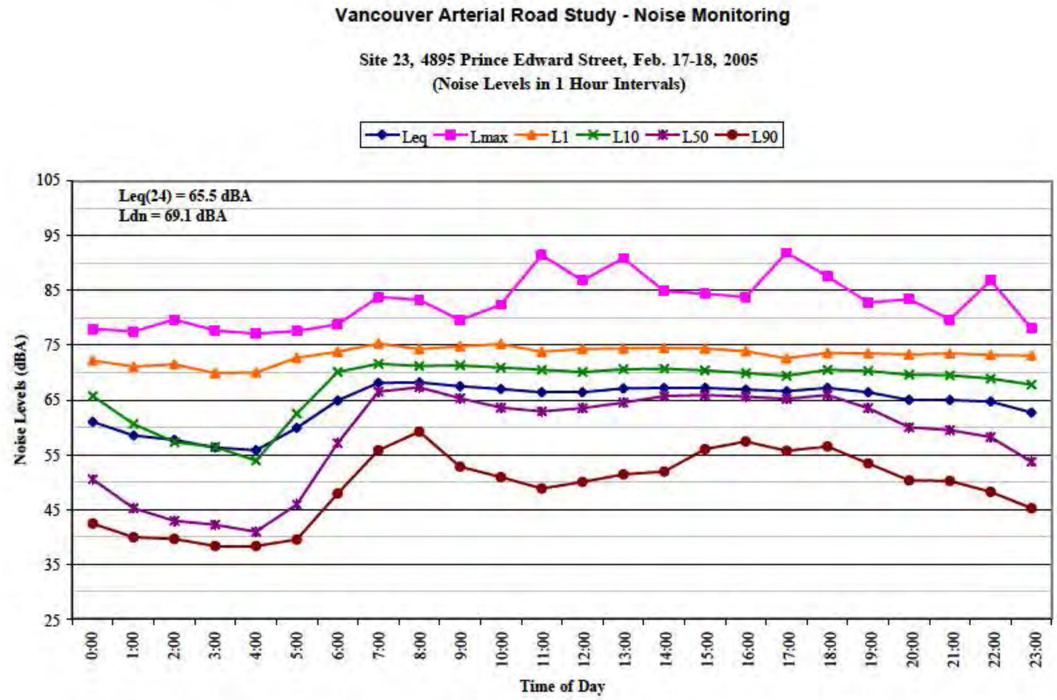
Site 21, 457 S.E.Marine Drive, Feb. 16-17, 2005
(Noise Levels in 1 Hour Intervals)

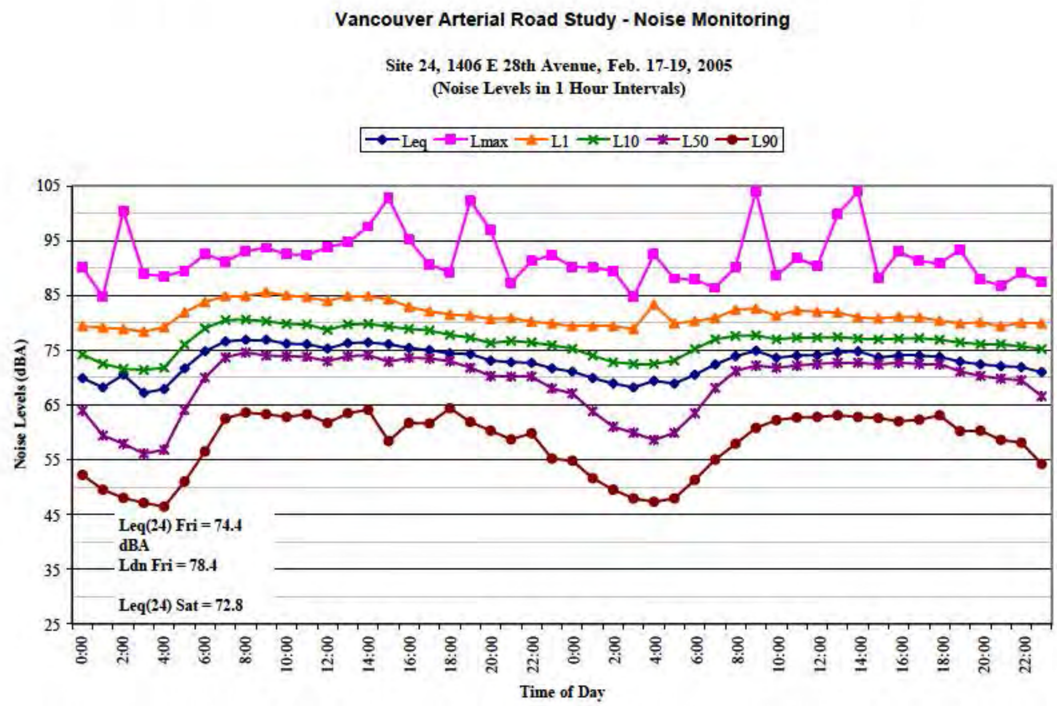


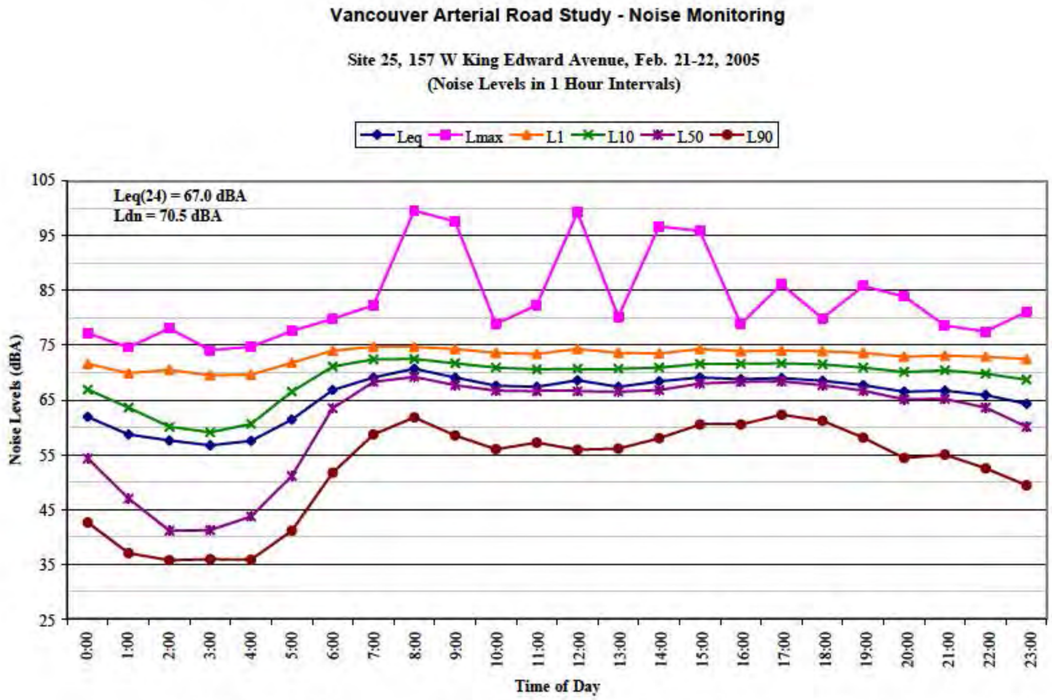
Vancouver Arterial Road Study - Noise Monitoring

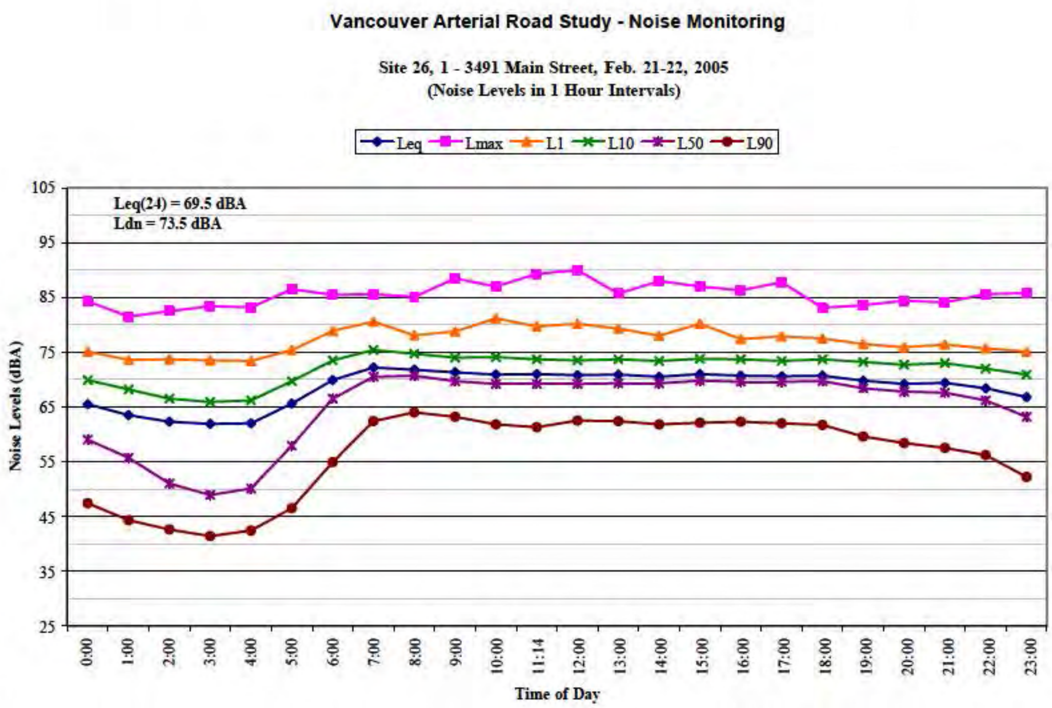
Site 22, 7870 Argyle Street, Feb. 16-17, 2005
(Noise Levels in 1 Hour Intervals)

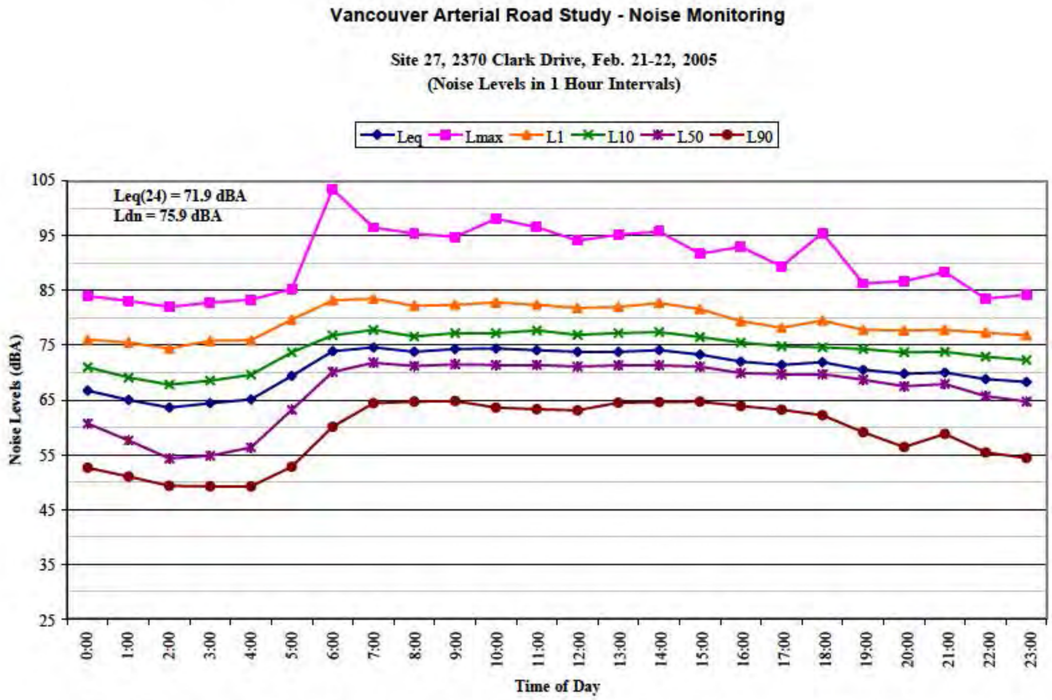


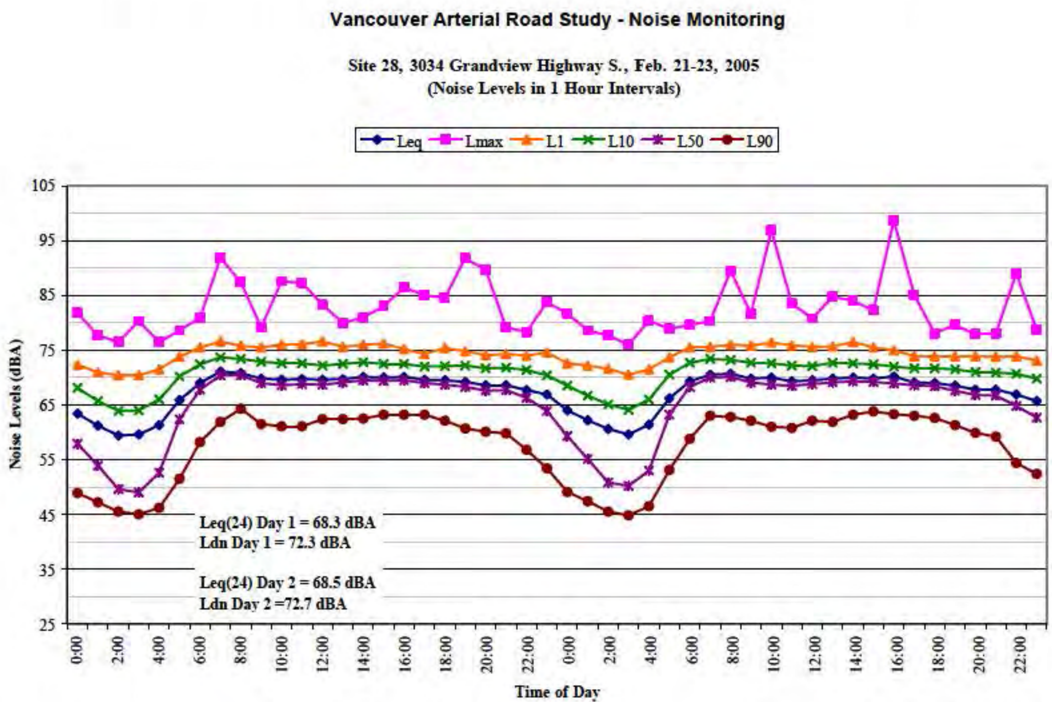

Vancouver Arterial Road Study - Noise Monitoring
Site 23, 4895 Prince Edward Street, Feb. 17-18, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 65.5 dBA
Ldn = 69.1 dBA
Noise Levels (dBA)
Time of Day

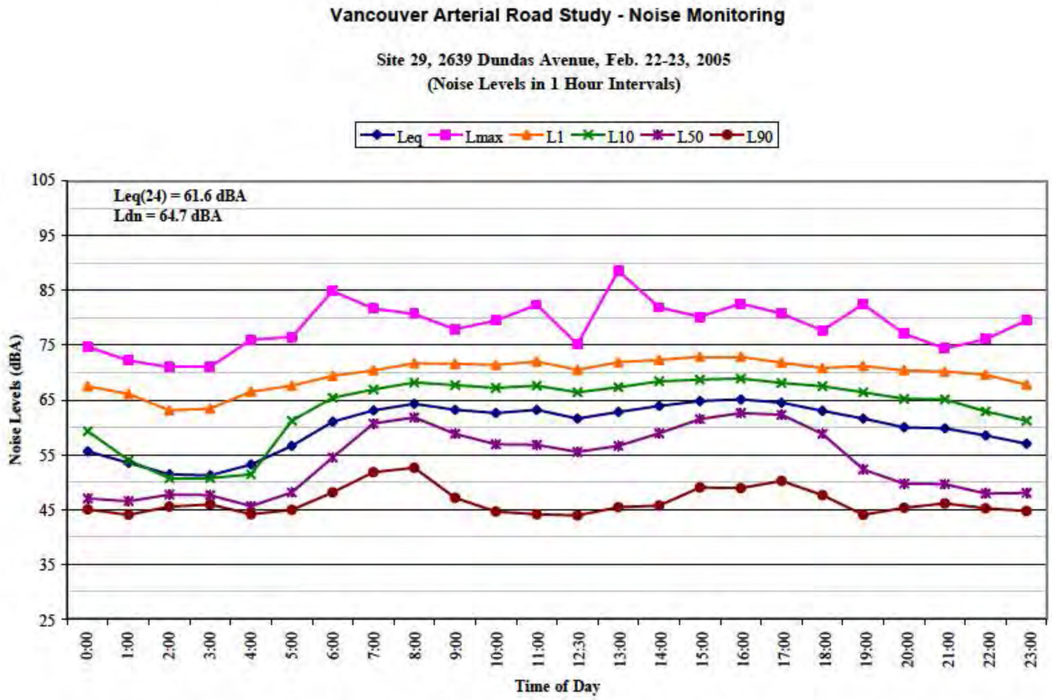

Vancouver Arterial Road Study - Noise Monitoring
Site 24, 1406 E 28th Avenue, Feb. 17-19, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) Fri = 74.4 dBA
Ldn Fri = 78.4
Leq(24) Sat = 72.8
Noise Levels (dBA)
Time of Day

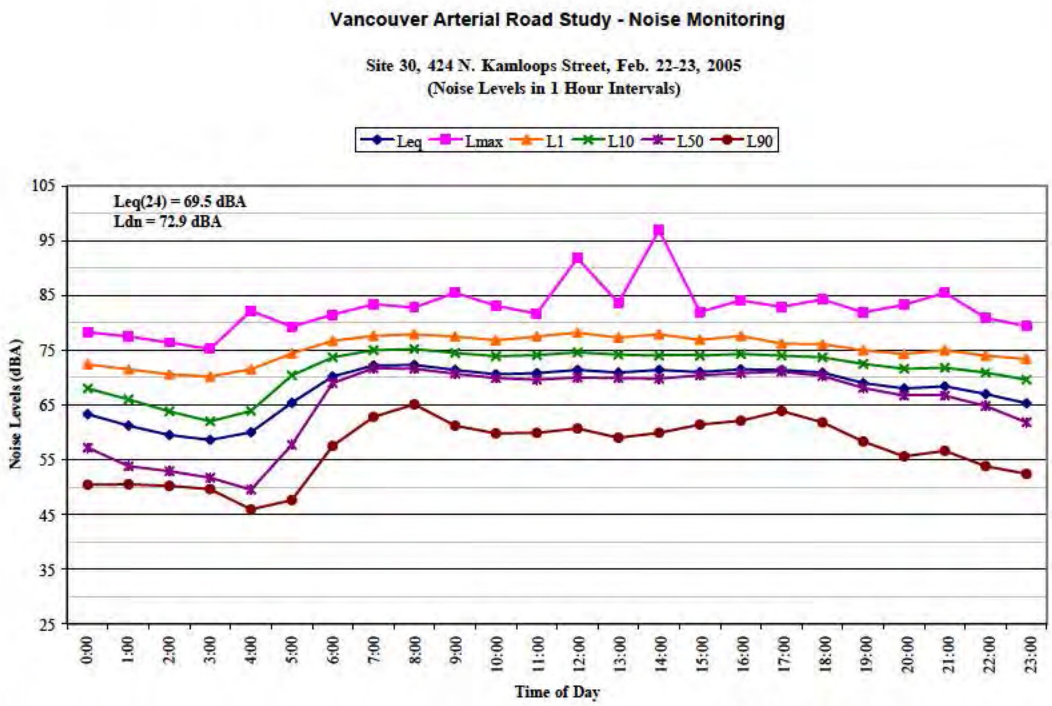

Vancouver Arterial Road Study - Noise Monitoring
Site 25, 157 W King Edward Avenue, Feb. 21-22, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 67.0 dBA
Ldn = 70.5 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 26, 1 - 3491 Main Street, Feb. 21-22, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 69.5 dBA
Ldn = 73.5 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 27, 2370 Clark Drive, Feb. 21-22, 2005
(Noise Levels in 1 Hour Intervals)
Leq Lmax L1 L10 L50 L90
Leq(24) = 71.9 dBA
Ldn = 75.9 dBA
Noise Levels (dBA)
Time of Day

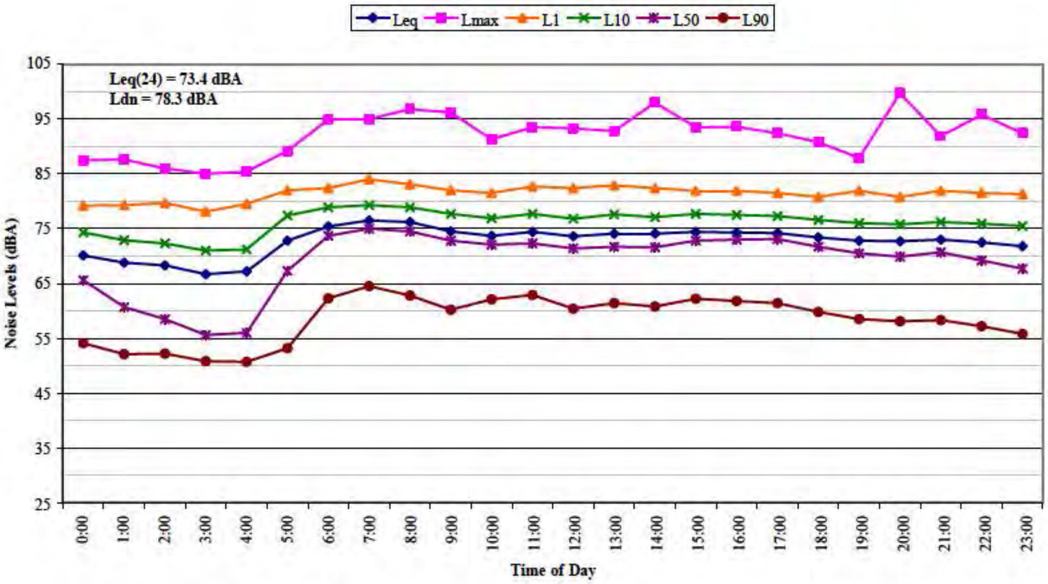

Vancouver Arterial Road Study - Noise Monitoring
Site 28, 3034 Grandview Highway S., Feb. 21-23, 2005
(Noise Levels in 1 Hour Intervals)
Leq Lmax L1 L10 L50 L90
Leq(24) Day 1 = 68.3 dBA
Ldn Day 1 = 72.3 dBA
Leq(24) Day 2 = 68.5 dBA
Ldn Day 2 =72.7 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 29, 2639 Dundas Avenue, Feb. 22-23, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 61.6 dBA
Ldn = 64.7 dBA
105
95
85
75
65
55
45
35
25
Noise Levels (dBA)
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:30
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 30, 424 N. Kamloops Street, Feb. 22-23, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(24) = 69.5 dBA
Ldn = 72.9 dBA
105
95
85
75
65
55
45
35
25
Noise Levels (dBA)
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

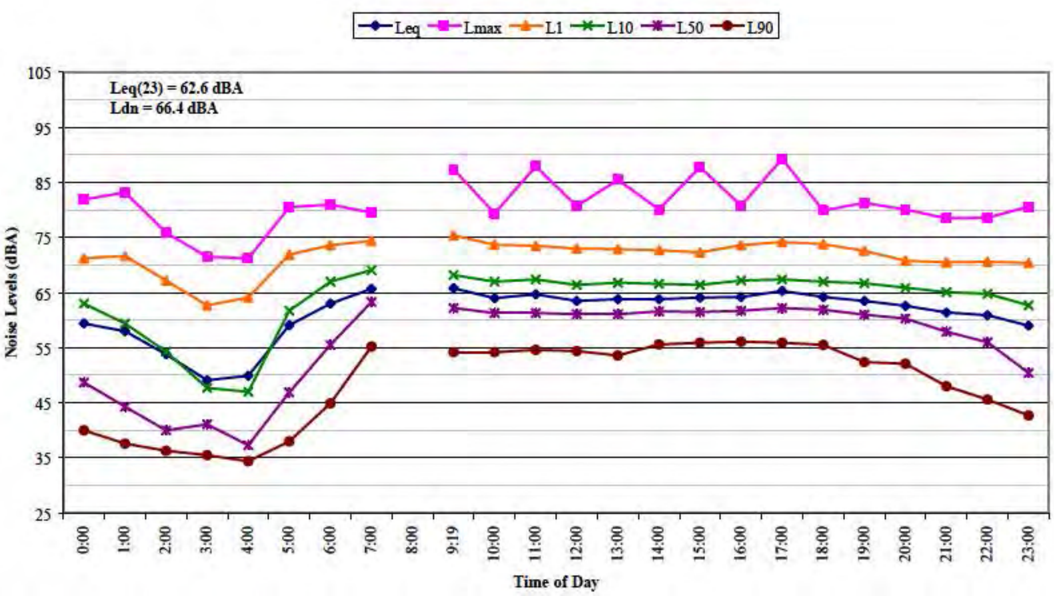
Vancouver Arterial Road Study - Noise Monitoring

Site 31, 201-2125 E. Hastings Street, Feb. 22-23, 2005
(Noise Levels in 1 Hour Intervals)



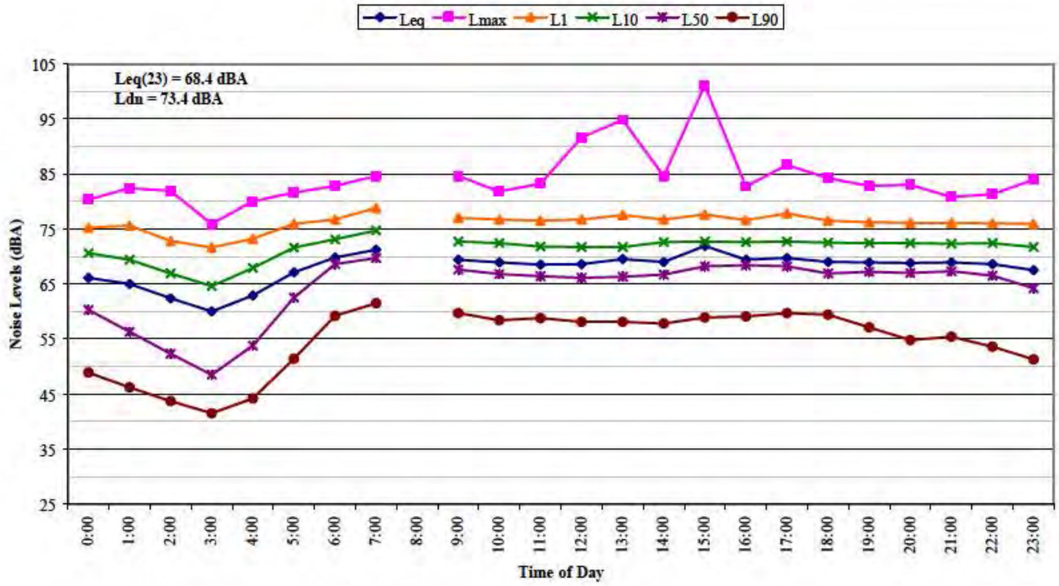
Vancouver Arterial Road Study Noise Monitoring

Site M1, 3479 W 41st Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Hour Intervals)



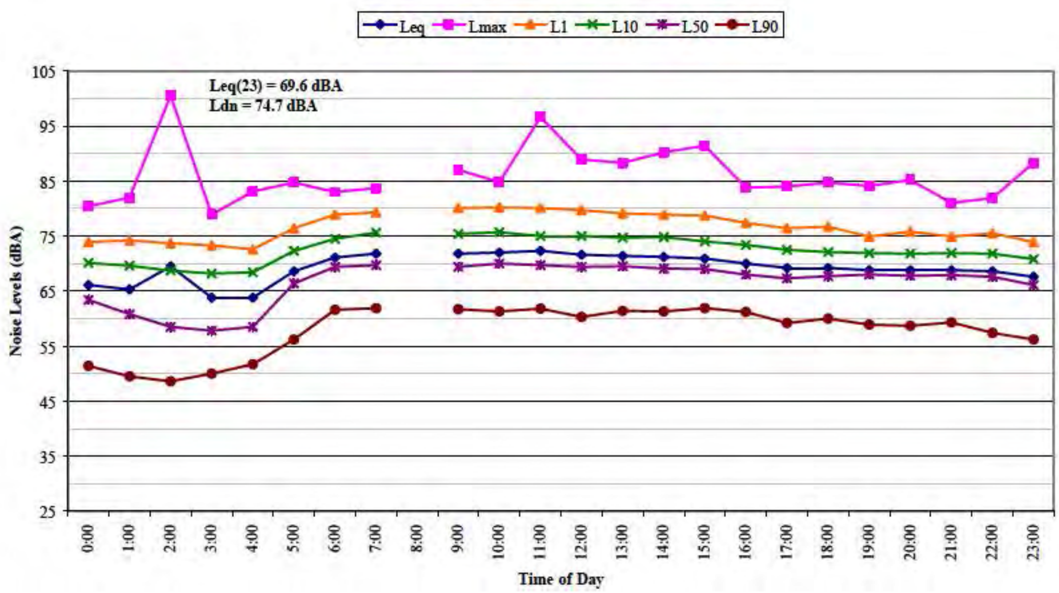
Vancouver Arterial Road Study - Noise Monitoring

Site M2, 1508 W 58th Avenue, Feb. 15-16, 2005
(Noise Levels in 1 Hour Intervals)



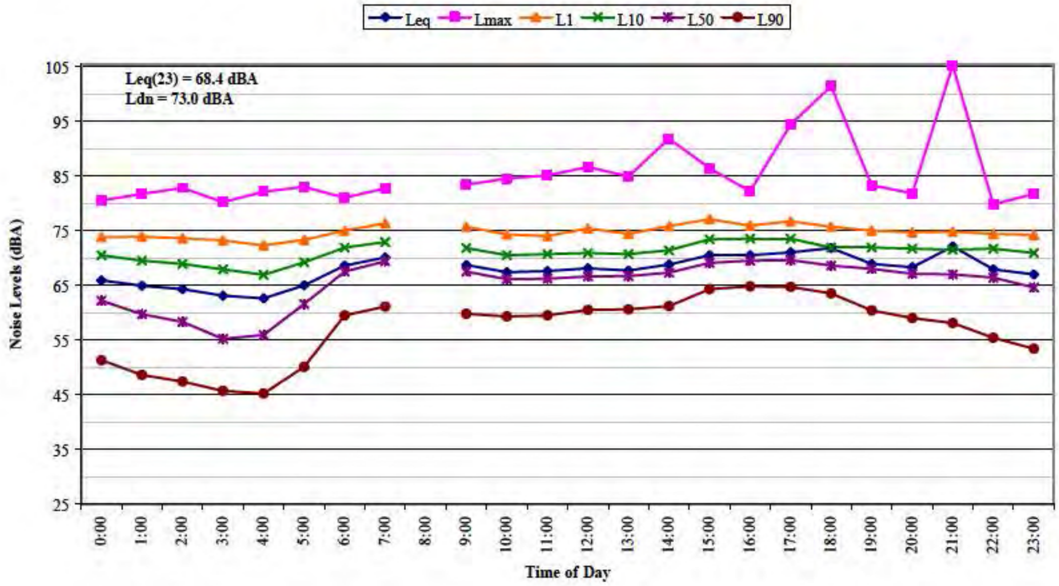
Vancouver Arterial Road Study - Noise Monitoring

Site M3, 7108 Knight Street, Feb. 16-17, 2005
(Noise Levels in 1 Hour Intervals)



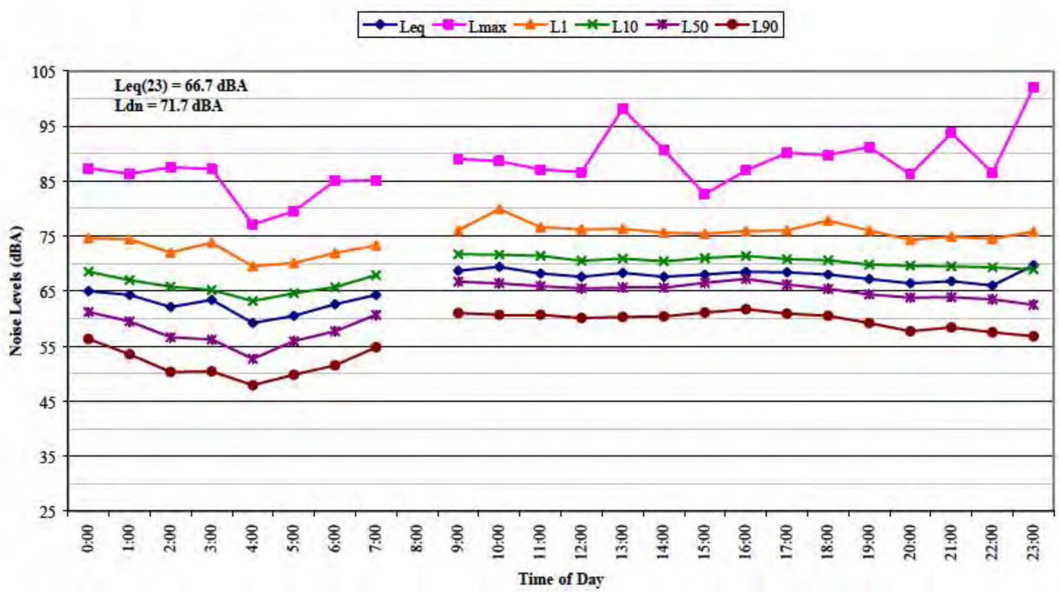
Vancouver Arterial Road Study - Noise Monitoring

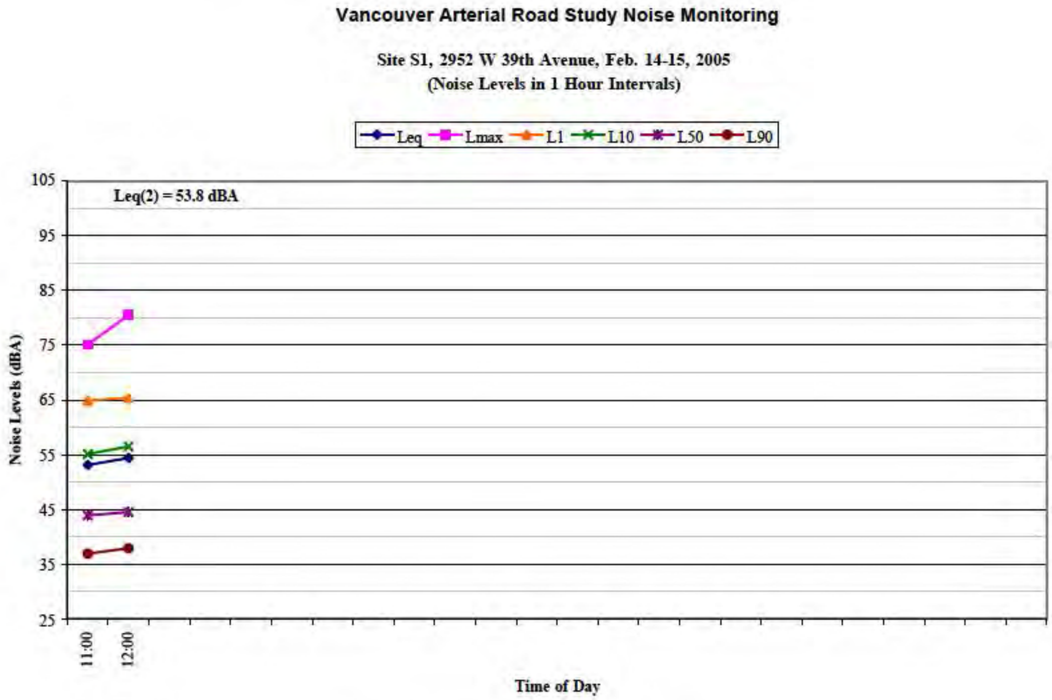
Site M4, 800 Kingsway Street, Feb. 17-18, 2005
(Noise Levels in 1 Hour Intervals)

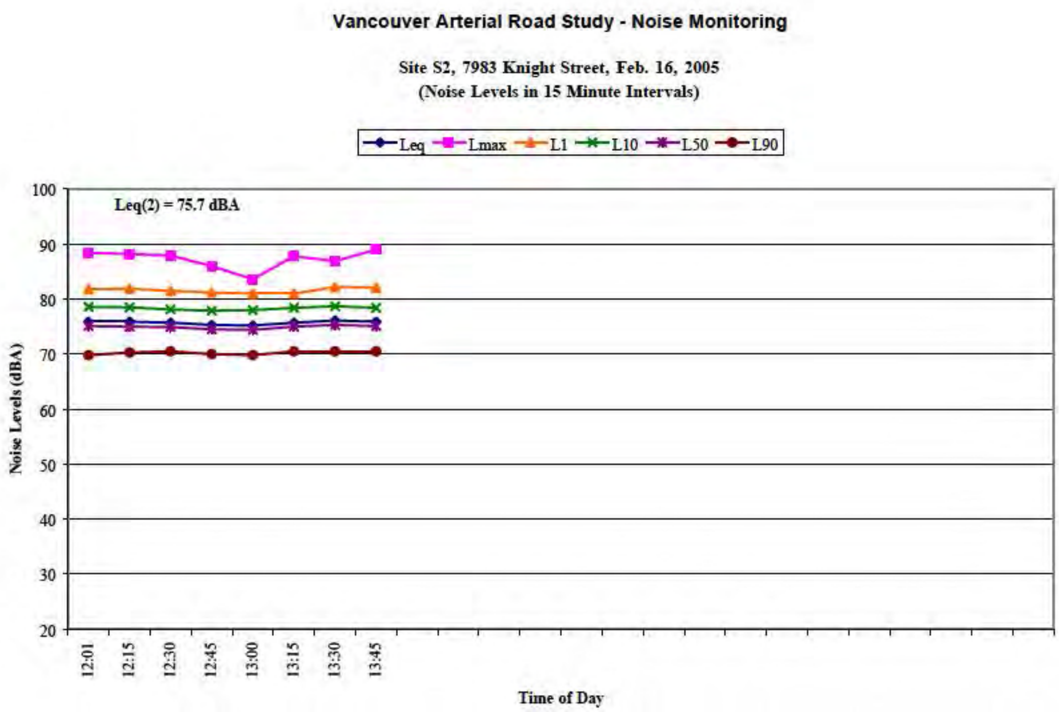


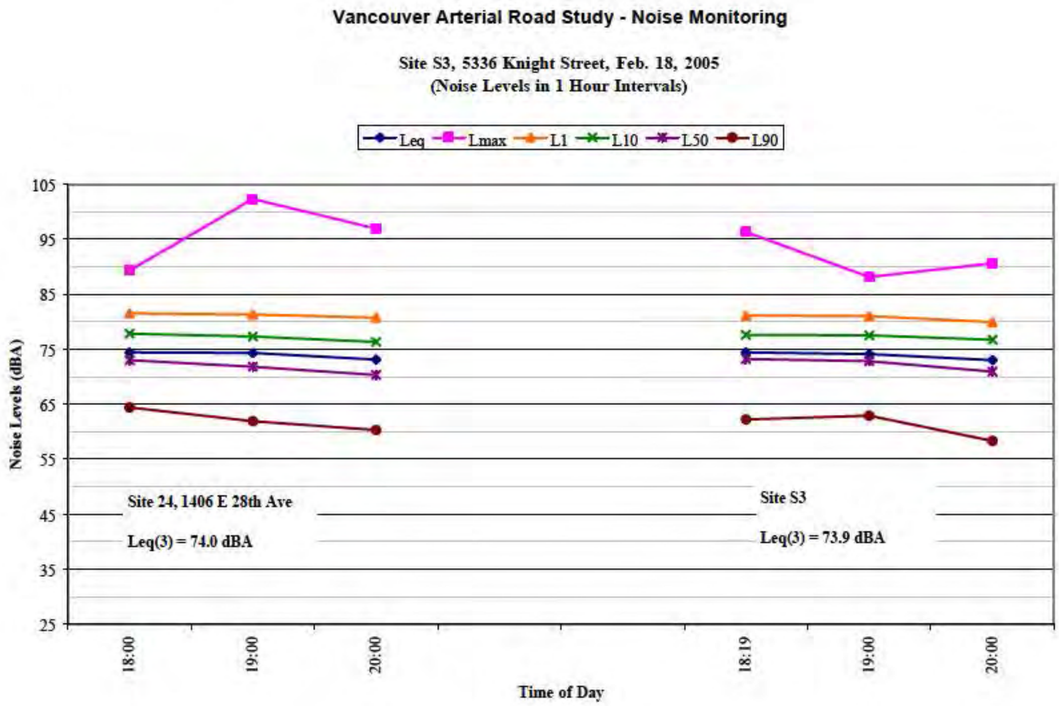
Vancouver Arterial Road Study - Noise Monitoring

Site M5, Commercial Dr. at E 8th St., Feb. 18-19, 2005
(Noise Levels in 1 Hour Intervals)

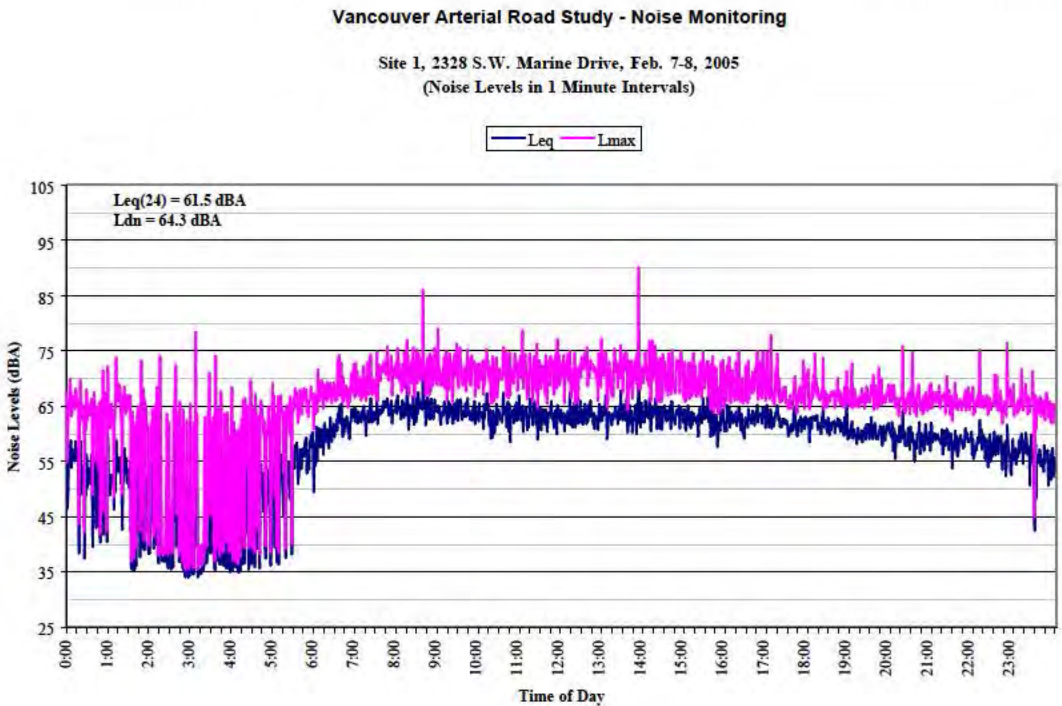


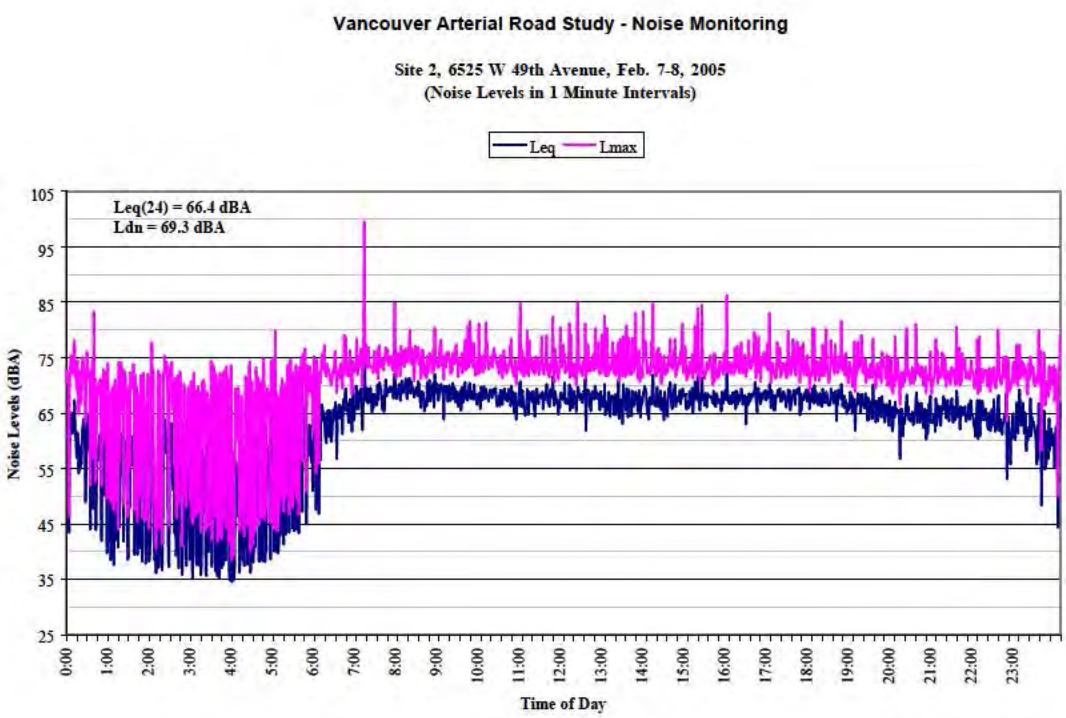

Vancouver Arterial Road Study Noise Monitoring
Site S1, 2952 W 39th Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(2) = 53.8 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
11:00
12:00
Time of Day

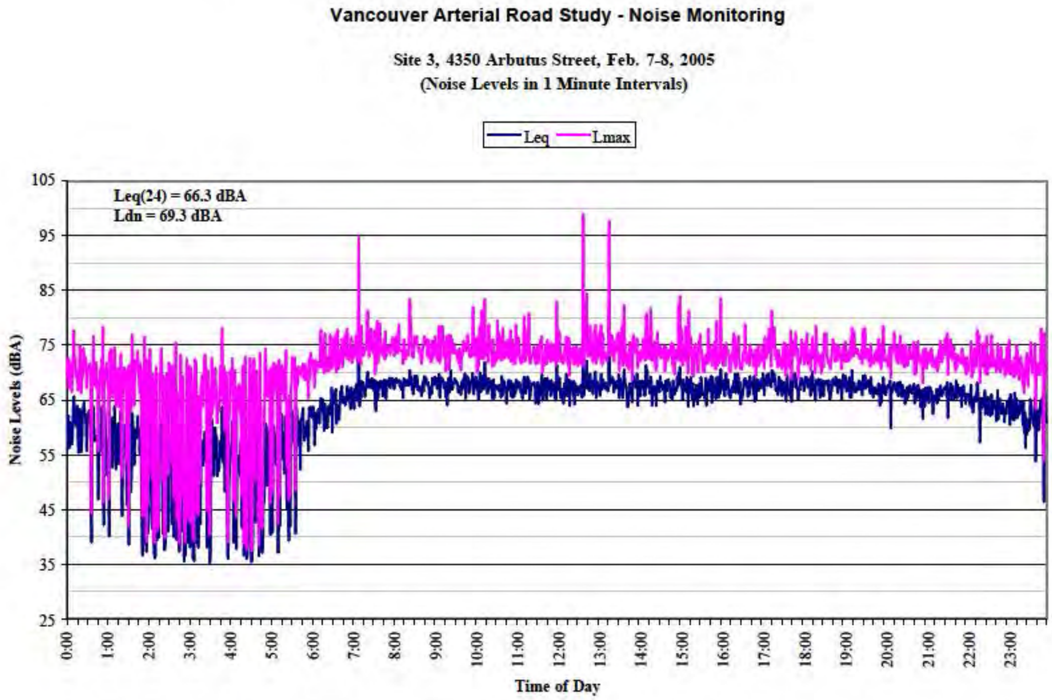

Vancouver Arterial Road Study - Noise Monitoring
Site S2, 7983 Knight Street, Feb. 16, 2005
(Noise Levels in 15 Minute Intervals)
Leq
Lmax
L1
L10
L50
L90
Leq(2) = 75.7 dBA
Noise Levels (dBA)
100
90
80
70
60
50
40
30
20
12:01
12:15
12:30
12:45
13:00
13:15
13:30
13:45
Time of Day

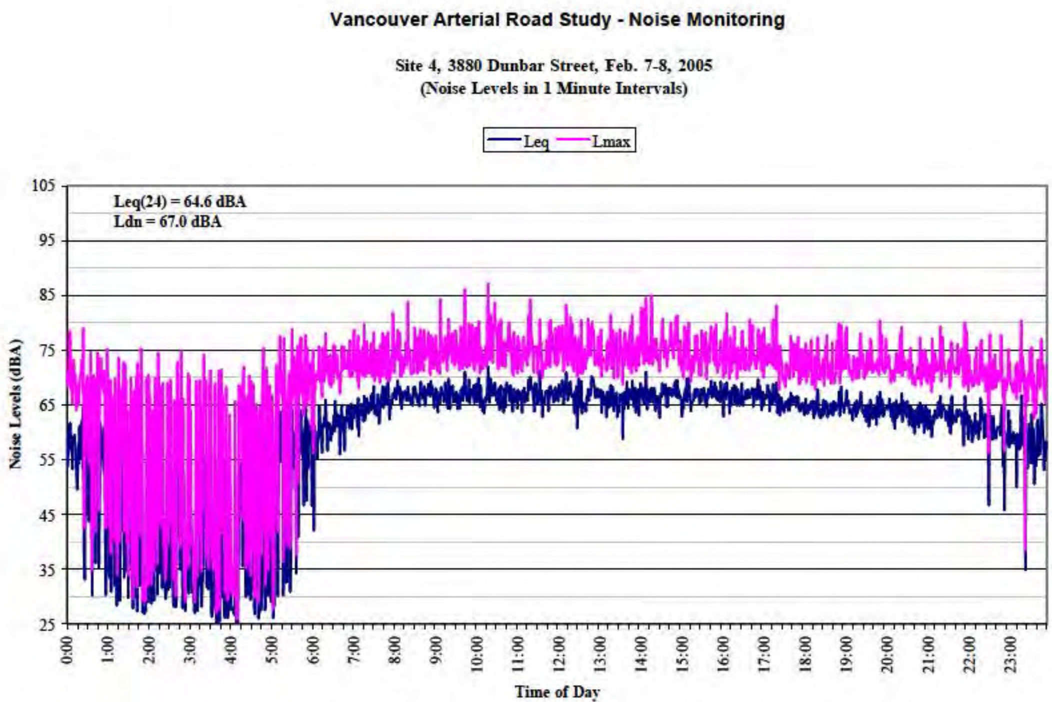

Vancouver Arterial Road Study - Noise Monitoring
Site S3, 5336 Knight Street, Feb. 18, 2005
(Noise Levels in 1 Hour Intervals)
Leq
Lmax
L1
L10
L50
L90
105
95
85
75
65
55
45
35
25
Noise Levels (dBA)
Site 24, 1406 E 28th Ave
Leq(3) = 74.0 dBA
Site S3
Leq(3) = 73.9 dBA
18:00
19:00
20:00
18:19
19:00
20:00
Time of Day

APPENDIX C – MONITORING SITE RESULTS, 1-MINUTE INTERVALS



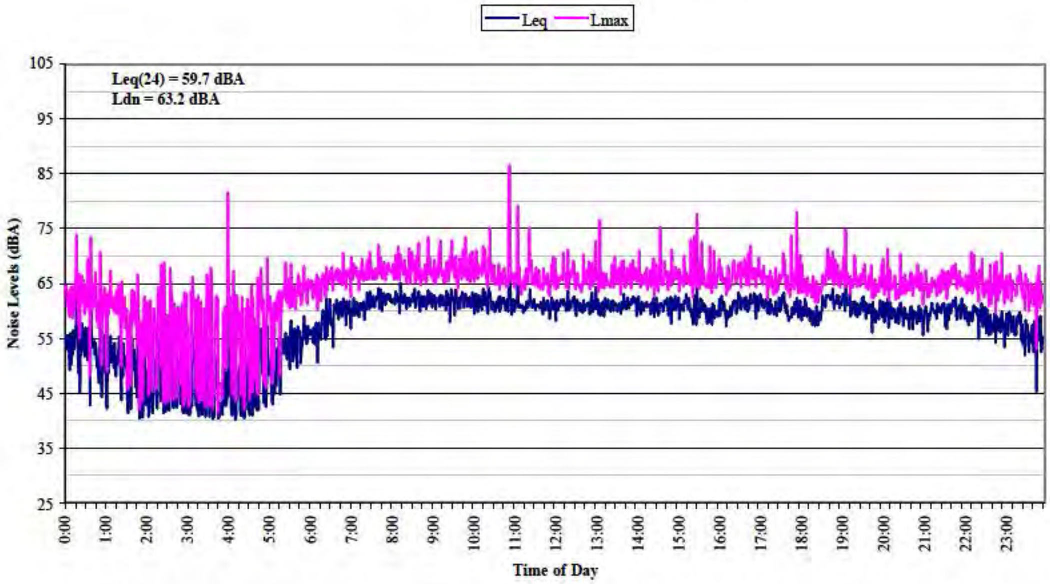



Vancouver Arterial Road Study - Noise Monitoring
Site 3, 4350 Arbutus Street, Feb. 7-8, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 66.3 dBA
Ldn = 69.3 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 4, 3880 Dunbar Street, Feb. 7-8, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 64.6 dBA
Ldn = 67.0 dBA
Noise Levels (dBA)
Time of Day

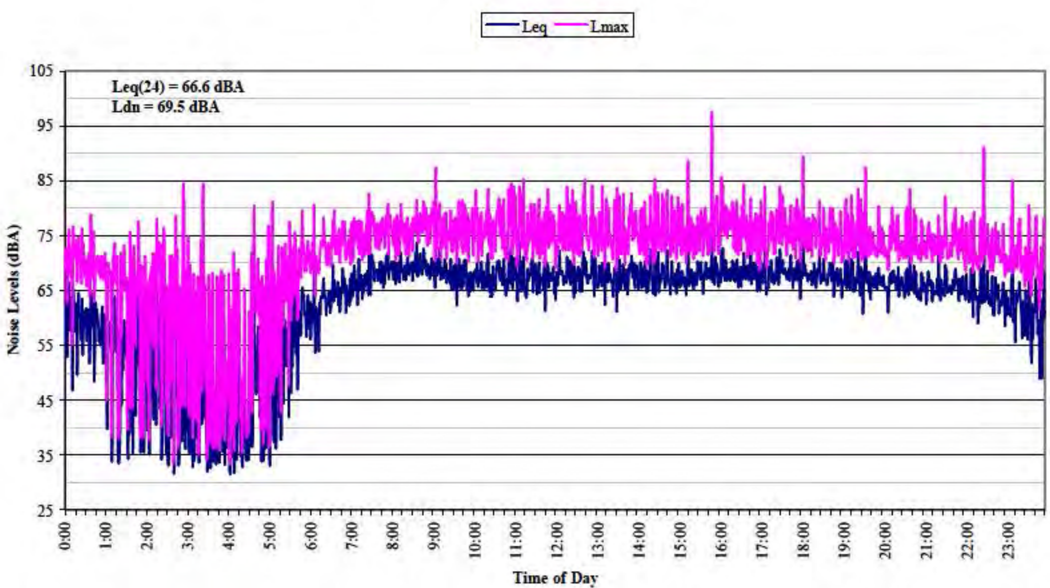
Vancouver Arterial Road Study - Noise Monitoring

Site 5, 1668 W 16th Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Minute Intervals)



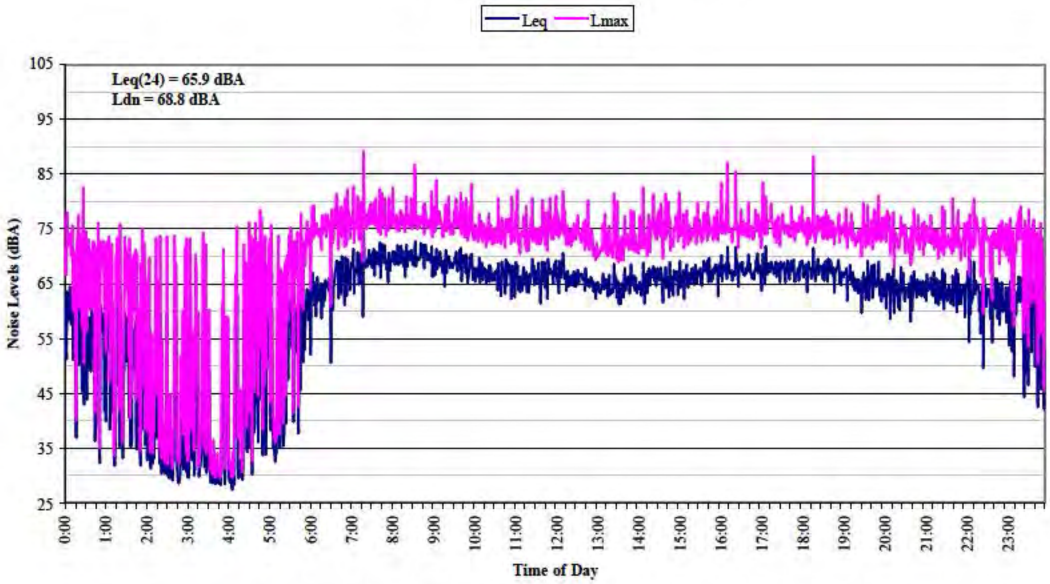
Vancouver Arterial Road Study - Noise Monitoring

Site 6, 3828 W 10th Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Minute Intervals)



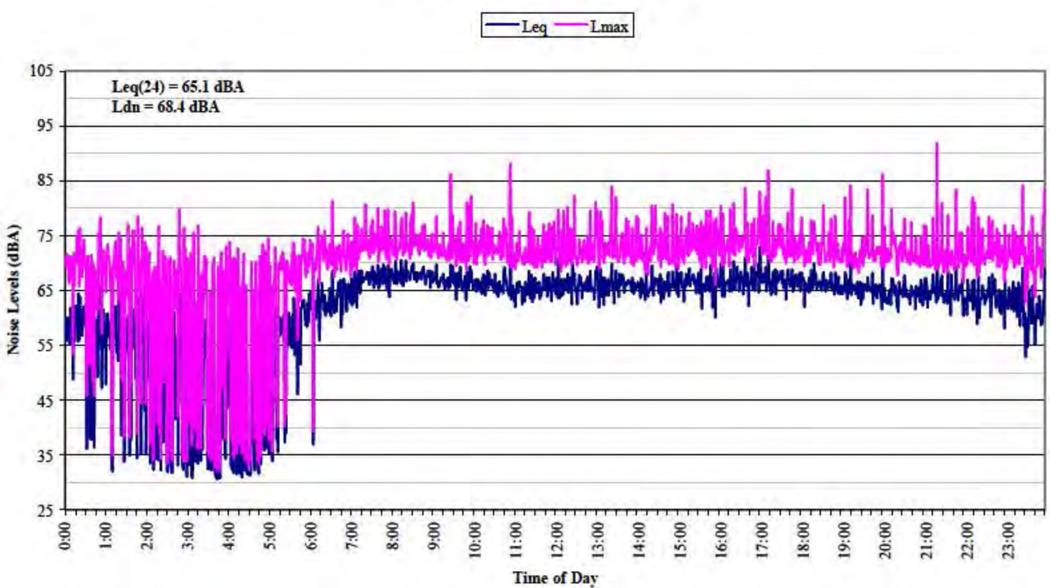
Vancouver Arterial Road Study - Noise Monitoring

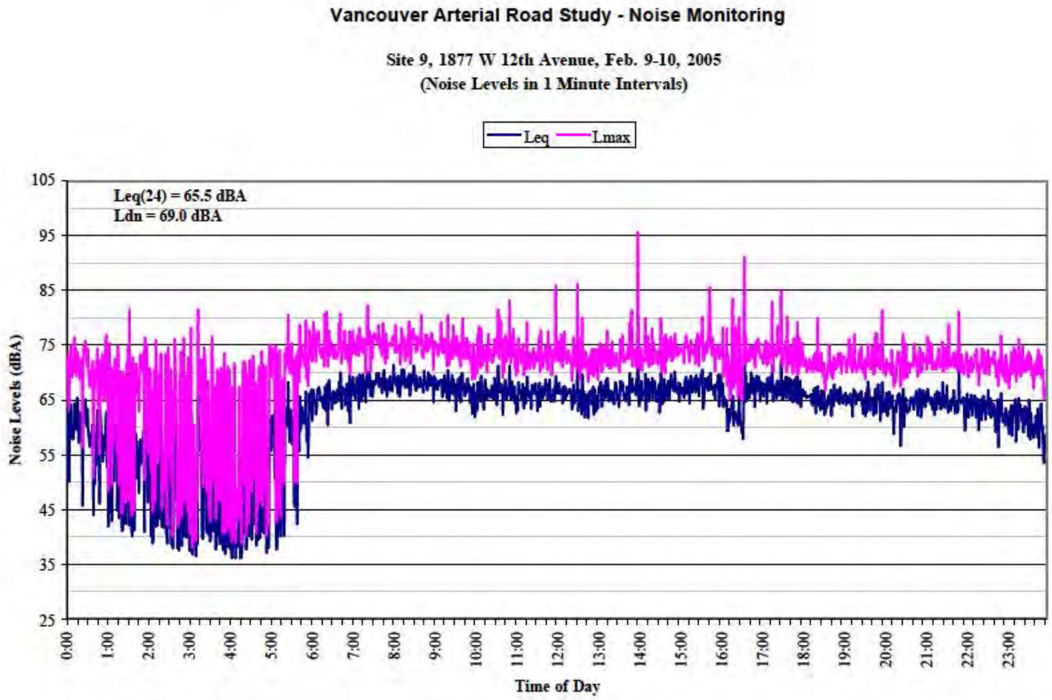
Site 7, 123 - 1985 Wallace Street, Feb. 8-9, 2005
(Noise Levels in 1 Minute Intervals)

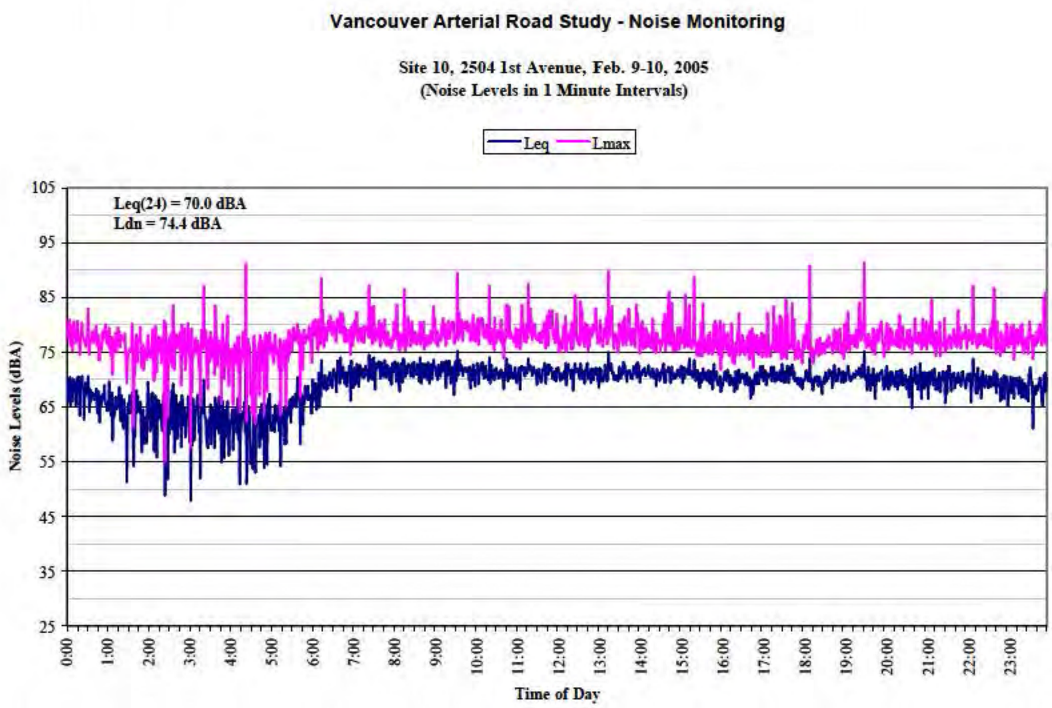


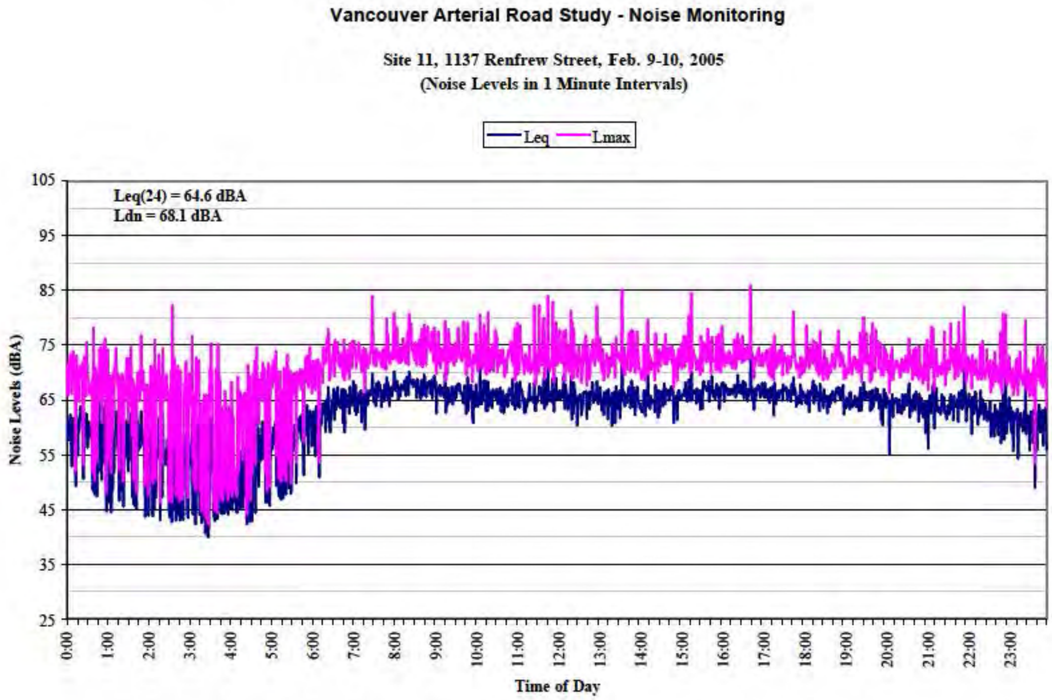
Vancouver Arterial Road Study - Noise Monitoring

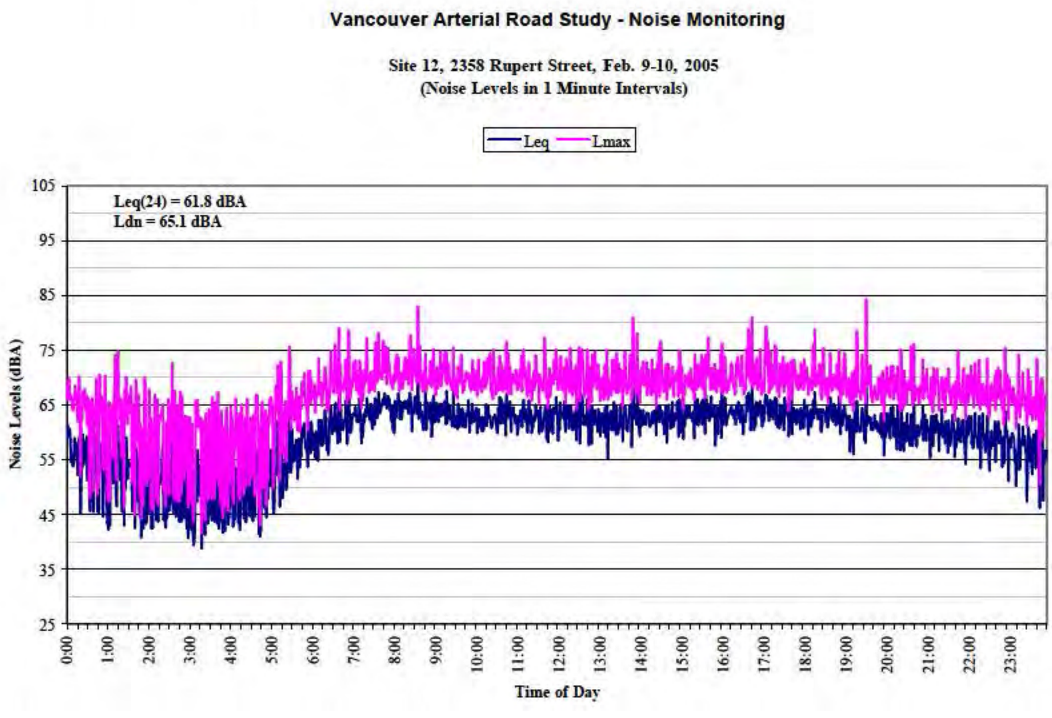
Site 8, 2505 Cornwall Avenue, Feb. 8-9, 2005
(Noise Levels in 1 Minute Intervals)

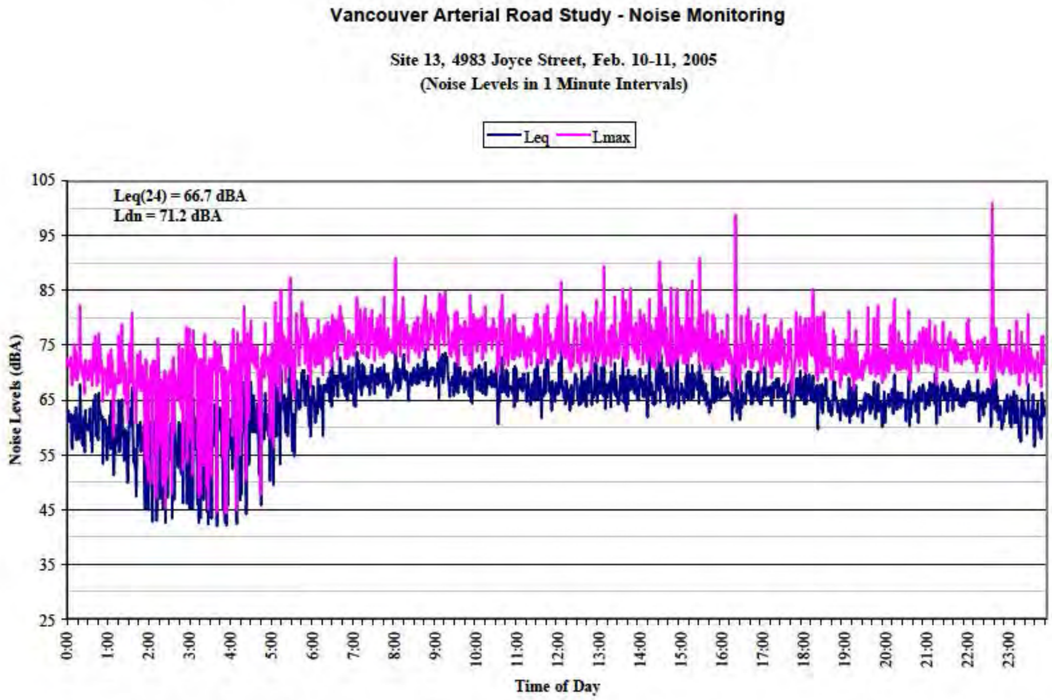


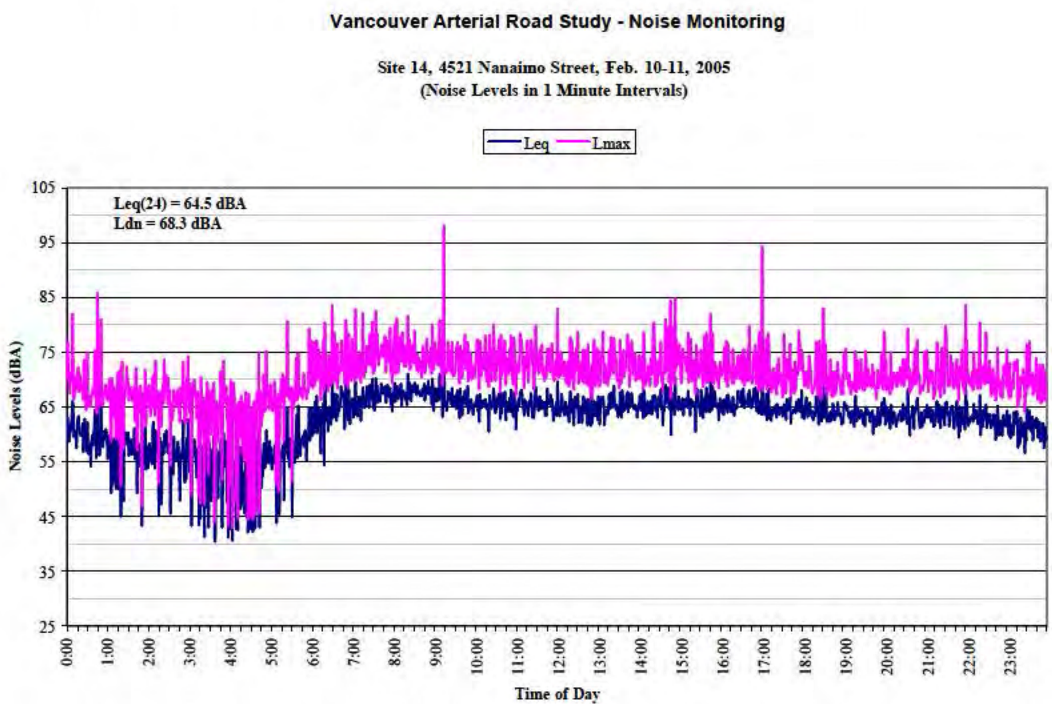

Vancouver Arterial Road Study - Noise Monitoring
Site 9, 1877 W 12th Avenue, Feb. 9-10, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 65.5 dBA
Ldn = 69.0 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 10, 2504 1st Avenue, Feb. 9-10, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 70.0 dBA
Ldn = 74.4 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 11, 1137 Renfrew Street, Feb. 9-10, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 64.6 dBA
Ldn = 68.1 dBA
Noise Levels (dBA)
Time of Day

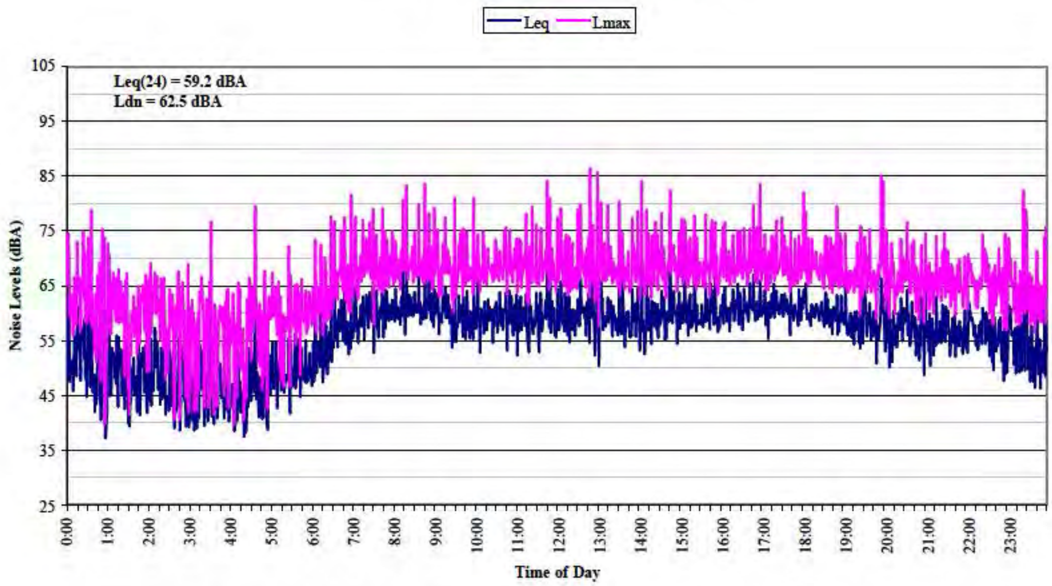

Vancouver Arterial Road Study - Noise Monitoring
Site 12, 2358 Rupert Street, Feb. 9-10, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 61.8 dBA
Ldn = 65.1 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 13, 4983 Joyce Street, Feb. 10-11, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 66.7 dBA
Ldn = 71.2 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 14, 4521 Nanaimo Street, Feb. 10-11, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 64.5 dBA
Ldn = 68.3 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

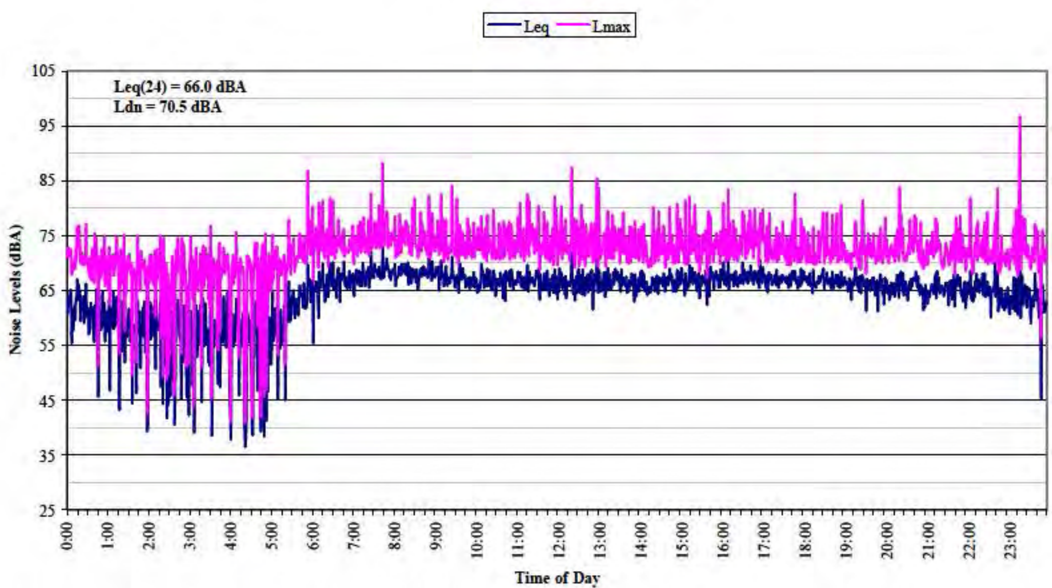
Vancouver Arterial Road Study - Noise Monitoring

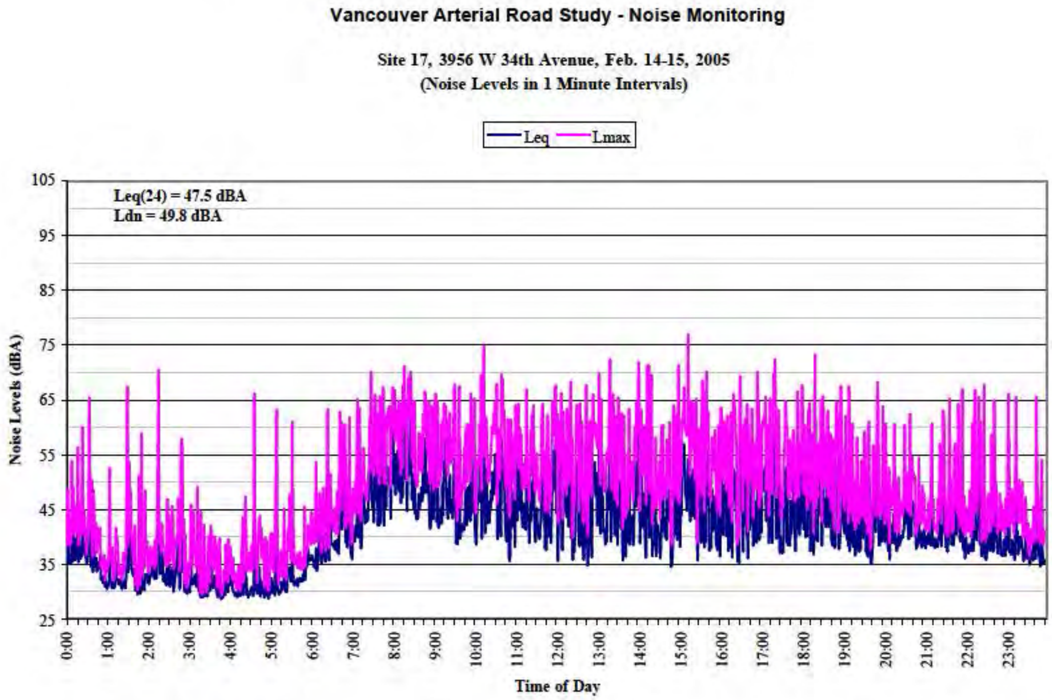
Site 15, 7057 Elliot Street, Feb. 10-11, 2005
(Noise Levels in 1 Minute Intervals)

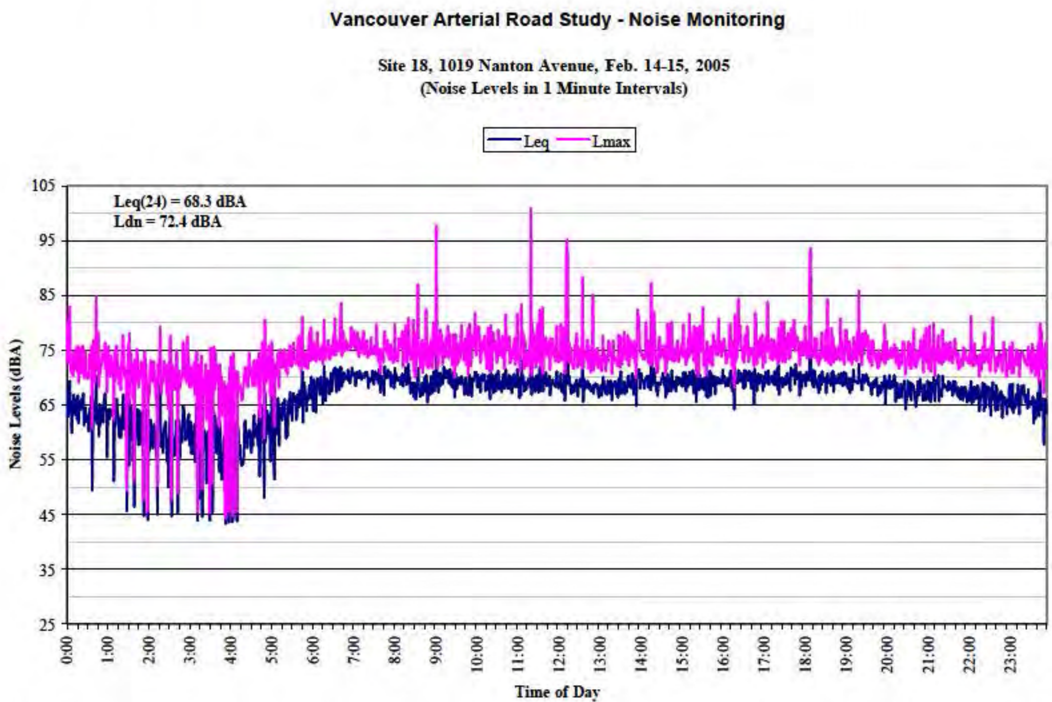


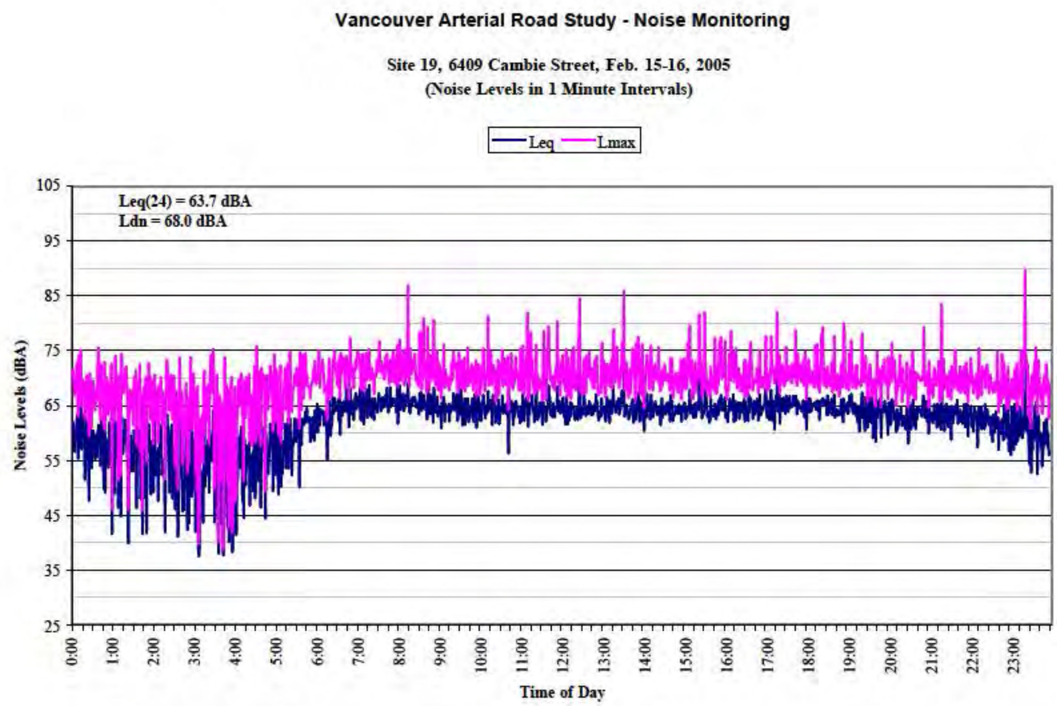
Vancouver Arterial Road Study - Noise Monitoring

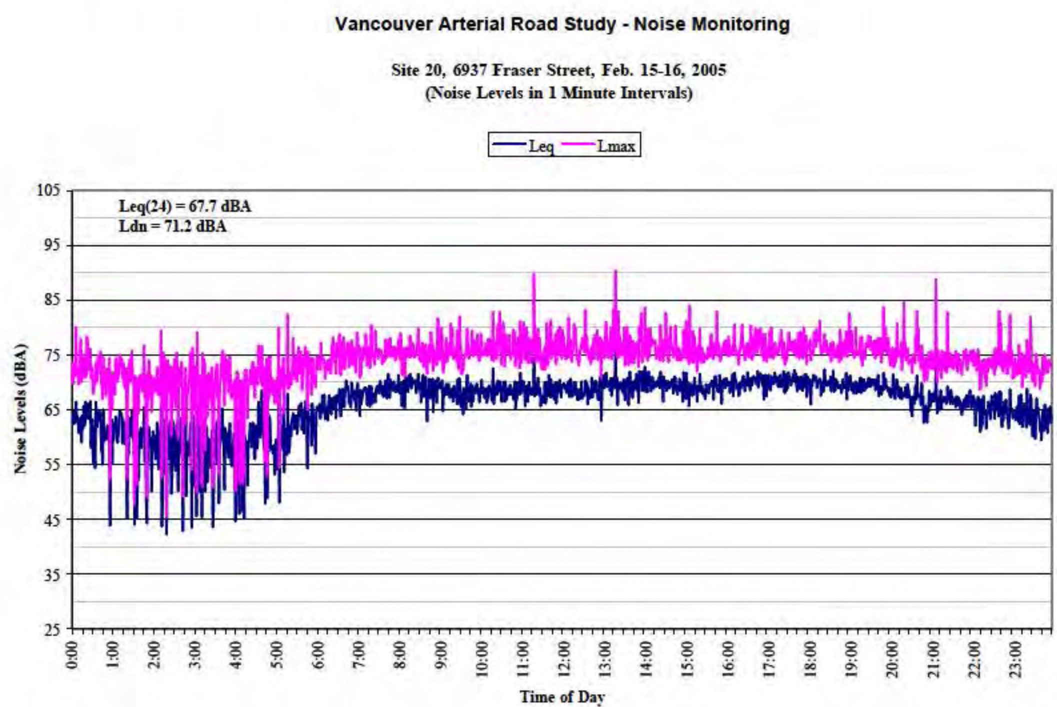
Site 16, 6749 Kerr Street, Feb. 10-11, 2005
(Noise Levels in 1 Minute Intervals)

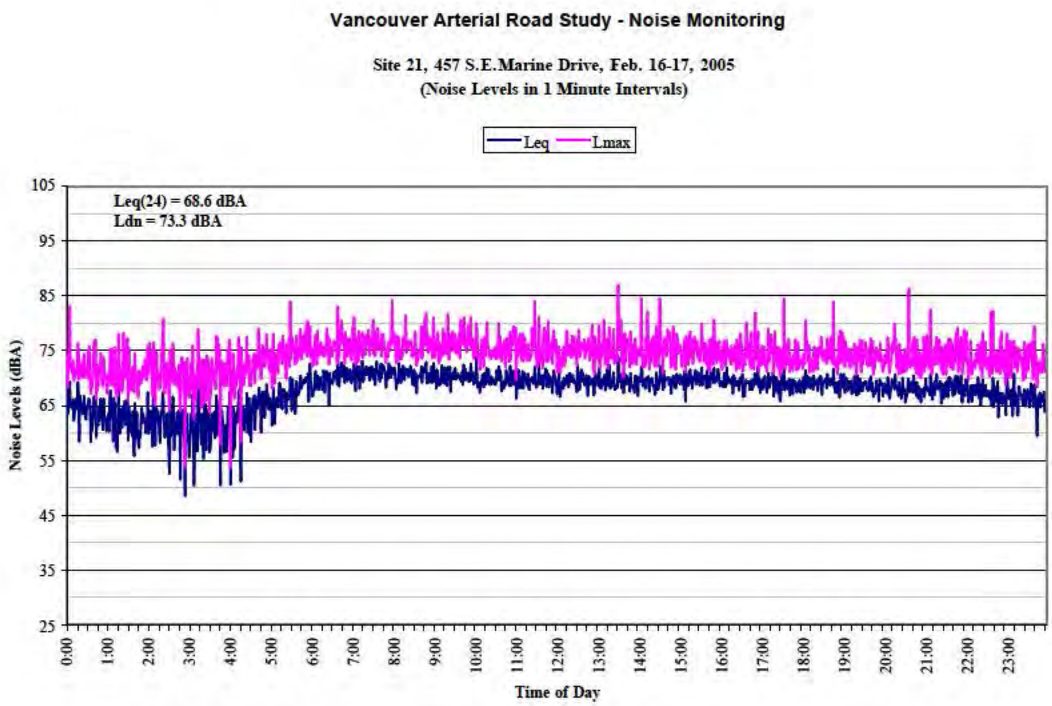


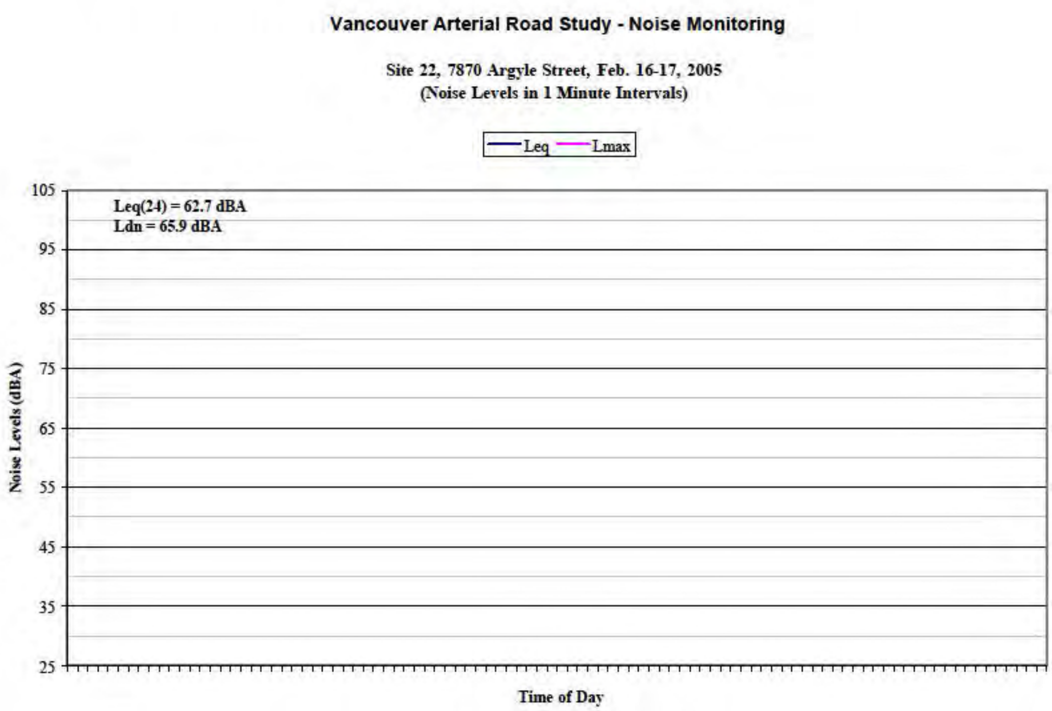

Vancouver Arterial Road Study - Noise Monitoring
Site 17, 3956 W 34th Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 47.5 dBA
Ldn = 49.8 dBA
Noise Levels (dBA)
Time of Day

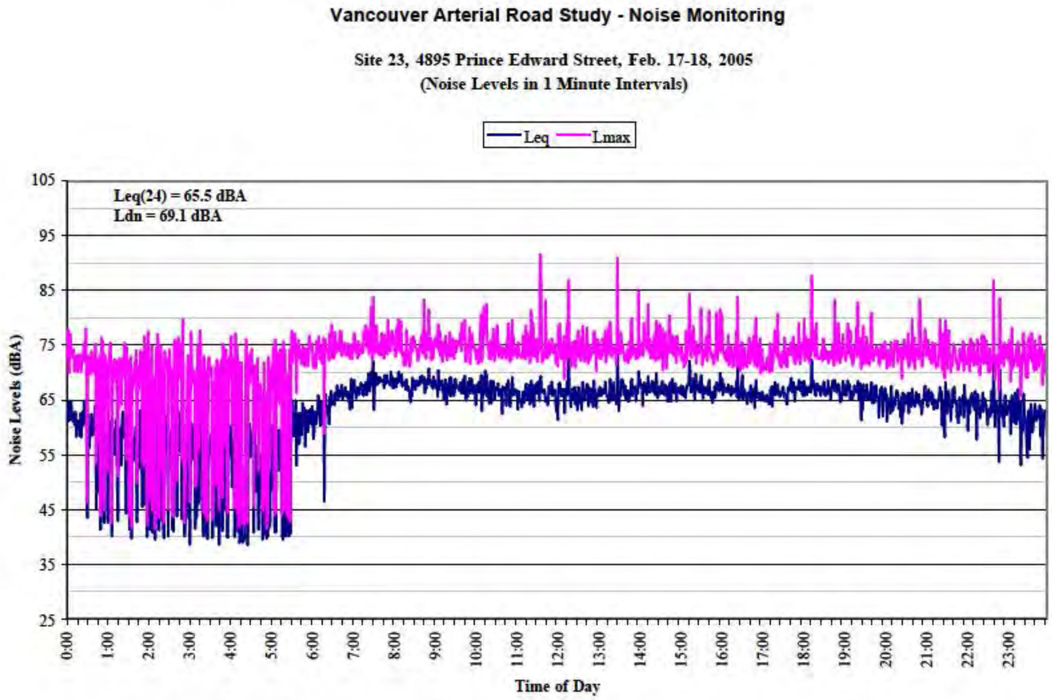

Vancouver Arterial Road Study - Noise Monitoring
Site 18, 1019 Nanton Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 68.3 dBA
Ldn = 72.4 dBA
Noise Levels (dBA)
Time of Day

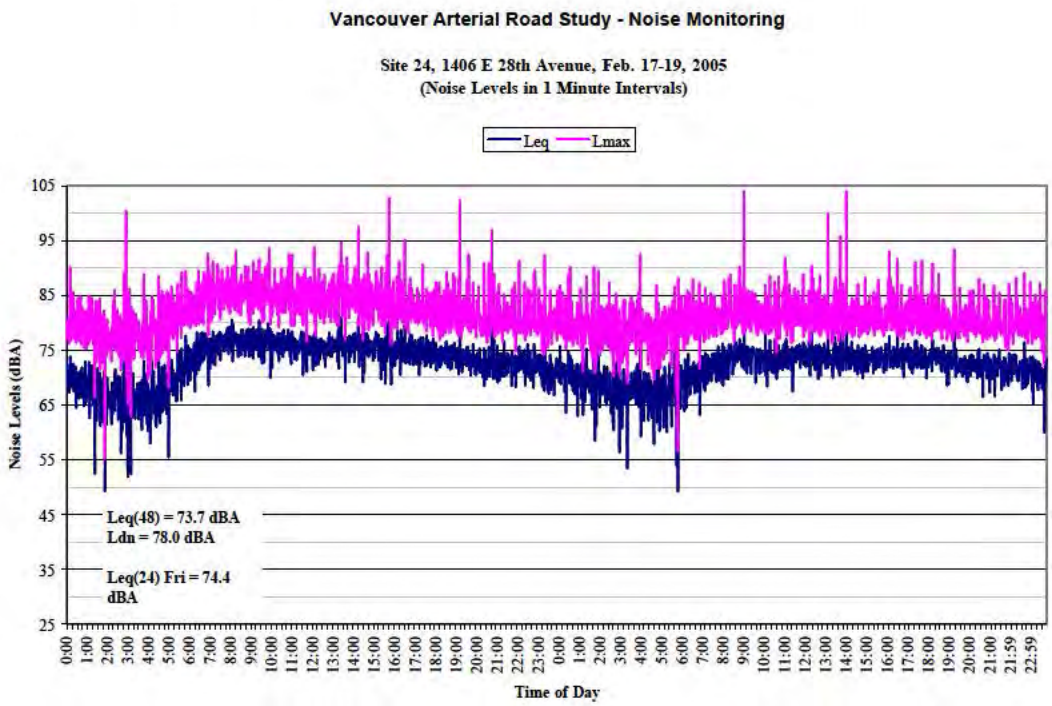

Vancouver Arterial Road Study - Noise Monitoring
Site 19, 6409 Cambie Street, Feb. 15-16, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 63.7 dBA
Ldn = 68.0 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

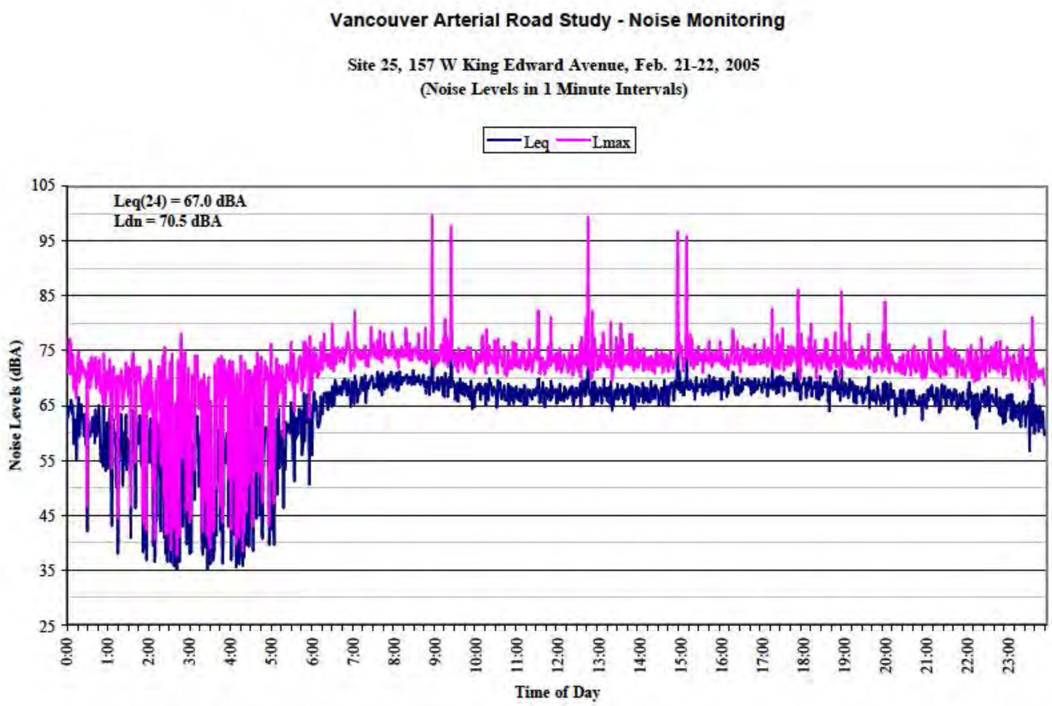

Vancouver Arterial Road Study - Noise Monitoring
Site 20, 6937 Fraser Street, Feb. 15-16, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 67.7 dBA
Ldn = 71.2 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

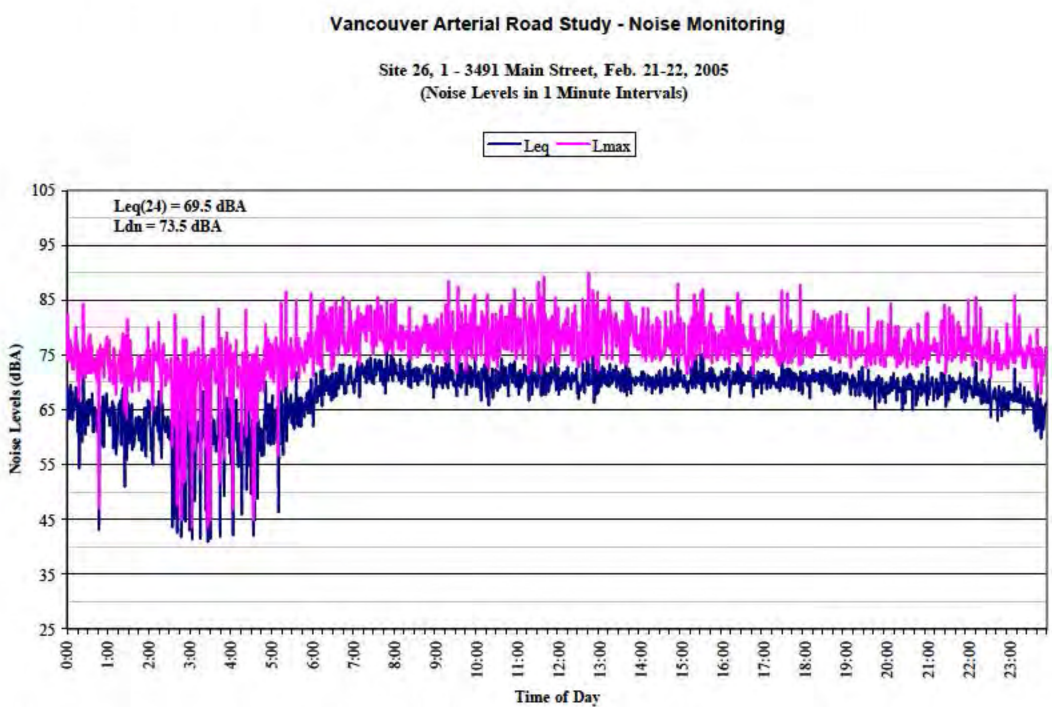

Vancouver Arterial Road Study - Noise Monitoring
Site 21, 457 S.E.Marine Drive, Feb. 16-17, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 68.6 dBA
Ldn = 73.3 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 22, 7870 Argyle Street, Feb. 16-17, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 62.7 dBA
Ldn = 65.9 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 23, 4895 Prince Edward Street, Feb. 17-18, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 65.5 dBA
Ldn = 69.1 dBA
Noise Levels (dBA)
Time of Day

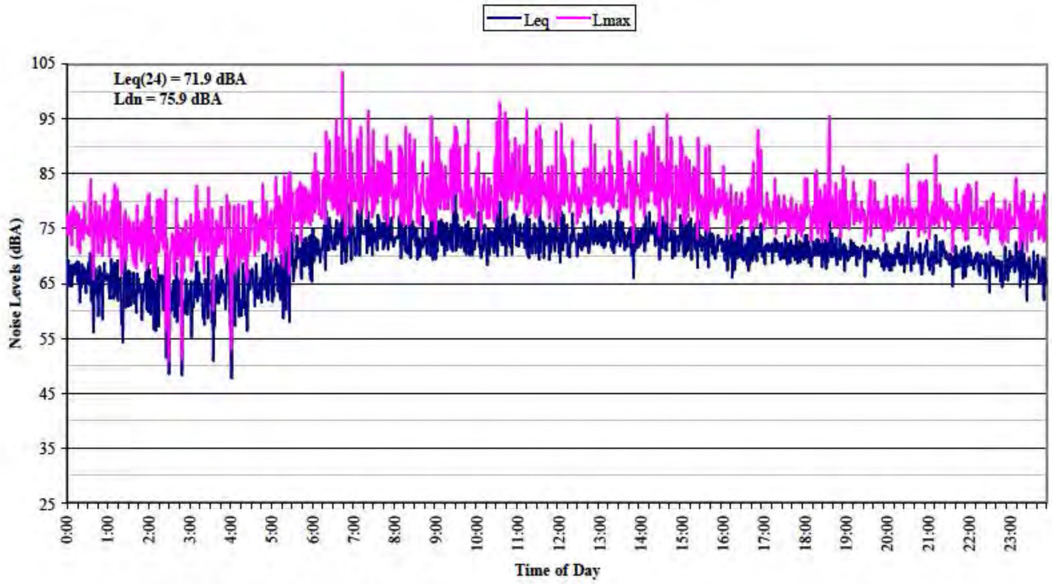

Vancouver Arterial Road Study - Noise Monitoring
Site 24, 1406 E 28th Avenue, Feb. 17-19, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(48) = 73.7 dBA
Ldn = 78.0 dBA
Leq(24) Fri = 74.4 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 25, 157 W King Edward Avenue, Feb. 21-22, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 67.0 dBA
Ldn = 70.5 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 26, 1 - 3491 Main Street, Feb. 21-22, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 69.5 dBA
Ldn = 73.5 dBA
Noise Levels (dBA)
Time of Day

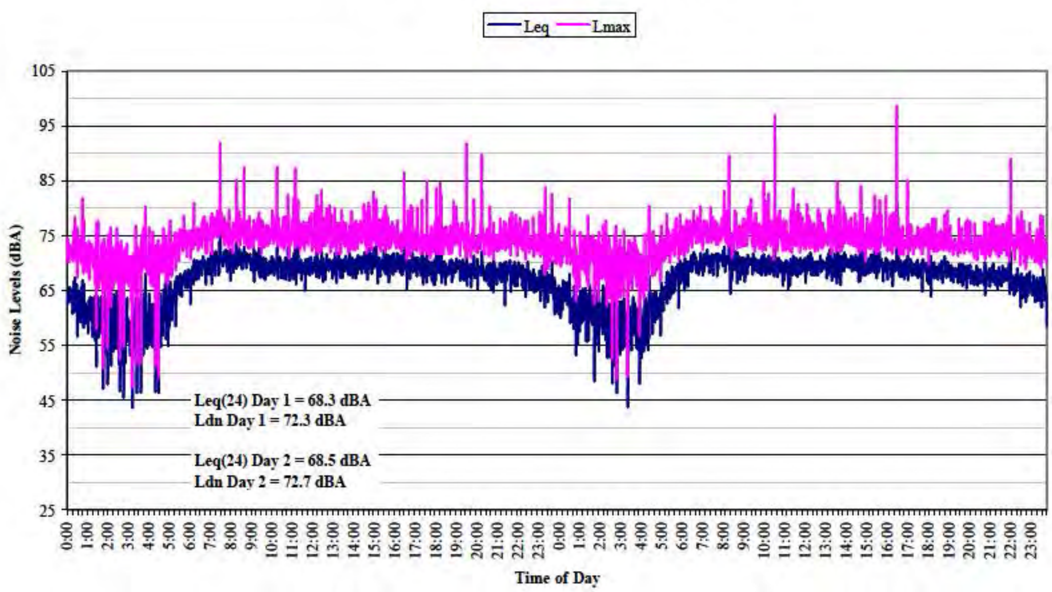
Vancouver Arterial Road Study - Noise Monitoring

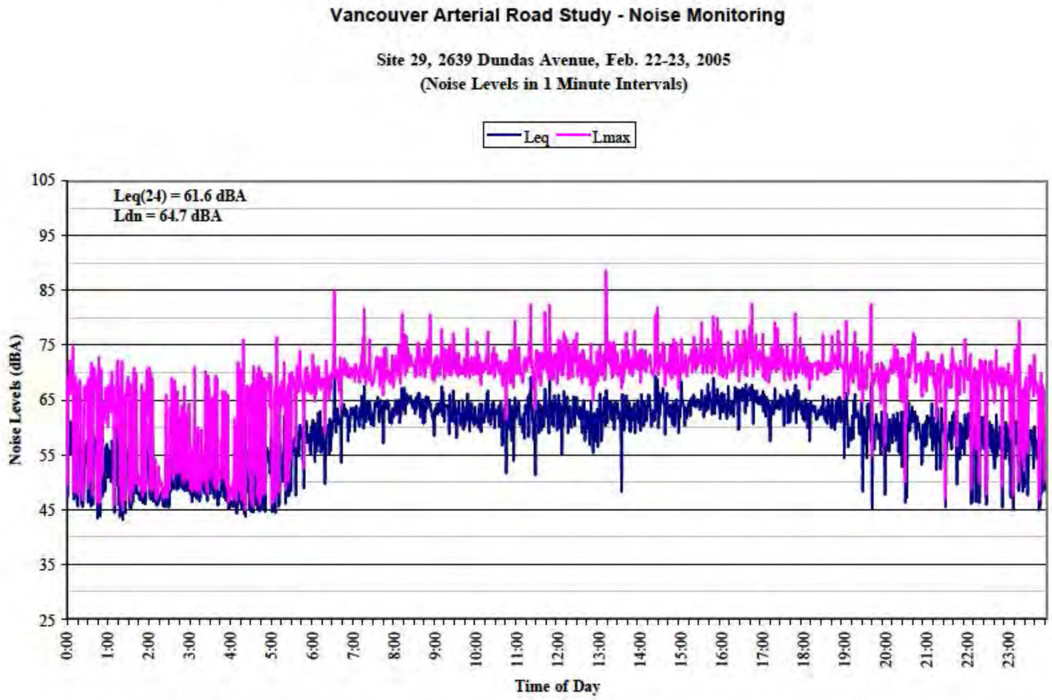
Site 27, 2370 Clark Drive, Feb. 21-22, 2005
(Noise Levels in 1 Minute Intervals)

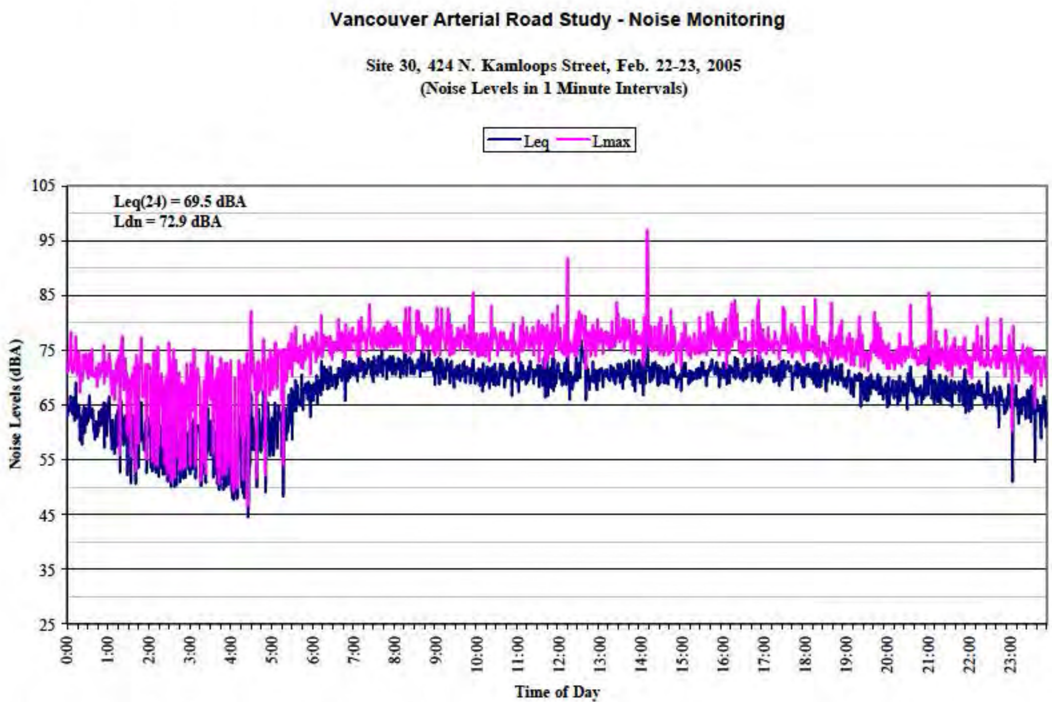


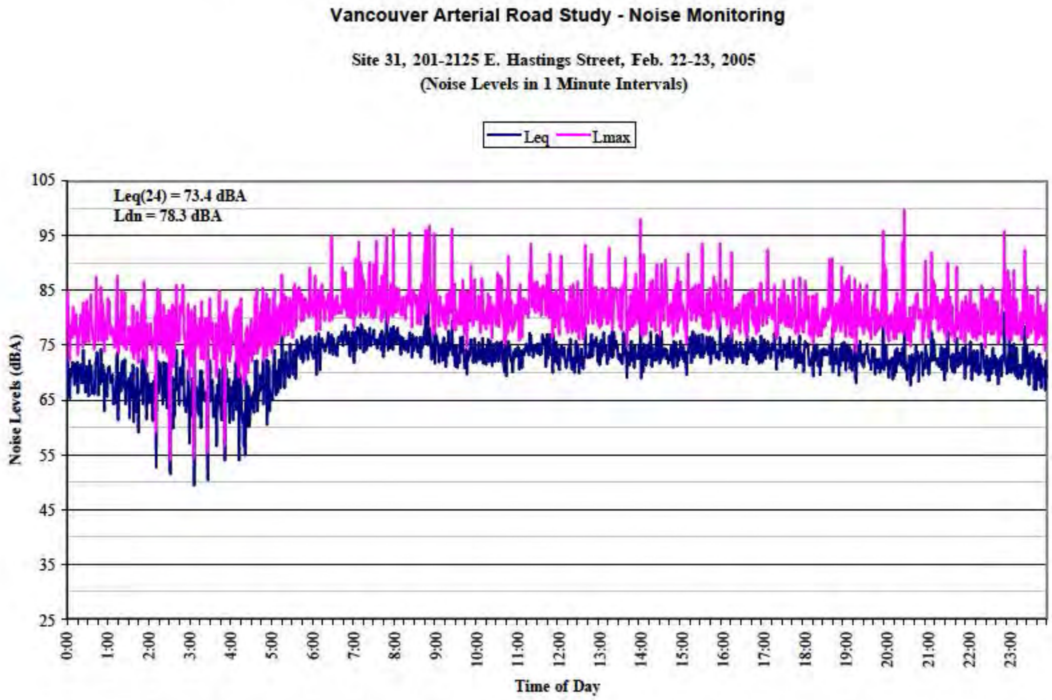
Vancouver Arterial Road Study - Noise Monitoring

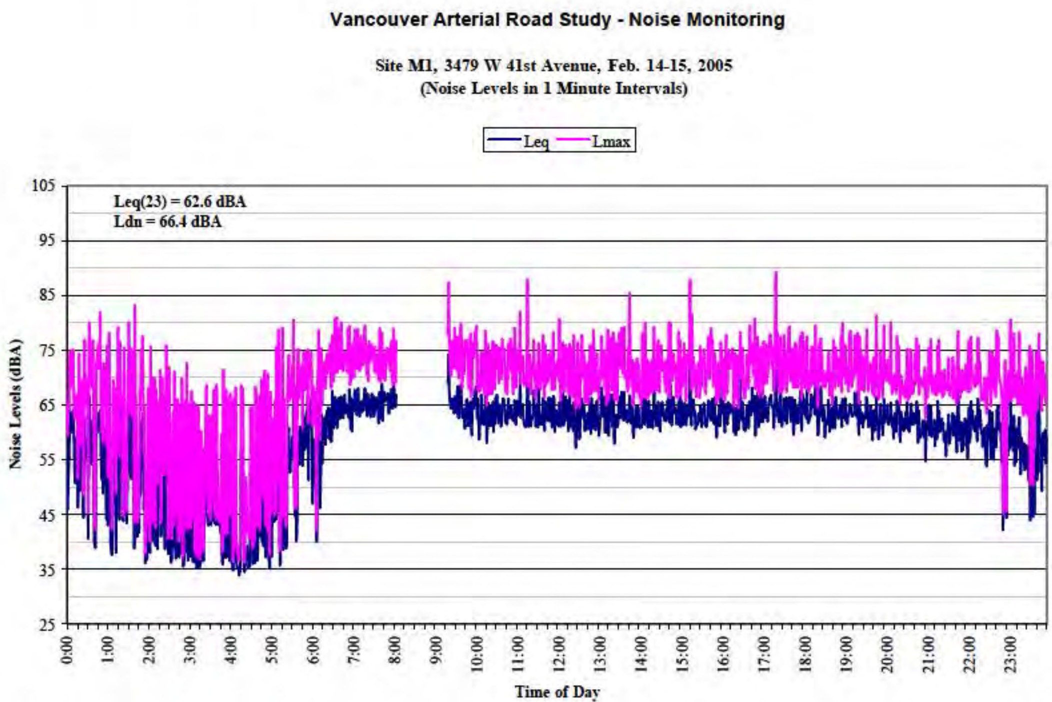
Site 28, 3034 Grandview Highway S., Feb. 21-23, 2005
(Noise Levels in 1 Minute Intervals)

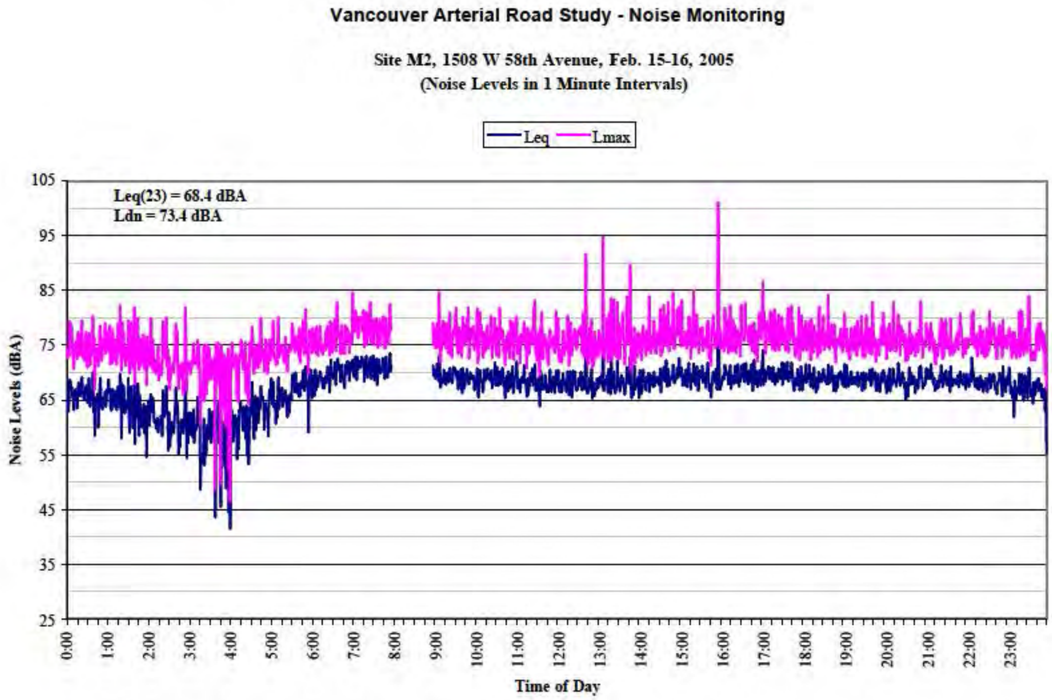


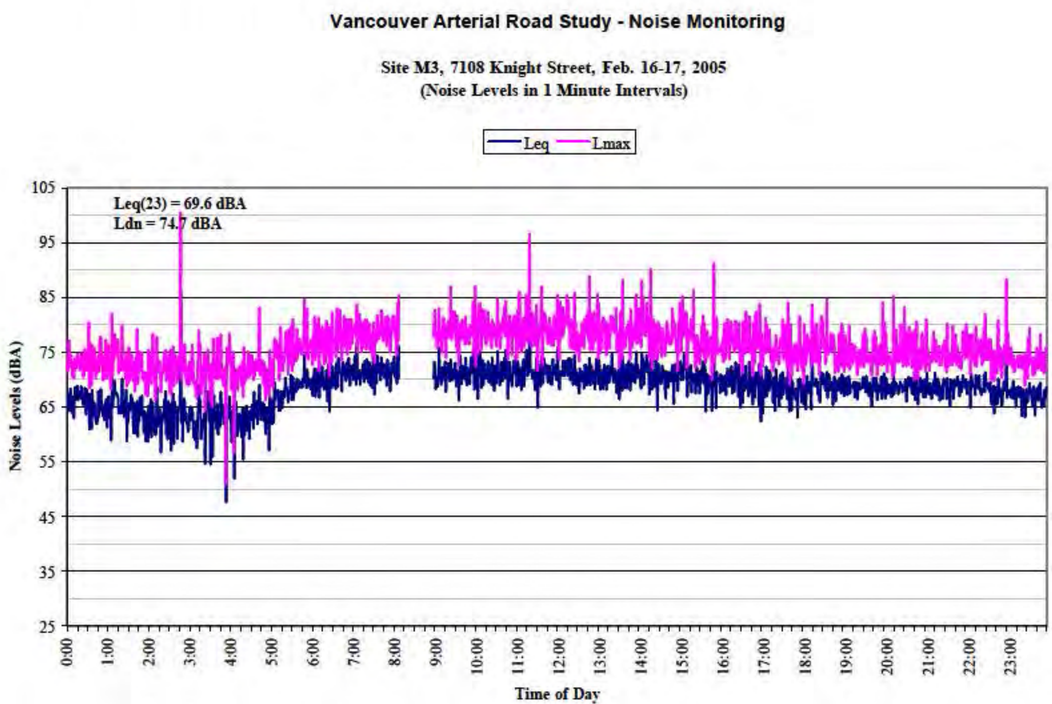

Vancouver Arterial Road Study - Noise Monitoring
Site 29, 2639 Dundas Avenue, Feb. 22-23, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 61.6 dBA
Ldn = 64.7 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 30, 424 N. Kamloops Street, Feb. 22-23, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 69.5 dBA
Ldn = 72.9 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site 31, 201-2125 E. Hastings Street, Feb. 22-23, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(24) = 73.4 dBA
Ldn = 78.3 dBA
Noise Levels (dBA)
Time of Day

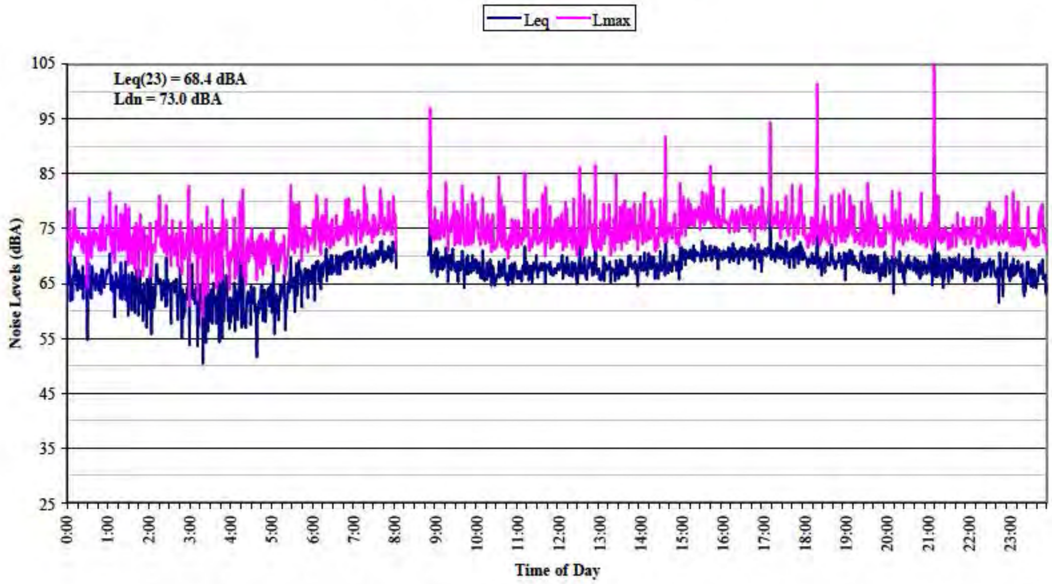

Vancouver Arterial Road Study - Noise Monitoring
Site M1, 3479 W 41st Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(23) = 62.6 dBA
Ldn = 66.4 dBA
Noise Levels (dBA)
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site M2, 1508 W 58th Avenue, Feb. 15-16, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(23) = 68.4 dBA
Ldn = 73.4 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site M3, 7108 Knight Street, Feb. 16-17, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(23) = 69.6 dBA
Ldn = 74.7 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day

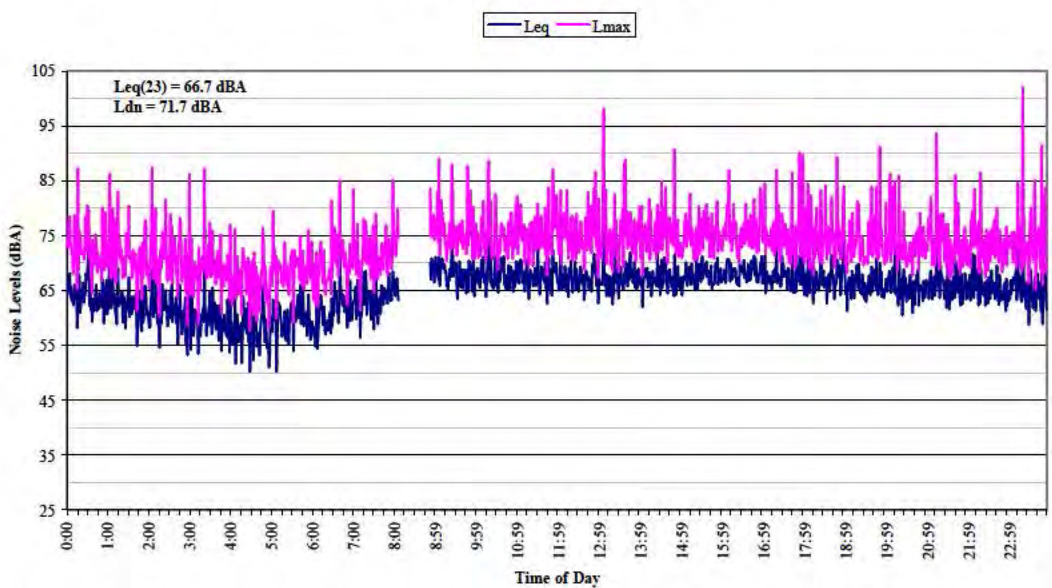
Vancouver Arterial Road Study - Noise Monitoring

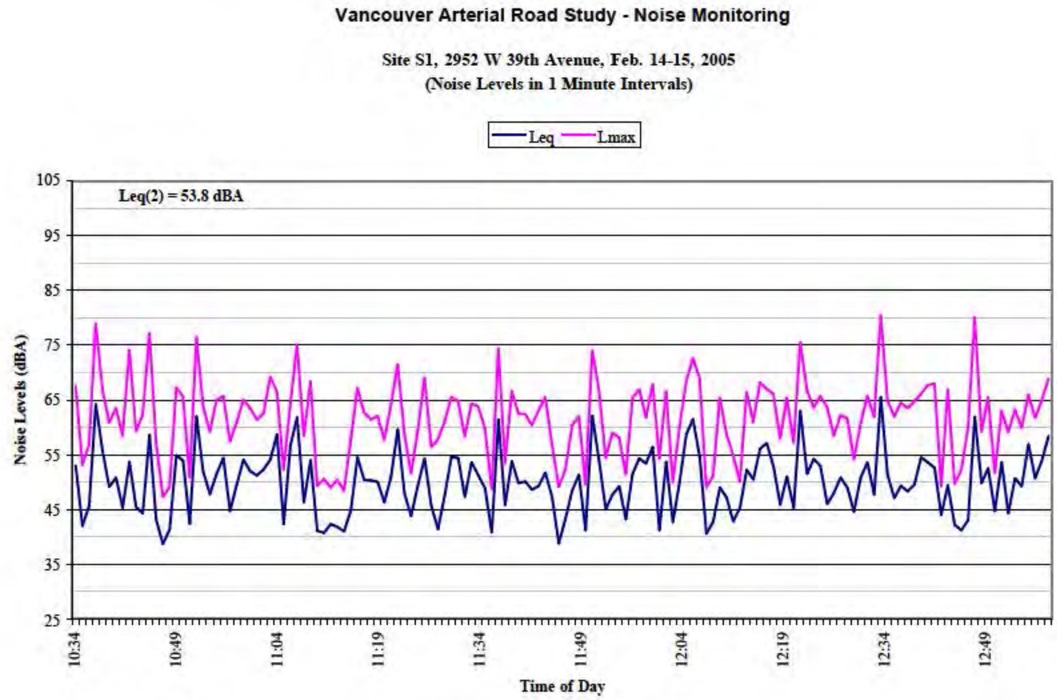
Site M4, 800 Kingsway Street, Feb. 17-18, 2005
(Noise Levels in 1 Minute Intervals)

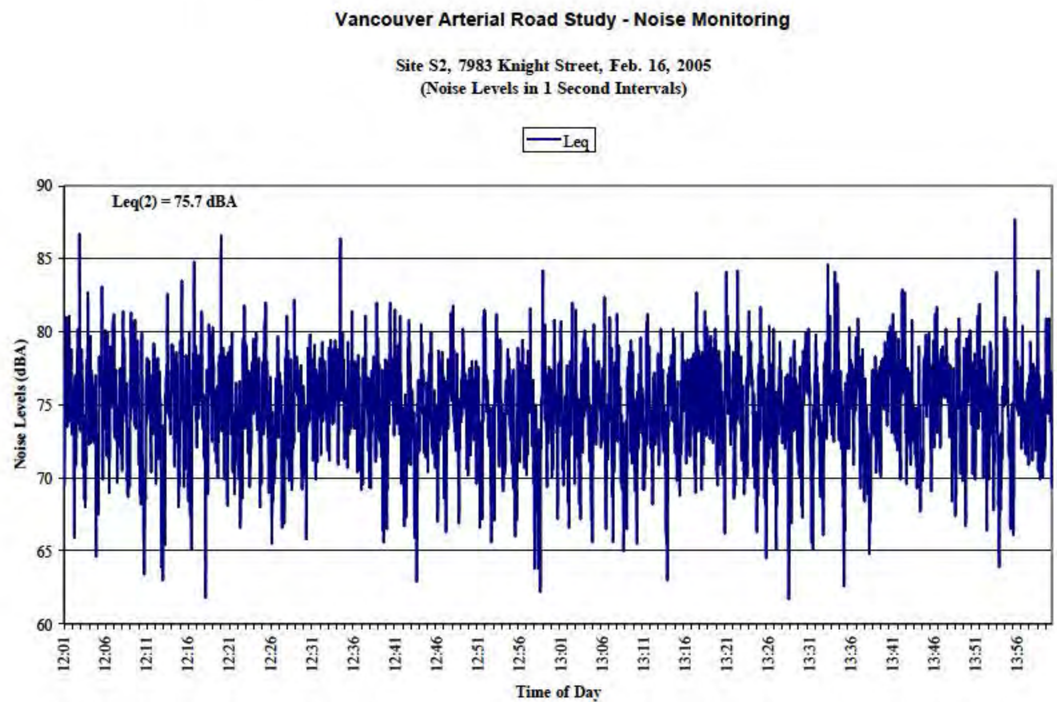


Vancouver Arterial Road Study - Noise Monitoring

Site M5, Commercial Dr. at E 8th St., Feb. 18-19, 2005
(Noise Levels in 1 Minute Intervals)

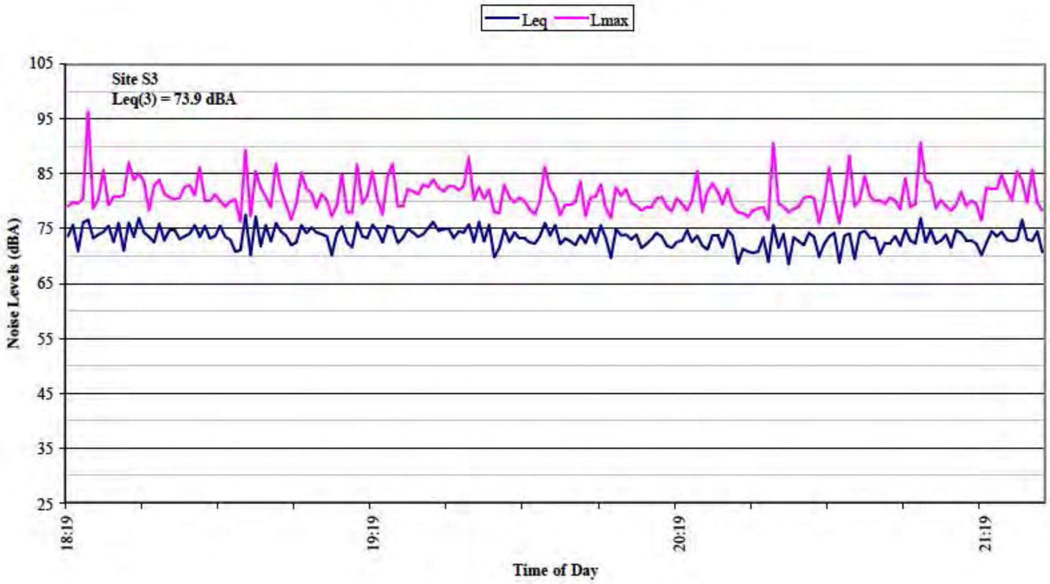



Vancouver Arterial Road Study - Noise Monitoring
Site S1, 2952 W 39th Avenue, Feb. 14-15, 2005
(Noise Levels in 1 Minute Intervals)
Leq
Lmax
Leq(2) = 53.8 dBA
Noise Levels (dBA)
105
95
85
75
65
55
45
35
25
10:34
10:49
11:04
11:19
11:34
11:49
12:04
12:19
12:34
12:49
Time of Day


Vancouver Arterial Road Study - Noise Monitoring
Site S2, 7983 Knight Street, Feb. 16, 2005
(Noise Levels in 1 Second Intervals)
Leq
Leq(2) = 75.7 dBA
Noise Levels (dBA)
90
85
80
75
70
65
60
12:01
12:06
12:11
12:16
12:21
12:26
12:31
12:36
12:41
12:46
12:51
12:56
13:01
13:06
13:11
13:16
13:21
13:26
13:31
13:36
13:41
13:46
13:51
13:56
Time of Day

Vancouver Arterial Road Study - Noise Monitoring

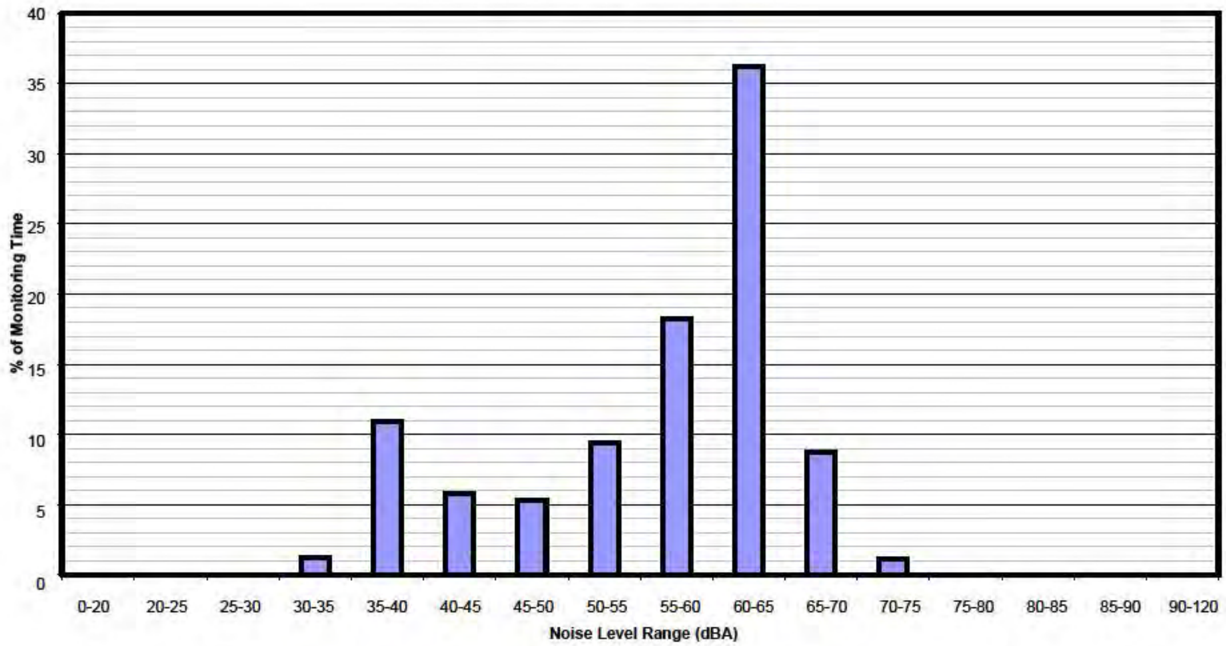
Site S3, 5336 Knight Street, Feb. 18, 2005
(Noise Levels in 1 Minute Intervals)



APPENDIX D – MONITORING SITE RESULTS, HISTOGRAMS

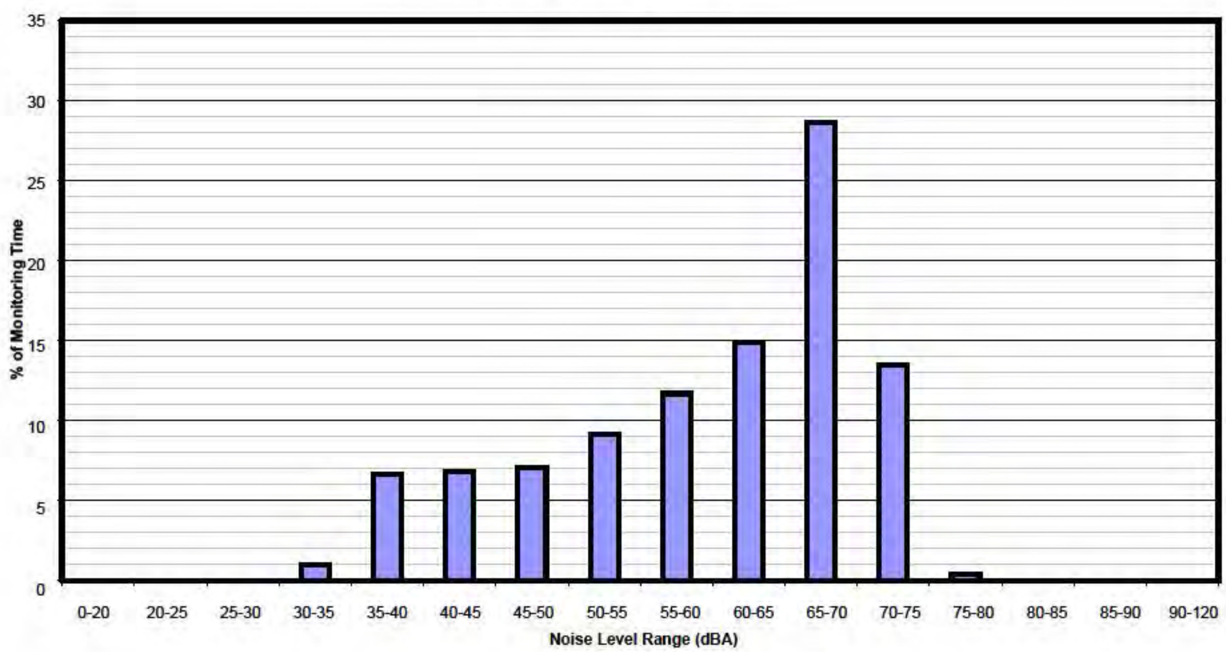
Vancouver Arterial Road Study - Noise Monitoring

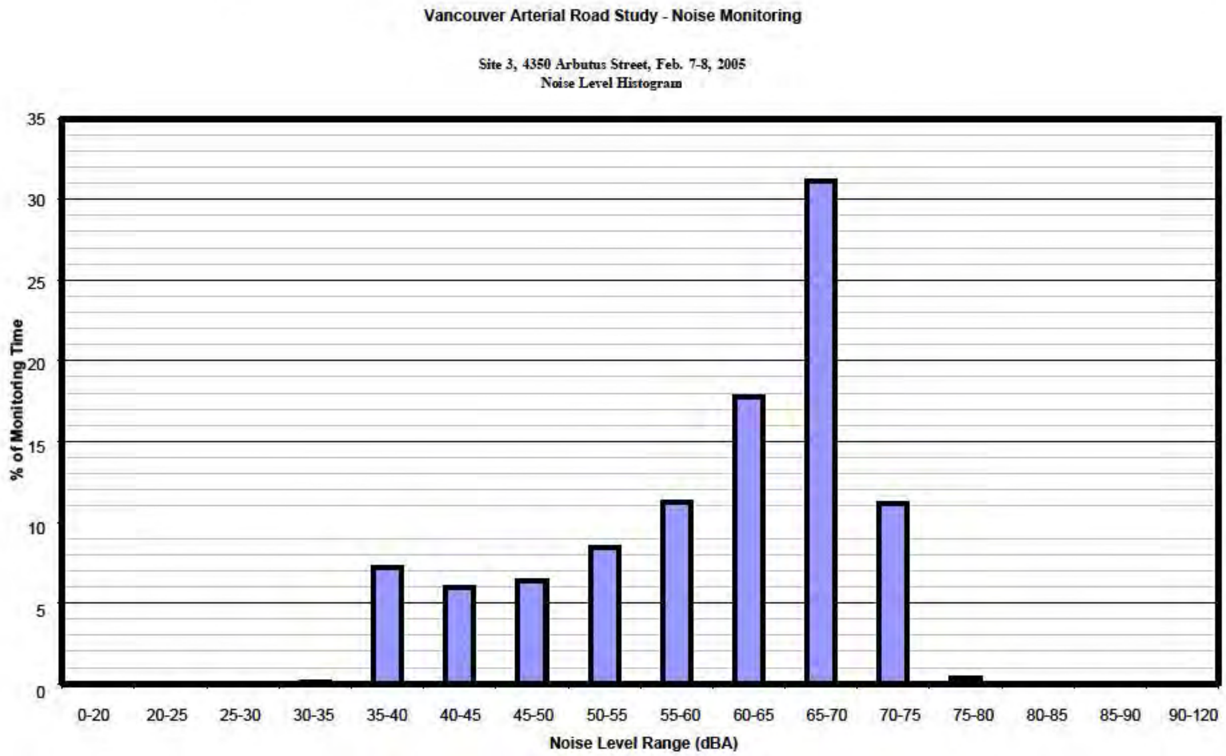
Site 1, 2328 S.W. Marine Drive, Feb. 7-8, 2005
Noise Level Histogram

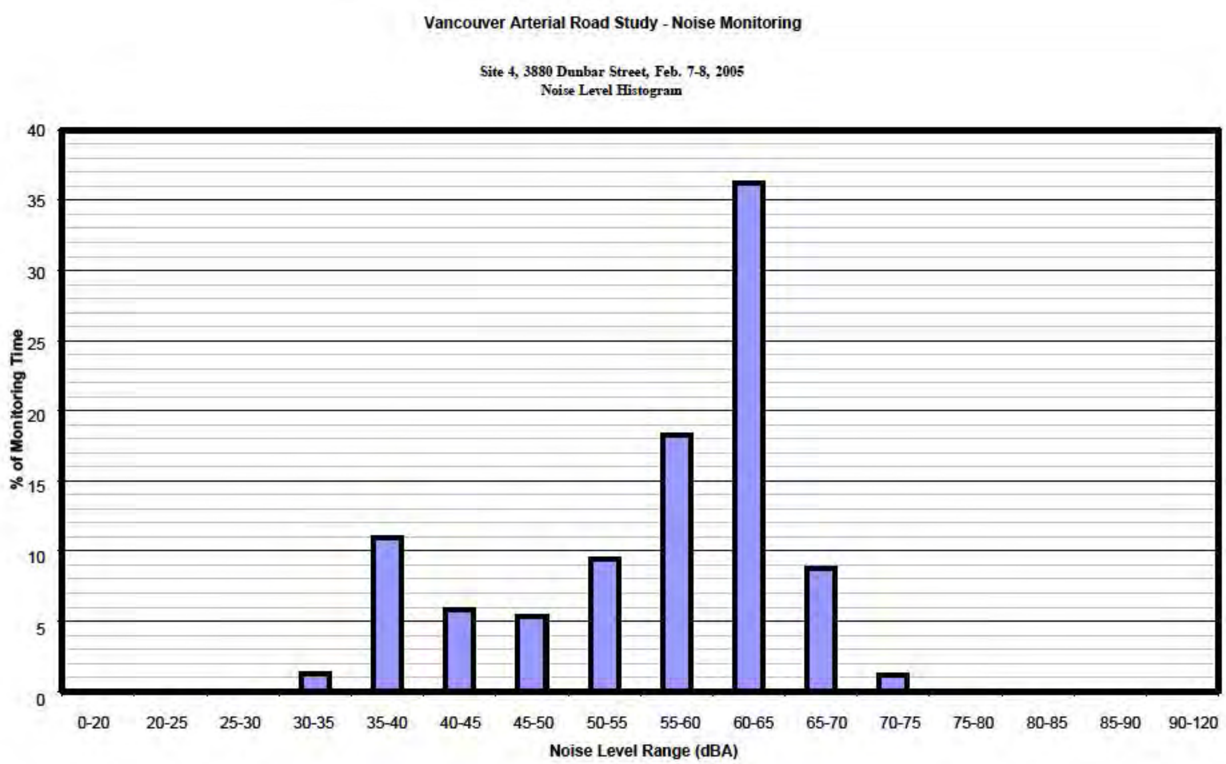


Vancouver Arterial Road Study - Noise Monitoring

Site 2, 6525 W 49th Avenue, Feb. 7-8, 2005
Noise Level Histogram

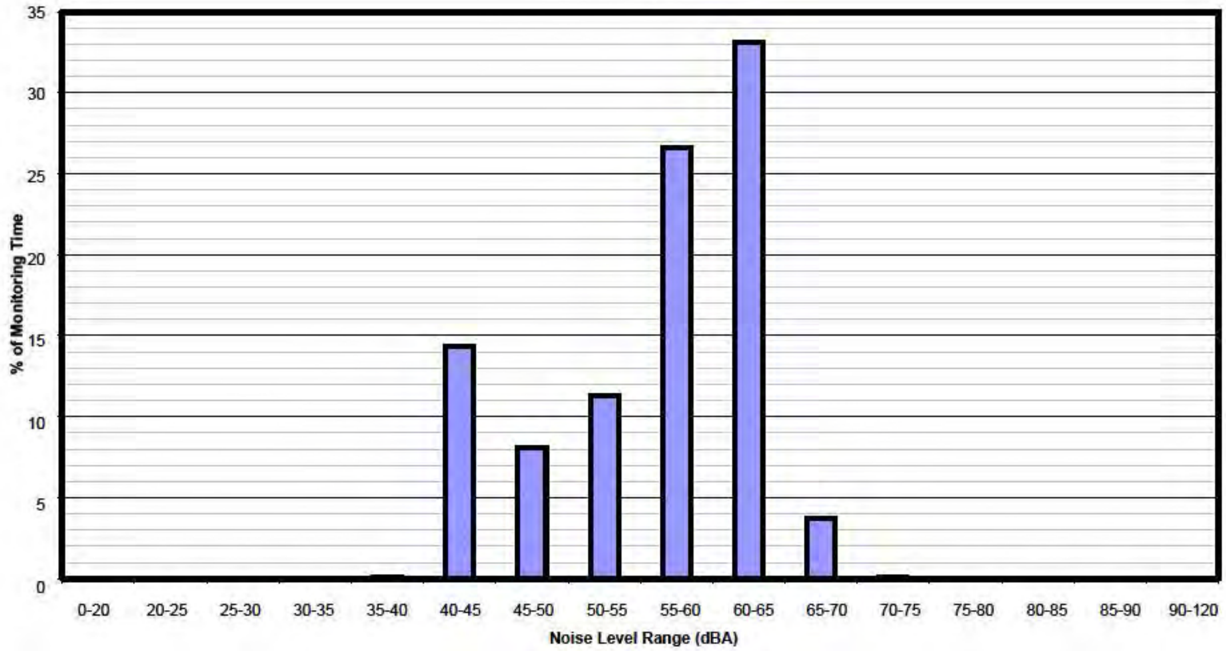



Vancouver Arterial Road Study - Noise Monitoring
Site 3, 4350 Arbutus Street, Feb. 7-8, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 4, 3880 Dunbar Street, Feb. 7-8, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

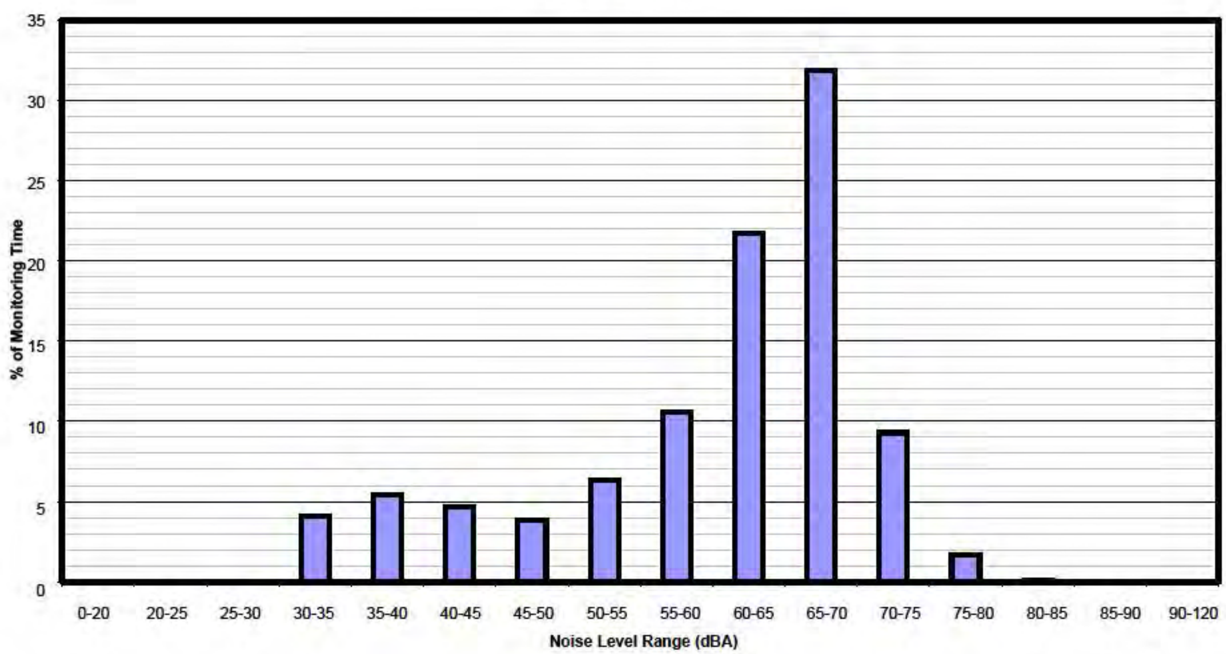
Vancouver Arterial Road Study - Noise Monitoring

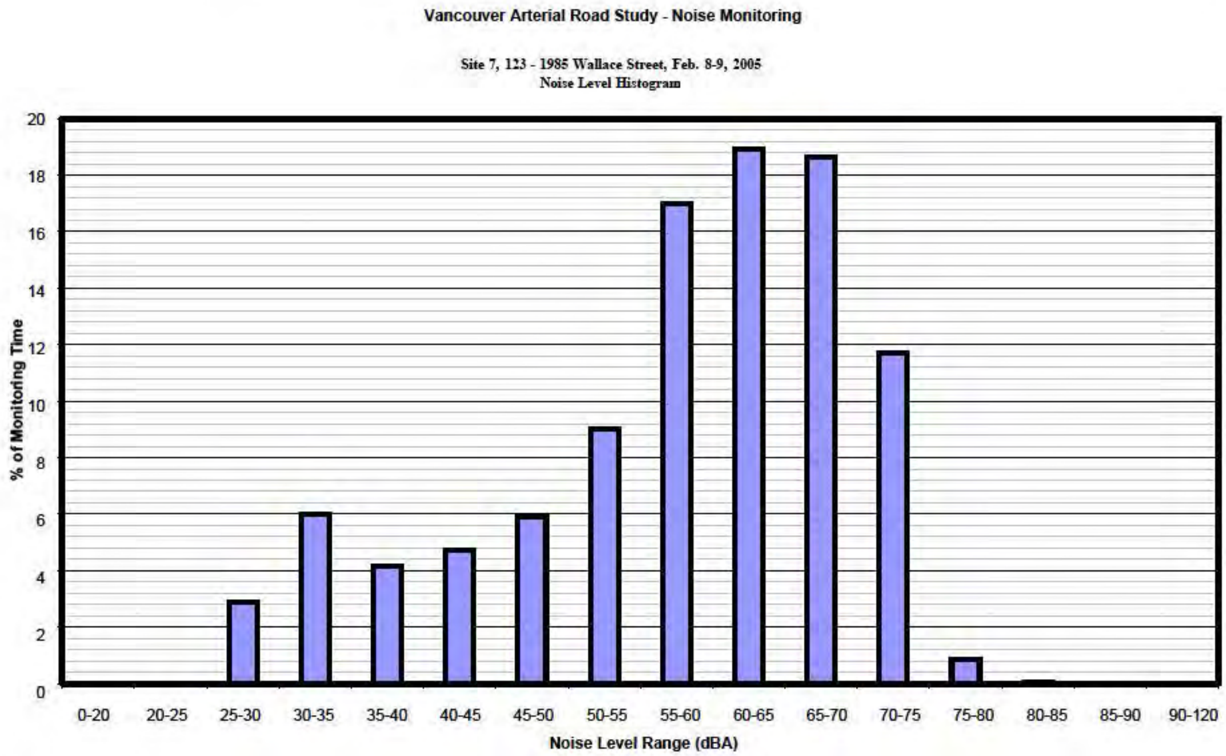
Site 5, 1668 W 16th Avenue, Feb. 8-9, 2005
Noise Level Histogram

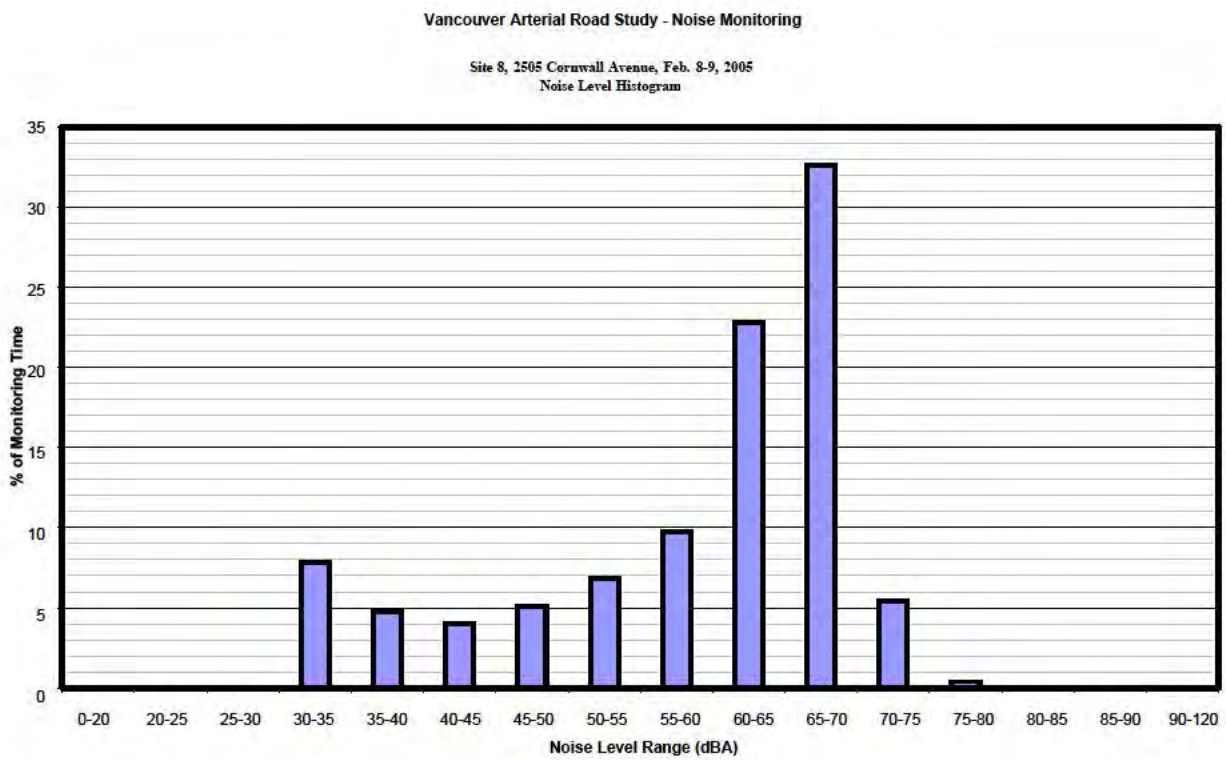


Vancouver Arterial Road Study - Noise Monitoring

Site 6, 3828 W 10th Avenue, Feb. 8-9, 2005
Noise Level Histogram

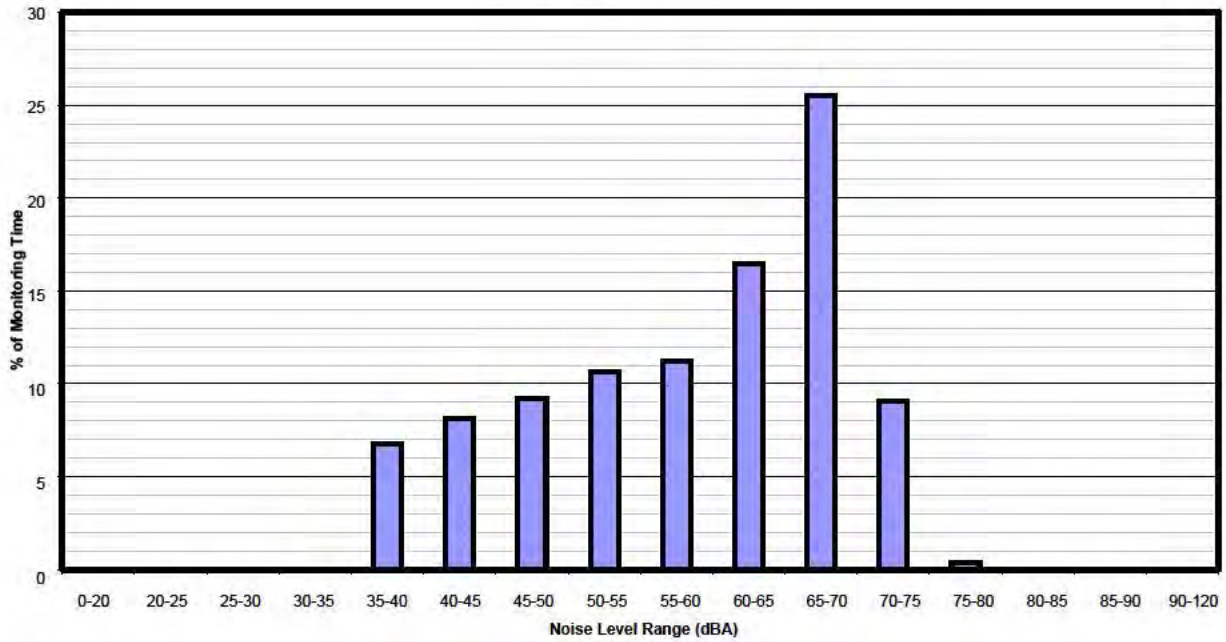



Vancouver Arterial Road Study - Noise Monitoring
Site 7, 123 - 1985 Wallace Street, Feb. 8-9, 2005
Noise Level Histogram
% of Monitoring Time
0
2
4
6
8
10
12
14
16
18
20
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 8, 2505 Cornwall Avenue, Feb. 8-9, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

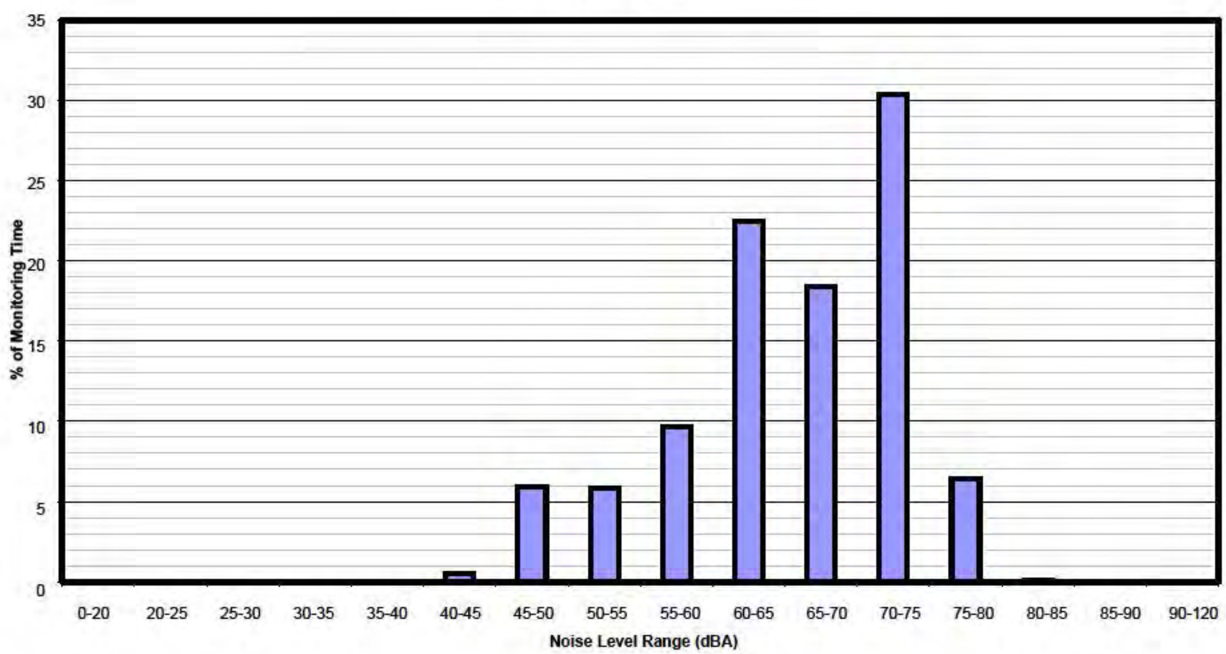
Vancouver Arterial Road Study - Noise Monitoring

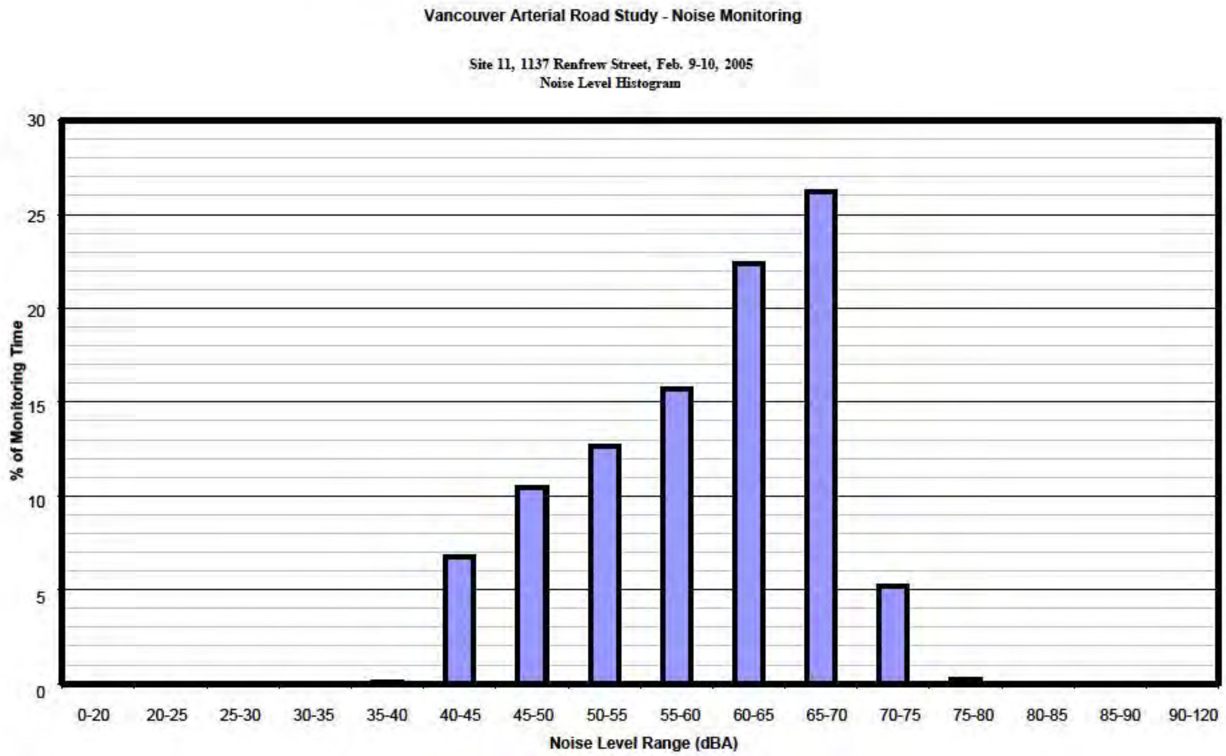
Site 9, 1877 W 12th Avenue, Feb. 9-10, 2005
Noise Level Histogram

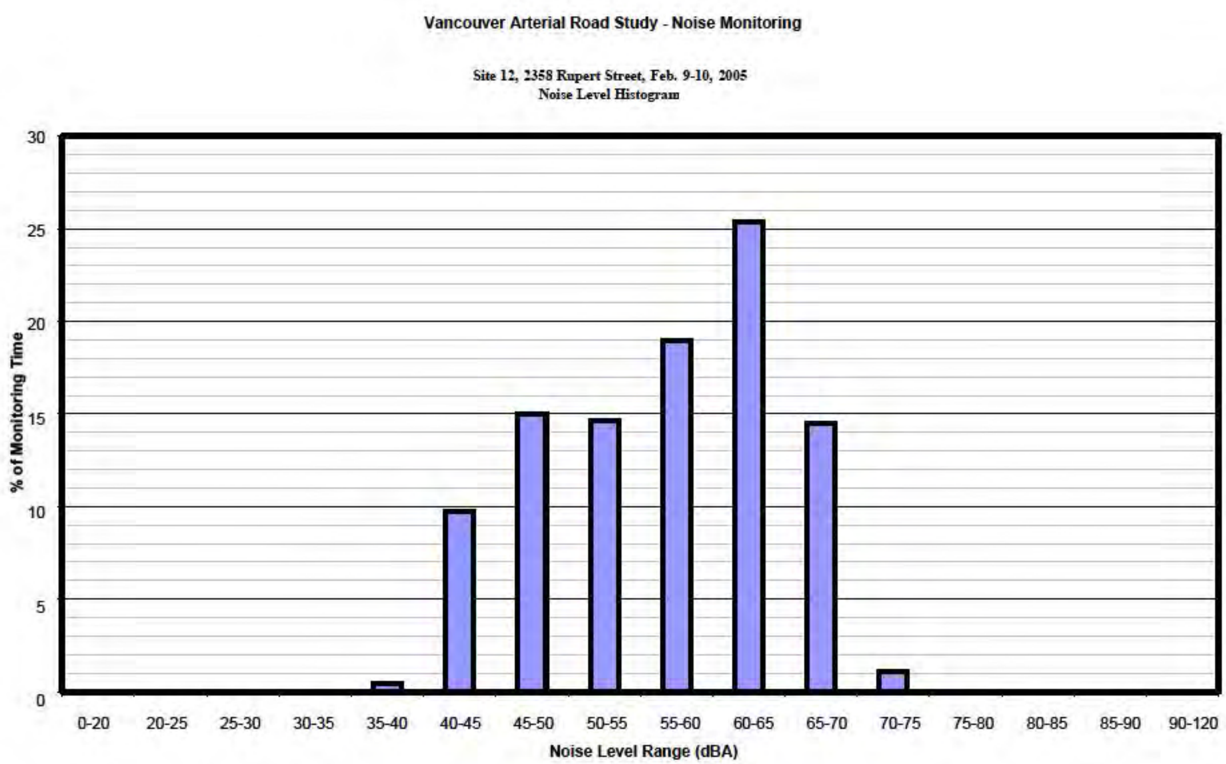


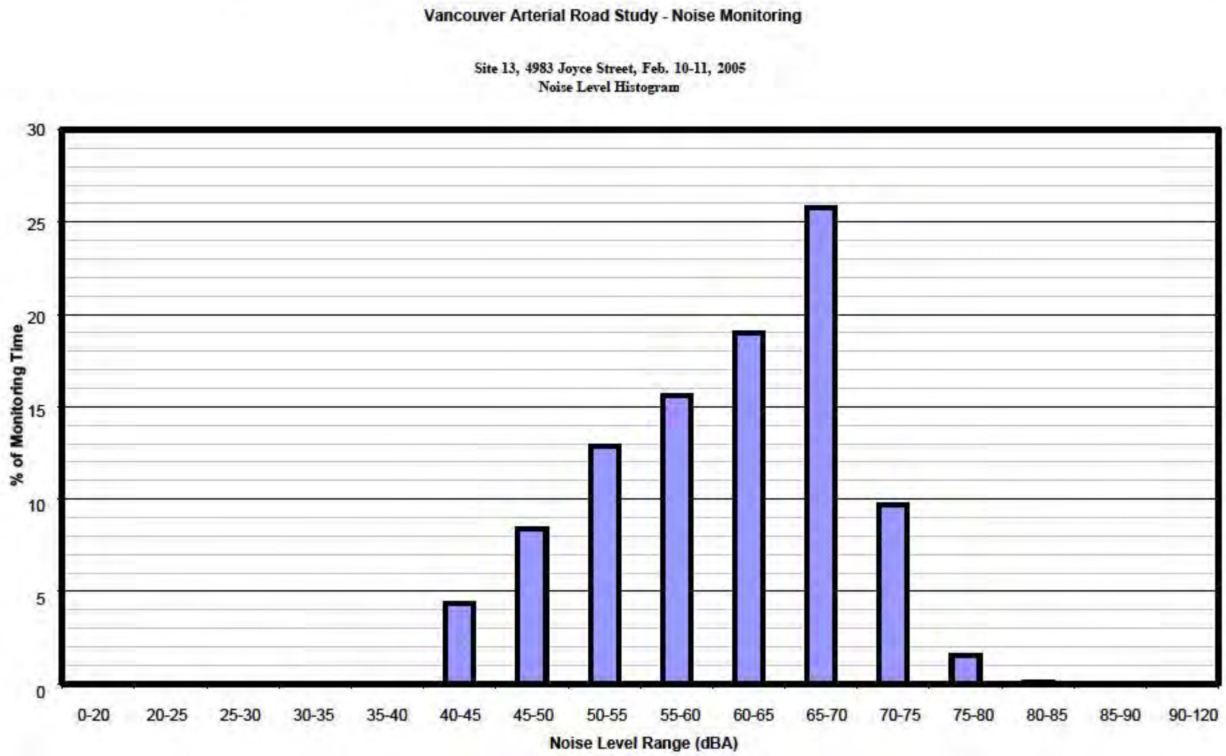
Vancouver Arterial Road Study - Noise Monitoring

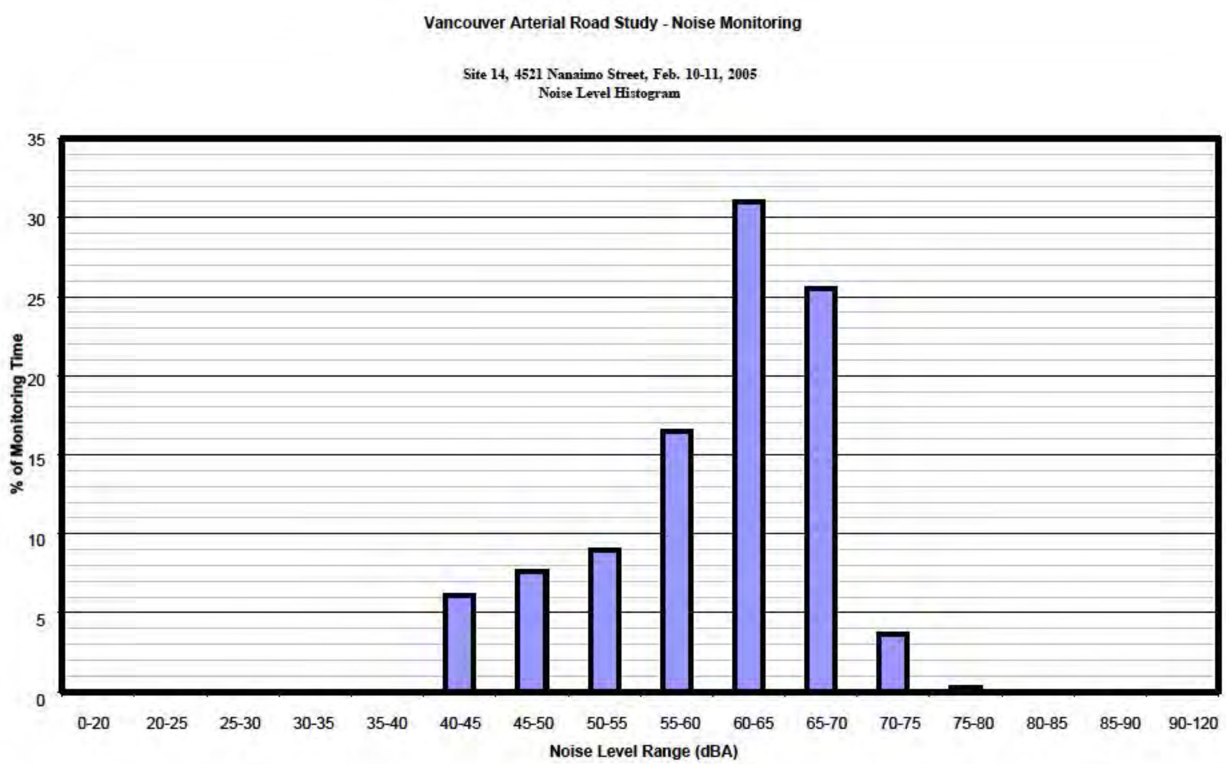
Site 10, 2504 1st Avenue, Feb. 9-10, 2005
Noise Level Histogram

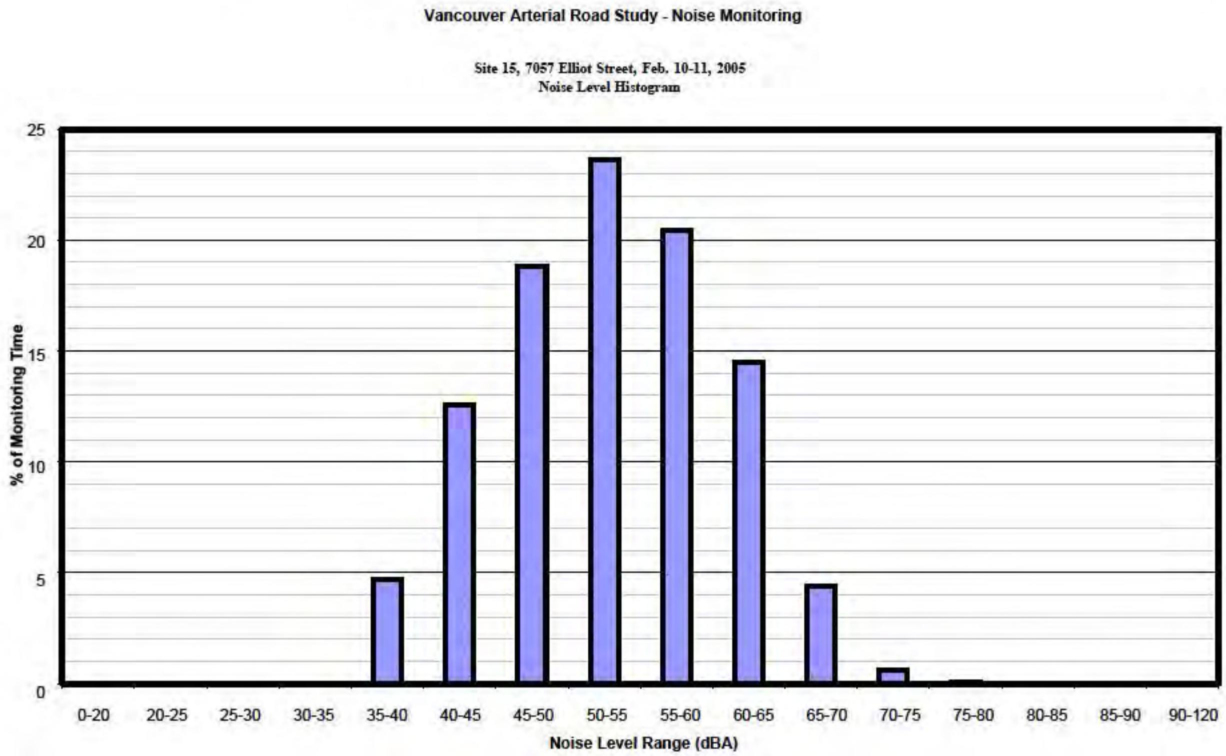


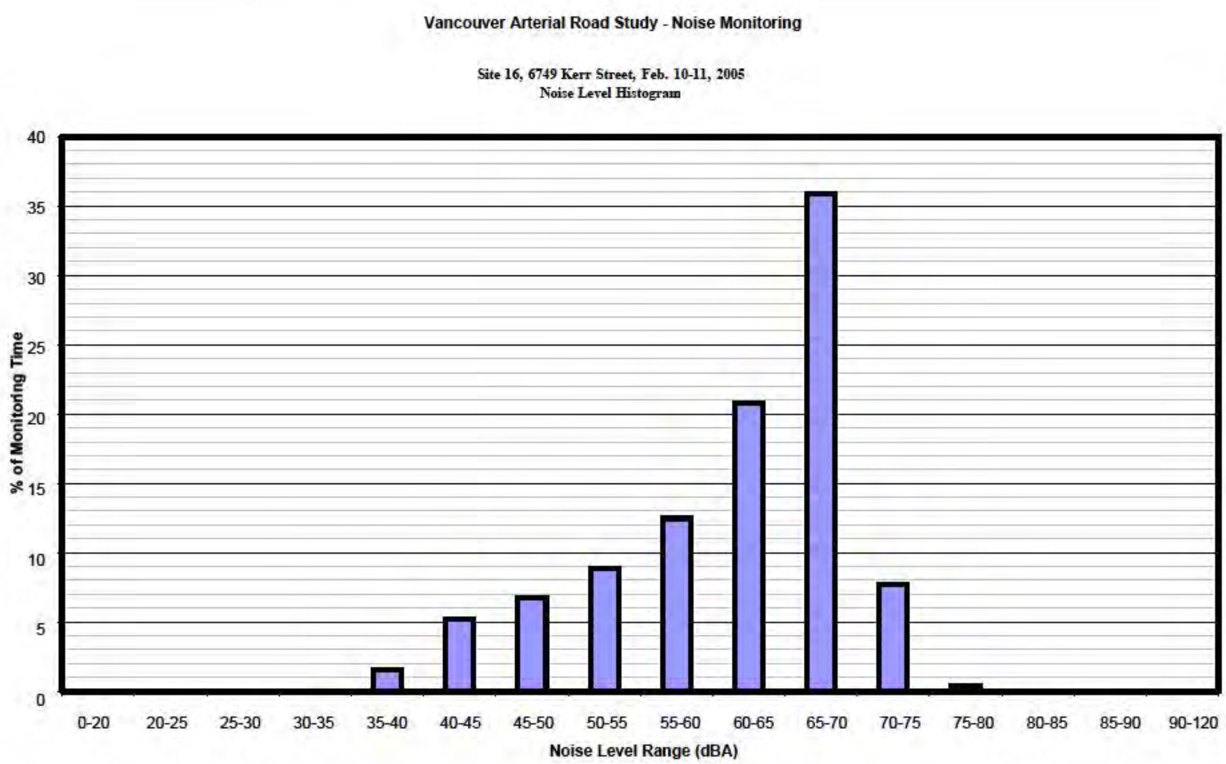

Vancouver Arterial Road Study - Noise Monitoring
Site 11, 1137 Renfrew Street, Feb. 9-10, 2005
Noise Level Histogram
% of Monitoring Time
30
25
20
15
10
5
0
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

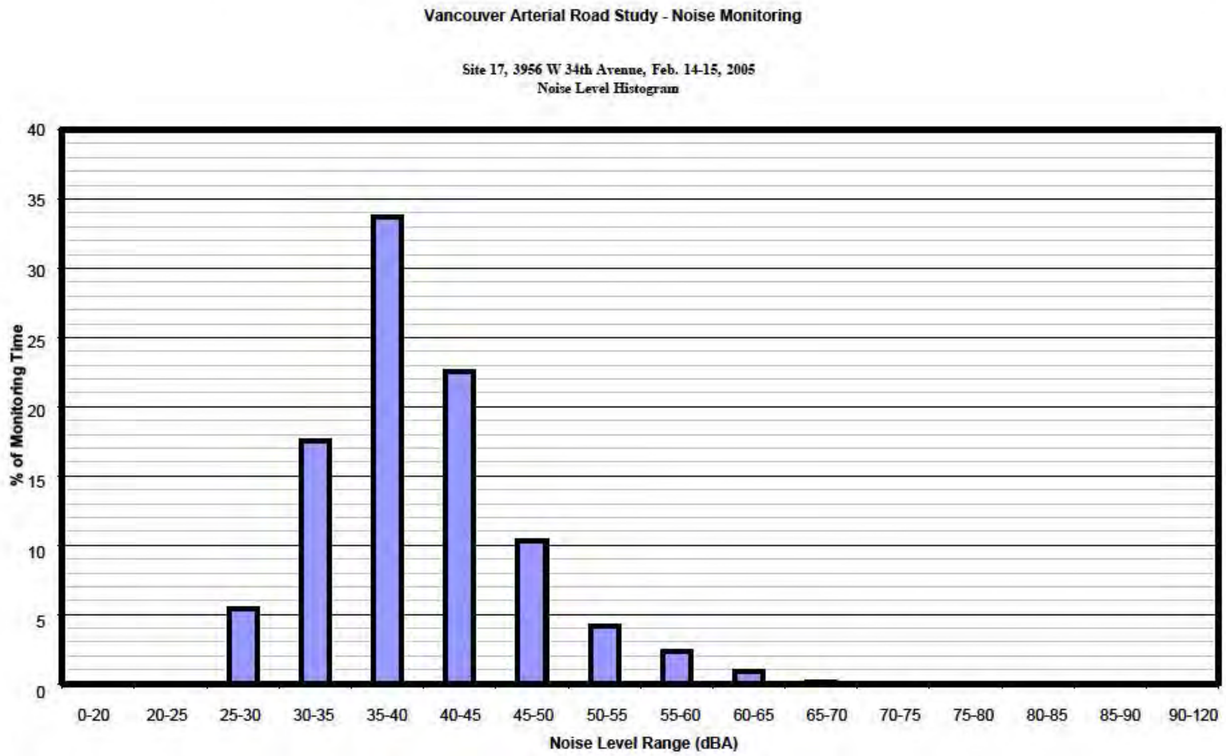

Vancouver Arterial Road Study - Noise Monitoring
Site 12, 2358 Rupert Street, Feb. 9-10, 2005
Noise Level Histogram
% of Monitoring Time
30
25
20
15
10
5
0
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

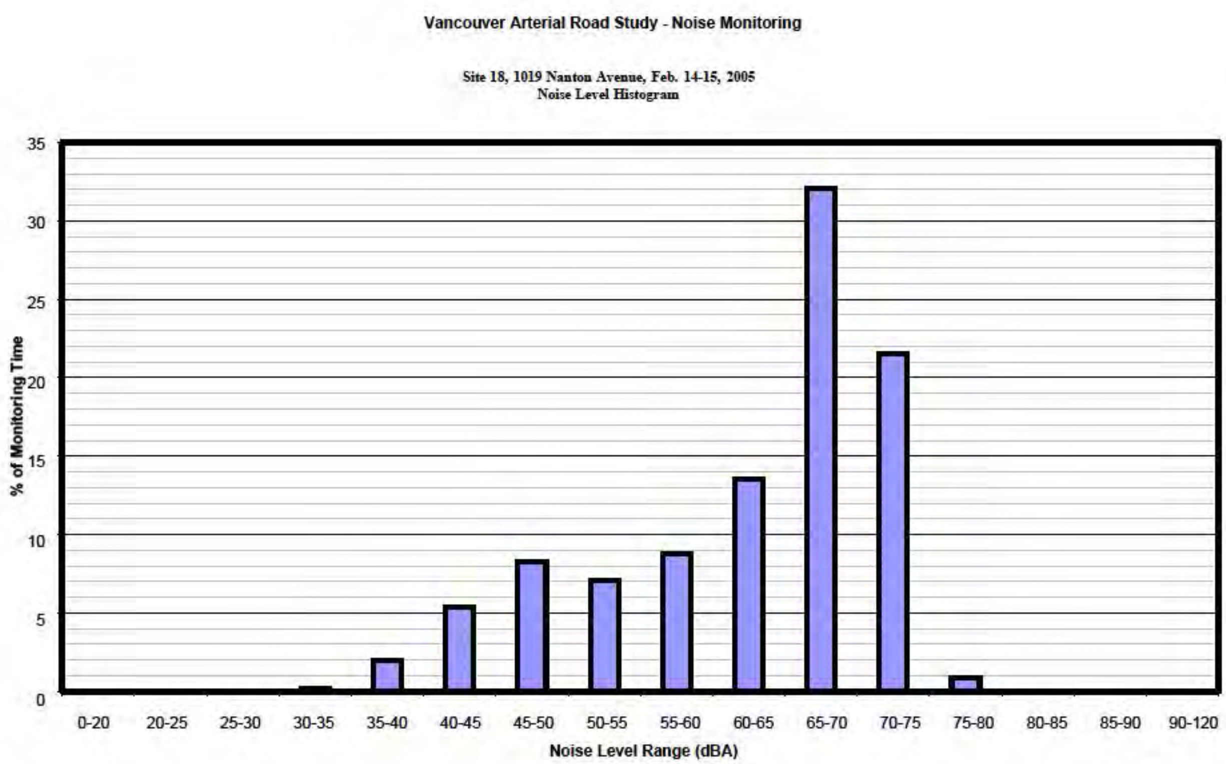

Vancouver Arterial Road Study - Noise Monitoring
Site 13, 4983 Joyce Street, Feb. 10-11, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 14, 4521 Nanaimo Street, Feb. 10-11, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 15, 7057 Elliot Street, Feb. 10-11, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

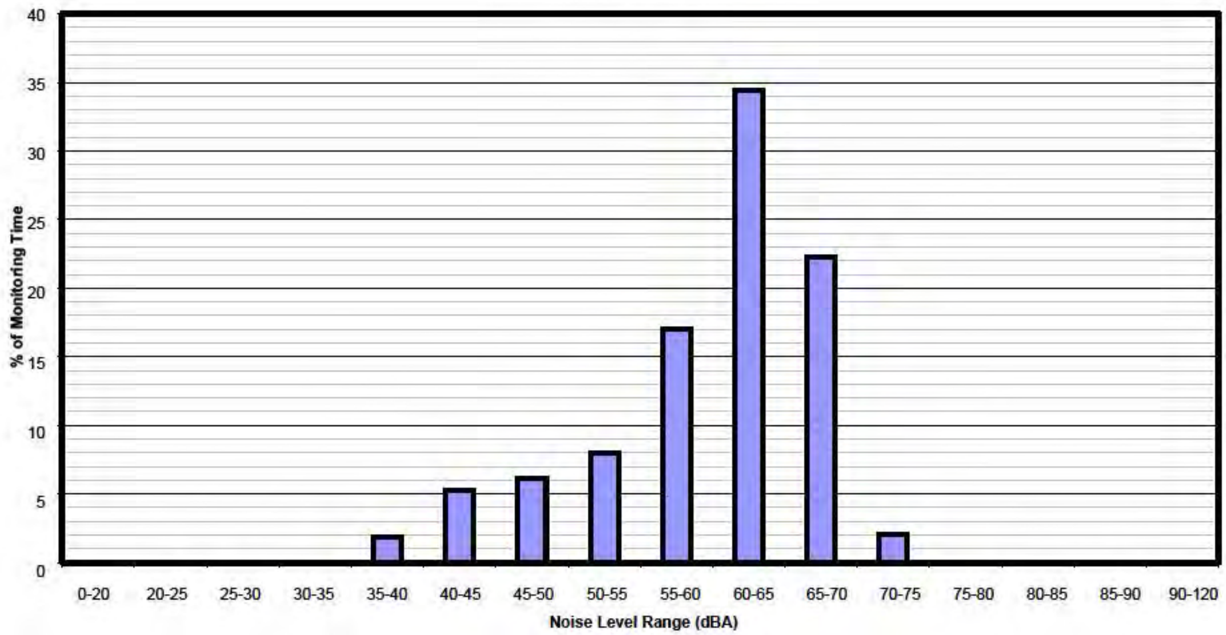

Vancouver Arterial Road Study - Noise Monitoring
Site 16, 6749 Kerr Street, Feb. 10-11, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 17, 3956 W 34th Avenue, Feb. 14-15, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 18, 1019 Nanton Avenue, Feb. 14-15, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

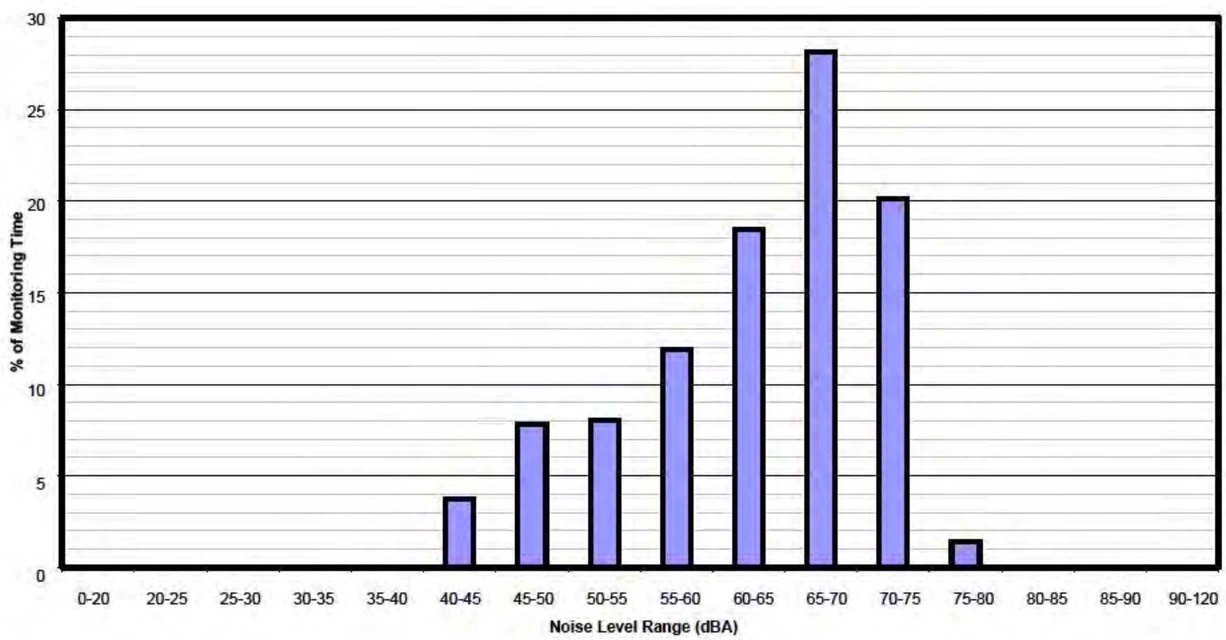
Vancouver Arterial Road Study - Noise Monitoring

Site 19, 6409 Cambie Street, Feb. 15-16, 2005
Noise Level Histogram



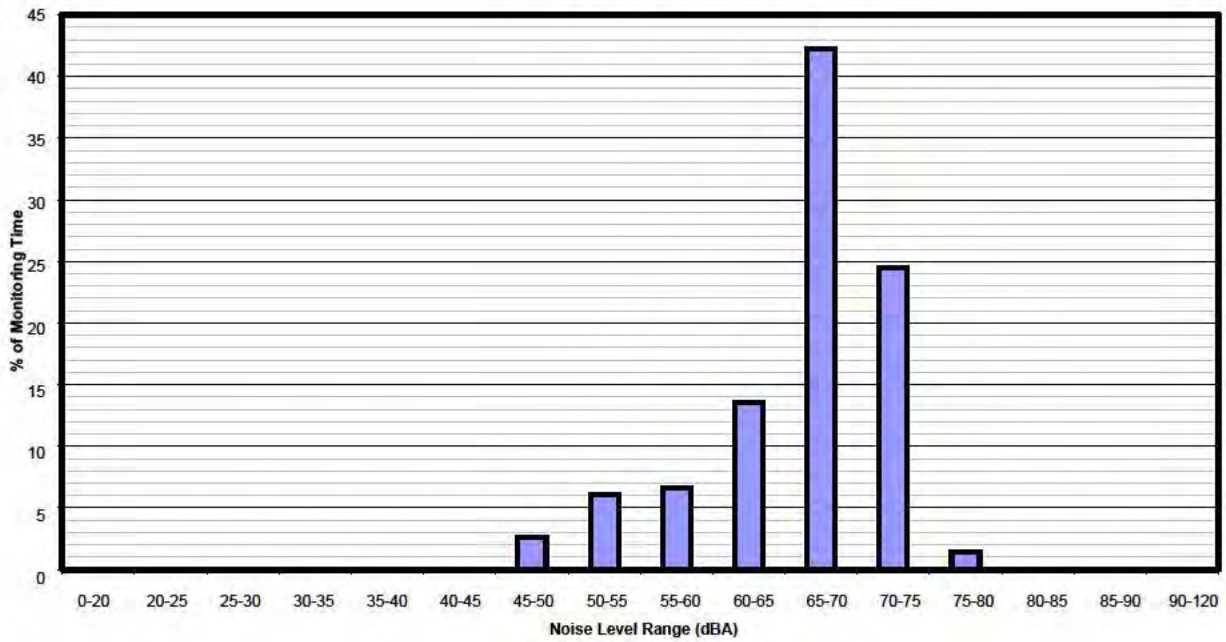
Vancouver Arterial Road Study - Noise Monitoring

Site 20, 6937 Fraser Street, Feb. 15-16, 2005
Noise Level Histogram



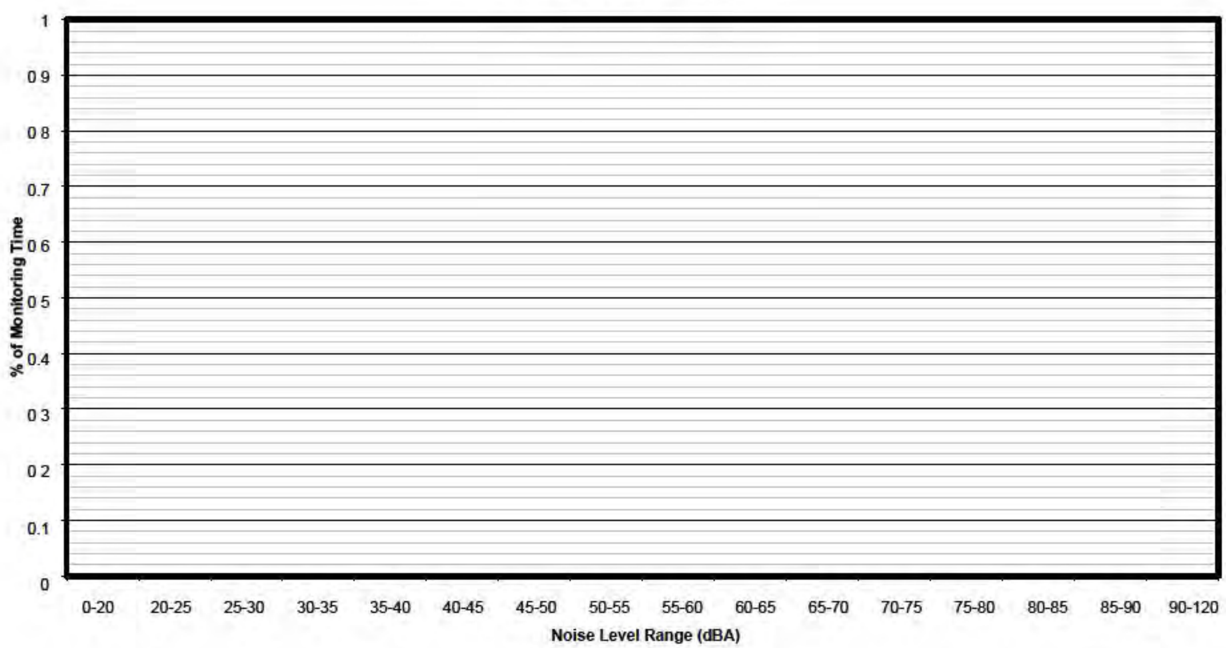
Vancouver Arterial Road Study - Noise Monitoring

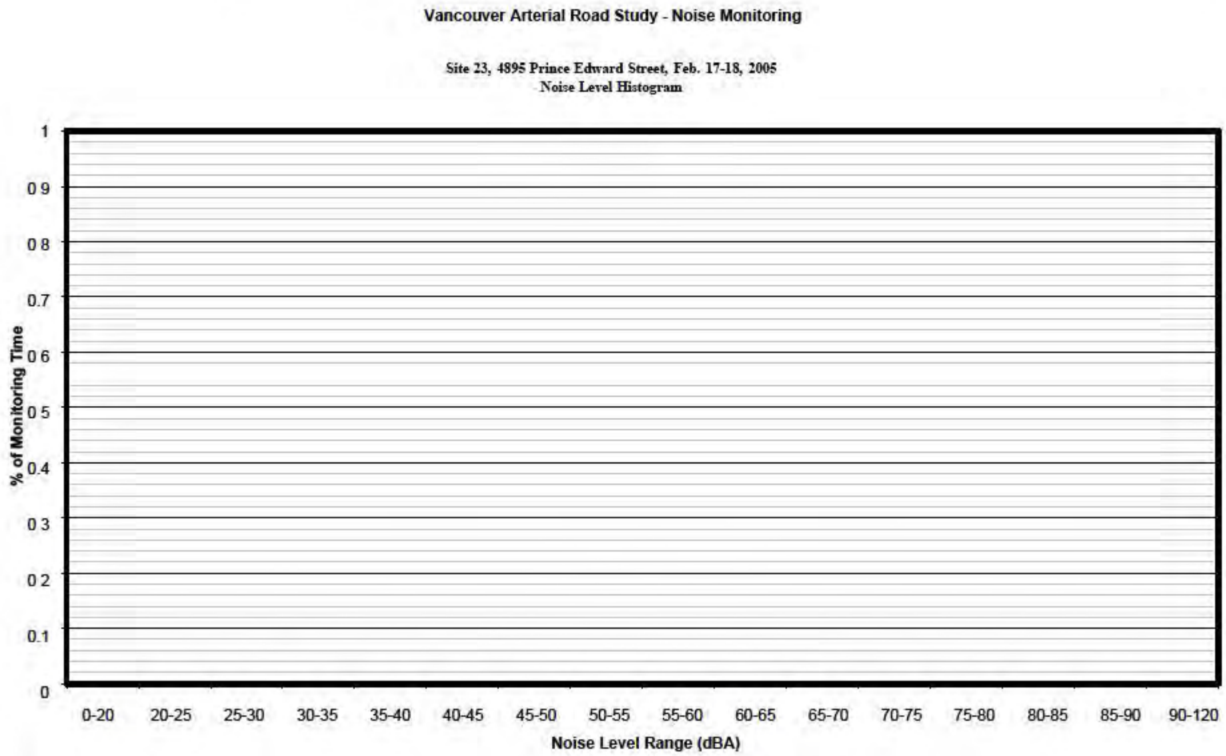
Site 21, 457 S.E.Marine Drive, Feb. 16-17, 2005
Noise Level Histogram

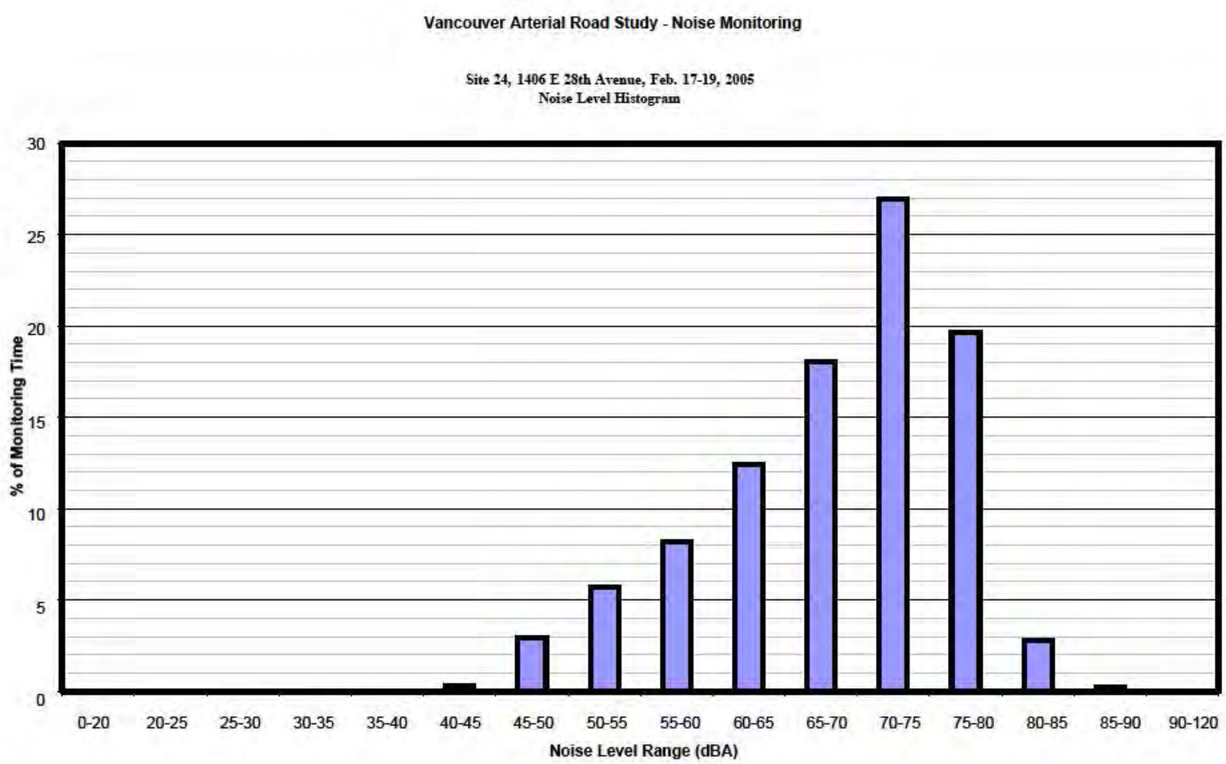


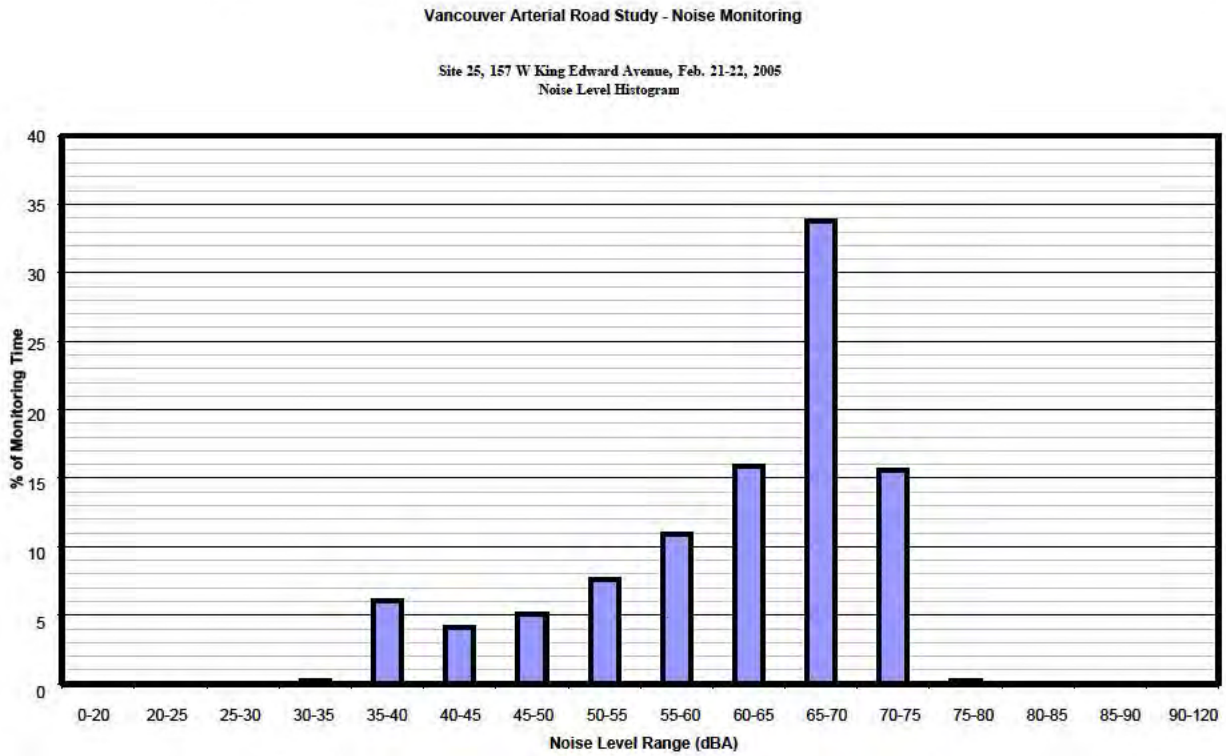
Vancouver Arterial Road Study - Noise Monitoring

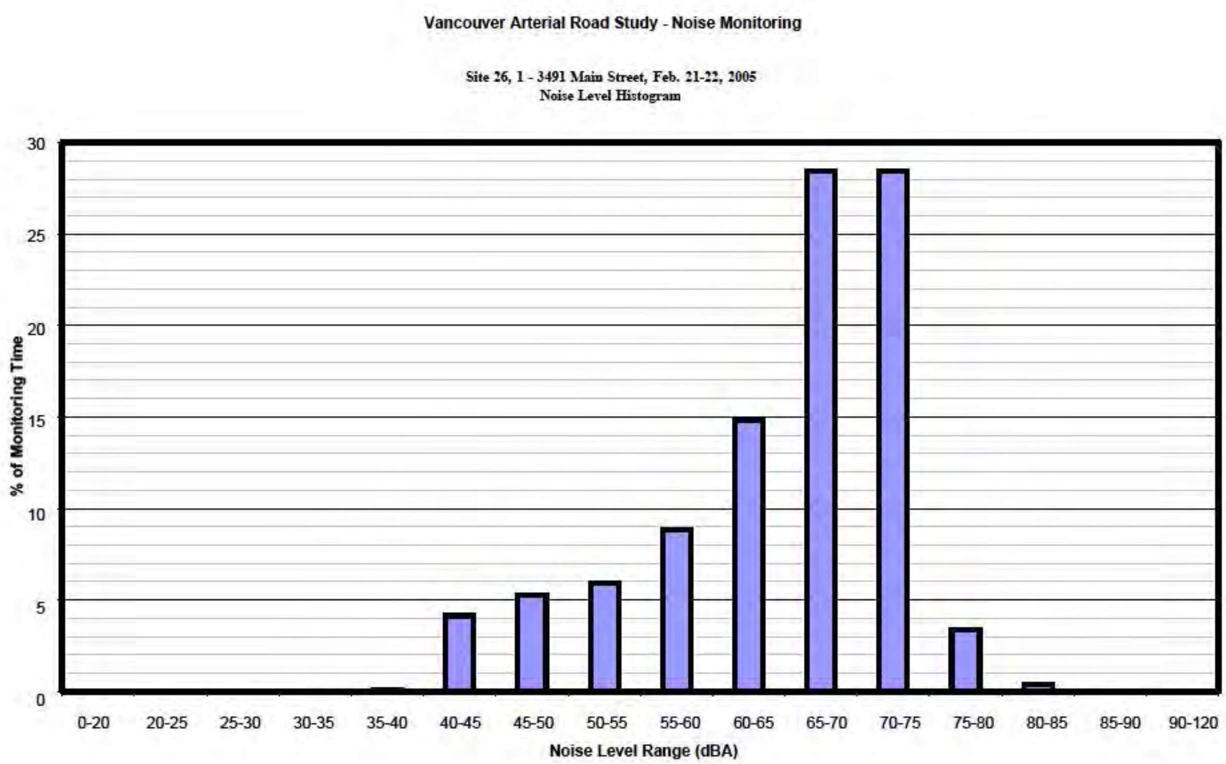
Site 22, 7870 Argyle Street, Feb. 16-17, 2005
Noise Level Histogram

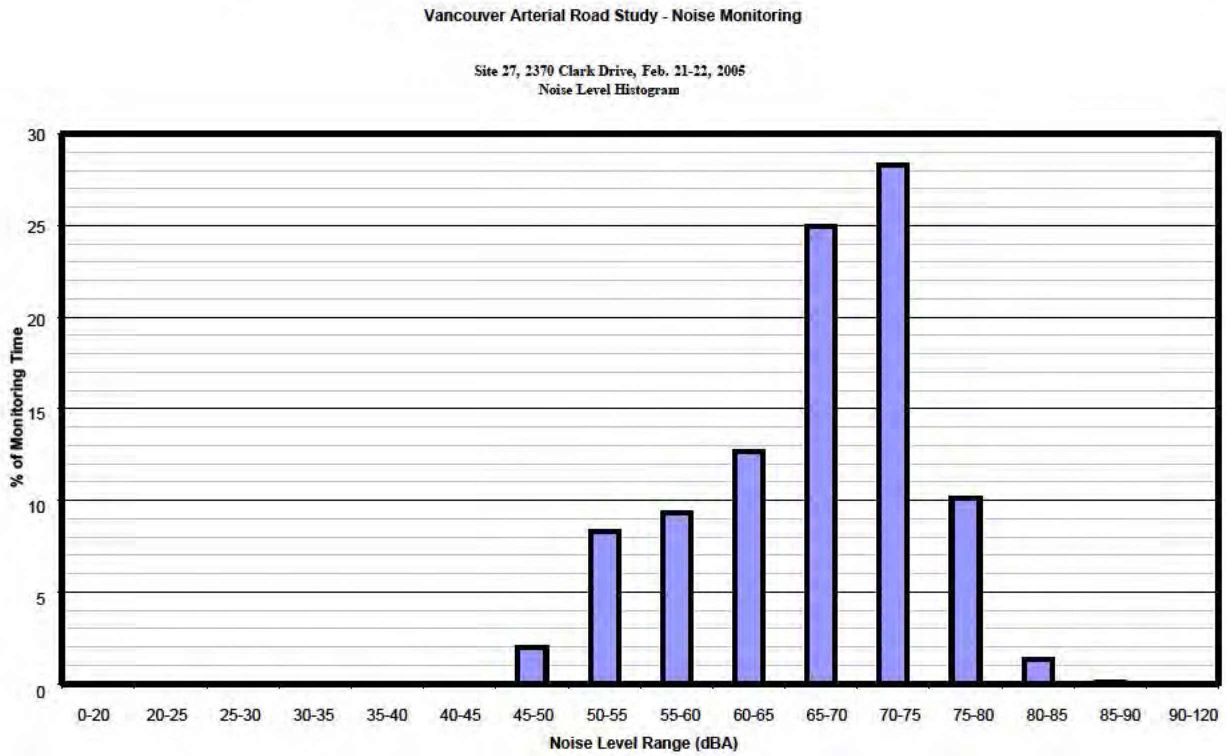


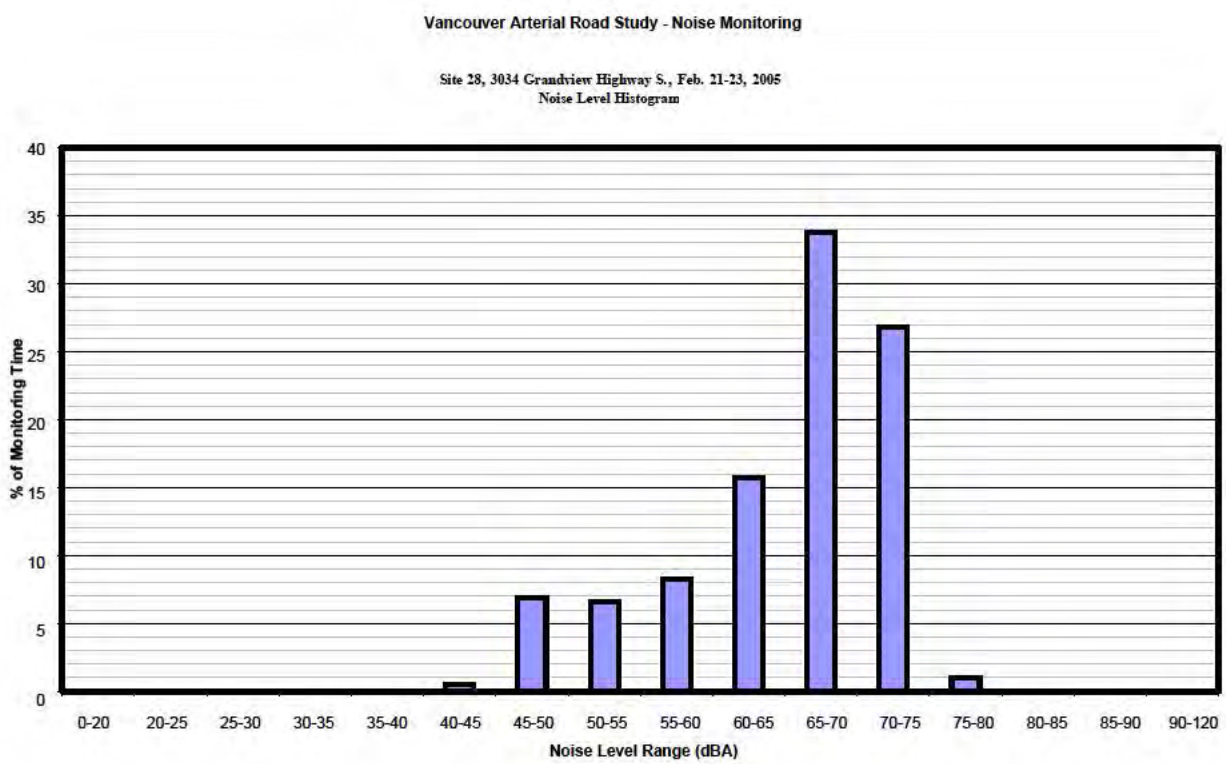

Vancouver Arterial Road Study - Noise Monitoring
Site 23, 4895 Prince Edward Street, Feb. 17-18, 2005
Noise Level Histogram
% of Monitoring Time
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 24, 1406 E 28th Avenue, Feb. 17-19, 2005
Noise Level Histogram
% of Monitoring Time
30
25
20
15
10
5
0
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 25, 157 W King Edward Avenue, Feb. 21-22, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

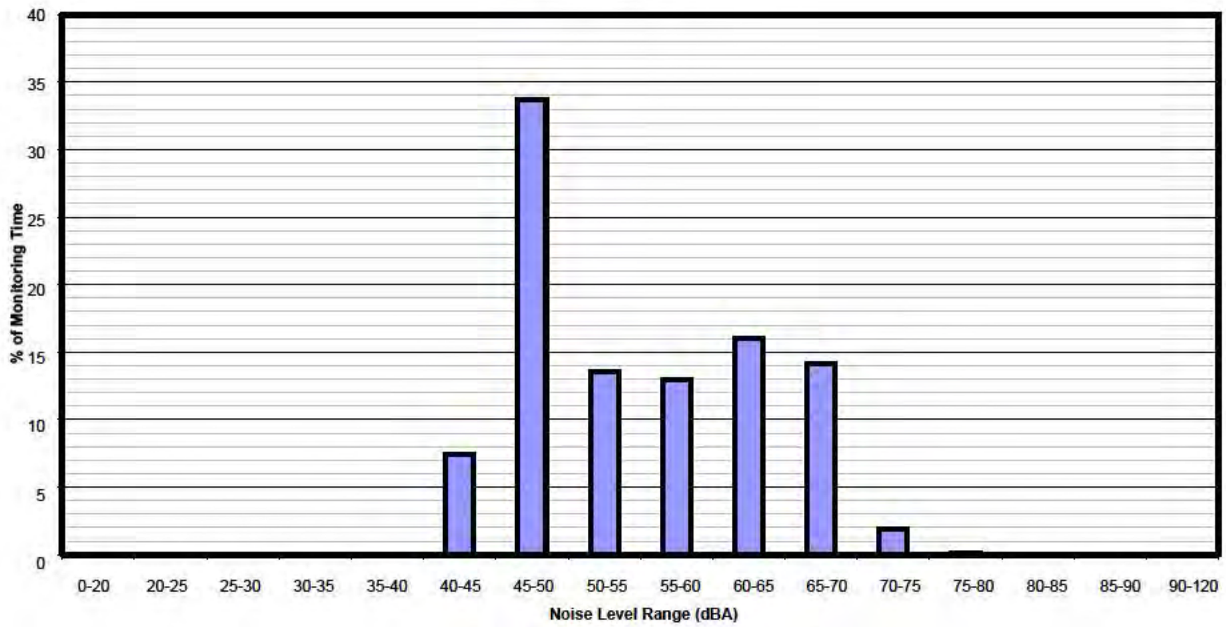

Vancouver Arterial Road Study - Noise Monitoring
Site 26, 1 - 3491 Main Street, Feb. 21-22, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 27, 2370 Clark Drive, Feb. 21-22, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site 28, 3034 Grandview Highway S., Feb. 21-23, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

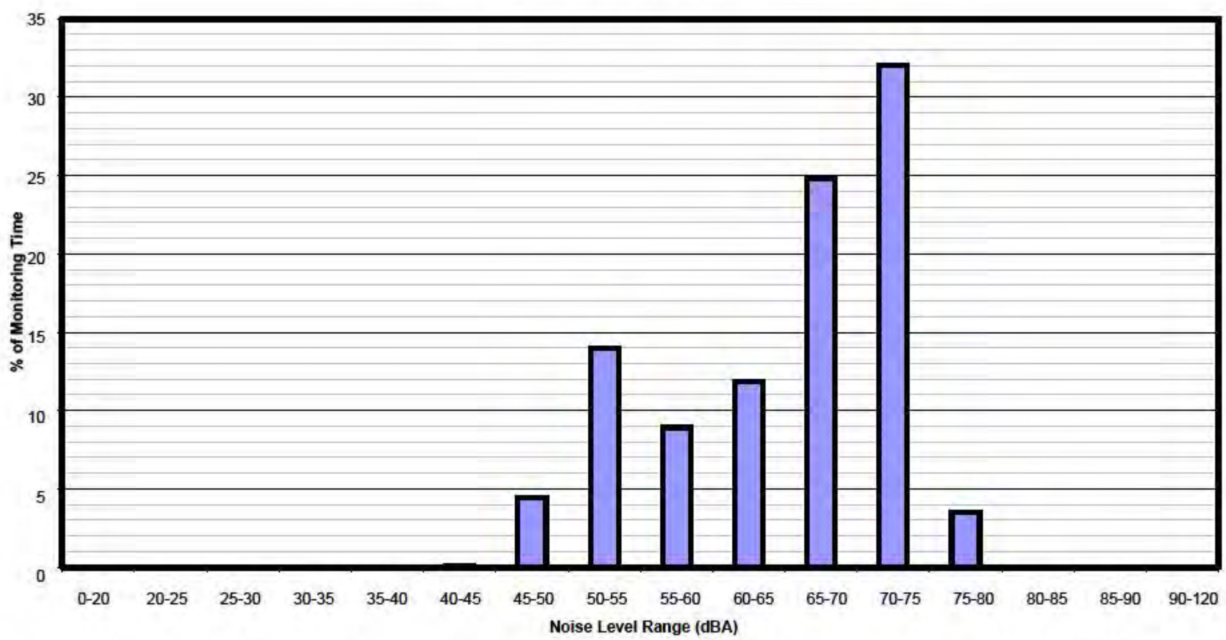
Vancouver Arterial Road Study - Noise Monitoring

Site 29, 2639 Dundas Avenue, Feb. 22-23, 2005
Noise Level Histogram



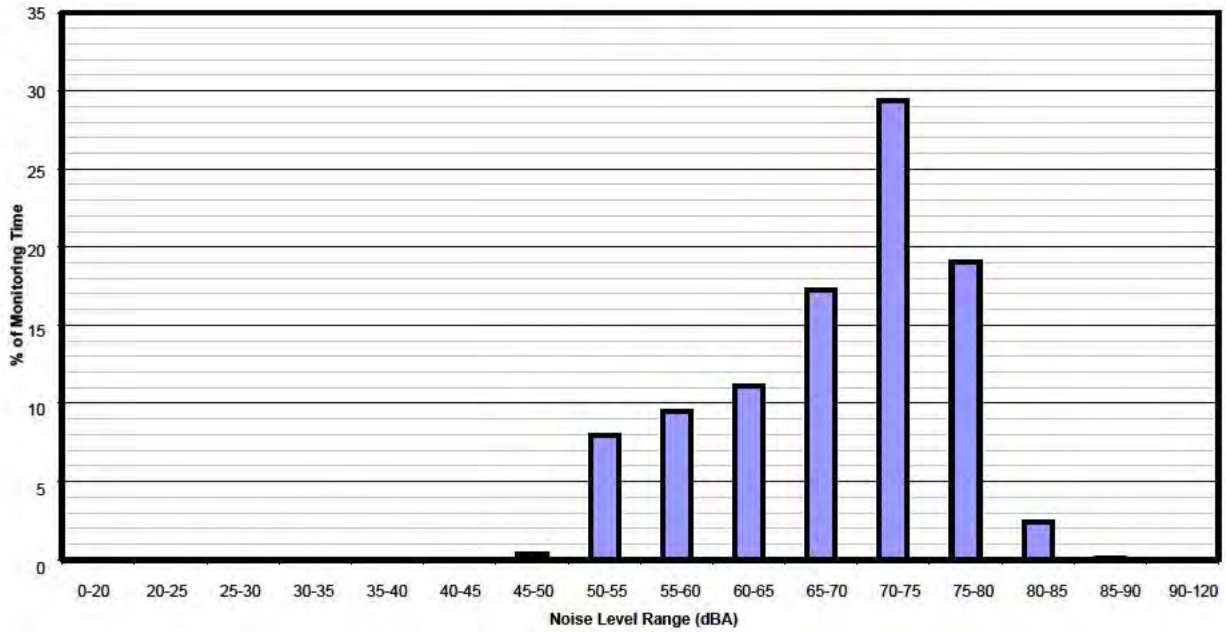
Vancouver Arterial Road Study - Noise Monitoring

Site 30, 424 N. Kamloops Street, Feb. 22-23, 2005
Noise Level Histogram



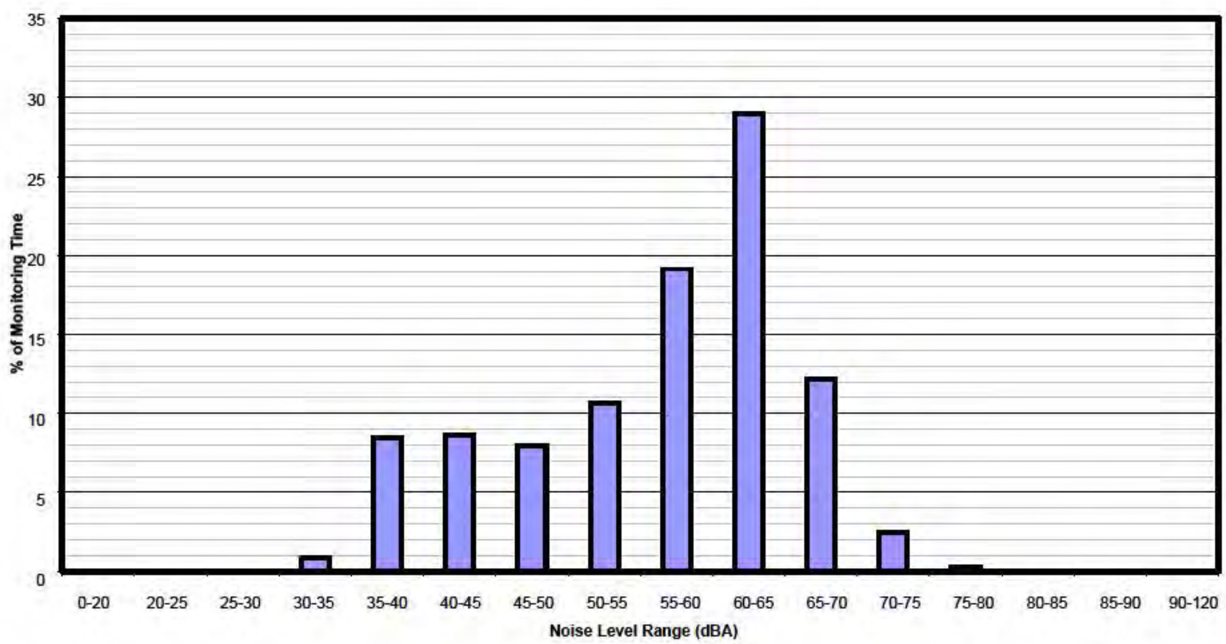
Vancouver Arterial Road Study - Noise Monitoring

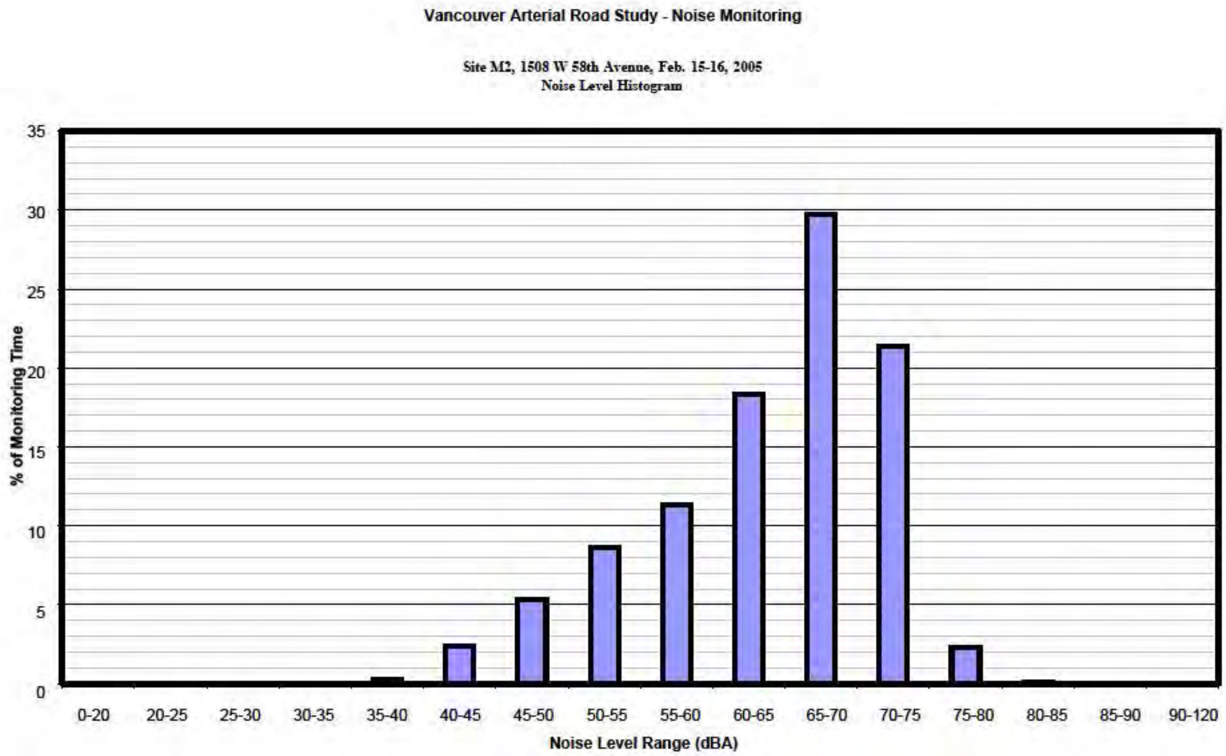
Site 31, 201-2125 E. Hastings Street, Feb. 22-23, 2005
Noise Level Histogram

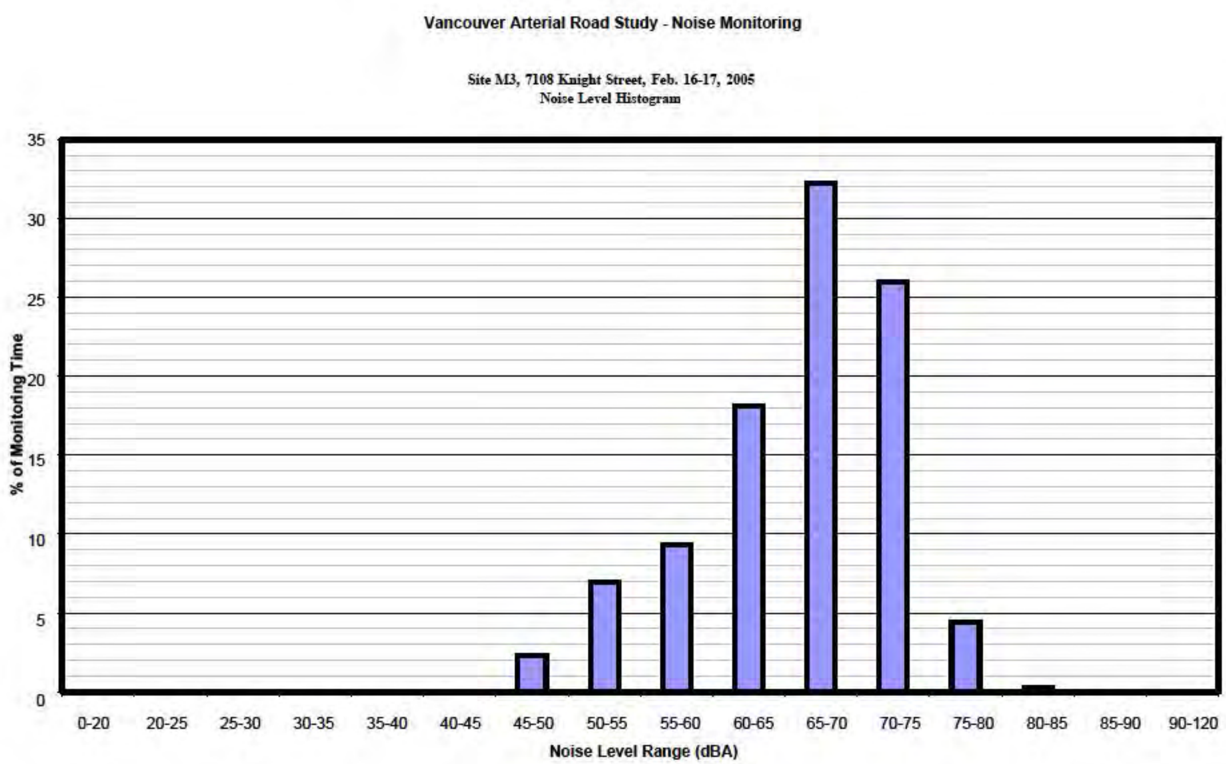


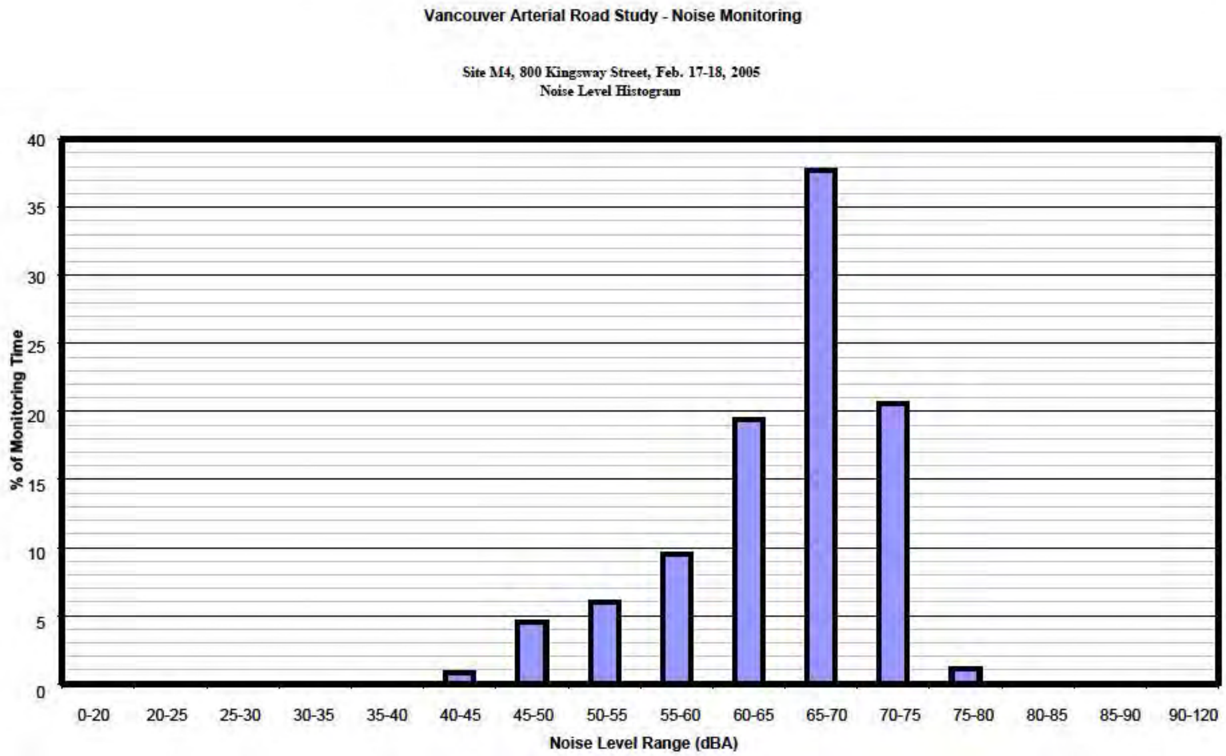
Vancouver Arterial Road Study - Noise Monitoring

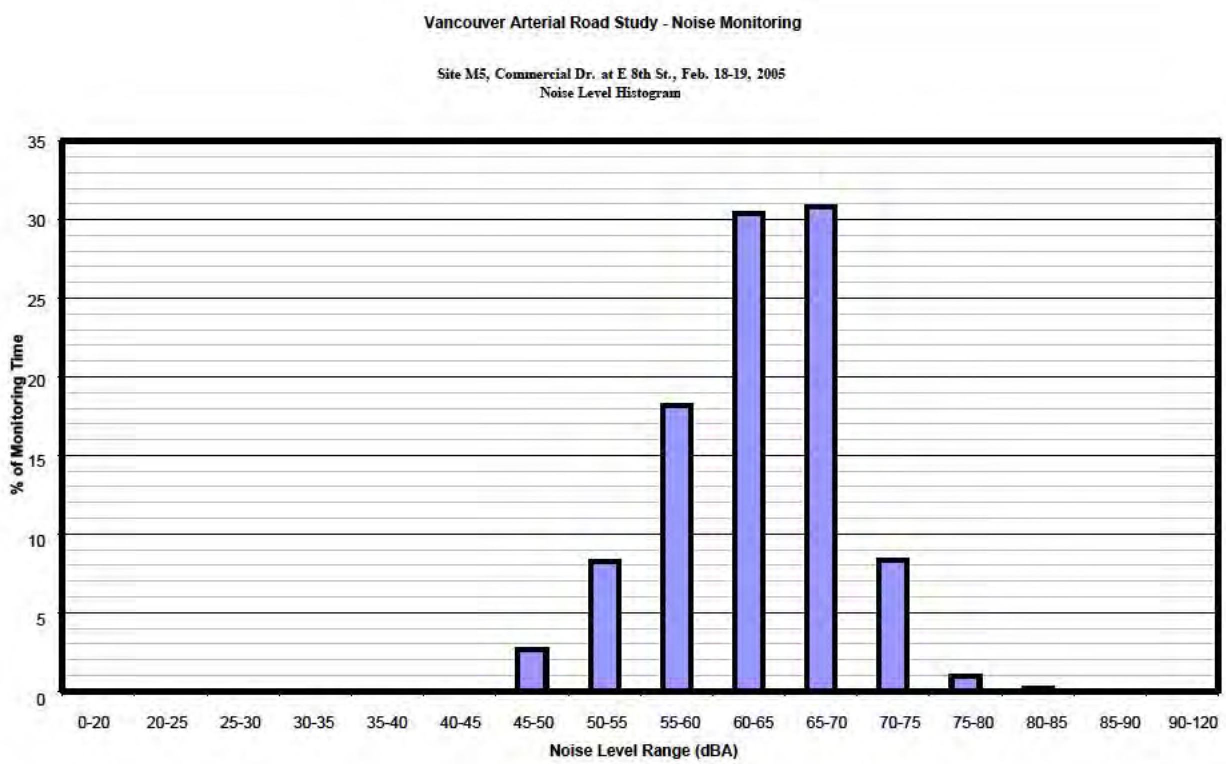
Site M1, 3479 W 41st Avenue, Feb. 14-15, 2005
Noise Level Histogram




Vancouver Arterial Road Study - Noise Monitoring
Site M2, 1508 W 58th Avenue, Feb. 15-16, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site M3, 7108 Knight Street, Feb. 16-17, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site M4, 800 Kingsway Street, Feb. 17-18, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
40
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)


Vancouver Arterial Road Study - Noise Monitoring
Site M5, Commercial Dr. at E 8th St., Feb. 18-19, 2005
Noise Level Histogram
% of Monitoring Time
0
5
10
15
20
25
30
35
0-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-120
Noise Level Range (dBA)

TRAFFIC NOISE LEVELS

AND TRAFFIC NOISE COMPOSITION

ON ARTERIAL ROADS STUDY;

RESULTS OF MANNED NOISE MONITORING

Prepared for:

City of Vancouver
453 West 12th Avenue
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Prepared by:

Wakefield Acoustics Ltd.
301 – 2250 Oak Bay Avenue
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V8R 1G5

June, 2005

TABLE OF CONTENTS

1.0 INTRODUCTION

This report, Deliverable 2 of Contract PS04083 for the City of Vancouver, provides the results of the arterial road manned noise monitoring recently performed by ***Wakefield Acoustics Ltd.*** It explains the methodology utilized in the manned monitoring, and interprets the results obtained. Various graphs and charts have been included to illustrate the results of the manned noise monitoring for each of the five sites and to quantify intrusive noise events created by various arterial traffic related noise sources. The various prominent arterial road noise sources are rated in terms of their overall intrusiveness and potential mitigation measures are introduced.

2.0 METHODOLOGY

2.1 FIELD MEASUREMENTS

2.1.1 Selection of Manned Noise Monitoring Sites

The distribution of the noise monitoring sites throughout the city is illustrated in Figure 2.1. The red dots represent sites where 24-hour unmanned monitoring was conducted while the white dots indicate the five locations at which manned monitoring was carried out and the blue dots show locations where short-term unmanned monitoring was conducted. The five manned noise monitoring sites were selected from the total of thirty-six monitoring locations to reflect the range of noise exposures and traffic mixes from quieter non-truck route arterials such as West 41st Avenue to major truck and transit routes such as Knight Street. The five manned monitoring sites are listed below:

- Site M1 – 3479 West 41st Avenue,
- Site M2 – 1508 West 58th Avenue (corner of W 58th and Granville Street),
- Site M3 – 7108 Knight Street,
- Site M4 – 800 Kingsway,
- Site M5 – corner of 8th Avenue and Commercial Drive.

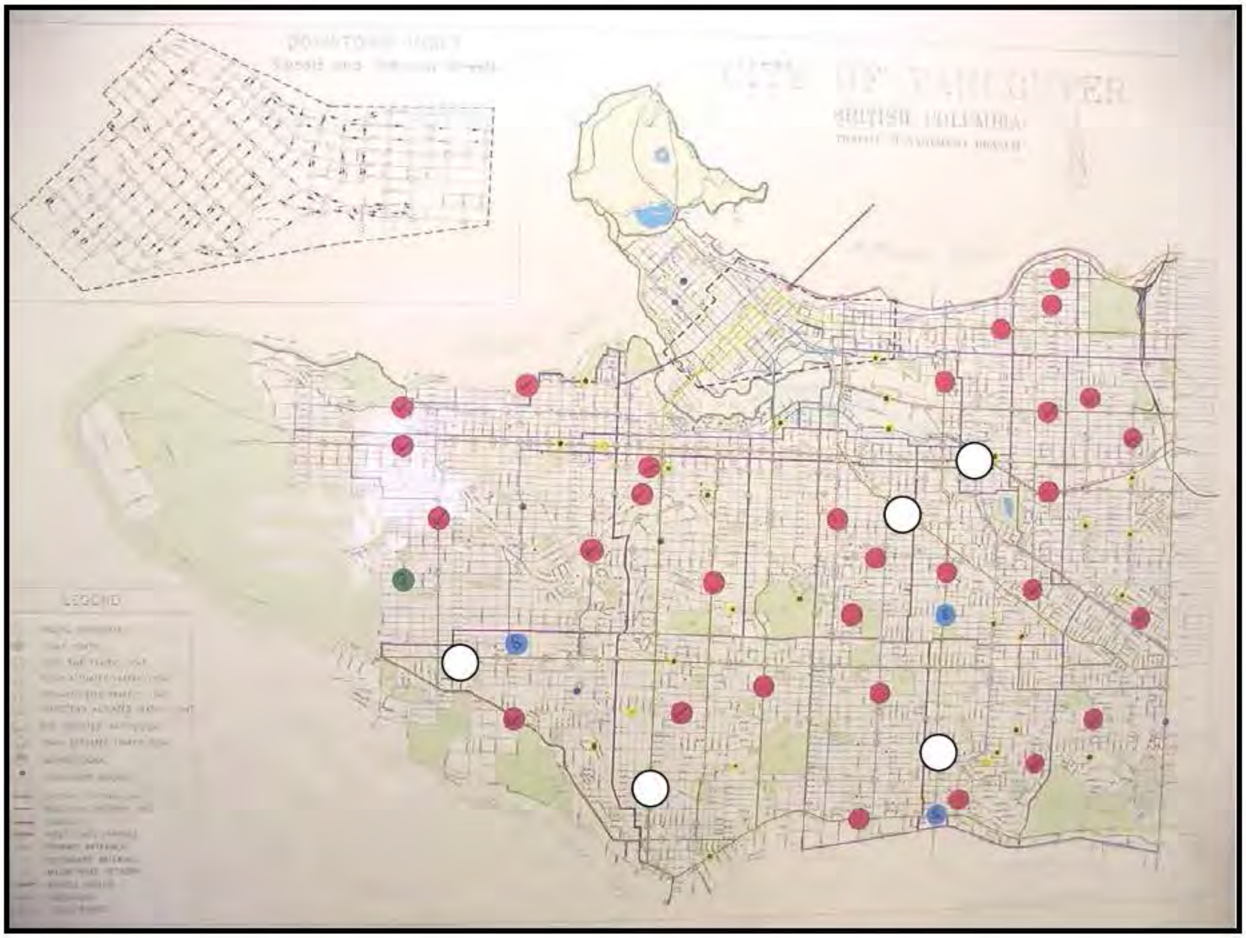


Figure 2.1 – Manned Noise Monitoring Site Locations

2.1.2 Logging of Noise Events

The roughly 23 hours of continuous manned monitoring sessions at each site involved three pairs of field engineers, each covering 7 to 8-hour shifts. The field engineers manually logged the nature and time of identifiable noise events such as created by buses, heavy trucks, engine (Jake) brakes, sirens, inadequately muffled cars, boom cars, motorcycles and car alarms. These events were subsequently correlated with the records of maximum noise levels (L_{max}'s) and equivalent sound levels (L_{eq}'s) that were continuously stored at two second intervals in the sound level meters. As well as logging identifiable noise events, the field engineers also used a Larson-Davis Model 2800 Real Time Analyzer to measure and store the frequency spectra of a number of samples of different arterial road noise sources.

2.1.3 Manned Monitoring Instrumentation and Procedures

Manned noise monitoring was conducted using Larson-Davis Model 820 and 812 Community Noise Analyzers and a Larson-Davis Model 2800 Real-Time Frequency Analyzer. These digital instruments sample the ambient sound level many times per second and store the resulting sound level data for subsequent analysis and display. Two logging sound level meters were used at each manned monitoring site. The first, a LD Model 812, was set to collect a complete statistical description of the noise environment in one hour (60 minutes) intervals as requested in the study terms of reference. The second, a LD Model 820 having larger memory capacity, was set to collect the same data in one minute (60 seconds) intervals. For each interval, these instruments stored a variety of noise descriptors including the Equivalent Sound Level, or L_{eq} (a single-number descriptor of the average sound energy level over any selected time period), minimum (L_{min}) and maximum (L_{max}) levels, and several Exceedance Levels (L_5, L_{10}, L_{50} and L_{90}), which represent the sound levels that were exceeded for various percentages of the interval time. To facilitate the identification of individual relatively brief noise events within the noise records, the LD Model 820's "History Mode" was utilized to sample and store the L_{eq} and L_{max} in two second intervals. All noise descriptors described above are expressed in units of A-weighted decibels, or dBA.

The LD Model 2800 Real-Time Analyzer was used to sample the sound spectra (plots of sound level versus frequency in 1/3rd octave bands) of passing vehicles (*and other noise events*) with a field engineer manually starting and stopping the instrument and storing the spectra. Noise event spectra were typically based on a 5 to 15 second sample of the noise in question.

2.1.4 Quality Control / Quality Assurance

The LD Model 812's and 820's comply with ANSI S1.4 [1983] standards for Type 1 Sound Level Meters. These meters as well as the field calibrator (Larson Davis Type CA200 Acoustic Calibrator) were checked and calibrated by a certified Calibration Laboratory within a year of the monitoring program. The meters were field-calibrated before and after each monitoring period using the LD CA200. The microphones were mounted on poles approximately 1.7 m above ground level in positions where overall community noise exposures were considered to be representative of residential facades facing the arterial road. The level of surety of the manned noise monitoring results is ±0.5 dBA due to instrumentation. Variation in 24-hour daily traffic noise exposures due to traffic volume and speed variations and meteorological conditions is generally within ±1.0 dBA. The substantial observed variation in the noise levels produced by specific types of traffic noise sources (trucks, buses) is principally due variations in the noise output of the sources and/or the setback distance, not the instrumentation.

2.2 DATA ANALYSIS

2.2.1 Selecting an Appropriate Noise Event Descriptor

One of the primary purposes of the manned noise monitoring was to determine the range of noise levels typically produced by various arterial road noise sources. The two noise descriptors most commonly used to quantify and rank the significance of individual noise events are the L_{max} and the SEL. The L_{max} (maximum level) is the highest instantaneous sound level observed during the noise event while the SEL (Sound Exposure Level or Single Event Level) is essentially a measure of the sound energy content of a noise event. While SEL provides a somewhat more complete description of a noise event since it accounts for both sound level and duration, it is typically more difficult to measure in arterial road or highway situations (i.e. involving a stream of traffic rather than distinct individual vehicle pass-by's) due to the overlap of noise from closely spaced events. SEL is then more appropriate for use with more clearly discrete events such as aircraft flyovers. Furthermore, for a given roadway situation with quite uniform vehicle speeds and a constant setback distance, durations of vehicle pass-by noise events are fairly constant. In such situations, SEL and L_{max} are strongly correlated, with the SEL value typically exceeding the L_{max} by 5 to 8 dBA depending on event duration. For these reasons, L_{max} is considered to be the most appropriate descriptor for identifying and comparing noise events produced by various arterial road noise sources under normal arterial traffic flow conditions.

2.2.2 Noise Event (L_{max}) Histograms

Histograms have been created that show the range and distribution of L_{max}'s from prominent arterial road noise sources at each of the four manned sites for which detailed noise event data was available[1]. At each site up to 50 L_{max} samples were selected for the various noise event sources. For common noise events such as from heavy truck pass-bys, the full 50 samples were selected, while for less common sources (where less than 50 events of a given type were observed) all available events were sampled. It was not considered necessary to take more than 50 L_{max} samples of each source since it was found that, by the time this number was reached, the histograms were approaching normal distributions and mean values had stabilized. The noise event histograms for all sites were then combined to create global histograms for the various prominent arterial road noise sources. Since each site was at a somewhat

[1] No L_{max}'s were available for Site M1 due to data loss.

different setback from the centerline of the road, the L_{max}'s were first normalized to an average setback of 18.2 m before being combined.

2.2.3 Selection of an Intrusive Noise Event Threshold

Another objective of the manned noise monitoring has been to determine the numbers and level ranges of noise events at each site which may be considered to be truly intrusive, that is events which are considered to be capable of significantly interfering with the activities of residents or causing significant annoyance. To do this, it was necessary to identify a threshold level above which brief noise events can begin to have these negative effects within residential areas. The following describes the reasoning behind the selection of such a threshold.

Speech Interference

Interference with speech (directly or on the phone) as well as with listening to radio, TV or music constitutes one of the principal impacts of excessive noise within and around residents. Continuous or quasi-continuous noise which approaches 60 dBA begins to interfere with normal face-to-face speech communication at a separation distance of 1 to 2 m. More specifically, adequate (99%) sentence intelligibility can typically be maintained (with slightly raised voices) in noise with a level of 55 dBA, but intrusive noise levels should not exceed 40 dBA for 100% speech intelligibility. This later criterion is based on the mean of the 45 dBA threshold of the U.S. Environmental Protection Agency (EPA, 1974) and the 35 dBA threshold of the World Health Organization (WHO, 1999) which takes into account speech intelligibility when listening to complicated messages. Therefore, while some speech interference can occur at much lower levels, significant interference will begin to be experienced outdoors at 1 to 2m separation when intrusive noise levels approach 60 dBA, with the degree of interference increasing with the level and duration of the noise. Typical Canadian house constructions provide from 10 to 15 dBA of noise insulation when windows are open slightly for ventilation and from 20 to 30 dBA when windows are tightly closed. Choosing the median value for typical house façade attenuation of 20 dBA suggests that significant speech interference may then begin to be experienced indoors when noise levels outdoors at the house façade approach 80 dBA.

Sleep Disturbance

Sleep disturbance due to noise, which includes delays in going to sleep and shifts to lighter sleep stages as well as actual awakenings, is a more personalized and therefore more variable type of noise impact. The likelihood of sleep disturbance by a given noise event depends on the sleep stage (i.e. the "depth" of sleep) that the person is in at the time of the event. The potential for sleep disturbance increases with both the intensity and duration of the noise. While some degree of sleep disturbance from ongoing, or steady, noise has been indicated (WHO 1999) at levels exceeding 30 dBA, studies of sleepers in their homes have found that, to have any significant likelihood of sleep disturbance (i.e., a 2% chance of arousal or behavioral awakening per noise event), a brief, intermittent community noise event of a few seconds duration must approach a level of 60 dBA at the sleeper's position. To reach such a threshold indoors, noise levels outdoors would then typically need to be 20 dBA higher– i.e. about 80 dBA.

Annoyance

Annoyance reactions to noise are even more personalized than sleep disturbance, with some people being able to live contentedly in very high noise environments such as along highways or near airports while others are driven to distraction when even modest levels of unwanted sound enter their residences or yards. Quite commonly, annoyance is a byproduct of having had noise interfere with speech, listening to radio, TV or music and/or disturbing sleep. However, annoyance, its associated stress effects and the potential for negative reactions/complaints can also result from noise at levels well below those required to create significant activity interference (other than sleep disturbance by steady noise). The likelihood that individuals or groups of residents will be annoyed by a particular intrusive noise depends on many factors including the level and character (e.g., tonal, impulsive, sudden onset) of the noise, the time and pattern of exposure (day or night, season of year, steady or intermittent), activity engaged in at time of exposure, information content of noise, previous experience and associations with the noise in question and attitudes towards the noise maker.

While it has been found that, for a given exposure level, normal road traffic noise tends to create less annoyance than aircraft noise and more annoyance than rail noise, for the reasons given above, it is difficult to identify a threshold level above which the individual noise events begin to create significant levels of annoyance.

Threshold Level for Intrusive Noise Events

While it is acknowledged that some degrees of indoor speech interference, sleep disturbance and associated annoyance can be expected at maximum outdoor noise event levels of less than 80 dBA, the intent here has been to select a threshold which both defines noise events which are clearly disruptive and permits individual noise events to be clearly identified and extracted from the noise level histories. A threshold of L_{max} 80 dBA achieves these objectives. It is also consistent with a threshold that has been used in aircraft noise studies such as the "Vancouver International Airport, Third Runway Environmental Impact Assessment to identify aircraft noise events with significant community disturbance potential. In the VIA Third Runway EIA, Transport Canada set this threshold at SEL 85 dBA. As described in Section 2.2.1, The SEL is a measure of the total sound energy to which a listener is exposed during a noise event and as such is dependent on both the level and duration of the event. For a typical aircraft noise event with duration of 20 seconds, the SEL is roughly 10 dBA greater than the L_{max} so that an aircraft overflight reaching an L_{max} of 75 dBA would typically have an SEL of about 85 dBA. Compared to aircraft overflight, arterial road traffic noise events are relatively brief, so that to produce an SEL of 85 dBA, the L_{max} would need to higher than 75 dBA. If it is considered that the typical road vehicle noise event is about 1/3rd as long as the typical aircraft overflight (i.e., 6 to 7 seconds), then the required L_{max} for road vehicles would be roughly 80 dBA.

Therefore, since an L_{max} of 80 dBA at the façade of a typical residence represents the onset of potentially significant speech and sleep interference indoors, and since this maximum level corresponds well with the threshold used by Transport Canada for individual aircraft noise events, ***any noise event with an L_{max} of 80 dBA or higher has herein been considered to be intrusive.***

2.2.4 Frequency Spectra of Prominent Arterial Road Noise Sources

The spectral nature (frequency content) of a sound influences how "noisy" and intrusive it is perceived to be. Our hearing is more acute in the mid and high-frequency range that at lower frequencies and we are particularly sensitive to the presence of pure tones in noise. We are therefore interested in the frequency content, or "spectra", of significant arterial traffic-related noises. Towards this end, spectra from a number of noise sources were measured using a Larson-Davis 2800 Real-Time Frequency Analyzer. At each of the manned monitoring sites, frequency spectra of various prominent noise sources were measured, stored and subsequently averaged over all sites. The majority of the spectra were measured between the hours of 11:00 PM and 6:00 AM when traffic was light and background noise levels therefore relatively low - conditions which facilitate the measurement of noise from individual vehicles.

3.0 RESULTS

3.1 SITE DESCRIPTIONS

Site M1 – 41st Avenue West

Site M1 was located at 3479 W 41st Ave, on the north side of the street. This section of W 41st consists of a single east bound lane and two west bound lanes with parallel parking on both sides of the street and an eastbound bus stop nearby. The traffic mix was typical of an arterial road that is not a truck route, consisting of a variety of passenger cars, city buses, medium trucks and the occasional **motorcycle??** and heavy truck. The microphones were placed in the front yard of the house at a setback of 20.1 m from the centerline of 41st Avenue. The front yard was elevated approximately 0.3 m above the road and the microphones were mounted on poles 1.7 m above the front yard. The terrain between the road and the microphones was a mixture of pavement and grass. Fair weather (sunny day, clear night, light breezes) prevailed during the 24-hour manned monitoring period which extended from 08:30 a.m. February 14 to 07:30 a.m. February 15, 2005.

Note: The one-minute interval and two-second history data were lost at this site due, it is believed, to an unidentified party tampering with the LD 820 sound level meter. As a result, no data is available for presentation or discussion for this site. However, the data obtained at this site with the LD 812 meter was not corrupted and was presented in the form of a detailed statistical noise level history as part of Deliverable 1.

Site M2 – Granville Street

Site M2 was located at 1508 W 58th Ave, on the **SW????** corner of W 58th and Granville. Granville Street is a major commuter (non-truck) route consisting of three southbound and three northbound lanes carrying heavy volumes of traffic consisting largely of passenger vehicles, a variety of transit and commercial buses and medium trucks. The microphones were set up in the residence's front yard at a setback of 16.5 m from the centerline of the Granville Street. The front yard was depressed 0.8 m below the road and the microphones were mounted on poles 1.7 m above the front yard. The terrain between the road and the microphone was a mix of hard and soft ground. Fair weather (sunny day, clear night, light breezes) prevailed during the 24-hour manned monitoring period which extended from 08:30 a.m. February 15 to 07:30 a.m. February 16, 2005.

Site M3 – Knight Street

Site M3 was located at 7108 Knight Street, on the east side of the street **near ????Avenue**. Knight Street is a major trucking route and at this location consists of three southbound and three northbound lanes supporting heavy volumes of commuter and commercial traffic consisting primarily of passenger vehicles, heavy trucks, medium trucks and city buses. The microphones were set up in the front yard at a setback of 22.7 m from the centreline of Knight Street. The front yard of the house was elevated approximately 0.9 m above the road and the microphones were mounted 1.7 m above the front yard. The terrain between the road and the microphone was a mix of pavement and grass. Fair weather (sunny day, clear night, light breezes) prevailed during the 24-hour manned monitoring period which extended from 08:30 a.m. February 16 to 07:30 a.m. February 17, 2005.

Site M4 – Kingsway

Site M4 was located at 800 Kingsway (Sammy's Carpets), on the south side of the street. Kingsway is a major arterial and consists of three southbound and three northbound lanes supporting heavy volumes of commuter and commercial traffic comprised primarily of passenger vehicles, medium trucks and city buses. While Kingsway is a designated truck route, heavy truck volumes are relatively low. Kingsway operates as a 6-lane road only from 3 PM - 6 PM, at all other times it operates as a 4-lane road due to parallel parking on both sides of the street. The microphones were set up in the parking lot of Sammy's Carpets, just off of the sidewalk at a setback of 18.3 m from the centreline of the road and at a height of 1.7 m above the ground. The intervening terrain from the road to the microphone was primarily paved with a little bit of soil near the microphone. Fair weather (sunny day, clear night, light breezes) prevailed during the 24-hour manned monitoring period which extended from 08:30 a.m. February 17 to 07:30 a.m. February 18, 2005.

Site M5 – Commercial Drive

Site M5 was located at the corner of 8th Avenue and Commercial Drive on the west side of Commercial. Commercial Drive is a major arterial consisting of two southbound and two northbound lanes supporting heavy volumes of commuter and commercial traffic comprised primarily of passenger vehicles, city buses, medium trucks, the occasional **motorcycle???** and heavy truck although this portion of Commercial Drive is not a designated truck route. Site M5 was located near the Broadway Skytrain station and also near southbound and northbound bus stops **on Commercial Drive??**. The microphones were set up just behind the sidewalk at a setback of 15.2 m from the centreline of Commercial Drive and at a height of 1.7 m above ground. The terrain between the road and the microphone was primarily covered with pavement with a bit of grass near the microphone. Fair weather (sunny day, clear night, light breezes) prevailed during the 24-hour manned monitoring period which extended from 08:30 a.m. February 18 to 07:30 a.m. February 19, 2005.

3.2 L_{MAX} HISTOGRAMS OF NOISE SOURCES ON ARTERIAL ROADS

Using data obtained from the four manned monitoring sites at which detailed event data was available, L_{max} histograms have been created for the following arterial road noise sources:

- Regular City Buses,
- Trolley Buses,
- Articulated City Buses,
- Bus Air Brake Releases,
- Skytrains,
- Medium Trucks,
- Heavy Trucks,
- Squealing Brakes,
- Motorcycles,
- Emergency Vehicle Sirens,
- Sports Cars / Other Vehicles with Loud Mufflers,
- “Boom” Cars.

The complete L_{max} histograms for each noise source are presented in Appendix B while their key attributes are summarized in Table 3.1 below. For each of the above noise sources, Table 1 shows the range of L_{max}’s observed, the mean, or average, L_{max} value, and the Standard Deviation of the L_{max} values – the latter being a statistical measure of the degree of “scatter” which the L_{max}’s exhibit about the mean value. For a noise source producing L_{max}’s which exhibit a truly “normal” distribution, 68% of the values would fall within one Standard Deviation of the mean, 95% would fall within two Standard Deviations while 99.7% would fall within three.

In Table 3.1 the various noise sources have been listed in decreasing order of the average L_{max} they produce. It is seen that with a mean value of 95.7 dBA and a range of 82 to 105 dBA, emergency vehicle sirens create by far the highest L_{max}'s. Motorcycles place a distant second with a mean L_{max} of 77.5 dBA while heavy trucks, squealing brakes and articulated buses are grouped as a close third with means of 76.3 to 76.4 dBA.

It should be noted that the use of engine (Jake) brakes by heavy trucks was not

Table 3.1; Summary of L_{max} Distributions for Twelve Arterial Road Noise Sources

Source	No. of Samples	L_{max} (dBA)		
		Range	Mean	Std. Dev
Emergency Vehicle Sirens	13	82-105	95.7	7.0
Motorcycles	33	67-87	77.5	5.1
Engine (Jake) Brakes	13	72-83	77.3	3.4
Heavy Trucks	145	66-84	76.4	3.1
Articulated Buses	100	69-85	76.3	3.3
Squealing Brakes	69	62-95	76.3	6.2
Sports Cars[2]	142	68-87	75.5	3.7
Regular Buses	171	66-83	74.6	3.6
Trolley Buses	107	61-84	74.0	4.9
Medium Trucks	198	66-84	73.9	3.0
Bus Air Brake Release	19	68-90	73.7	5.3
"Boom" Cars	30	65-85	72.0	3.6
Skytrain	50	66-80	70.9	3.1

[2] The noise source category "Sports Cars" also includes any vehicle with an unusually loud exhaust system

3.3 INTRUSIVE NOISE EVENTS

Table 3.2 summarizes the results of the intrusive noise event analysis. It is the result of the extraction from the manned monitoring data collected between February 14 and 19, 2005 at Sites M2, M3, M4 and M5 of all identifiable noise events with L_{max}'s equaling or exceeding the 80 dBA "Intrusive Event" threshold established in Section 2.2.3 herein. Table 3.2 ranks the various sources of noise by the number of truly intrusive events of each type observed over the four days of manned monitoring. It also shows the average L_{max} of all intrusive events of each type and the average amount by which the L_{max}'s of these intrusive events exceeded the background noise level (as defined by the L_{90}) at the time of their occurrence. Appendix C illustrates the distributions of these three parameters in the form of bar-charts. Appendix D contains noise level histories of L_{max}, L_{eq}, and L_{90} at one minute intervals for each of the manned sites, with the sources of selected noise event L_{max}'s identified.

Note that Table 3.2 contains all identified sources of intrusive noise events ($L_{max} \geq 80$ dBA) regardless of how many such events were observed whereas Table 3.1 contains only those sources for which their were sufficient observed events to permit a useful histogram to be generated.

Table 3.2; Source Distribution of Intrusive Noise Events

Source	No. of Intrusive Events (Lmax ≥ 80 dBA)[3]	Avg. L_{max} (dBA)	Average dBA by which L_{max} Exceeded L_{90}
Heavy Truck	144	81.7	18.9
Unidentified	130	82.9	21.5
Medium Truck	24	81.3	20.4
Vehicle Horn	21	84.3	22.7
Trolley Bus	16	81.3	18.3
Squealing Brakes	14	84.9	22.0
Emergency Vehicle Siren	13	95.8	34.6
Car w/ Loud Exhaust	12	82.0	20.5
Articulated Bus	10	82.9	22.2
Motorcycle	10	84.9	24.0
Bus	10	82.0	21.5
Sports Car	9	83.3	24.2
Dump Truck	9	83.2	21.5
Fire Truck	6	82.8	19.6
Pick-up Truck	5	83.2	21.5
Skytrain	5	83.5	22.5
Trolley Bus Brake Release	3	88.7	29.4
Shouting	3	92.0	29.4
Squealing Tires	2	84.8	27.1
Engine (Jake) Brake	1	81.1	14.8
SUV	1	80.6	16.4
Exhaust Backfire	1	80.2	23.2
Boom Car	1	85.7	28.3
Fan Belt	1	86.1	29.3
Train	1	85.8	17.4
Garbage Truck	1	83.1	26.2
Asphalt Layer	1	85.2	25.0
Tractor	1	83.1	15.7
Regular Car	1	91.0	27.7
Street Cleaner	1	81.4	21.1

[3].In the one case (Site M2) in which noise levels were measured at a setback distance different from that of a typical house façade, the threshold was adjusted to reflect noise levels that would be expected to occur at the façade.

3.4 FREQUENCY CONTENT (SPECTRA) OF PROMINENT ARTERIAL NOISES

The average 1/3-octave band frequency spectra created by seven arterial road noise sources and groups of related sources are presented in Appendix E. Spectra are shown both in their linear, or unweighted, condition (light blue) as directly measured by the microphones and with the A-weighting applied (dark blue) to illustrate the how the various frequencies components would be perceived by people with normal hearing, i.e., more sensitive to high frequency sound than lower frequency sound. The dark blue bars then indicate the relative loudness of the various frequency components and therefore their contribution to the intrusiveness of the particular type of noise. Error bands are included on the unweighted spectra to define the range of sound levels measured within each 1/3 octave frequency band. **Also presented are spectra of typical background noise at each of the four ??? five sites???????**

- City diesel buses
- Trolley buses **(mislabeled)**
- Articulated Diesel Buses;
- Heavy and Medium Trucks
- Skytrains
- Passenger Vehicles (Cars, Minivans, Pickup Trucks, etc.)
- Sports Cars
- Boom Cars
- Emergency Vehicle Sirens

4.0 DISCUSSION

4.1 ASSESSING THE SIGNIFICANCE OF ARTERIAL ROAD NOISE SOURCES

4.1.1 Assessment Approach

The intrusiveness of a given type of noise depends on many parameters including its intensity or loudness, its frequency content, its temporal nature (suddenness, impulsiveness) and its prevalence (how often its occurs and how long it persists) during both daytime and nighttime. In order to assess the relative importance of the various arterial road noise sources to the overall urban noise environment and to establish mitigation concepts and priorities for arterial traffic noise impacts throughout the City, it is necessary to somehow rate the overall intrusiveness of the various types of noise taking into account as many of the above parameters as possible. A rating system has therefore been developed based principally on the numbers of events of each type that were observed to meet or exceed the L_{max} 80 dBA threshold for truly intrusive noise events established in Section 2.2.3 and on the average L_{max}'s of these truly intrusive events. Corrections are have then been applied to these basic noise event frequency and loudness measures to reflect the character of each type of noise as well as their spatial and temporal distributions. A final correction has been applied to reflect the "value" of each type of noise, that is, its necessity or usefulness to the community as a whole. The results of this procedure have been expressed in terms of pure numbers (rather than decibels) which are indicative the relative overall intrusiveness of the individual arterial road noise sources on a city-wide basis. However, when interpreting these nose source rankings, it should be kept in mind that they are based on the results of manned 24-hour noise monitoring conducted at just four locations.

4.1.2 Relevant Noise Event Parameters and their Ratings

The following arterial road noise event parameters have been considered in this assessment procedure:

1. ***Average Intensity/Loudness*** –. The perceived loudness of a given type of noise roughly doubles (i.e., 100% increase) with each 10 dBA increases in its sound level as expressed in decibels. For example a truck pass-by event that produces an L_{max} of 85 dBA at the sidewalk will generally be perceived as being twice as loud as one which produces 75 dBA at the same location, and four times as loud as one which produces only 65 dBA. Similarly, a 5 dBA increase in noise level corresponds to about a 40% increase in perceived loudness. On this basis, if we assign a loudness rating of "1.0" to a noise

source with an average L_{max} equal to the 80 dBA threshold, then an event with an average L_{max} of 85 would have a loudness rating of "1.4", one with an L_{max} of 90 dBA would have a loudness rating of "2.0" while one with an L_{max} of 95 dBA would be rated at "2.8".

2. ***Intrusive Character*** – Noises which are characterized by pure tones (whines, hums, squeals), pronounced bass (rumble, booming), pronounced high frequency content (hiss), strong rhythmic patterns, suddenness (unexpectedness) or impulsiveness are found to be inherently more intrusive and disturbing that those with a neutral character such as distant traffic noise or properly balanced airflow noise. While the details of how these undesirable noise characteristics are dealt with vary among different noise standards and guidelines, the general approach is to apply penalties (increases) to the A-weighted level of the noise in question to bring it up to the level of a neutral sound (such as distant traffic) that would be judged equally noisy or annoying. Such corrections have ranged from 3 to 6 dBA for tonal or other undesirable frequency content up to 12 dBA for highly impulsive noises such as gunfire. A simplified approach has been taken here in which noises having some undesirable content are applied a 5 dBA penalty (equating to a 40% increase in judged loudness/noisiness) while those with pronounced or multiple undesirable content(s), are given a 10 dBA penalty (twice as loud/noisy).

3. ***Frequency of Occurrence*** - This parameter represents the numbers of noise events of each type which tend to occur during a typical time period such as a 24-hour day. Again it has been based on the total numbers of truly intrusiveness (L_{max} ≥ 80 dBA) noise events which were noted during 24-hours of monitoring at all four manned sites. Frequency-of-occurrence values have then been taken directly from the second column of Table 3.2.

4. ***Spatial Distribution or Pervasiveness*** – The parameter attempts to reflect the fact that different noise sources have different distributions throughout the City and therefore directly affect different numbers of residents. A simple scale has been used which applies a values of "1.0" to those sources (such as medium trucks, sports cars and vehicle horns) that are considered to occur with roughly equal likelihood throughout the entire arterial road network, while sources (such as heavy trucks and trolley buses and Skytrains) which have more limited spatial distributions are given values less than 1.0 roughly corresponding to their partial distributions over the arterial road network. These values should be considered more indicative of a general ranking than a precise quantitative rating since they have been established to a greater degree through application of judgment than rigourous analysis.

5. ***Temporal Distribution* –** This parameter attempts to reflect the relatively greater importance (from the perspective of intrusiveness) of noise events occurring during the late evening and nighttime hours compared to those which occur only during normal daytime hours. Nighttime and evening noise penalties have a long history in community noise impact assessment and, again while various approaches have been taken, the most widely utilized involves application of a 10 dBA penalty to the levels of noise events occurring at night (usually between10 pm and 7 am), while some procedures also apply a 5 dBA penalty to events occurring during evening hours (typically 7 to 10 or 11 pm). A similar, but non-rigourous, approach has been taken herein based on general understandings of the temporal patterns typically exhibited by the various prominent arterial road noise sources. Again a 10 dBA penalty would result in an effective doubling in the perceived loudness, noisiness or intrusiveness of the particular noise event. For example, those noise sources which are very unlikely to be experienced at night on most arterial roads (e.g. dump trucks) would have no penalty applied and would then receive an intrusiveness rating of "1.0", while those that are likely to be experienced throughout some but not all nighttime hours (e.g. buses and Skytrains which operate for 18 to 20 hours/day) would be given a 5 dBA penalty and a rating of "1.4". Any source which was equally likely to occur during any nighttime hour as any daytime hour would receive a 10 dBA penalty and a rating of"2.0"

6. ***Necessity/Usefulness*** – The parameter is somewhat unique in community noise assessment but it is felt that it may be helpful in identifying those noise sources which might logically be considered for mitigation measures given the practical constraints of arterial traffic noise control. It is intended to reflect the value (necessity or usefulness) of the noise source in the communal sense. Is the source serving a critical or useful function in the community or is it simply producing noise for the perceived benefit of the noise maker and perhaps limited numbers of the exposed population who are "into" that type of thing. Again, a somewhat arbitrary scale has been developed which acts to reduce (by applying a rating less than 1.0) the inherent intrusiveness of noises which serve some useful or critical purpose while increasing the intrusiveness (by applying a rating greater than 1.0) of noise sources with little or no associated communal benefit. An example of the former would be an ambulance siren while an example of the latter might be a "boom car". Noise sources (such a heavy and medium trucks and buses) which serve important functions but which do not rely on producing loud noise for their effectiveness, would receive a "neutral" rating of 1.0. Sources such as inadequately muffled exhausts or squealing brakes which serve no purpose and could be controlled through maintenance, are given a rating somewhat greater than 1.0.

4.1.3 Rating the Overall Intrusiveness of Various Arterial Road Noise Sources

The rating system described above has been applied to the various prominent noise sources identified during the manned monitoring program including most of the sources listed in Table 3.2. The results of this analysis are summarized in Table 4.1. Before reviewing the results of Table 4.1 and considering their implications for the development of a mitigation strategy for arterial traffic noise, the following limitations of this exercise should be acknowledged:

1. The analysis has been based on the results of 24-hour periods of manned monitoring at just four separate locations and therefore while its outcomes are considered to be indicative of the relative importance of various noise sources, it cannot be assumed that these results are truly representative of the entire arterial road network,

2. It was decided in the field that, when monitoring on busy bus routes, particularly during rush hours, L_{max}'s would be noted down for only a portion of all bus pass-bys events. While more than adequate numbers of bus events were obtained to create average L_{max} values (see Table 3.1) and to develop the bus L_{max} histograms shown in Appendix B, the numbers of bus noise events which actually met or exceeded the L_{max} 80 dBA threshold are expected to have been somewhat underrepresented.

3. The above procedure has relied quiet heavily on the application of professional judgment, particularly in the selection of rating values for Spatial and Temporal Distribution and Necessity/Usefulness. As a result, while the outcomes are considered to follow the proper trends, the absolute values of the Overall Noise Source Ratings and the associated Source Rankings could vary significantly if the process was to be repeated by different investigator or following a refinement of the spatial and temporal distribution information.

4.1.4 Most Intrusiveness Noise Sources

Having acknowledged its limitations, the above procedure identified Heavy Trucks as the noise source with the highest Overall Intrusiveness Rating by a comfortable margin, with Squealing Brakes coming a quite distant second while Vehicle Horns and Emergency Vehicle Sirens ranked a fairly close third and fourth respectively. Table 4.1 reveals that Heavy Trucks achieved their top rating largely due to the high numbers of

Noise Source	Noise Parameters and Ratings						Overall Intrusiveness	
	Average L_{max}'s ≥ 80 dBA (Rel. Loudness)	Intrusive Character	Frequency of Occurrence L_{max} ≥ 80 dBA	Spatial Distribution	Temporal Distribution	Necessity / Usefulness	Rating	Ranking
Heavy Trucks	81.7 (1.125)	1.0	144	0.5	1.5	1.0	121.5	1
Medium Trucks	81.3 (1.094)	1.0	24	1.0	1.0	1.0	26.3	8
Vehicle Horns	84.3 (1.347)	2.0	21	1.0	1.5	0.75	63.7	3
Trolley Buses	81.3 (1.094)	1.2	16	0.2	1.4	1.0	5.9	14
Squealing Brakes	84.9 (1.404)	2.0	14	1.0	1.5	1.25	73.7	2
Emergency Vehicle Sirens	95.8 (2.989)	2.0	13	1.0	1.5	0.5	58.3	4
Loud Exhausts	82.0 (1.149)	1.4	12	1.0	1.5	1.5	43.4	6
Articulated Buses	82.9 (1.223)	1.2	10	0.3	1.0	1.0	4.44	16
Motorcycles	84.9 (1.404)	1.4	10	1.0	1.5	1.5	44.2	5
City Bus (Diesel)	82.0 (1.149)	1.0	10	0.7	1.4	1.0	11.3	9
Sports Cars	83.3 (1.257)	1.2	9	1.0	1.5	1.5	30.5	7
Dump Truck	83.2 (1.248)	1.0	9	0.8	1.0	1.0	9.0	11
Fire Truck	82.8 (1.214)	1.0	6	0.5	1.5	1.0	5.5	15
Pick-up Truck	83.2 (1.248)	1.0	5	1.0	1.0	1.0	6.2	13
Skytrain	83.5 (1.275)	1.4	5	0.1	1.4	1.0	1.25	19
Trolley Bus Brake Release	88.7 (1.828)	2.0	3	0.2	1.4	1.25	3.8	17
Squealing Tires	84.8 (1.395)	2.0	2	1.0	1.5	1.25	10.5	10
Boom Car	85.7 (1.485)	2.0	1	1.0	1.5	2.0	8.9	12
Engine (Jake) Brake	81.1 (1.079)	2.0	1	0.5	1.5	1.5	2.43	18

Table 4.1; Overall Intrusiveness Rating of Various Prominent Arterial Road Noise Sources

events meeting or exceeding the 80 dBA threshold, which in turn relates to the high volumes of Heavy Trucks on some arterial roads, particularly Knight Street. The persistence of lesser volumes of Heavy Trucks throughout the night was also significant factor. Note that Heavy Trucks were rated "most intrusive" in spite of only two of the four manned monitoring sites being located on designated truck routes and one of these, Kingsway, having relatively light truck volumes.

Squealing Brakes received their second place source ranking due in part to their relatively high average level, their intrusive character (piercing tonality) and their anticipated occurrence throughout the arterial road network and during both daytime and nighttime.

Vehicle Horns were ranked as the third most intrusive source due in part to their fairly high average level, their intrusive character (sudden and tonal), their fairly high occurrence rate and their anticipated broad spatial and temporal distributions.

Emergency Vehicle Sirens were ranked fourth due largely to their very high average level (15.8 dBA over the threshold) and their intrusive character (extremely tonal). Note that the overall intrusiveness rating of sirens was downplayed substantially by the "Necessity/Usefulness" parameter value of 0.5 which was intended reflect their importance to safety and the preservation of life, limb and property. If this parameter had not been included in the analysis, sirens would have attained an overall rating of 116.3 and been ranked a very close second to Heavy Trucks.

Motorcycles were ranked fifth most intrusive based on their fairly high average level, their moderate tonality, their wide distribution and a "Necessity/Usefulness" parameter value of 1.5 intended to reflect the opinion that some types of motorcycles make more noise than they need to largely for the perceived benefit of their owners.

Table 4.1 shows that Loud Exhausts and Sports Cars were ranked sixth and seventh respectively. Since the intrusive noise events levels associated with sports cars generally originate from their exhaust systems, these two source types might have been lumped together into one. If this had been done, their combined Overall Intrusiveness rating would have been 73.9 and they would have been ranked second just ahead of Squealing Brakes.

As was mentioned earlier in this section, during busy periods, not all bus noise events had their L_{max}'s noted down during the manned monitoring. If it is very conservatively assumed that only half of all bus events with L_{max}'s of 80 dBA or more were logged, then the numbers in the Frequency of Occurrence column for all types of buses would logically need to be doubled. This would cause the overall Intrusiveness Ratings of City Diesel Buses, Trolley Buses and Articulated Buses to increase from 11.3, 5.9 and 4.44

to 22.6, 11.8 and 8.88 respectively. The associated rankings of the three types of buses would of course also have to be adjusted. Trolley Buses would now rank tenth instead of fourteenth, while Articulated Buses would move from sixteenth to twelfth place. In spite of the doubling of their rating value, City Diesel Buses would retain their ninth place ranking. Even is all types of buses were then lumped together, producing a combined Overall Intrusiveness rating of 41.8, they would still be rated only seventh on the list of intrusive arterial road noise sources.

4.2 MITIGATION CONSIDERATIONS

The intent of the analysis described in Section 4.1 above is to assist in identifying measures that the City could consider implementing in order to reduce the overall impact of arterial traffic noise on the citizens of Vancouver. Provided again that the limitations of the above analysis are kept in mind, its results can provide initial directions along the path to developing an arterial road traffic noise mitigation plan. Towards this end, Table 4.2 displays the various mitigation options that could be considered for each of the ten most intrusive noise sources (as identified in Table 4.1) and assigns each option a rating on a three-point sale based on the anticipated overall effectiveness of the particular mitigation option when applied to a particular arterial noise sources. I

The mitigation option ratings of Table 4.2 are meant to be representative of the general applicability and potential effectiveness of the particular measure to the City as a whole. However, some of these options, such as noise barriers, would clearly be more appropriate and effective in some residential areas than others (e.g. in areas of largely single or two storey homes rather than in areas with many apartment buildings and condos), while other options may be . Other options, such as Vehicle Inspection and Law Enforcement & Regulation would require the involvement of other agencies.

It is seen that Low Noise Barriers receive the highest average Mitigation Potential Rating at 2.2 and is considered particularly effective in attenuating noises from sources located close to the pavement and which have substantial high-frequency content (e.g., brake and tire squeal). Low (1.5 to 2.5 m high) barriers would be somewhat less effective in reducing noise from sources, which while close to pavement, have substantial low-frequency content (e.g. some motorcycles, sports cars, loud exhausts).

Some of the mitigation options listed in Table 4.2 may be evaluated in the Cadna/A arterial road model that has been developed as part of this project. These include Low Noise Barriers, Speed Controls, Pavement Design, and Nighttime Heavy Vehicle Bans. For other options, such as Vehicle Testing, Law Enforcement and Education, the effects can not be modeled in Cadna/A but can perhaps be estimated using professional judgment in combination with basic acoustical principals.

Noise Source	Mitigation Approach							
	Low Noise Barriers	Law Enforcement & Regulation	Vehicle Inspections/ Maintenance	Vehicle Modification (Noise Control)	Speed Control / Signage	Nighttime Heavy Vehicle Ban/ Rerouting	Pavement Design or Maintenance	Education
Heavy Trucks	2	1	2	1	2	2	2	2
Squealing Brakes	3	2	3	1	1`	1	1	2
Vehicle Horns	2	2	1	1	1	1	1	2
Emergency Vehicle Sirens	2	1	1	1	1	1	1	1
Motorcycles	2	2	2	2	2	1	1	2
Loud Exhausts	2	3	3	2	2	1	1	2
Sports Cars	2	2	2	2	2	1	1	2
Medium Trucks	2	1	2	1	2	1	2	1
City Buses (Diesel)	2	1	1	2	2	2	2	1
Tire Squeal	3	2	1	1	1	1	1	2
Average Rating	**2.2**	**1.7**	**1.8**	**1.4**	**1.6**	**1.2**	**1.3**	**1.7**

Mitigation Potential Ratings; 1. Considerable Potential, 2. Some Potential, 3. Little or No Potential

Table 4.2; Potential Mitigation Options for the Ten Most Intrusive Arterial Road Noise Sources

APPENDIX A

COMMUNITY NOISE FUNDAMENTALS AND DESCRIPTORS

NOISE FUNDAMENTALS

What is Sound and How is it Made?

Vibrating surfaces such as engine housings, drumheads or loudspeakers and rapidly moving fluids such as in jet engine exhausts, produce minute fluctuations in atmospheric, or air, pressure. These pressure fluctuations spread out from the source in the form of expanding pressure waves in the air, much as a water wave on a pond spreads out from the point where a pebble has been dropped – their intensity steadily decreasing with distance from the source. Our ears, acting like microphones, sense these air pressure fluctuations and our brain interprets them as sound.

The Sound Pressure Level or "Decibel" Scale

The ear is capable of sensing sound, or "hearing", over an enormous range of intensities - from the faintest rustling of leaves to the roar of a nearby jet aircraft. The jet may produce sound that is one million times more intense than the rustling of leaves. Therefore, similar to the "Richter" scale which compresses the entire range of earthquake magnitudes into a 1 to 10 scale, the "Sound Pressure Level" or "Decibel" scale was developed to represent the even greater range of audible sound intensities within a compressed, or "logarithmic", scale. Within this scale, a Sound Pressure Level (SPL) of 0 decibels (dB) represents the threshold of hearing in the ear's most sensitive frequency range, while the thresholds of tickling or painful sensations in the ear occur at 120 to 130 dB. The accompanying poster shows the Sound Pressure Levels, or more commonly "sound levels", typically created by a variety of common sources in the community. Roughly speaking, each 10 dB increase in sound level corresponds to a "doubling of subjective loudness".

How is Sound Measured?

Sound is measured with instruments called "Sound Level Meters" which consist of a microphone in conjunction with an electronic amplifier, a display meter and commonly today, a digital memory for logging sound level data over time. These meters are calibrated before each use.

The Frequency or "Pitch" Sensitivity of the Ear - "A"-weighted Decibels

The normal range of sound frequencies audible to the young, healthy ear is from 20 cycles per second, or Hertz (Hz.) to about 20,000 Hz. The ear is much more sensitive to mid and higher frequencies (particularly the 500 to 4000 Hz, range) than to lower frequencies. To approximate the ear's frequency sensitivity, Sound Level Meters contain electronic weighting networks, the most widely used and appropriate for typical measurements in the community being the "A-weighting". Sound levels measured with this weighting in effect are called "A-weighted sound levels" and their unit of measurement is the "A-weighted decibel, or dBA".

What is Noise?

Noise is commonly referred to as "unwanted sound", because it interferes with human activities and/or creates annoyance. The judging of sound as noise is then, to a substantial degree, a personal or subjective matter since it depends on the situation, the activities engaged in as well as individual attitudes and sensitivity.

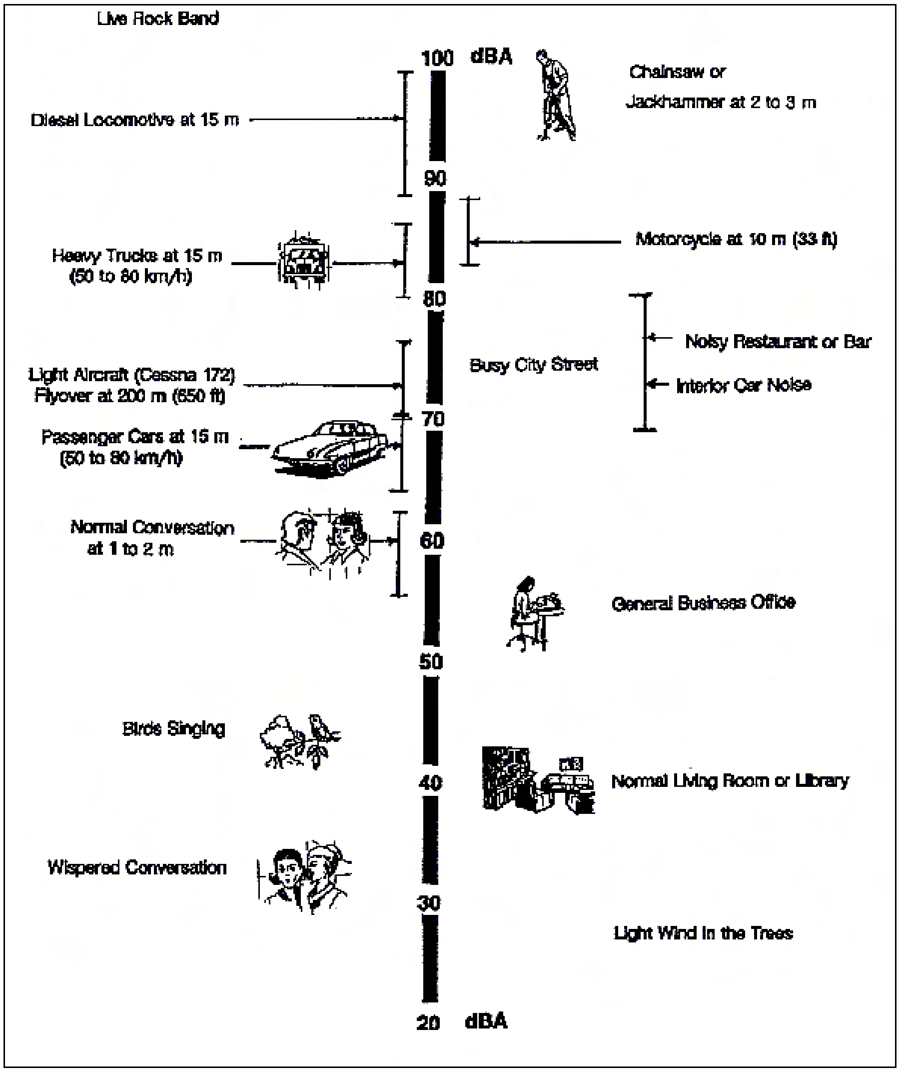


Figure A.1: Levels of Common Noises in the Community (dBA)

How is Sound Energy Lost?

Geometric spreading is the reduction in the intensity of sound waves as they move away from the source due to the spreading of their energy over progressively larger and larger areas.

Atmospheric absorption is the extraction of energy from sound waves as they pass through the atmosphere due to a variety of phenomena.

Ground effect attenuation is the reduction in sound intensity at a distance from the source caused by destructive interference between direct and ground-reflected sound waves and occurs where sound waves travel close to acoustically soft ground.

Principal Community Noise Level Descriptors

The principal descriptor of the baseline community noise environment provided by the monitoring is the 24-hour Equivalent Sound Level, or $L_{eq}(24)$. This is a widely-utilized, single-number descriptor of the average sound energy exposure over a 24-hour day and is employed in the B.C. Ministry of Transportation's noise impact mitigation policy as well as other community noise guidelines. The L_{eq} is that steady sound level which, over a given time period, would result in the same overall sound energy exposure as would the actual time-varying community noise level.

A variant of the $L_{eq}(24)$ is the Day-Night Average Noise Level, or L_{dn}. Like the $L_{eq}(24)$, the L_{dn} is an energy-averaged descriptor of daily noise exposure and is expressed in dBA. However, in computing L_{dn}, all noise levels occurring between 22:00 and 07:00 hours are increased by 10 dBA to reflect the greater sensitivity of residential communities to noise at night. Where noise environments are dominated by highway/road traffic noise (which tends to be substantially lower at night than during the day), these two daily-average noise descriptors yield fairly similar results. However, should industry, railway operations or other noisy activities be prominent and continue during the nighttime, the L_{dn} tends to be significantly higher than the $L_{eq}(24)$. For this reason, L_{dn} is an appropriate noise descriptor where significant nighttime noise is expected and is used in other guidelines.

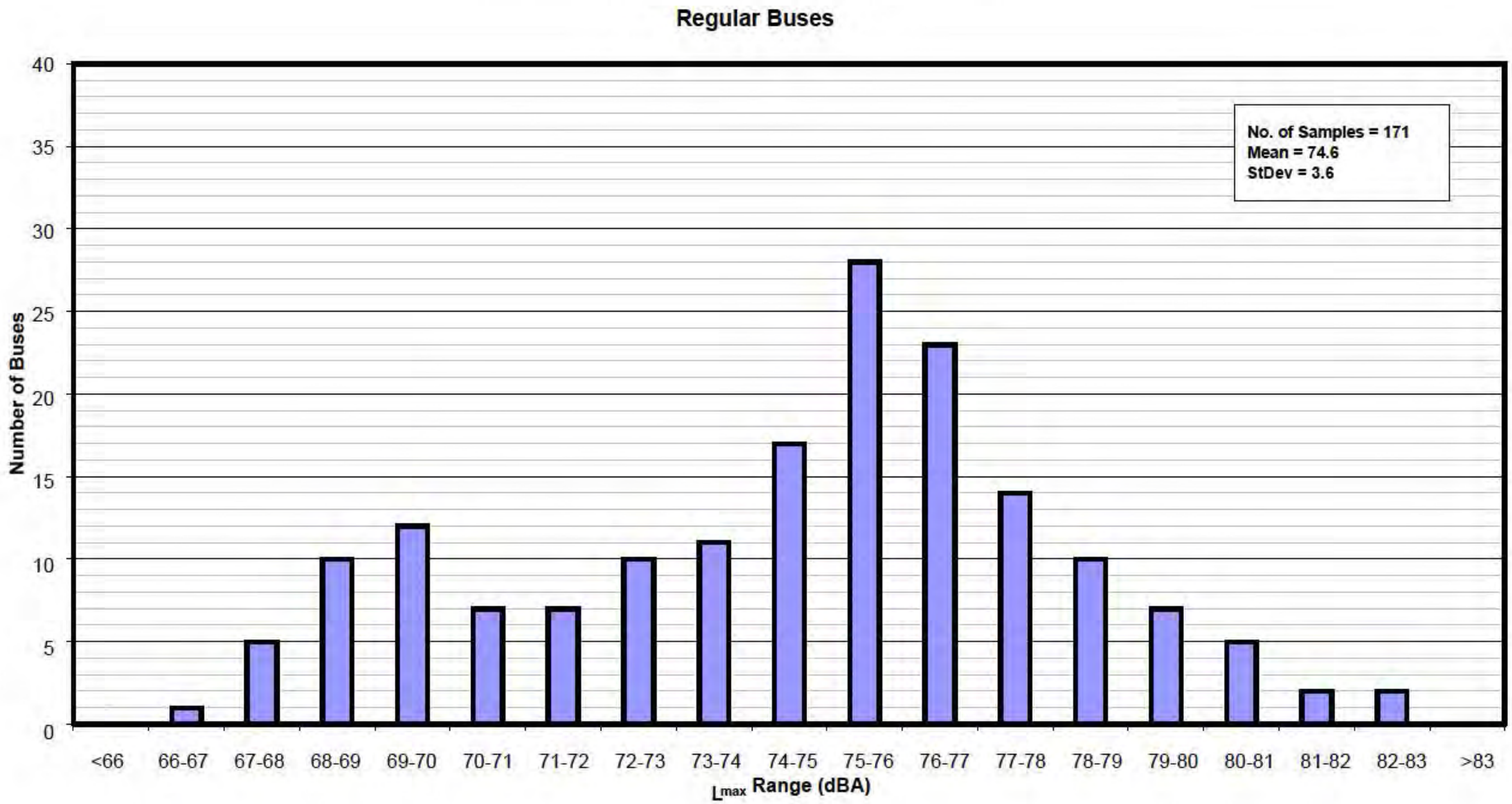
Other noise descriptors or quantifiers include the maximum sound level, or L_{max}, and exceedance levels, or L_n. The L_{max} is the highest sound pressure level measured over a defined time interval. The exceedance levels are those noise levels that were exceeded for a given percentage "n" of the monitoring time. For example, the L_{50} is that noise level exceeded 50% of the time, i.e. the median level, while the L_{90} is that noise level exceeded 90% of the time and hence may be considered the background noise level. In all cases, these noise levels are expressed in units of A-weighted decibels, or dBA. The "A-weighting" refers to the electronic weighting network built into most sound measuring devices (sound level meters) which simulate the frequency (or pitch) sensitivity of the human ear. Noise levels measured with this network in place are then expressed in A-weighted decibels, or "dBA".

APPENDIX B

HISTOGRAMS OF INDIVIDUAL SOURCE L_{MAX}'S

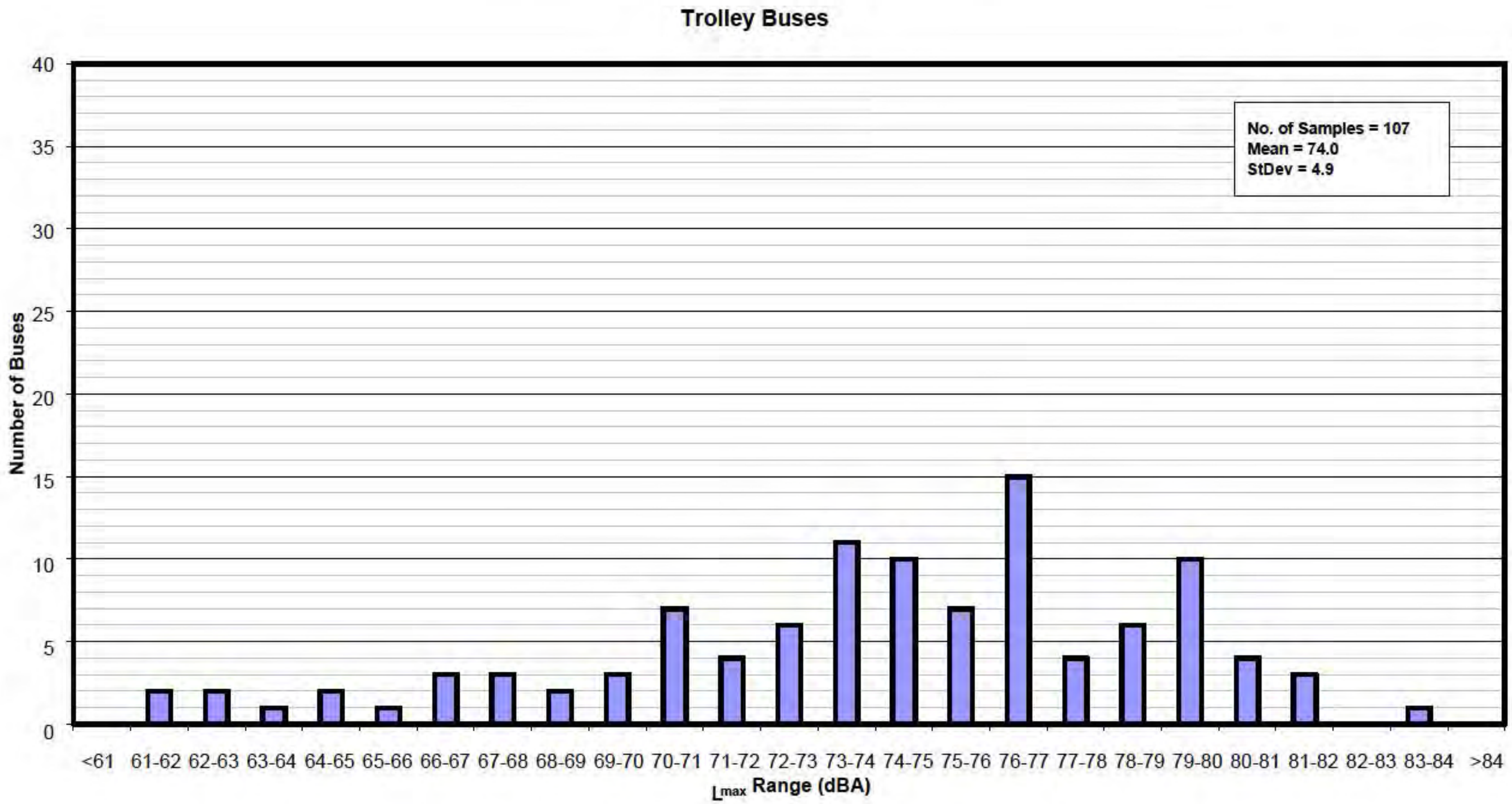
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

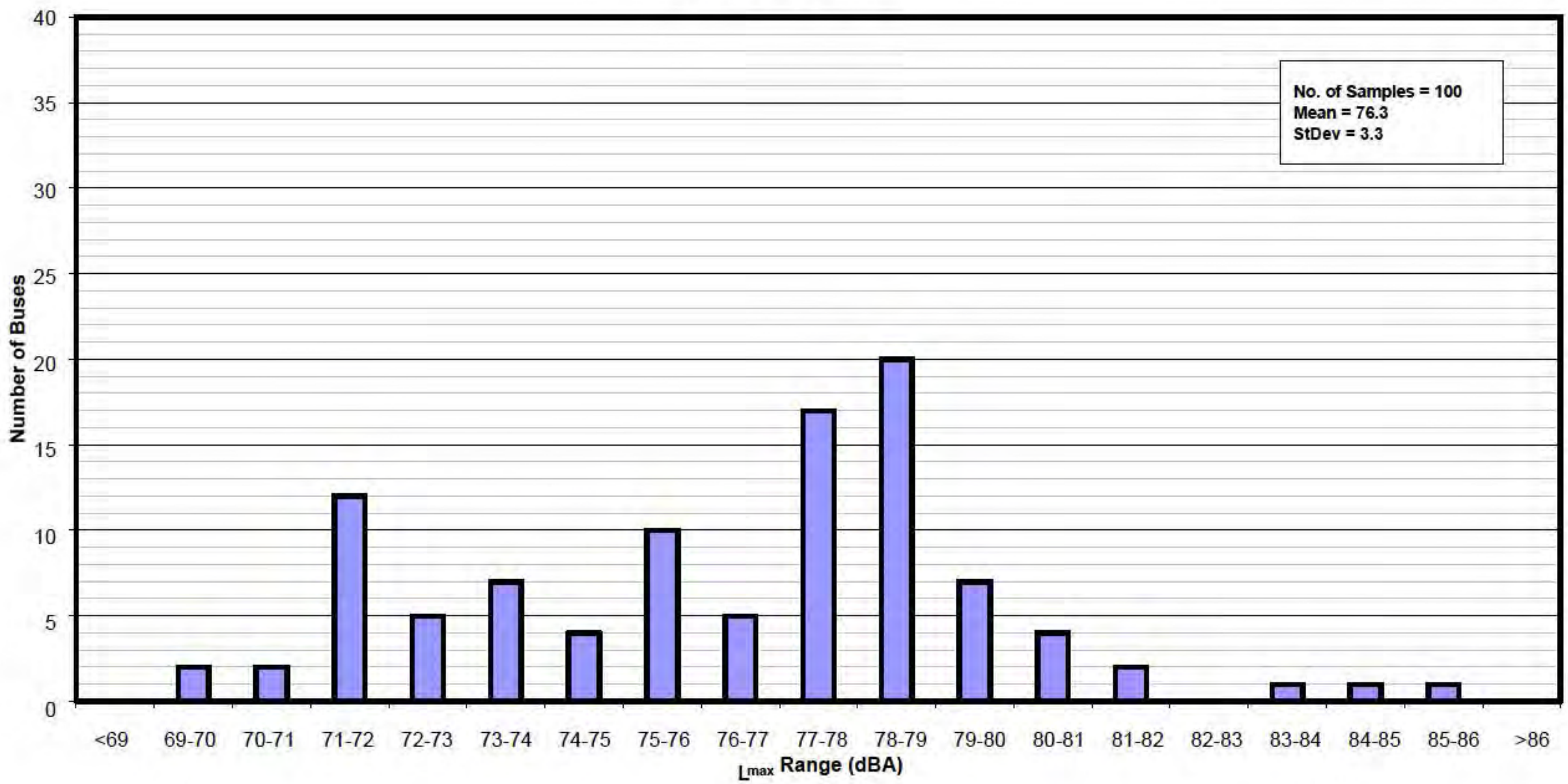
Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

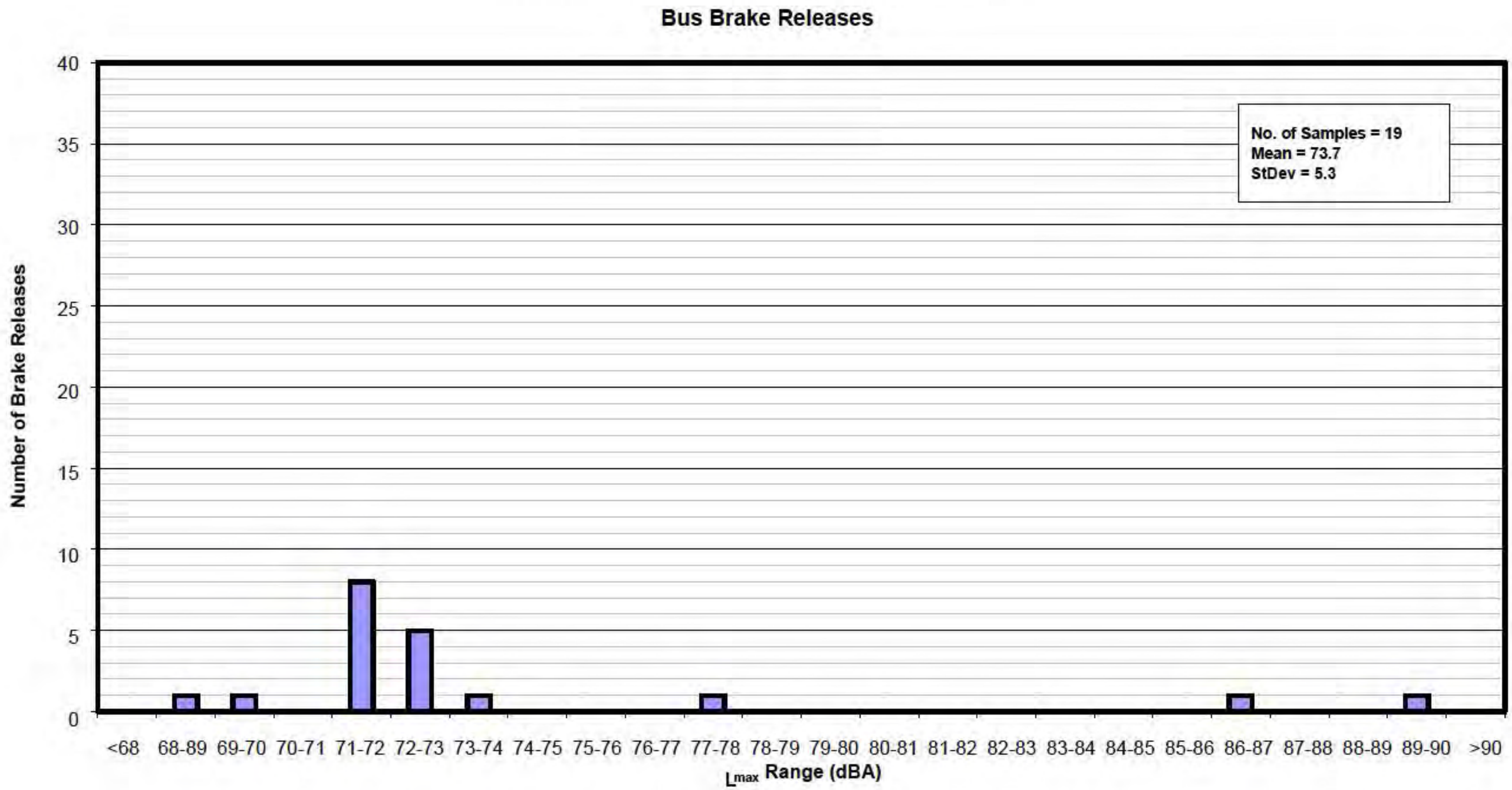
Feb. 15-19, 2005
Noise Level Histogram

Articulated Buses



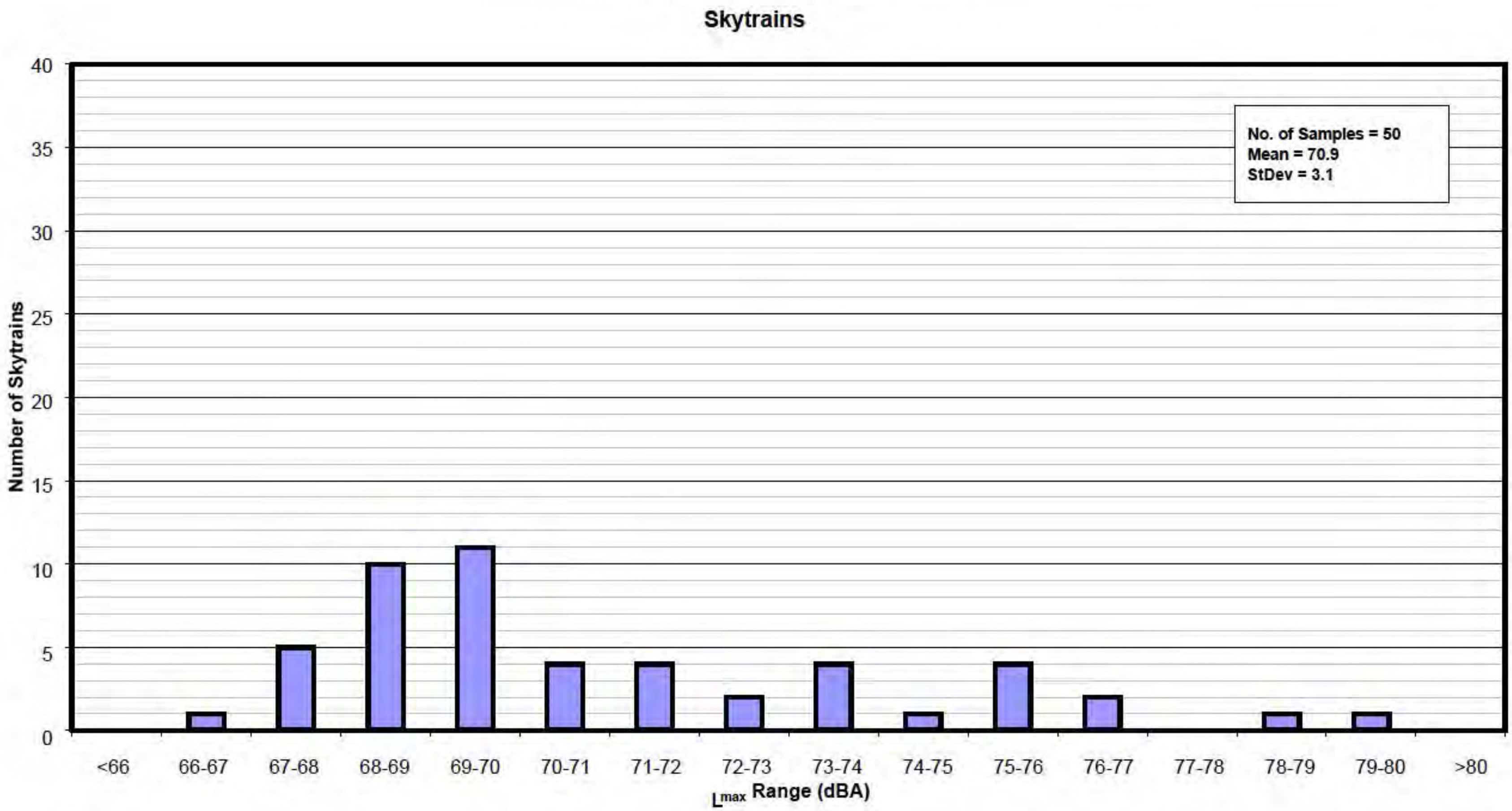
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



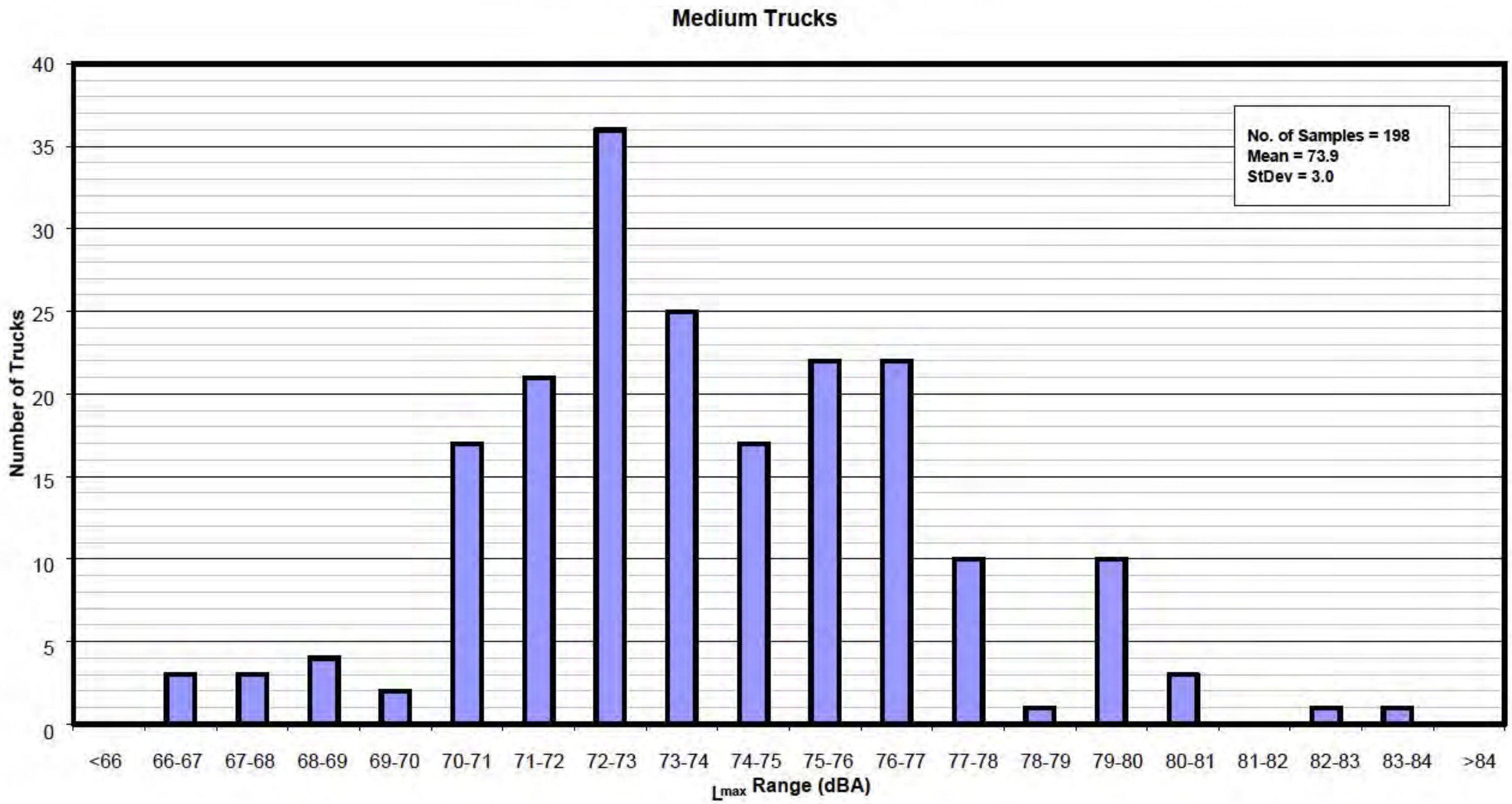
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



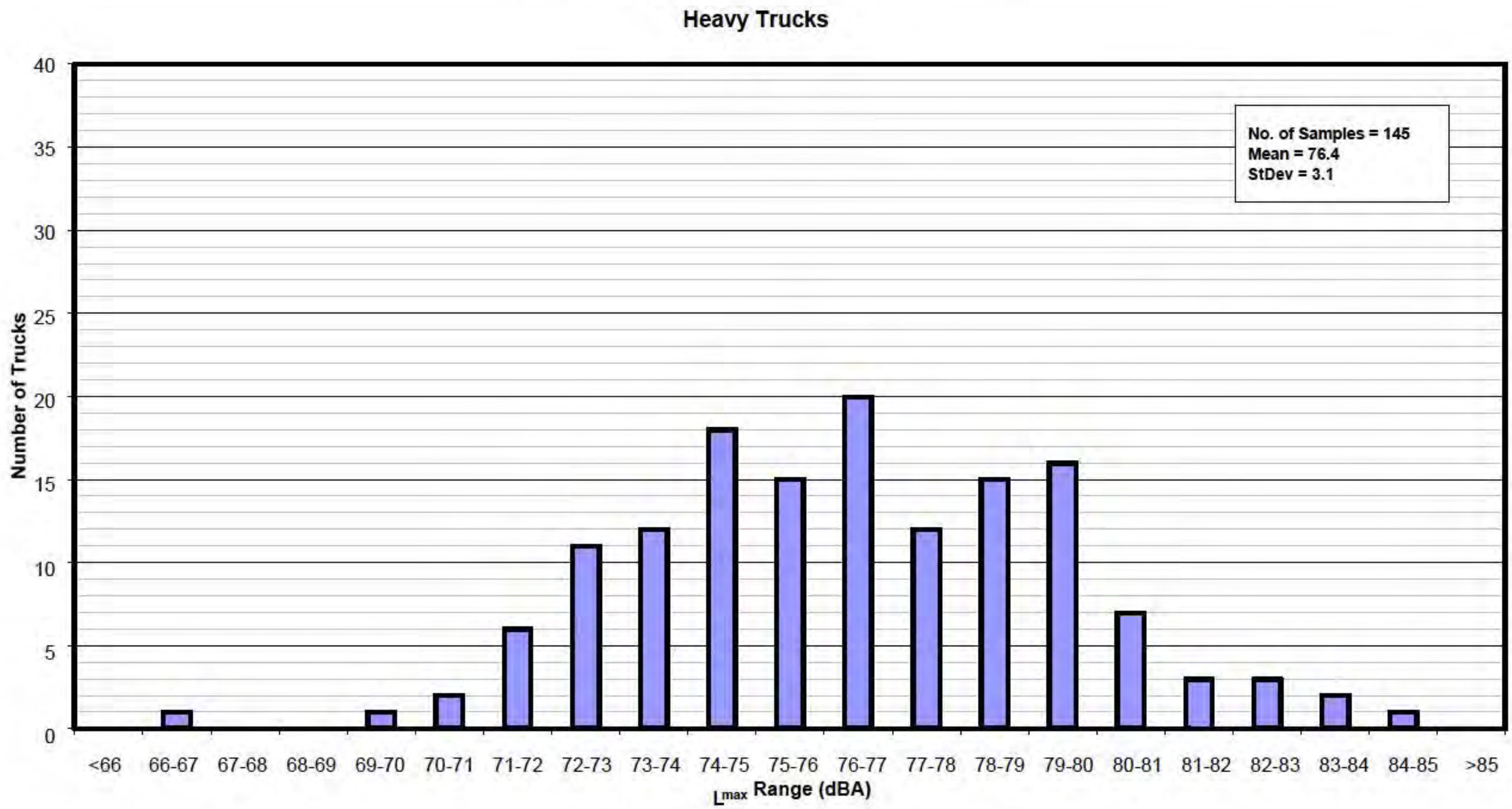
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

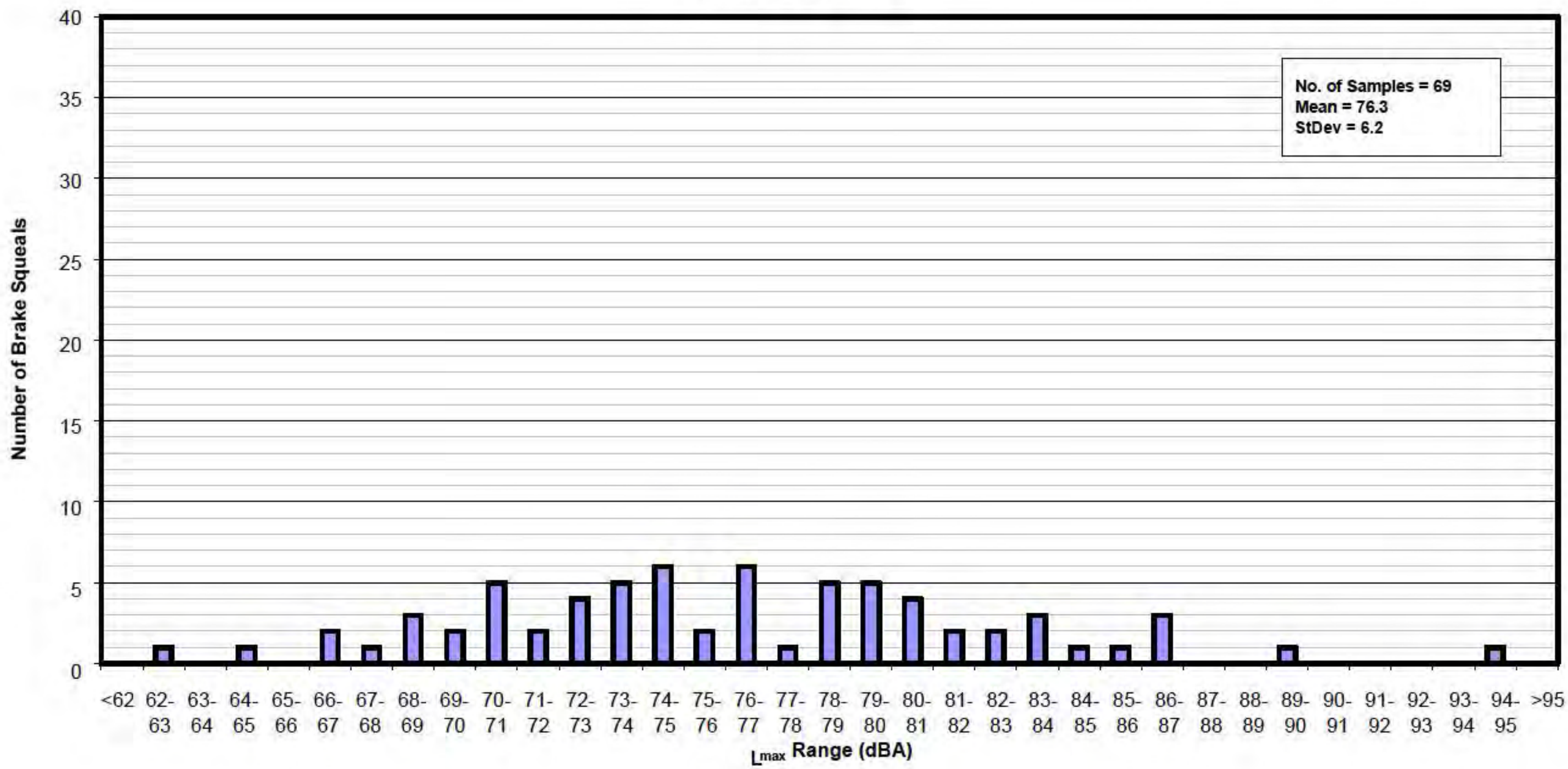
Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

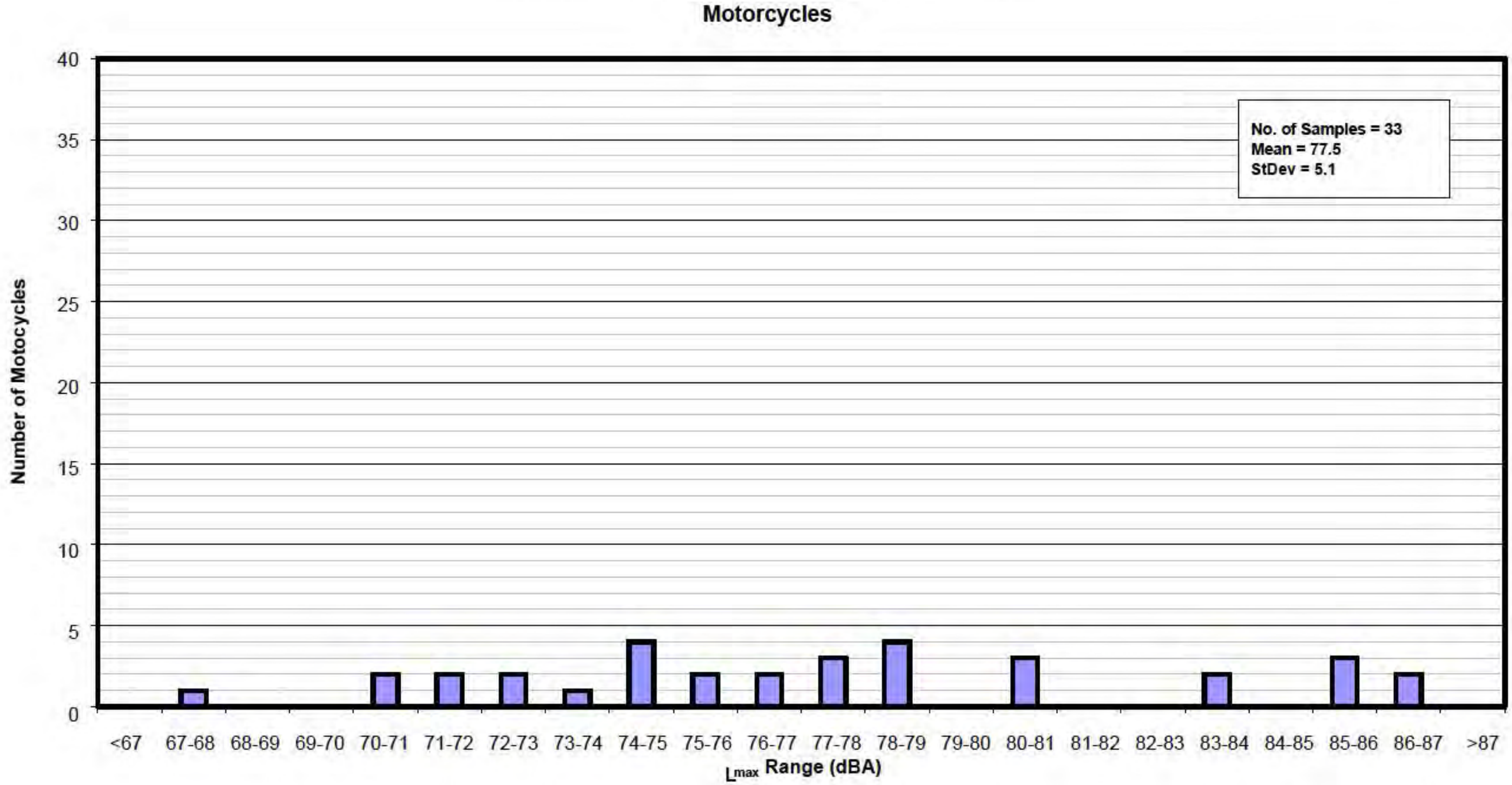
Feb. 15-19, 2005
Noise Level Histogram

Squealing Brakes



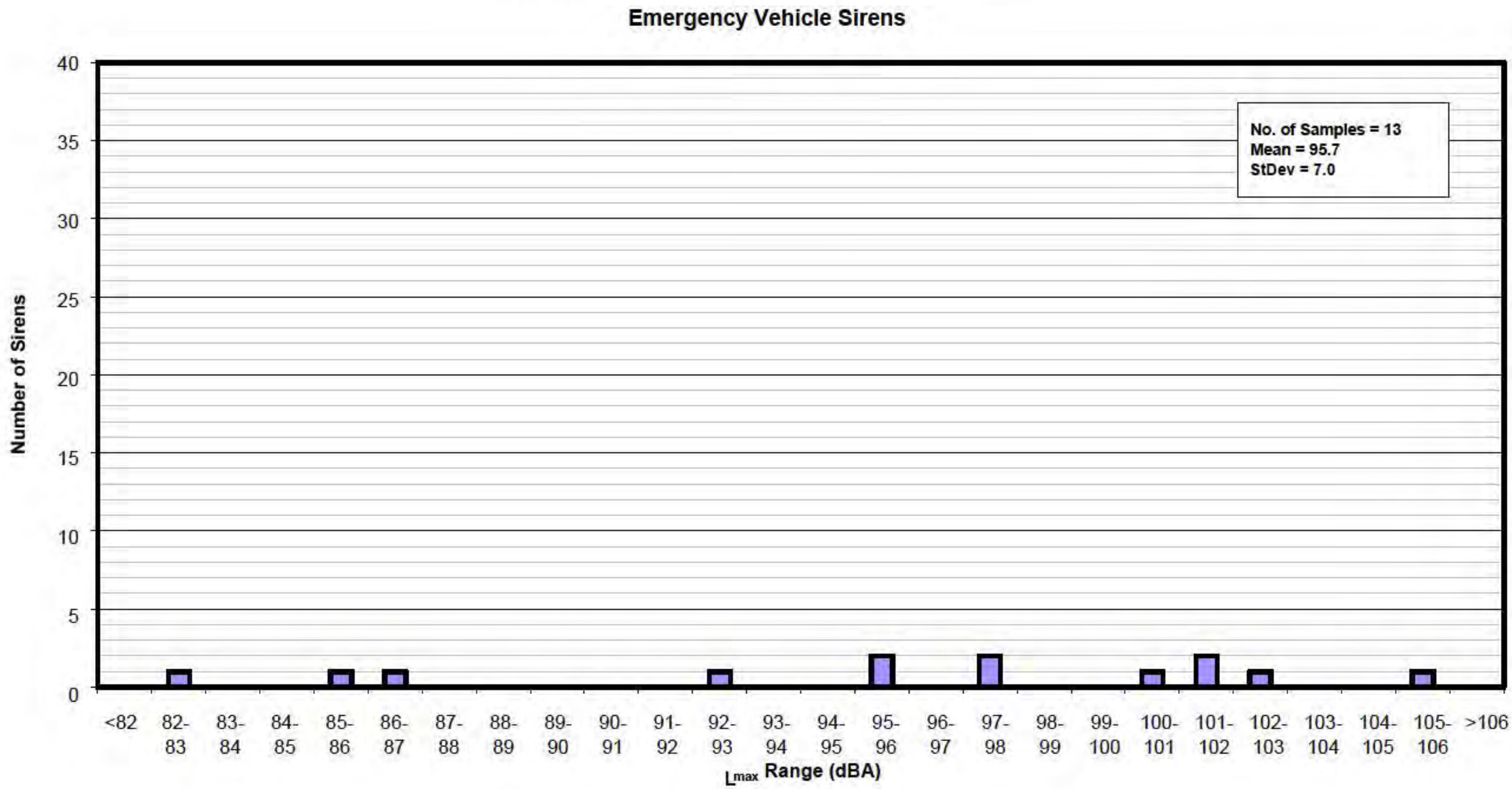
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



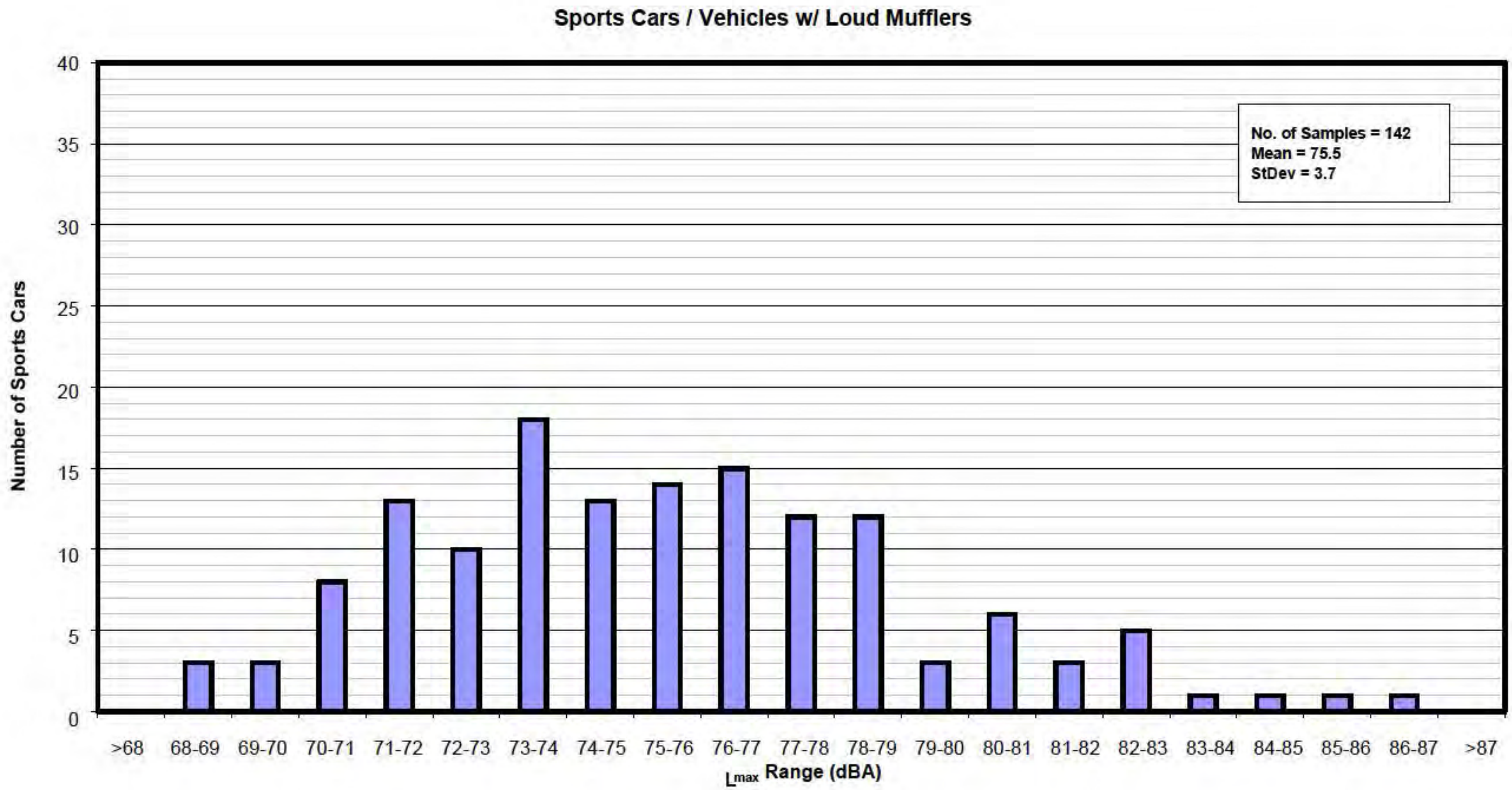
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



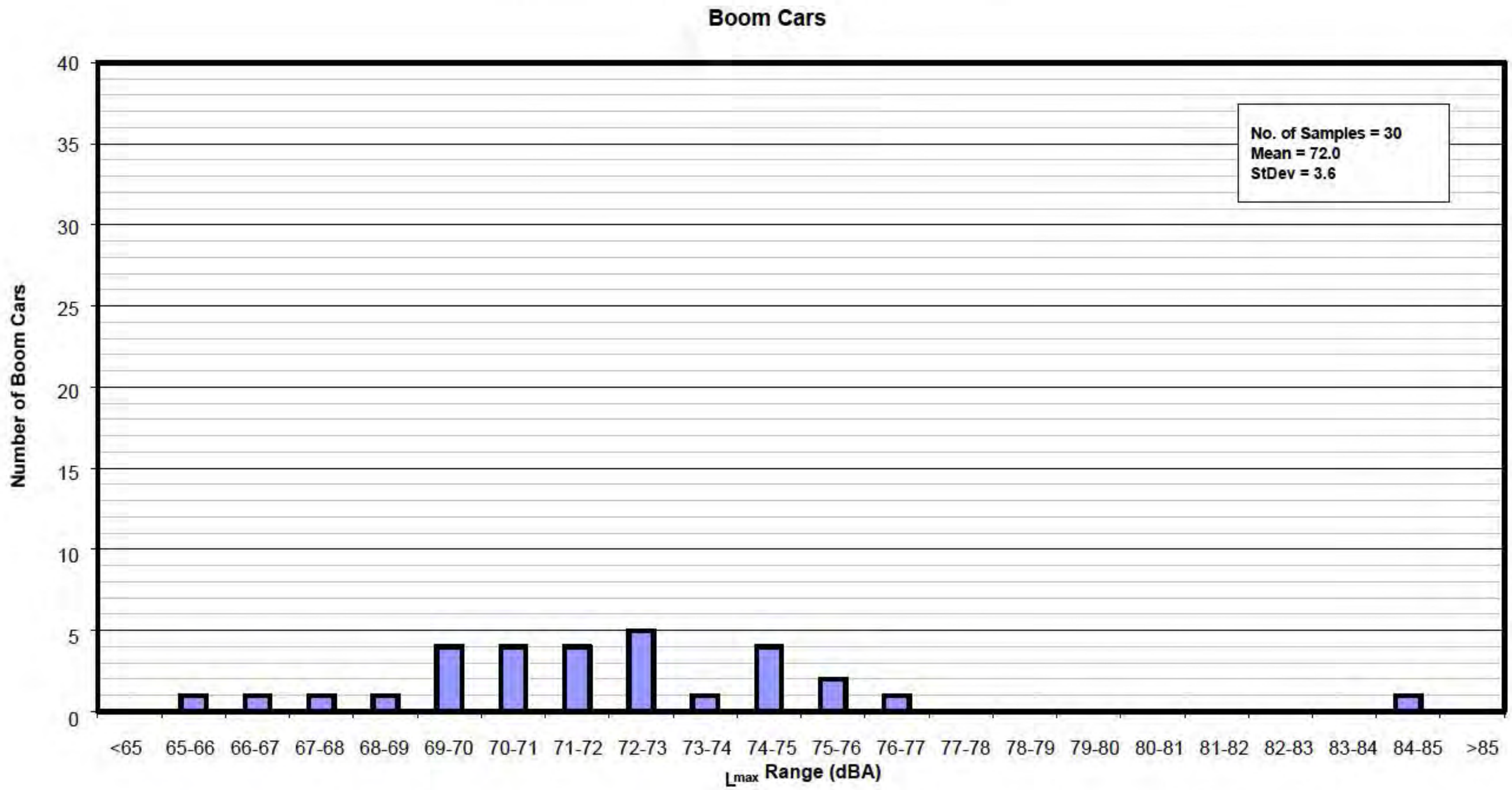
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram

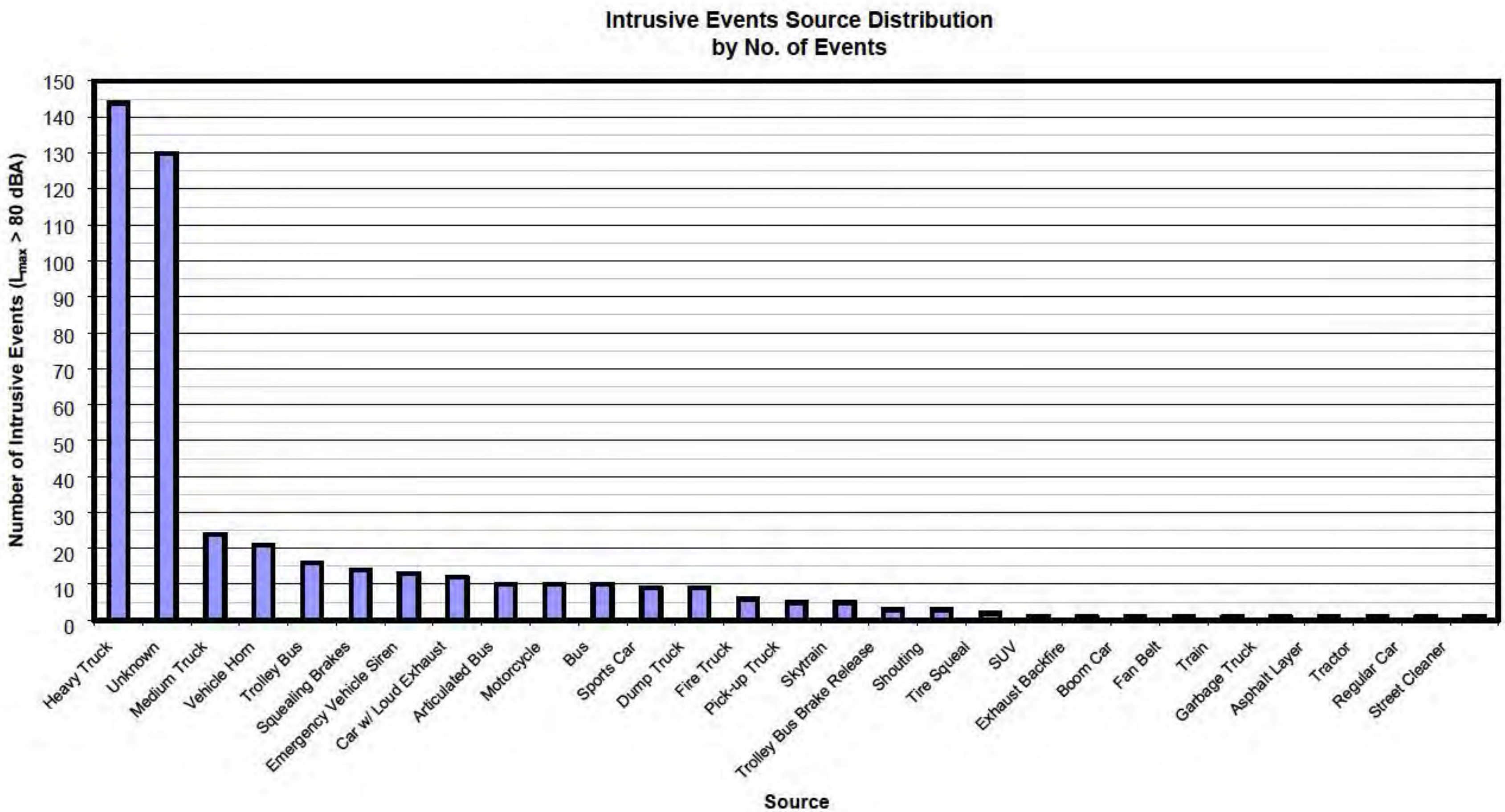


APPENDIX C

SOURCE DISTRIBUTIONS OF INTRUSIVE NOISE EVENTS

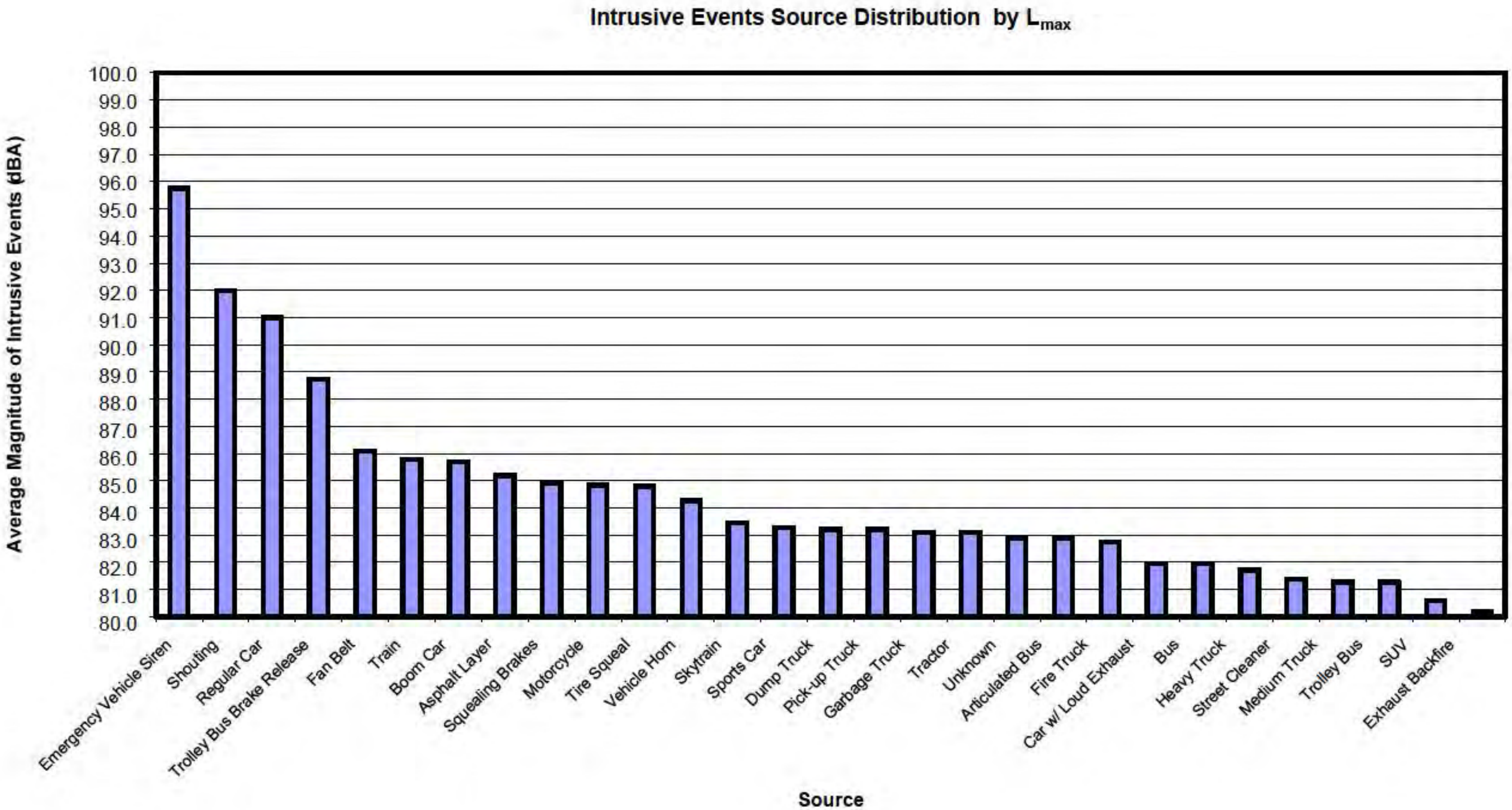
Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

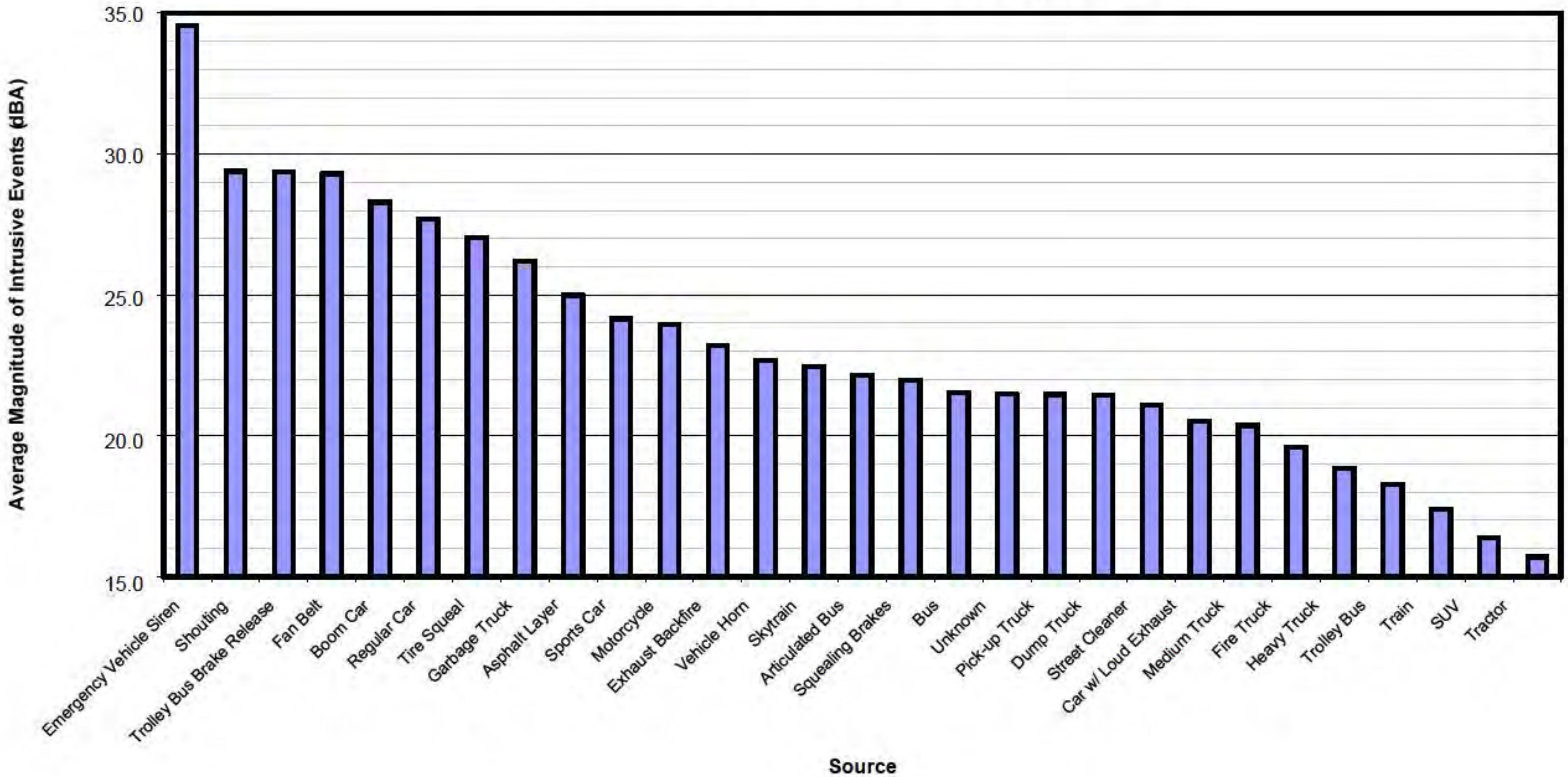
Feb. 15-19, 2005
Noise Level Histogram



Vancouver Arterial Road Study - Manned Noise Monitoring

Feb. 15-19, 2005
Noise Level Histogram

Intrusive Events Source Distribution by Excd of L_{90} by L_{max}

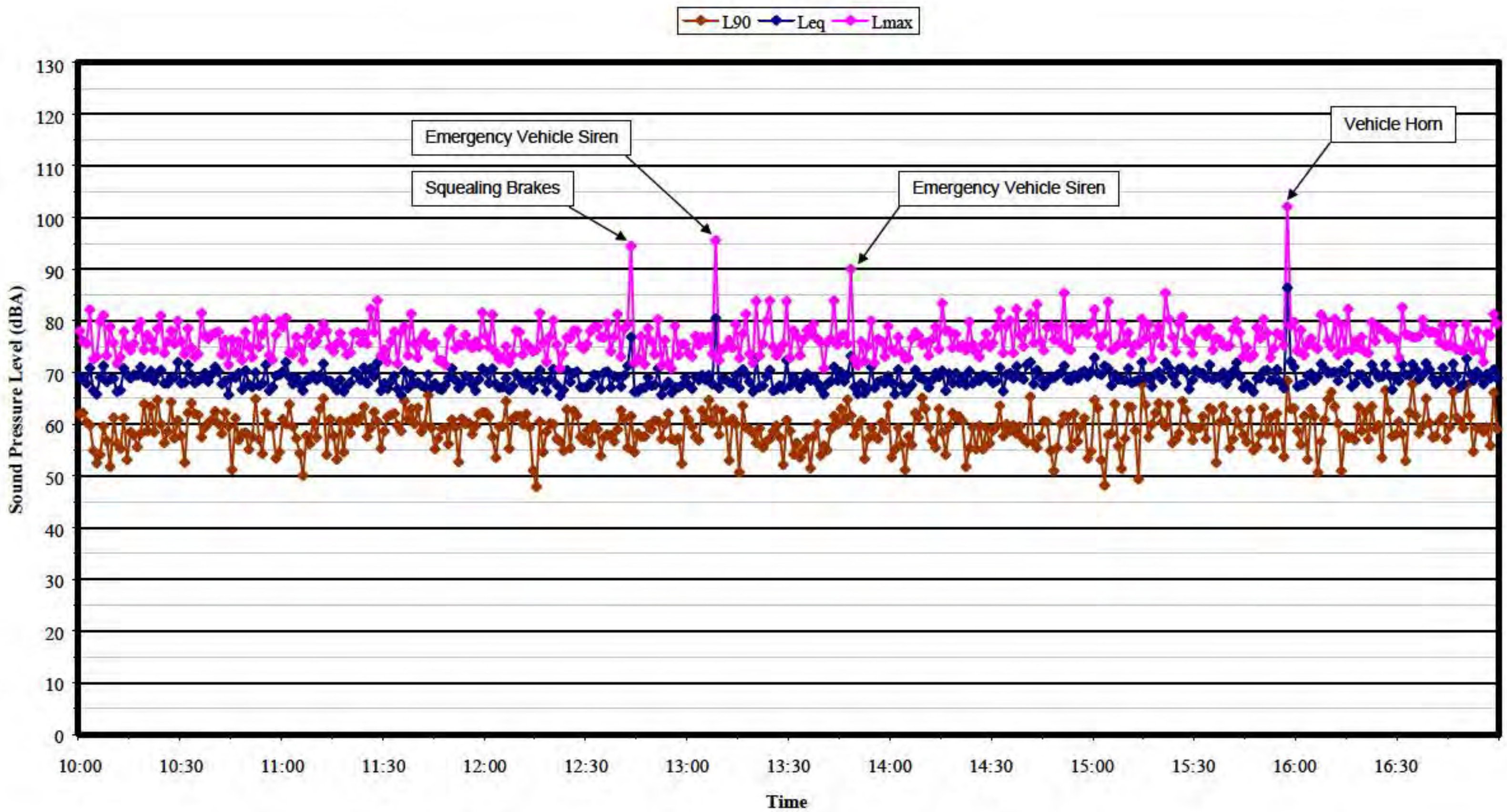


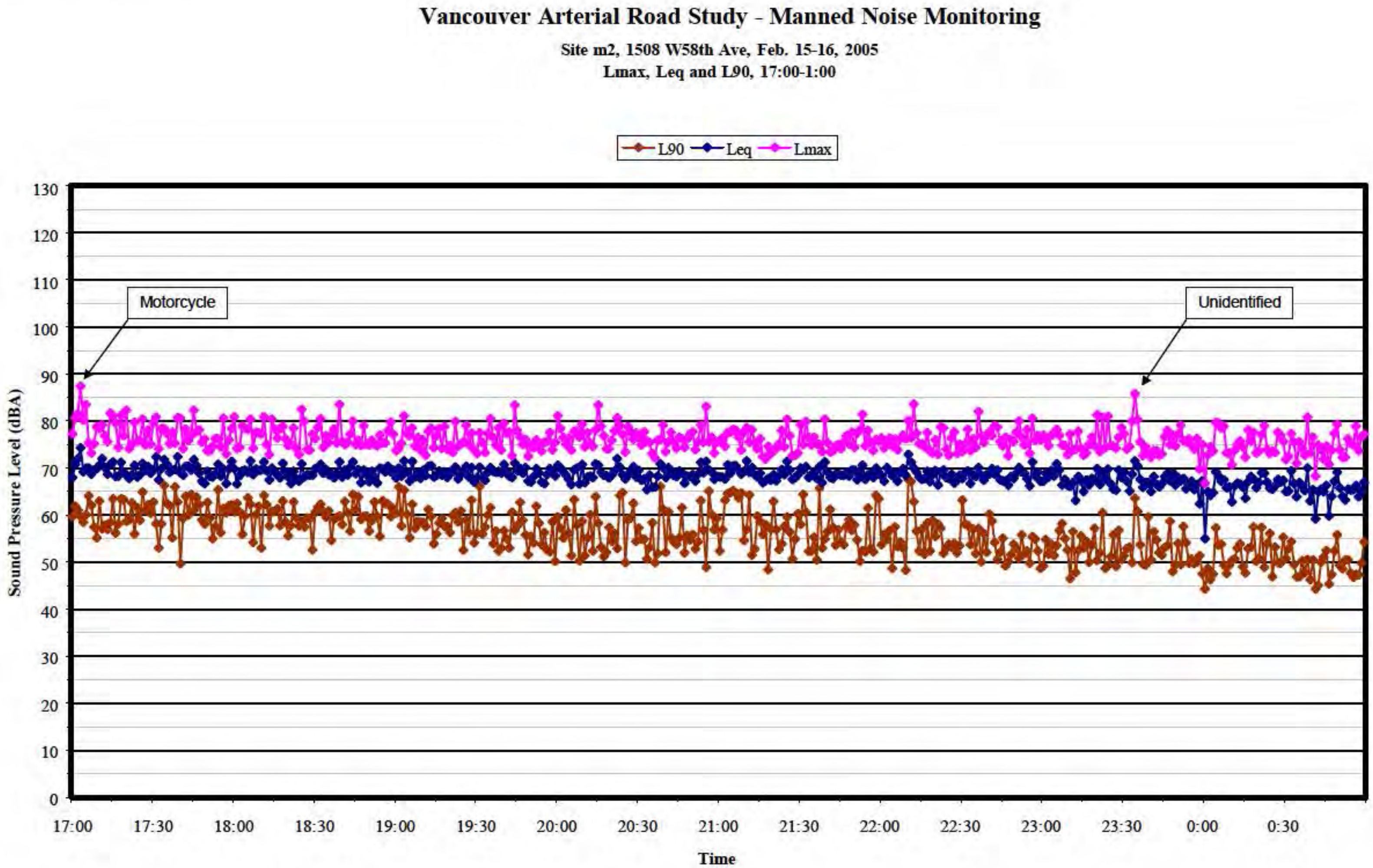
APPENDIX D

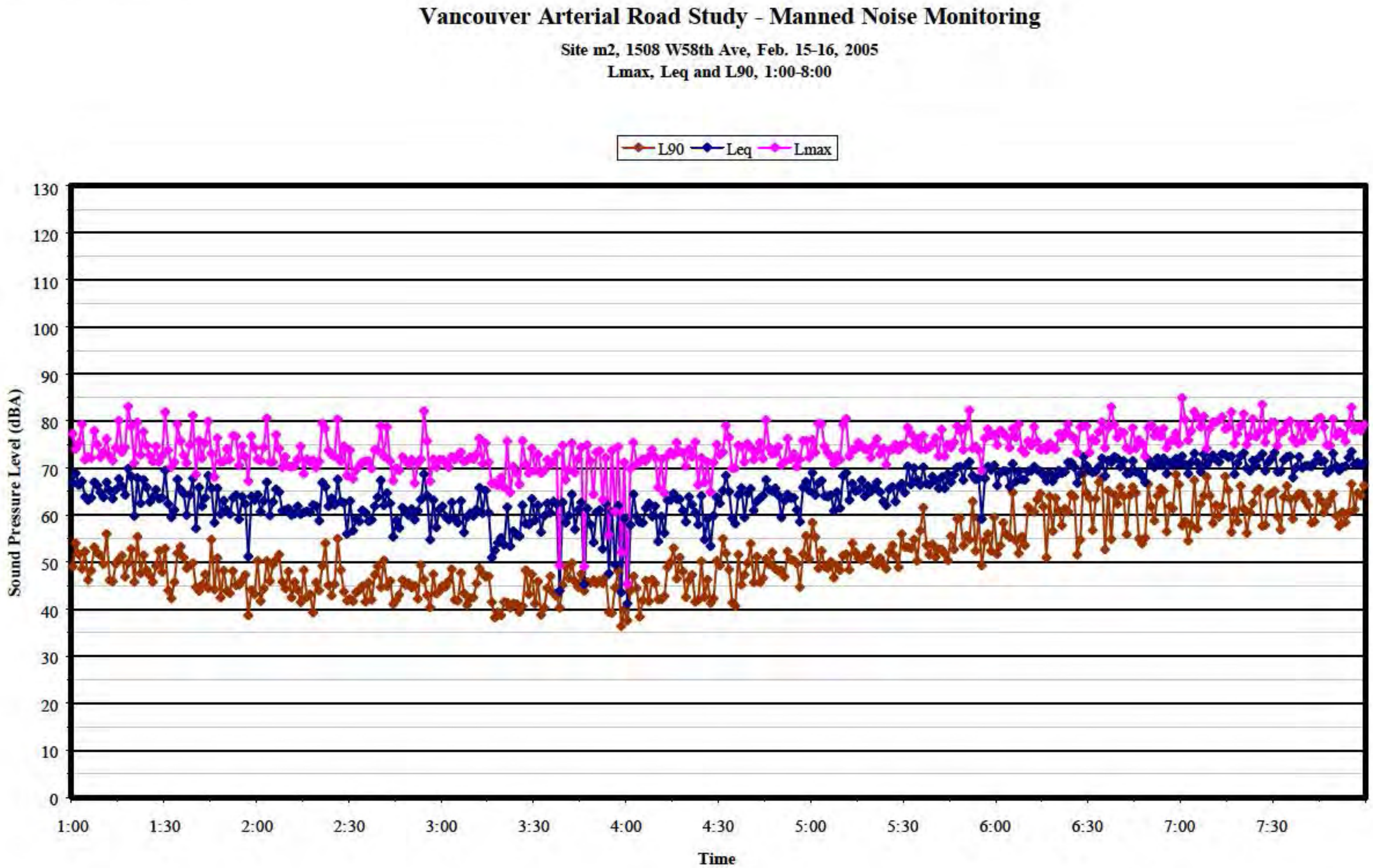
L_{MAX}, L_{EQ}, L_{90} HISTORIES AT ONE MINUTE INTERVALS

Vancouver Arterial Road Study - Manned Noise Monitoring

Site m2, 1508 W58th Ave, Feb. 15-16, 2005
Lmax, Leq and L90, 10:00-17:00




Vancouver Arterial Road Study - Manned Noise Monitoring
Site m2, 1508 W58th Ave, Feb. 15-16, 2005
Lmax, Leq and L90, 17:00-1:00
L90
Leq
Lmax
Motorcycle
Unidentified
Sound Pressure Level (dBA)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
0:00
0:30
Time


Vancouver Arterial Road Study - Manned Noise Monitoring
Site m2, 1508 W58th Ave, Feb. 15-16, 2005
Lmax, Leq and L90, 1:00-8:00
L90
Leq
Lmax
Sound Pressure Level (dBA)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1:00
1:30
2:00
2:30
3:00
3:30
4:00
4:30
5:00
5:30
6:00
6:30
7:00
7:30
Time