University of Southern Queensland
Faculty of Engineering and Surveying

A study of the ground and vegetation effects on the propagation of road traffic noise in south east Queensland

A dissertation submitted by

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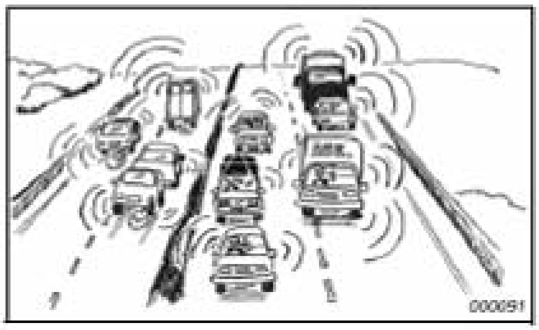

Figure 1: Generation of traffic noise (Bruel & Kjaer 2001)

ABSTRACT

South east Queensland’s booming population is creating a range of challenges for Main Roads. Traffic volumes in the metropolitan region are increasing by an average of 3.5% per annum (rolling average for the past five years), contributing to an increase in road traffic noise. Road traffic noise may affect community lifestyles, so the department is keen to identify whether or not its noise calculation model is predicting higher or lower noise levels than actually occur over various ground and vegetation types.

The type of ground or vegetation surface which sound (generated by traffic on a roadway) propagates over has an effect on the level of noise attenuation with increasing distance from the sources. Main Roads is interested in determining the attenuation of road traffic noise due to ground surface type, particularly for typical Australian bush.

Main Roads uses a United Kingdom methodology known as CoRTN (Calculation of Road Traffic Noise) to calculate road traffic noise. This model considers attenuation due to distance. However, there may be significant differences in the level of road traffic noise attenuation between the physical environments of England’s ground and vegetation types and Australia’s ground and vegetation types. This research project will aim to identify whether a correction factor for the L10 (1h) and L10 (18 hour) noise descriptors is needed for CoRTN, helping to ensure the noise predictions and calculations undertaken by Main Roads are suited to south east Queensland conditions.

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Acknowledgements

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Chapter 1 - Introduction

1.1 Background

The Department of Main Roads Queensland is conducting an environmental review of how vegetation and ground surface types affect the level of road traffic noise.

The Noise and Vibration section comes under the umbrella of the Infrastructure and Design Branch, within Main Roads. This section's roles include looking after all the road traffic noise monitoring within Queensland, the design and installation of noise barriers, and the assessment of development applications that are affected by the noise created by a state controlled road.

Road traffic noise that has an effect on local dwellings is measured to determine if it is under the Departmental criterion. If the road traffic noise is above the Departmental criterion, a noise assessment is undertaken to determine the size of noise barrier required. The noise levels, along with other data, are put into a model which predicts the increase in noise levels, over a period of 10 years (10 years is a criterion for the life of a noise barrier).

Previous investigations undertaken by Main Roads looked at the effectiveness of an earlier version of the CoRTN model (1977), which was calibrated for Australian conditions, in a report by (Saunders, Samuels et al. 1983). The current version of CoRTN (1988) is recognised as a suitable method to calculate road traffic noise and this report aims to fine tune the model's algorithms with the latest monitoring equipment.

The purpose of this report is the continuation of the data collection and analysis process of road traffic noise. The Department of Main Roads has been part/whole sponsor of a variety of reports previously commissioned, to increase the understanding of road traffic noise by analysing different aspects associated with traffic flow, pavements types, and monitoring techniques.

The literature review reports on the current knowledge of how traffic volumes, distance and environmental effects, change the level of road traffic noise in south east Queensland.

1.2 Initial Investigations

The details of noise propagation are very complex, especially over long distances. This is because of the interaction between the ground surface, intervening topography, the frequency of noise, and meteorological conditions such as wind speed, direction and gradient (e.g. wind speed increasing with height), humidity, and vertical and horizontal temperature gradients. Some conditions can work with others to enhance noise propagation, while other conditions can result in noise propagation reductions. Also, many of the conditions are highly variable over short periods of time.

From the start of the investigation process it was decided to locate three different types of landscapes of a similar dimensional area, and location with respect to the source, pavement surface type and road traffic noise level. The weather conditions during noise monitoring also needed to be similar. These sites were to show the differences between the soft ground which the CoRTN model is based on, and compare it with Australia’s hard surfaces, one with and the other without vegetation.

The hard ground soil types are of a similar consistency and although the cleared land would have been loosened by the removal of the original vegetation, the length of time since clearing occurred, and the site’s use as a cow paddock for more than 20 years, meant that both surface types were of a similar density and would have reflection properties.

Of these landscapes, the soft ground was primarily chosen for the effects of ground absorption, as the vegetation would not have a great effect on the decrease of noise levels. The vegetation was approximately 300mm in height over the whole of the landscape. The effects of vegetation in this case will be ignored.

The hard ground with vegetation landscape is expected to have no effects due to ground absorption, as the surface reflects the sound waves. Consequently, the vegetation will be ignored for this calculation. The major effect on noise levels at this location is expected to be due to the reverberation of the sound waves around the trees and the ground.

With hard ground without vegetation, metrological effects play a larger part in the sound propagation. This is because there is no vegetation to decrease wind speeds, and there are higher levels of heat radiation from the bare, flat surface.

All the monitoring was completed within one week under consistent metrological conditions.

1.3 Database

- Traffic data from the tube counters was collected by the Main Roads southern district staff during the week of the monitoring from Wednesday the 10th of August through to Wednesday the 17th of August. The data was comprised of 12 classes of vehicles from short “light” vehicles through to “heavy” triple road trains (see Appendix xyz) and these were then re-categorised into three broader groups of small, medium and large vehicles.

- Bruel and Kjaer (B&K) investigator data was collected at each site for 10 minute intervals. The download process from the B&K onto the main computer was completed using the B&K program, Evaluator Type 7820. Due to lack of time and experience using the Evaluator program, the files were exported to an Excel spreadsheet, as .txt files (see Appendix xyz), for further analysis.

- Davis weather station data was collected in five minute intervals, to provide an accurate account of the metrological conditions. This data was downloaded as a .txt file and then converted to an Excel spreadsheet (.xls) (see Appendix xyz) file for data analysis.

- Acoustic Research Laboratory noise logger (ARL-316) collected data in five minute intervals, which allowed for a five minute set-up time period while the B&K investigator was moved between monitoring positions. The data was downloaded as a .csv file, which automatically opens in an Excel spreadsheet.

- Radar data collected for the traffic speed was taken over a period of 30 minutes before the monitoring began, to confirm that average traffic speed was as per the sign posted recommended speed. The average speed recorded for each site was 100 km/h.

  At the hard ground without vegetation site, the speed zone of 100km/h was sign posted at approximately 400 metres from the monitoring site. The previous speed zone to the 100km/h was 80 km/h which was largely ignored by all vehicles, so additional traffic noise levels due to acceleration to the 100km/h zone were minimal.

- Rejection of data due to inconsistent weather conditions occurred on the morning of Wednesday the 17th of August. The weather conditions on this morning included rain periods and colder than normal temperatures and this meant the data collected on that day was rejected.

1.4 Evaluation of database

A file of all the respective Excel spreadsheets was set up for the three locations and these were called on by a main spreadsheet, in which the analysis between the different locations was done.

The traffic data collected by the tube counters at the site was based on hourly intervals, which was not ideal for the report, as all other measurements were in 5 and 10 minute intervals. The traffic data was only going to be used as a correlation between the noise levels and traffic. This should not affect the report, which is based on the noise level losses over distance.

The ARL-316 noise logger data and the metrological data were combined onto a standard Main Roads monitoring sheet for each location and height (see Appendix xyz).

A preliminary analysis of the data from the three sites showed good correlations between the monitored and the CoRTN-predicted data. Early analysis between the sites also showed an expected trend relating to how the noise levels and frequency range developed over distance.

1.5 Aims and Objectives

Using B&K data, the research will identify whether the mean and standard deviation from a trend line of the noise levels, over the 400m distance, are the same for the three sites. The research will also identify whether deviations in the measured data are small enough to allow for repeatability of the noise levels to be assumed.

The next step is to work with one noise propagation factor, either ground absorption (see Appendix xyz) or vegetation absorption (see Appendix xyz) depending on the site, on their own effects. Those effects due to other propagation factors like atmospheric absorption, wind and other environmental noise factors (see Appendix xyz p3), need to be assessed and accounted for.

With only one factor changing the noise levels over distance at each site, the analysis should be able to achieve a direct comparison between the three surface types and the respective CoRTN model, to determine if there needs to be changes to bring the modelled data in line with the measured data.

Chapter 2 – Literature Review

This section will review the literature findings as related to the general requirements of noise monitoring. The following section will discuss the road traffic noise – specific monitoring:

PURPOSE:

The purpose of this literature review is to:

- Report on the current state of knowledge on the atmospheric and ground effects on road traffic noise and the effects vegetation has on road traffic noise.
- Describe characteristics of the effects traffic volumes have in the propagation of road traffic noise.
- Provide a method for predicting road traffic noise as a function of distance and ground type. This method will show how the measured data is to be modified to take into account the environmental effects, other noise sources (contamination) and changes in traffic.

The literature review provides background information pertinent to the following research questions:

- What constitutes a functional method for calculating noise levels over distance?
- What are the vegetation effects on road traffic noise?
- What are the constraints to comparing the measured noise levels with those of modelled noise levels?
- What enhancements would be most valuable for maintaining the accuracy of noise monitoring?
- What are the environmental effects on the measurement of road traffic noise?

- What are appropriate mitigation measures, suggested monitoring methods, and compatible noise monitoring activities for ensuring the correct differentiation between the different environmental effects on road traffic noise?

DISCUSSION

What constitutes a functional method for modelling road traffic noise levels over distance?

To identify a functional method that will correctly model road traffic noise, the model needs to include many parameters such as: what type of noise is coming from the source; the way a human ear would hear the noise, and; also the external effects that alter the noise levels as it propagates

For a computer program to model noise levels, and a sound level meter to measure noise levels accurately, the levels have to be representative of what the human ear would hear in a same case scenario. The development of international standards allows for a choice of noise level adjustments, so that modelled and measured noise levels give an accurate account of the actual noise levels.

The following adjustments to the monitored noise levels were applied for this report:

“A” frequency weighting:
Sound is created when an object moves: the rustling of leaves as the wind blows, air passing through a musical instrument. The movements cause vibrations of the molecules in air, in waves like ripples on water. When the vibrations reach the ear, it is known as sound. Sound is quantified by a meter which measures units called decibels, dB(A). For highway traffic noise, an adjustment, or weighting, of the high and low-pitched sounds are made to approximate the way that an average person hears sounds. The adjusted sounds are called A- weighted levels dB(A). The A-weighted decibel scale begins at zero. This represents the faintest sound that can

be heard by humans with very good hearing. The loudness of sounds varies from person to person, so there is no precise definition of loudness. However, based on many tests of large numbers of people, a maximum sound pressure level is based on the average threshold of pain which is 140dB(A). A change in a sound pressure level of 3dB(A) is regarded as the minimum sound pressure level difference noticeable to the human ear (Bruel & Kjaer 2001).

Measuring Leq

At the start of the measurement, the L_{eq} (red line) is 0. It quickly rises and follows the input signal (the green line). As it is averaged over the entire measurement time, the variation of the L_{eq} becomes less and less.

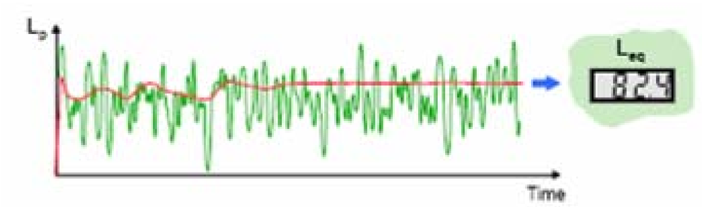


Figure 2: Measuring Leq (Bruel & Kjaer 2001)

The variations of the L_{eq} are larger at the start of the measurement period than later on. You can use the fact that the L_{eq} stabilises to determine when your measurement is complete. A stable level indicates a representative measurement.

The equivalent Sound Level L_{eq} is an electronically calculated mean RMS level which can integrate all the energy in a signal measured over a certain time period. L_{eq} can be considered as the continuous noise which would have the same total acoustic energy as the real fluctuating noise measured over the same period of time. Most often, the instantaneous sound pressure is A-weighted and the unit of L_{eq} therefore becomes dB(A) (Bruel & Kjaer 2001).

Time weighting:

The time weighting was initially implemented because the old sound level meters had a pointer to show changes in sound pressure levels. The measurements were hard to read with large/fast changes in sound levels so the time weighting was slowed down to improve readability. Using the current electronic

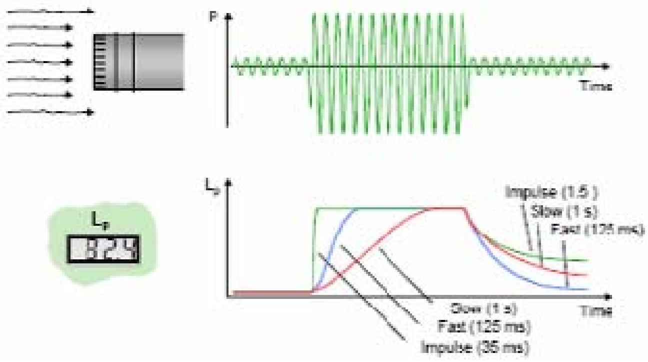


Figure 3: Time weightings (Bruel & Kjaer

technology, the readings can be set to the fast time weighting as it follows the input signal more closely.

All time weightings give same time levels with a long enough signal, and time weightings operate on the RMS (root mean square) signal.

IEC or ANSI standards

Measuring in accordance with standards: IEC (I.E.C 1979) or ANSI (A.N.S.I 1983).

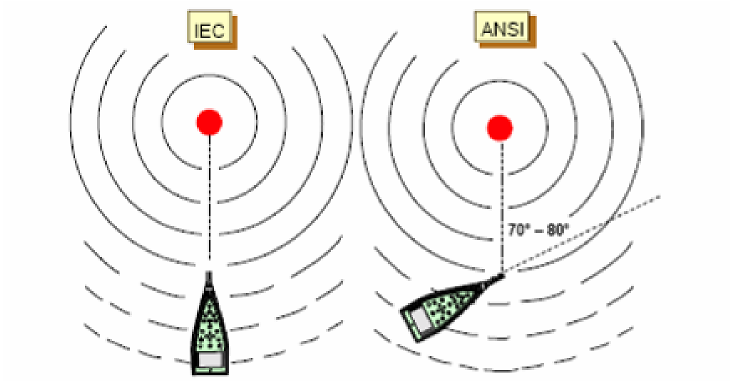


Figure 4: ANSI and IEC standards (Bruel & Kjaer 2001)

The two most important standards governing the design of sound level meters are the IEC publication 651 and the American National Standards Institute ANSI S 1.4. For practical purposes the two standards are completely alike, except for the direction of incidence of the sound field. The IEC specifies use of free field microphones and ANSI uses random incidence microphones. This means that when sound level measurements are made in accordance with IEC, a free field microphone should be used, and the sound level meter pointed towards the source (0° incidence). When measurements are made in accordance with ANSI, a random incidence microphone should be used, and the sound level meter held at an angle of 70° – 80° to the direction of incidence (Bruel & Kjaer 2001).

It would be desirable if forthcoming standards specify both the free field and the random incidence microphone as standard, and indicate when each should be used. For many sound level meters used today, the response of the microphone can be changed either by the use of a small corrector fitted on the microphone or electronically in the sound level meter.

Main Roads uses the IEC standard for all monitoring as per its code of practice.

2.2 What are the vegetation effects on road traffic noise?

Vegetative barriers, defined here as a series of narrow and dense trees or shrubs planted near a roadside, have long been applied with the purposes of landscaping and visual shielding.

As traffic volumes and congestion continue to increase throughout the world, the use of vegetation as a roadside noise barrier has gained interest. The effectiveness of conventional rigid noise barriers is well understood and proven, however there is a growing movement to avoid the closed-in look and feel of these structures in favour of more natural product. Hence, the use of vegetation and foliage to attenuate roadway noise has recently been studied more vigorously. These attenuation effectiveness studies have been conducted in the laboratory as well as in-situ environments. The majority of the recent research efforts have been centered on two categories - the study of vegetative barriers as measurable road noise attenuators, and the investigation of the psychological or perceived effectiveness of vegetative barriers(Hendriks 1989).

The effects of vegetation on the propagation of road traffic noise has been studied by different organisations, and although vegetation proved to be of statistical significance, the human perception of reductions in noise levels ranging from 0 – 3 dB(A) and averaging 0.9 dB(A) are not significant (Watts, Chinn et al. 1998).

Figure 4 shows a pictorial representation of how sound propagates through vegetation.

1. Noise attenuation by the forest floor
2. Diffusion by the trunks, branches and leaves.
3. The effect of the modification of meteorological profiles.

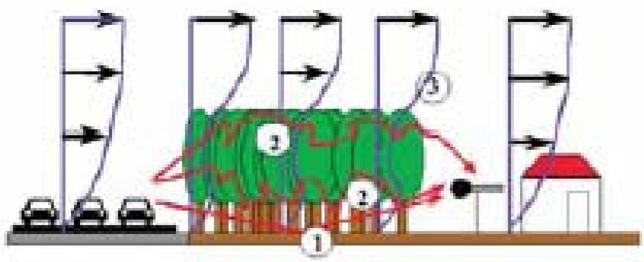


Figure 5: Representation of the various phenomena of a forest on sound propagation (CSTB RECHERCHE 2004)

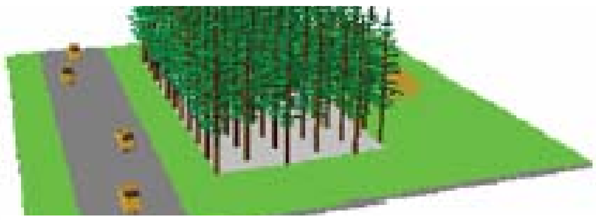


Figure 6: A strip of trees along a motorway (CSTB RECHERCHE 2004)

Sufficiently thick strips of trees play a significant role in noise attenuation when meteorological conditions are ‘favourable’ to propagation (CSTB RECHERCHE 2004).

2.2.1 Different types of vegetation

The effects of the vegetation plant structures showed significant differences in noise propagation. There were differences in noise levels as the same noise passed through different leaf shapes, with a broad succulent leaf showing the most noise-reducing properties. A detailed laboratory study by(Hendriks 1989) determined that foliage could actually act as an amplifier in the middle frequencies (500 Hz to 2000 Hz). This aspect is thought to be a natural phenomenon of animal vocalisations and communication patterns, but it has also been theorised that sound waves distribute flatly rather than spherically as they travel through vegetation.

The report (Watts, Chinn et al. 1998) concluded that as sound waves travel through obstacles like vegetation, the phase of the sound waves tend to bend toward the direction of transmission, hence focusing (and amplifying) the sound emissions. In the same study, it was determined that foliage acts best in the attenuation of high frequency ranges, typically 2000 Hz to 12,500 Hz, and that the actual mechanism of attenuation in these ranges is not clearly understood. It is generally accepted, though, that some combination of sound energy absorption and refraction occurs. In the low frequency ranges (<500 Hz), foliage tends to primarily modify the pitch of sound transmissions, resulting in only small measurable reductions.

2.2.2 Different thickness of vegetation

Use of vegetative barriers to attenuate roadway noise has been classically rejected due to the commonly accepted requirement that plantings must be sufficiently deep, up to 30 metres in some instances, to provide noticeable results.

2.2.3 Provides shielding from noise of visual

Trimming or removal of shrubs and trees along highways by maintenance or construction does not cause perceptible noise level increases to nearby residences. However, the sudden visibility of highway traffic previously shielded visually by the vegetation, and the possibility of a shift in sound frequencies, may bring on a renewed awareness of the presence of noise sources. This may result in additional noise complaints.

2.2.5 CoRTN. See (Appendix E)

Absorbent nature eg. Grass land, cultivated fields or plantations, an additional correction for ground cover often referred to as ground absorption needs to be taken into account. The correction is progressive with distance and particularly affects reception points close to the ground.

- o Figure (45) gives the correction for the ground absorption in terms of mean height of propagation (H) the distance (d) and the proportion of absorbing ground (I) between the edge of the nearside carriageway and the segment boundaries leading to the reception point R, see fig 2(a). It will slightly underestimate the attenuation effects.
- o Where the intervening ground cover is non-absorbent eg paved areas, rolled asphalt surfaces, water, the value of I is zero and no ground cover correction is applied.

Where the intervening ground cover is absorbent the correction given in figure 45 is to be applied where the value of I = 1. The value of H is taken to be average height above the intervening ground of the propagation path between the segment source line and the reception point. It is to be calculated along the bisector of the angle subtended by the segment source line at the reception point. Where the intervening ground is mainly flat, the value of H can be approximated by $0.5(h+1)$ metres, otherwise the value of H is calculated by taking the height of propagation above the ground at approximately equal intervals along the bisector, taking at least five height readings, and averaging the result. It should be noted that for values of H>$(d+5)/6$ metres, no ground cover correction is required. In exceptional circumstances when values of H<0.75 metres, H may be 0.75 metres and Chart 8 applied.

2.2.6 The effects of vegetations

- Noise reduction by belts of trees reduces the higher frequency range;
- The psychological effect was more important than the physical effect;

- The results suggest that narrow belts of trees and shrubs should not be used for noise screening purposes in the belief that, although they provide little physical noise reduction, they improve the perception of the noise through the mediating effect of improved visual appearance.

2.2.7 Vegetative noise barriers

The general conclusion of these efforts is that vegetative barriers are not an effective mitigation measure when compared to conventional rigid barriers, but do contribute some limited attenuation as well as providing an aesthetic improvement.

In more qualitative efforts, a significant amount of research has been conducted to understand the psychological affects of vegetative barriers in regards to roadway noise attenuation. These studies have typically consisted of non-technical surveys and questionnaires. It concluded that visualisation of the noise source impacted the perceived sound levels significantly; with small portions of a test vegetative barrier removed, participants felt that noise levels increased disproportionately.

Barriers such as walls or screens will act to create an acoustic shadow by obstructing the free flow of sound energy. The reduction in sound level within this shadow zone depends on frequency. At high frequencies the effect of the barrier is most pronounced, whereas at low frequencies much diffraction occurs at the edges, so the shadow effect is diminished.

2.2.8 Vegetation as a barrier

The literature generally suggests that the principal effect of plantings is psychological. By removing the noise source from view, plantings can reduce human annoyance with noise. The fact that people cannot see a highway can reduce their awareness of it, even though the noise remains. Another effect to consider is increased wind noise generated by the leaves of large trees, effectively masking other mid-high frequency sounds.

2.5 What enhancements would be most valuable for maintaining the accuracy of noise monitoring?

Noise assessment is generally about evaluating the impact of one specific noise source, like road traffic noise. This is not always an easy task. In practically every environment, a large number of different sources contribute to the ambient noise at a particular point

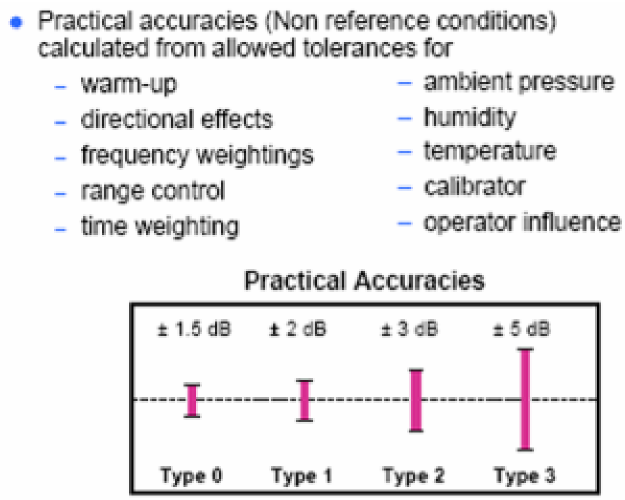


Figure 7: Accuracies of sound level meters (Bruel & Kjaer 2001)

Ambient noise is the noise from all sources combined – irrigation sprinklers, traffic noise, bird song, running water, etc.

Specific noise is the noise from the source under investigation. The specific noise is a component of the ambient noise and can be identified and associated with the specific source.

Residual noise is ambient noise without specific noise. The residual is the noise remaining at a point under certain conditions when the noise from the specific noise is suppressed.

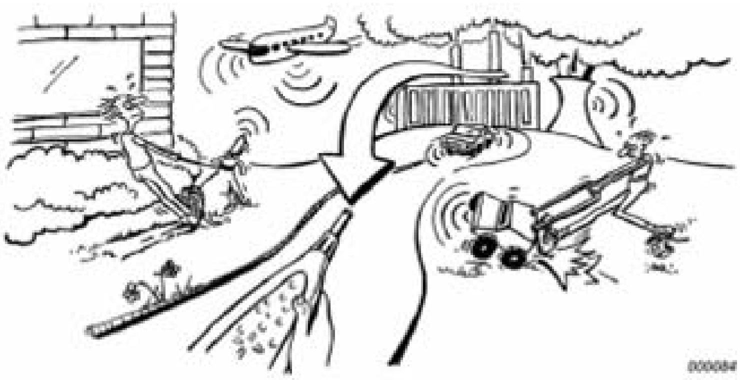


Figure 8: Ambient noises (Bruel and Kjaer 2001)

2.6 The accuracy of noise monitoring calculations

The accuracy of a particular calculation is dependant on several factors. The most important of these are scenario, levels, range, inputs and user skill.

Algorithms are optimised for use within a range of scenarios. In particular, road and rail traffic noise calculation standards are based on national databases of traffic noise emissions and can be limited in use in other countries where, in particular, the age and mix of the vehicles in use and driving/operating conditions are different. Thus, accuracy may vary with calculated noise levels, with the optimal accuracy occurring over a small or wider range of noise levels. However, most algorithms include provisions for ensuring accuracy over a wide range of noise levels.

A bigger problem is to ensure the quality of input data as the accuracy of the result is highly dependant on this. Topographical data, metrological and traffic flow data are areas in which care should be taken.

2.6.1 Advantages of calculation

- Detailed information about the position of a critical source;
- Independence from meteorological conditions;
- Evaluates hypothetical situations;
- Simple to update; and
- Less sensitive to background noise.

Figure 9: Modeled or measured (Bruel and Kjaer 2001)

2.6.2 Disadvantages of calculation

- Extensive data collection (noise, geometry, and site specifics that can't be modelled);
- Result accuracy more dependant on acoustical skills and "modelling" experience.

Like measurements, calculations can be used in environmental noise assessment. Additional uses include identifying prominent sources for noise reduction, noise management through investigations of the effect of future changes in noise environment, and noise mapping.

By using up-to-date GIS or AutoCAD files to generate topographical data, measuring sound power levels on site, and performing traffic flow counts at selected check points, the the risk of erroneous data can be reduced. Finally, user skill and experience, both with environmental noise assessment and with the calculation algorithm itself, play an important part in optimising the result.

Used correctly within the range of scenarios for which they have been designed, the algorithms ensure global accuracies to within 3dB.

2.7 What are the environmental effects on the measurement of road traffic noise?

- Sound velocity depends upon temperature, altitude, air composition, etc.

2.7.1 Humidity

A 10% increase in relative humidity can cause an additional 35 dB per 300 m of air absorption as shown in Table 1 (BOHN 1988) below.

Table 1: Velocity of sound in dry air versus temperature

Temperature (°C)	Velocity (m/s)	Temperature (°C)	Velocity (m/s)
0	331.45	23	345.12
1	332.06	24	345.71
2	332.66	25	346.29
3	333.27	26	346.87
4	333.87	27	347.45
5	334.47	28	348.02
6	335.07	29	348.60
7	335.67	30	349.18
8	336.27	31	349.75
9	336.87	32	350.33
10	337.46	33	350.90
11	338.06	34	351.48
12	338.65	35	352.05
13	339.25	36	352.62
14	339.84	37	353.19
15	340.43	38	353.76
16	341.02	39	354.32
17	341.61	40	354.89
18	342.20		
19	342.78		
20	343.37		
21	343.96		
22	344.54	(Evens, Sutherland et al. 1972)	

Table 2: Percentage increase in speed of sound (re 0°C), due to moisture in the air only. Temperature effects not included as they pertain to humidity.

Temperature °C	Relative Humidity %									
	10	20	30	40	50	60	70	80	90	100
5	0.014	0.028	0.042	0.056	0.070	0.083	0.097	0.111	0.125	0.139
10	0.020	0.039	0.059	0.078	0.098	0.118	0.137	0.157	0.176	0.196
15	0.027	0.054	0.082	0.109	0.136	0.163	0.191	0.218	0.245	0.273
20	0.037	0.075	0.112	0.149	0.187	0.224	0.262	0.299	0.337	0.375
30	0.068	0.135	0.203	0.272	0.340	0.408	0.477	0.546	0.615	0.684
40	0.118	0.236	0.355	0.474	0.594	0.714	0.835	0.957	1.08	1.2
(Evens, Sutherland et al. 1972)										

Table 3: Total sound absorption in dB/300m versus relative humidity as a function of frequency at 20°C

Frequency kHz	Relative Humidity %										
	0	10	20	30	40	50	60	70	80	90	100
2	1.26	11.7	5.31	3.33	2.54	2.18	2.00	1.92	1.89	1.89	1.92
4	2.70	31.0	19.0	11.9	8.52	6.75	5.71	5.06	4.63	4.34	4.14
6.3	4.54	47.1	41.2	27.6	20.0	15.6	13.0	11.2	9.98	9.10	8.45
10	8.01	61.6	79.7	62.5	47.4	37.5	31.0	26.6	23.5	21.1	19.4
12.5	10.9	68.1	103	89.7	70.9	57.0	47.5	40.8	35.9	32.3	29.5
16	15.9	76.2	130	129	108	89.6	75.5	65.2	57.6	51.8	47.2
20	23.0	85.6	156	172	155	133	114	99.4	88.1	79.4	72.5
(Evens, Sutherland et al. 1972)											

- There is a critical range of relative humidity occurring between 10 and 40%. Within the range, the increase in sound absorption is greatest. This range also represents the most common relative humidity uncounted (BOHN).
- For large areas with highly reflecting surfaces, air absorption at the high frequencies can be the dominant phenomenon, and the change in absorption due to relative humidity can be the dominant factor determining the frequency range being monitored (BOHN).

- For frequencies below 2 kHz, sound absorption due to relative humidity is not significant and is ignored (BOHN).

2.7.2 Temperature

Temperature gradients create effects similar to those of wind gradients, except that they are uniform in all directions from the source. On a sunny day with no wind, temperature decreases with altitude, giving a “shadow” effect for sound. On a clear night, temperature may increase with altitude, “focusing” sound on the ground surface.

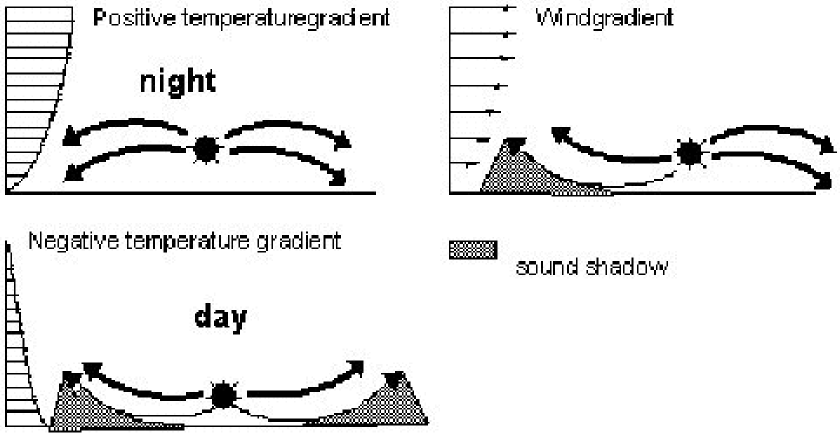


Figure 10: Temperature and wind gradients (Bruel & Kjaer 2001)

Perception of sound

Sound is any pressure variation that can be detected by the human ear. The number of pressure variations per second is called the frequency of sound, and is measured in hertz (Hz). The normal hearing for a healthy young person ranges from approximately 20Hz to 20000Hz.

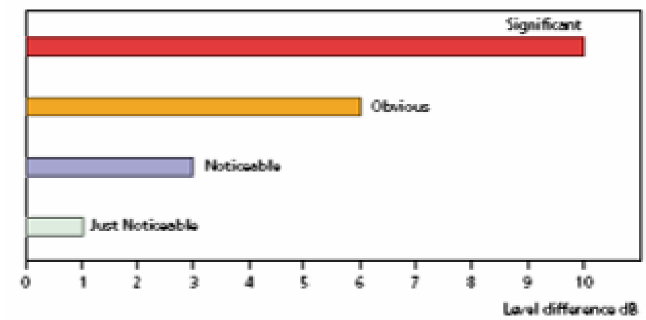


Figure 11: The perception of sound (Bruel & Kjaer 2001)

In terms of sound pressure levels, audible sound ranges from the threshold of hearing at 0dB to the threshold of pain at 130dB and over. Although an increase of 6dB represents a doubling of the sound pressure, an increase of about 8-10dB is required before the sound subjectively appears to be significantly louder. Similarly, the smallest perceptible change is about 1dB.

- We need to provide a balance between providing efficient road transport infrastructure and controlling the adverse affects of road use.

- A study conducted in 1986 (Hede et al. 1986) indicates the extent of road traffic noise impacts throughout Australia. The study involved interviews with a large random sample of the Australian population. Twenty-one per cent of Australians described themselves as being personally affected by noise pollution - more than for water, air or waste pollution. Of the sources of environmental noise, the most important was road traffic noise, with 17% of the population describing it as the noise they would most like to get rid of. The survey found that 6% of Australians were highly annoyed, and 21% moderately annoyed, by traffic noise, with 13% claiming disturbance to listening activities, and 12% claiming disturbance to sleep.

- There are apparent deficiencies in using a single value for L_{eq} and L_{10} descriptors for predicting certain types of disturbance, particularly in relation to sleep.

- Existing noise criteria for local roads have been developed over a period of time, resulting in a piecemeal approach that has relied on both L_{eq} and L_{10} descriptors and that does differentiate day/night periods (also see section 2.7.2).

- Residents tend to be more sensitive to new noise sources than to existing noise sources of the same noise level.

- Long term strategies: limitations on exhaust brake use; restricted access for heavy vehicles to sensitive areas; improved planning, design and construction of adjoining land use developments; and alternative methods of freight haulage.

- Options include designing developments so that sensitive land uses are protected from excessive noise through the use of options such as optimal location and orientation on the site, well planned internal layouts, noise insulating building materials and construction methods that facilitate noise control.

- There are often high costs and practical difficulties associated with retro-fitting noise controls.

- Improved noise design requirements for buildings near heavily trafficked roads.

2.7.3 Ground effects

Sound reflected by the ground interferes with the directly propagated sound.

The effect of the ground is different for acoustically hard (e.g. concrete or water), soft (e.g. grass, trees or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to take into account the frequency content of the noise source and the type of ground between the source and the receiver.

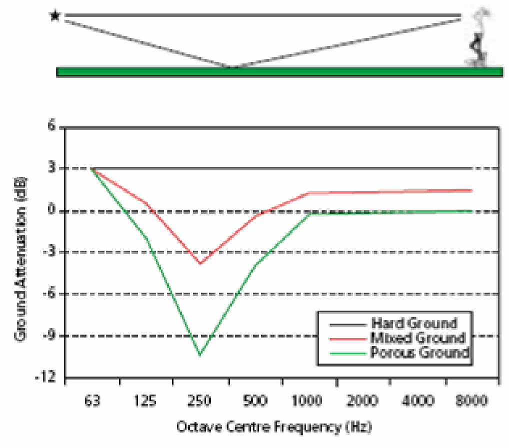


Figure 12: Ground absorption (Bruel and Kjaer 2001)

Wind

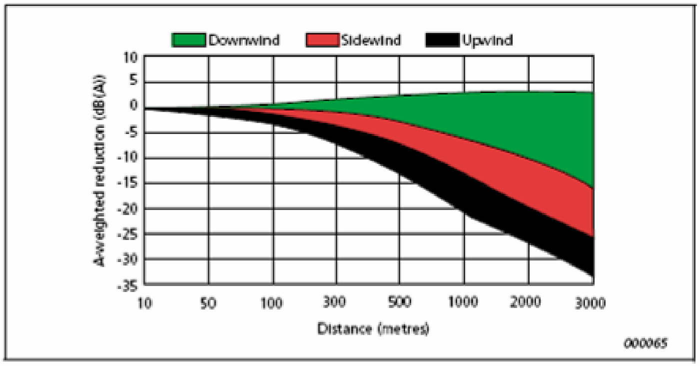


Figure 13: The effects of wind direction on attenuation (Bruel and Kjaer 2001)

Wind speed increases with altitude, which will bend the path of sound to "focus" it on the downside and make a "shadow" on the upwind side of the source. At short distances, up to 50 metres, the wind has minor influence on the measured sound level. For longer distances, the wind effect becomes appreciably greater. Downwind, the level may increase by a few dB, depending on wind speed. But measuring upwind or side-wind, the level can drop by over 20dB, depending on wind speed and distance. Downwind measurements were taken for the report as the deviation is smaller and the result is also conservative.

2.8 What are appropriate mitigation measures, suggested monitoring methods, and compatible noise monitoring activities for ensuring the correct differentiation between the different environmental effects on road traffic noise?

When aiming to reduce the effects of environmental noise on people, the following aspects must be considered:

- Noise sources;
- Transmission path, and;
- The types of homes in which people live.

The most common source of environmental noise is road traffic. Road traffic noise accounts for more than 90% of unacceptable noise levels (daytime LAeq> 65dB(A) in Europe. Other forms of transportation noise such as train and aircraft noise is a more local problem but can still annoy many people.

Outdoor noise levels usually decrease with increasing distance from the source because of geometric spreading of the noise energy over a bigger surface and absorption of the noise by the atmosphere and by the ground. Barriers can achieve additional reduction of noise levels.

The sound insulation of buildings is the final barrier to the potentially intruding effects of environmental noise.

2.8.1 The source

Most countries encourage manufacturers to produce quieter cars and trucks by imposing noise limits on individual vehicles. These "pass-by" noise rating limits have been reduced over the past 20-30 years by approximately 8 dB(A) for cars and 15dB(A) for lorries.

Some national governments (e.g. Norway and Italy) have implemented legislation to include tests on noise

Figure 14: Statistical pass-by testing (Bruel & Kjaer 2001)

emissions from vehicles during normal service. These tests are usually carried out by garages as part of general tests on the condition of the vehicle; others perform spot checks. Even so the ever-increasing number of vehicles means that the overall noise levels have not been reduced.

Road surfaces can be improved to give lower noise output. Porous asphalt and the newer “thin noise-reduced surfaces” have shown reductions of 2-6dB(A). Railway noise can be reduced by the use of welded track laid on a concrete bed with elastic/resilient pads or mats.

2.8.2 Transmission path

The obvious method of reducing noise is to move people as far away as possible from the source of environment noise. However, this is often impractical, so additional attenuation in the form of noise barriers can be applied.

The barrier height and the position of the noise source and/or receiver relative to it are crucial to the amount of noise reduction that can be achieved. Effective barriers with heights ranging from 1.5 metres (Japanese railway noise) to 10 metres (US ground based airport operation) have been reported. Barrier heights for road traffic noise reduction are typically between 3 metres and 7 metres. In addition, the frequency spectrum of the noise source will affect the achievable reduction. Low frequencies, compared to high frequencies, are poorly attenuated by barriers. In some cases, the performance of barriers can be improved by applying sound absorbing material, avoiding parallel, reflective surfaces and shaping or angling barriers to avoid multiple reflections.

2.8.3 Sound insulation of buildings

The final stage of ensuring that people are not disturbed by environmental noise in their homes is to provide sufficient sound insulation from the external noise levels. This is called Façade sound insulation, and is measured in terms of a standardised level difference (DnT,tr) or the sound reduction index (R’tr).

Different countries approach this in different ways as shown by the following examples:

- In some countries, a minimum level of façade sound insulation is required.
- In other countries (e.g. UK) additional insulation is provided when the external noise sources are particularly high (airports and traffic noise).
- New houses are not allowed to be built if the ambient noise levels of environmental noise are high (e.g. Planning and Policy Guidance 24 in the UK).
- Resultant interior noise level is classified poor if it is above 35 dB(A) or very good if it is below 20 dB(A).

2.8.5 Range of sound pressure

- Road traffic noise can disturb activities within residences such as
    - o Conversation, either in person or on the telephone
    - o Watch and listening to television
    - o Sleeping

Relaxing, listening to music, reading and other passive indoor activities

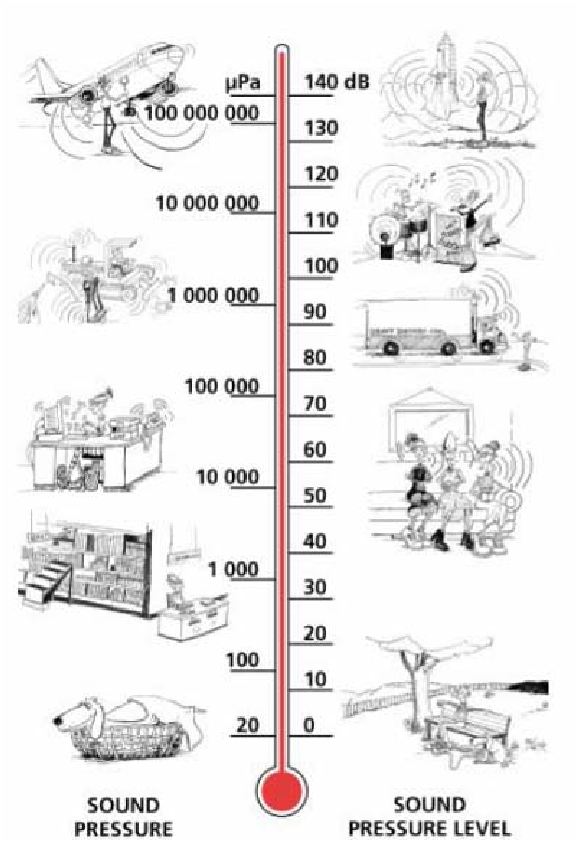


Figure 15: Sound pressure and sound pressure levels (Bruel and Kjaer 2001)

Chapter 3 - CoRTN model

CoRTN is the model of choice in Main Roads (QDMR) to produce noise level estimates. It is an accurate, simple, and user friendly method to predict noise levels.

The CoRTN model was developed by the UK Department of Transport in 1988. It predicts noise at a reception point located at a certain distance from a road. The prediction is based on many factors, including basic noise level based on vehicle composition, road surface, grade, etc; propagation effects such as distance attenuation and ground absorption capacity, and; site layout features, e.g. screening effects and reflection from surfaces.

It generally gives an uncertainty of 1-2 dB (Saunders, Samuels et al. 1983), however it obviously relies on the accuracy of the input data. The CoRTN model assumes a source of height 0.5 metre, and a distance of 3.5 metres from the edge of the road. Noise is estimated one metre in front of the most exposed part on an external wind or door when taking measurements off a dwelling. Moderate wind velocities and directions are assumed. The model does not take background noise into account such as planes and irrigation sprinklers etc, therefore it must be used with caution in particular applications where the $L_{eq} > L_{10}$. If the $L_{eq} > L_{10}$ the recorded noise is generally thought to be background rather than road traffic noise.

3.1 The method shown in the CoRTN flow chart (see appendix D) commences with a relationship between L_{10} (18hour) at a reference point 10 metres from the nearside carriageway edge and traffic flow over the 18 hour day from 0600 to 2400 hours. This relationship assumes the traffic is composed of cars travelling at a uniform speed of 75 km/h along a straight, flat road. From there it goes on to provide a series of relationships that ‘correct’ this value for the actual speed and heavy vehicle content of the traffic in question, as well as the road gradient and the road surface. The attenuation of noise with increasing distance from its source is dealt with in subsequent charts which plot corrections for these attenuations against distance over soft and hard grounds.

3.2 CoRTN correction charts (see Appendix D).

3.2.1 Correction for mean traffic speed (V) and Percentage heavy vehicles (p).
The CoRTN model does not have a classified vehicle category. For its calculation, it combines the flow of all vehicles in veh/h and considers the hourly

flow of all vehicles (V) and the hourly flow of heavy vehicles (p). Based on the CoRTN model, for the calculation of the sites for this report, the vehicles are combined into three categories. Therefore, the hourly flow of these three categories combined is used.

3.2.2 Correction for distance as a function of horizontal distance from edge of nearside carriageway (d) and the relative height between the reception point and the effective source position (h).

3.2.3 Correction for ground absorption as a function of horizontal distance from the edge of the near carriageway (d), the average height of propagation (H) and the proportion of absorbent ground.

3.2.4 Prediction of basic noise level hourly L_{10} in terms of total hourly flow (q).

The free field:

This term describes sound propagation in idealised free space where there are no reflections. These conditions hold in open air (sufficiently far enough away from the ground) or in an anechoic room where all the sound striking the walls is absorbed. Free field propagation is characterised by a 6dB drop in sound pressure level and intensity level (in the direction of sound propagation) each time the distance from the source is doubled. This is simply a statement of the inverse square law. The relationship between sound pressure and sound intensity (magnitude only) is also known.

The near field of a source:

Very close to a source, the air acts as a mass-spring system which stores the energy. The energy circulates without propagating and the region in which it circulates is called the near field. Only sound intensity measurements for sound power determination can be made here. For this report the near field area was not monitored.

Chapter 4 - Methodology

The intent of this project is to determine whether the measured noise levels match those predicted by the CoRTN model by refining the distance attenuation rates, preferably shown in a chart format. With the measured and the modelled values shown graphically, it should be easy to establish if a correction factor is warranted.

By far the majority of traffic noise prediction is made for urban and suburban freeways. These are, after all, the causes of most of the noise complaints in residential areas and need to be addressed most frequently. Therefore, it was decided to measure traffic noise attenuation rates at site along heavily travelled multi-lane highways.

The ground surface types to be monitored are large areas with homogeneous ground cover and soil conditions. The ideal sites would approximate an infinite line source emanating a continuous high noise level, with an ambient noise level that is very low. The possibility of finding the perfect site should be balanced with the knowledge that there are always going to be some fluctuations with the noise source, especially road traffic noise levels and that the ambient noise is going to play a part in the noise levels the greater the distance between the source and the receiver.

In order to measure distance attenuation rates of vehicle noise, measurements need to be made a minimum of two different distances from the source. The difference between the two measurements, when properly corrected, may then be used to determine a change to the noise levels due to ground absorption.

All sites require traffic corrections for the traffic volume, speed and composition (e.g. percentage of commercial vehicles) and the same road surface. The noise levels can be corrected to a reference traffic volume, speed and composition.

To ensure the data gathering is consistent between sites, meteorological equipment will be installed at each site to provide information about weather conditions during the monitoring phase. Some measurements may have to be aborted due to adverse weather conditions.

After the areas for monitoring have been identified, the set up of the noise monitoring equipment will need to be considered. Factors to consider include the distance between the road and the equipment, and microphone height.

The project will require trials of a combination of the above factors. The noise monitoring equipment will be in place at each site for a period of 10 minutes. The L10 (10 min) and the leq (10 min) will be measured during each sample, to compare these to ensure measurement of road traffic noise. The signal to noise ratio should be at least 6 db(a) and preferably 10 db(a). That is, the traffic noise measured must exceed the background noise by these values. Generally this is very difficult to achieve when measurements are made at more than around 100 to 150 metres from the roadside.

4.1 Measurement procedure

Microphone position The microphone should be placed at a height of 1.2 metres above the road surface and with the diaphragm or other sound-sensitive surface horizontal (grazing incidence). Where possible, free-field conditions should apply. However there should be no sound reflecting surfaces (other than the ground) within 15 metres of the microphone position.

Microphone calibration

The B&K and the ARL-316 are to be calibrated at each location. In each case, a reference signal at the beginning and end of the monitoring session was completed by a calibrator set at constant frequency of 94 dB, which is the equivalent sound pressure level of 1 Pa.

Sampling times

Ten minutes should be enough for each data collection interval as the continuous source noise levels should not fluctuate to give false readings.

4.2 Physical conditions for measurement

- o Road surface: Measurements are to be made when the road surface in the measurement is dry.
- o Wind: Measurements should be made where the wind direction is such as to give a component from the nearest part of the road towards the reception point exceeding the component parallel to the road;
    1. the average wind speed at a height of 1.2 metres and mid-way between the road and the reception point is not more than 2 m/s in the direction from the road to the reception point;
    2. the wind speed at the microphone in any direction should not exceed 10 m/s.

In all cases it is recommended that a wind shield be used on the microphone and that measurements should only be carried out when the peaks of wind noise at the microphone are 10dB(A) or more below the measured value of L_{10}.

Chapter 5 - Description of monitoring locations

Site locations for this report included two sites without vegetation and one with vegetation.

The criteria for the locations were as follows:

- The bush location had to have sufficient vegetative mass (including density, width and height).
- The source had to have a zero gradient.
- The ground level for each location had to be within a one metre height of the pavement surface.
- The locations without vegetation had to be open, without any significant obstacles or reflected surfaces.
- All locations had to be approximately the same dimensions with special attention given to the length of the source. The locations selected for the report had neighbouring properties of a similar type to the one being monitored. Each location had to have a breadth to accommodate a variety of monitoring sites up to 400 metres from the source.
- The source was to be of the same type. For this report the Warrego Highway was chosen for all sites. It consists of a dual carriageway without any crash barriers. The pavement surface type was also consistent, being dense graded asphalt.
- There had to be a sufficient amount of traffic, giving the site a continuous noise source and minimising the chances of contamination from background noise levels.

5.1 Soft ground site

The first monitoring was a barley plantation where the crop had a height of approximately 300 mm. The soil was irrigated and cultivated, leaving it loose and moist to the touch. The vegetation was of constant density over the whole area and had a thin leaf appearance which moved easily in the breeze. The CoRTN model has a correction for soft ground, which in the case of intensively cultivated or planted areas, will slightly underestimate attenuation effects.

Figure 16: Soft ground monitoring site (Photos by Robert Grant)

5.2 Hard ground without vegetation site

The second monitoring site was the hard ground without vegetation. This cow paddock was extremely hard, to the extent that it was impossible to insert a tent peg into the ground by hand. The vegetation was virtually non-existent and the grass was dead, hard under foot and didn't move around in the wind. The ground did have cracks in some areas, which appeared after the initial site inspection due to drought conditions. The number of cracks would allow some ground absorption to occur but on the whole, the cracks were small in number, allowing the hard ground to be classified as having no absorption **and therefore no ground cover correction is applied.**

Figure 17: Hard ground without vegetation (Photos by Robert Grant)

5.3 Hard Ground with vegetation

The third site to be monitored was a dry Schlerophyll forest, also known as hard ground with vegetation e.g. typical “Australian bush”.

At this site the vegetation was densely packed and included large tall gum trees, hard grass of approximately 400 mm in length, succulent cactus, medium density bushes of 2 metres in height and the whole area was also intertwined with lantana. This area was very hard to walk through, and the ground was extremely hard with no apparent cracks under the ground vegetation.

Figure 18: Hard ground with vegetation (photos by Robert Grant)

Chapter 6 - Equipment

B & K Investigator

For the set up of the B&K Investigator, the following tasks were completed to ensure the accuracy of the noise monitoring process:

Turbulent noise reduction for a given microphone – windscreen combination: one may determine whether or not the measured noise level is caused by the wind or from the noise source. Take measurements with and without windscreen for comparison and for a correction factor.

Instrument stray pick-up: to minimise pickup, the site selected had the proper orientation of the instrument with respect to the magnetic field.

Calibration

Before measurements can be undertaken, it is important to calibrate the microphone and instrument together. This will check the function of the measurement system and ensure that high accuracy can be obtained, allowing comparison to be made between measurements taken at different times.

Figure 19: Calibration of the B&K Investigator (Bruel & Kjaer 2001)

Calibration should therefore be made before each series of measurements and it is recommended that the calibration is repeated after a series of measurements as a double check.

Acoustic calibration

Acoustic calibration is normally preferable, since the whole system from microphone to indicating device will be checked. To carry out acoustic calibration, fit the calibrator on to the microphone, making sure it fits snugly. Switch on the calibrator and adjust the read out on the indicating device to the sound level produced by the calibrator being used. Two different calibrators are available for acoustic calibration: a pistonphone and an acoustical calibrator.

- The measurement position should, in general, be far enough away from reflecting surfaces such as the ground, walls and the operator.
- For most practical purposes a type (class)1 sound level meter is the most versatile.
- The sound level meter should be calibrated before and after each measurement.

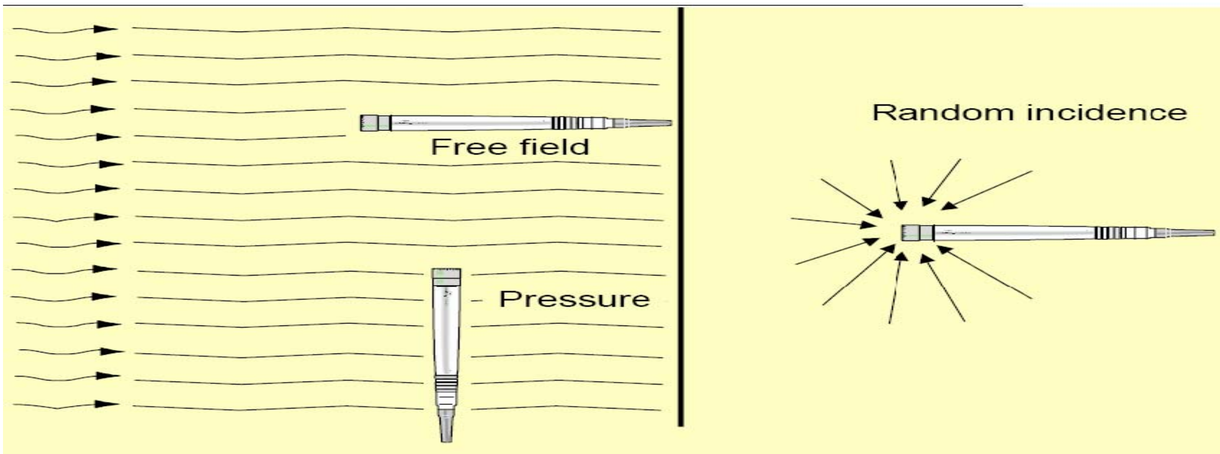


Figure 20: Types of microphones (Bruel and Kjaer 2001)

Types of microphones

Microphones are divided into three types according to their responses in the sound field: free field, pressure, and random incidence.

Free field microphones have uniform frequency response for the sound pressure that existed before the microphone was introduced into the sound field. It is important to note that any microphone will disturb the sound field, but the free field microphone is designed to compensate for its own disturbing presence.

The pressure microphone is designed to have a uniform frequency response to the actual sound level present. When the pressure microphone is used for measurement in a free sound field, it should be orientated at a 90° angle to the direction of the sound propagation, so that the sound grazes the front of the microphone.

The **random incidence microphone** is designed to respond uniformly to signals arriving simultaneously from all angles. When used in a free field it should be orientated at an angle of 70° – 80° to the direction of propagation. For this report a random incidence microphone was attached to the B&K and then the settings within the B&K were used to convert the microphone to a free field type electronically.

Free field correction

When a microphone is placed in a sound field, it modifies the field. The illustration shows a free field where sound comes from only one direction. The sound pressure in this field without the microphone is called p_o.

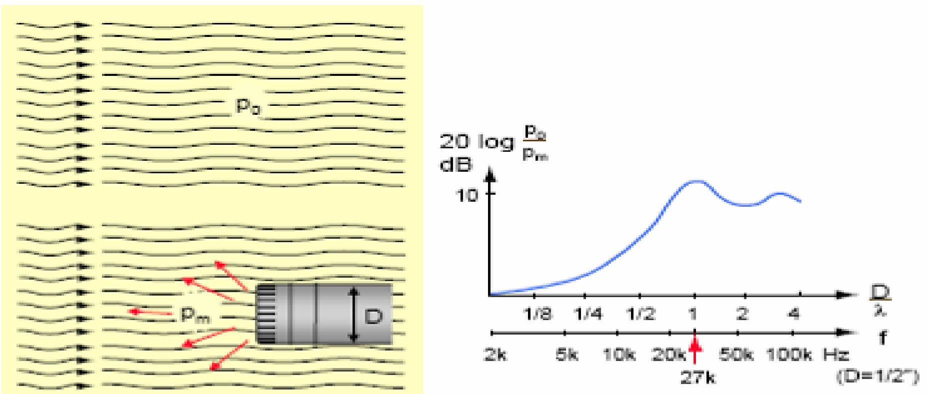


Figure 21: Free field correction (Bruel & Kjaer 2001)

When the microphone is placed in the field a pressure rise will take place in front of the microphone, caused by local reflections, and the microphone will measure too high a sound pressure p_m. This rise in "sensitivity" is frequency dependant, with a maximum at the frequency where the wavelength is equal to the diameter of the microphone, D/λ. If the corresponding frequency axis for a ½' microphone is plotted along the D/λ axis it is seen that the increase starts at 2 kHz with a maximum of approximately 10dB at 27 kHz

6.2 Davis weather station

The Davis weather station was set up in an open area free from obstacles which might disturb the wind flow.

The weather station collected data on rain fall, temperature, barometric pressure, humidity, wind speed and direction. The weather station was set up on 5 minute logging intervals to allow for small changes in data to be recorded instead of being averaged over a larger interval.

Figure 22: Davis weather station (Photo by Robert Grant)

6.3 Noise logger

The ARL-316 noise logger was located permanently at a distance of 10 metres from the nearside edge of the carriageway. This secondary logger is used as a check for the B&K data and to confirm if noise levels are changing due to distance, rather than traffic fluctuations.

Figure 19 shows the ARL-316 whilst downloading the day's data and with the reference calibrator attached.

Figure 23: ARL-316 Noise logger (Photo by Robert Grant)

Chapter 7 - Data format, statistical analysis and summary

7.1 Verification of Road Traffic Noise model with the use of a Bruel & Kjaer hand held noise analyser.

For the verification of the measured data, the database was broken down into weather data, logger data, traffic data, and B&K data.

The weather data for each of the sites was checked and was within the relevant standard (Standards Association of Australia 1984). The wind direction for all sites was blowing in a downwind direction towards the B&K microphone for a high percentage of the time. The wind speed had an average of 4.1 m/s and the barometric pressure was an average of 1021 hPa (See Appendix I).

The ARL-316 logger data was categorised into the two monitoring heights for each location. The five minute intervals were then averaged, in the data formatting, to get the same 10 minute interval that the B&K was set on (See appendix I). For charts which compare the logger data, the B&K data and the CoRTN model (see figures 31 to 35).

The CoRTN data went through several steps to ensure it was statistically viable to use, and was then compared with the measured values. The tests included the CHITEST, the CORREL and the R^2. The CoRTN correction sheets were also used (See Appendix C) to obtain the equations for the relevant correction for either distance, or distance and ground absorption. These values were then added to the original predicted values

- CHITEST tests for independence by verifying the predicted results with the measured results. The CHITEST values become more significant when they are equal to or above five. The data input was the corrected values of the CoRTN model and the B&K L_{10} noise levels. In this case, the CHITEST values are too small for any significance. This may be due to the small segments and deviations in the data.

- CORREL tests for the correlation coefficient between the CoRTN model and the B&K L_{10}. For this test the correlation value equals one if both data sets are the same. From this test it was determined that the soft ground and the hard ground with vegetation had great correlation and the hard ground without vegetation only had good correlation.

- R^2 tests the correlation coefficient through the CoRTN and B&K data. Its value is interpreted as the proportion of the differences in the CoRTN data to the differences in the B&K data. A value of one shows good correlation and with similar results to the CORREL test, the soft and hard grounds with vegetation rated as great and the hard ground was rated as good (See table 4)

The next step for the B&K data was to directly compare the measured and predicted L_{10} values on a scatter chart. The two data sets used were the corrected CoRTN and the B&K L_{10} values. The chart has a line running diagonally across it which shows the point where the predicted values equal the measured values. If the CoRTN values are above this line, they can be viewed as being over-predicted and those below the line can be viewed as under-predicted (see figures 24 to29).

Summary

From the charts it can be determined that the correlation between the data sets was good and therefore acceptable to use for the analysis. The results were then plotted on charts for analysis.

The hard ground with vegetation at 1.5 metres shows the CoRTN model is over-predicting the measured L_{10} values by 3.5 dB(A) shown in figure 24.

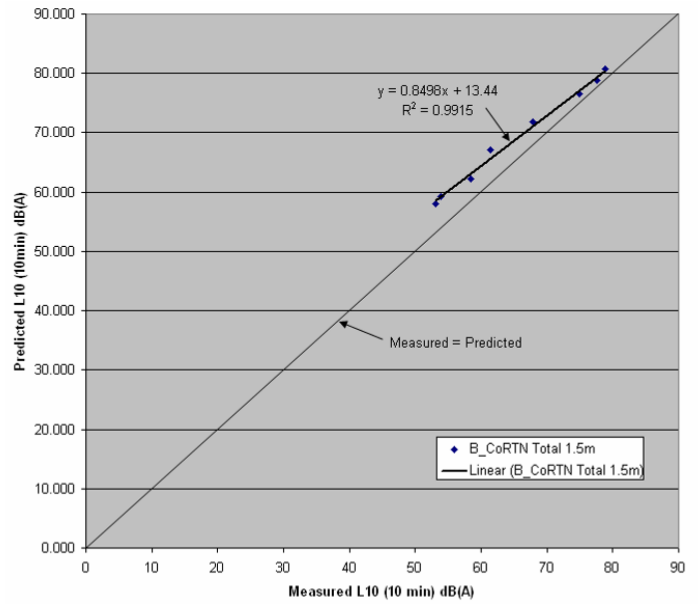


Figure 24: Predicted L10 (10min) plotted against measured L10 (10 min) for the hard ground with vegetation. 1.5 m

The hard ground with vegetation at 3.5 metres shows the CoRTN model predicting the measured L_{10} values accurately in figure 25.

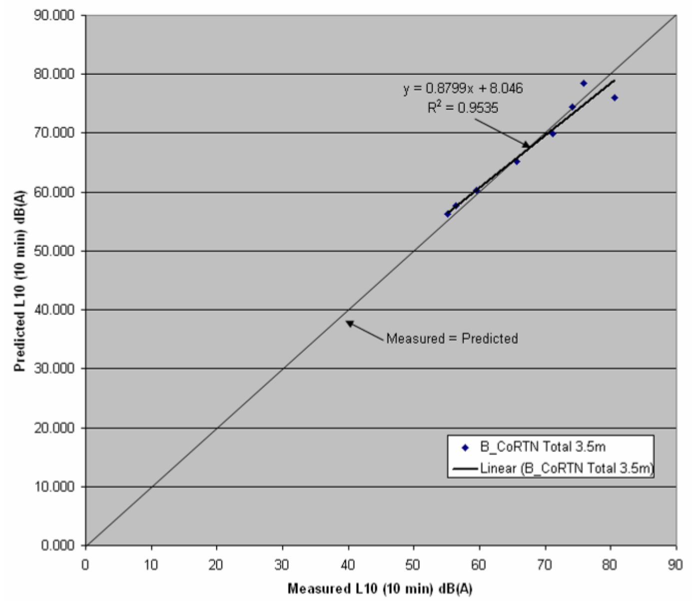


Figure 25: Predicted L10 (10min) plotted against measured L10 (10 min) for the hard ground with vegetation. 3.5 m

The soft ground at 1.5 metres shows the CoRTN model under-predicting the measured L_{10} values by 1.5 dB(A) in figure 26.

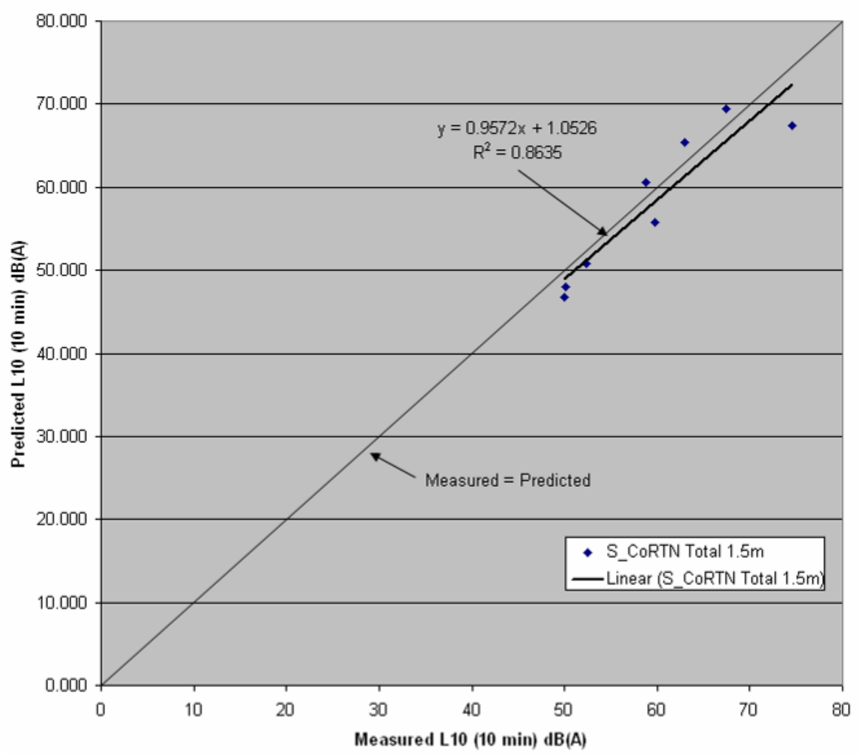


Figure 26: Predicted L10 (10min) plotted against measured L10 (10 min) for the soft ground without vegetation. 1.5 m

The soft ground at 3.5 metres shows the CoRTN model under-predicting the measured L_{10} values by 2.5 dB(A) in figure 27.

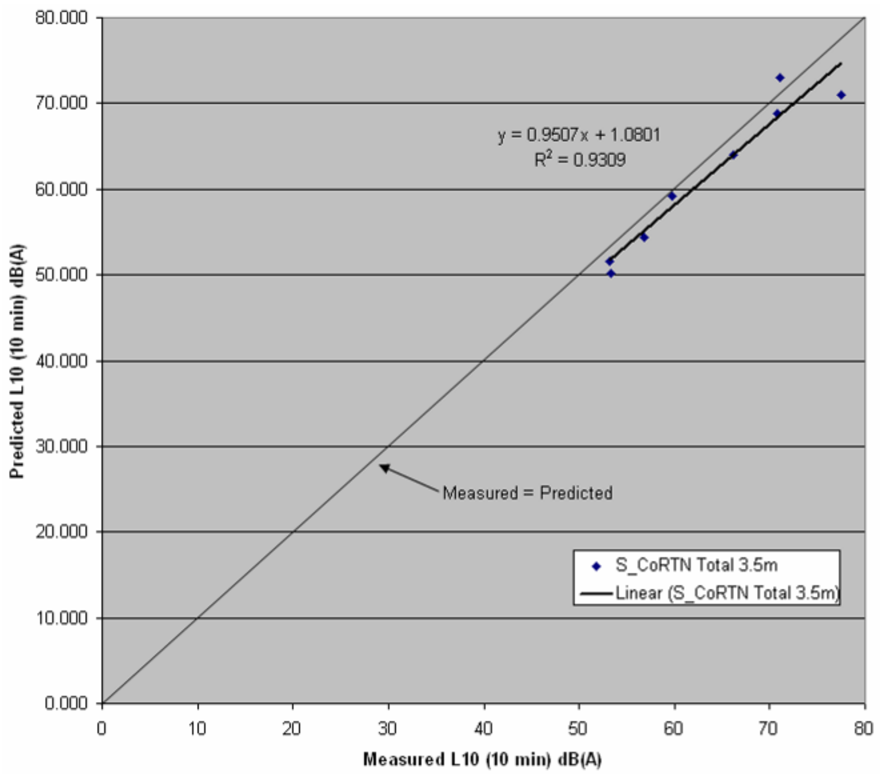


Figure 27: Predicted L10 (10min) plotted against measured L10 (10 min) for the soft ground without vegetation. 3.5 m

The hard ground with vegetation at 1.5 metres shows the CoRTN model under-predicting the measured L_{10} values by 1.5 dB(A) in figure 28.

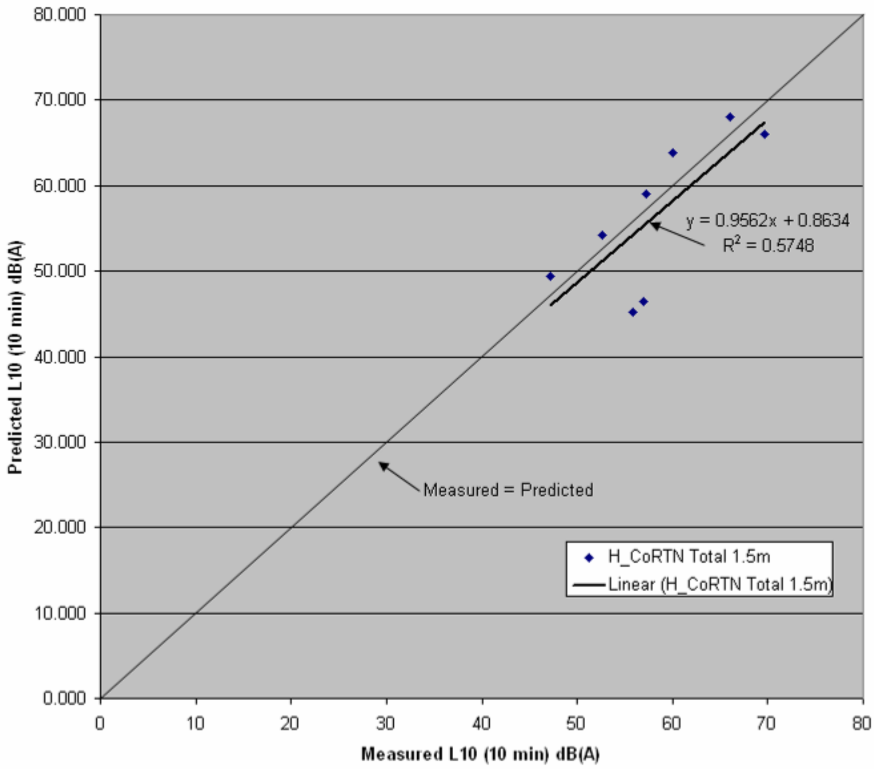


Figure 28: Predicted L10 (10min) plotted against measured L10 (10 min) for the hard ground without vegetation. 1.5m

The hard ground without vegetation at 3.5 metres shows the CoRTN model predicting the measured L_{10} values accurately in figure 29.

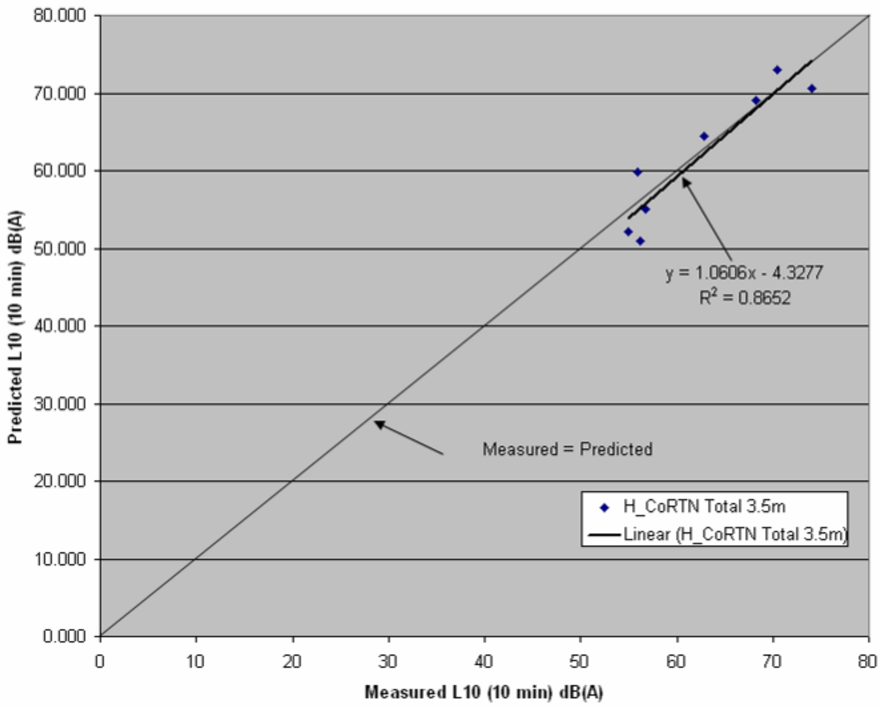


Figure 29: Predicted L10 (10min) plotted against measured L10 (10 min) for the hard ground without vegetation. 3.5m

Noise levels verses distance for the soft ground without vegetation at 1.5 metres. Figure 30 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

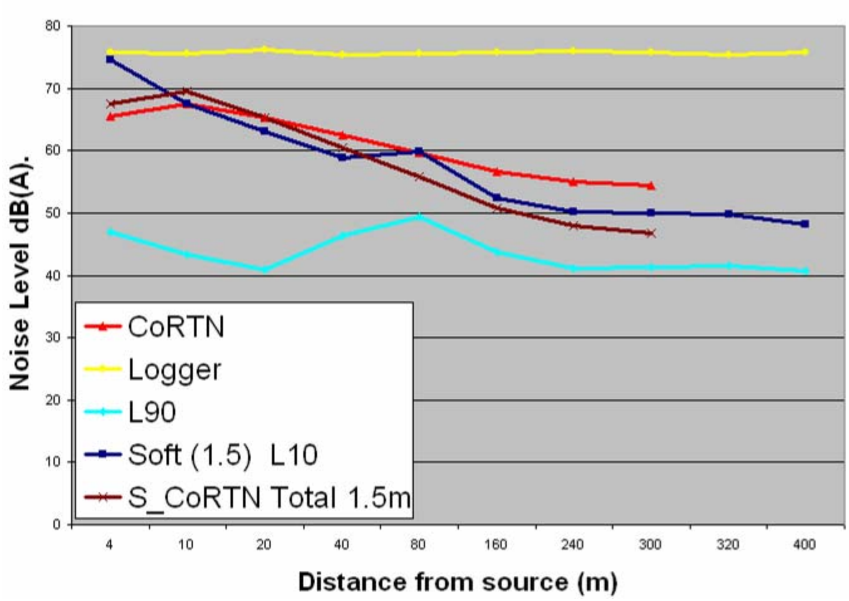


Figure 31: Noise levels Vs distance for ground at 1.5 m

The noise levels verses distance for the soft ground without vegetation at 3.5 metres. Figure 31 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

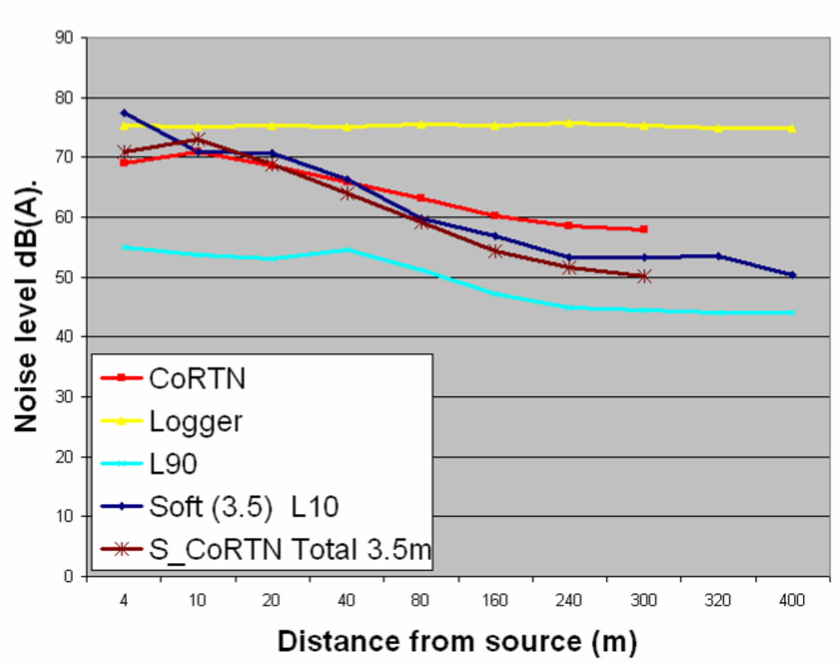


Figure 30: Noise levels verses distance for soft ground at 3.5 m

The noise levels verses distance for the hard ground without vegetation at 1.5 metres. Figure 32 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

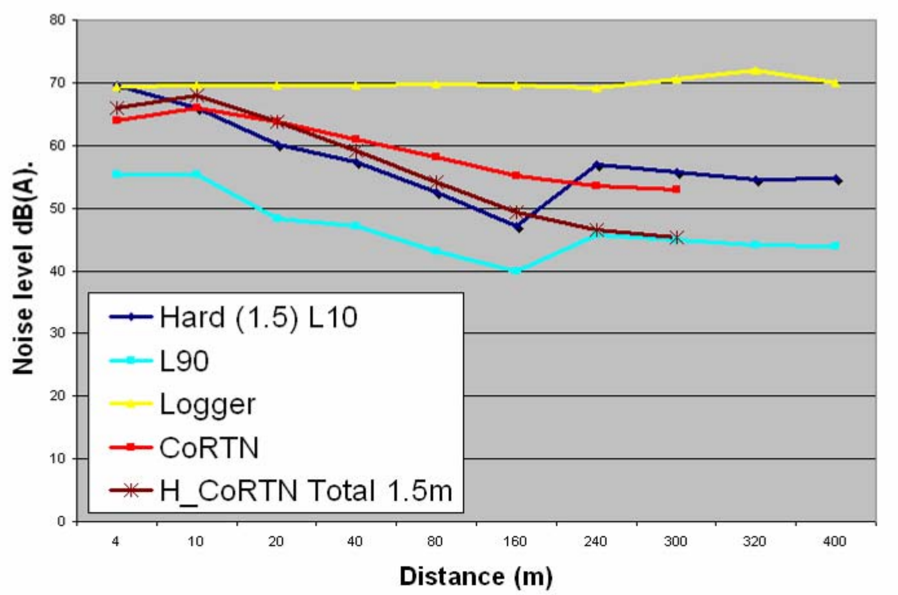


Figure 32: Noise levels verses distance for hard ground without vegetation at 3.5 m

The noise levels verses distance for the hard ground without vegetation at 3.5 metres. Figure 33 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

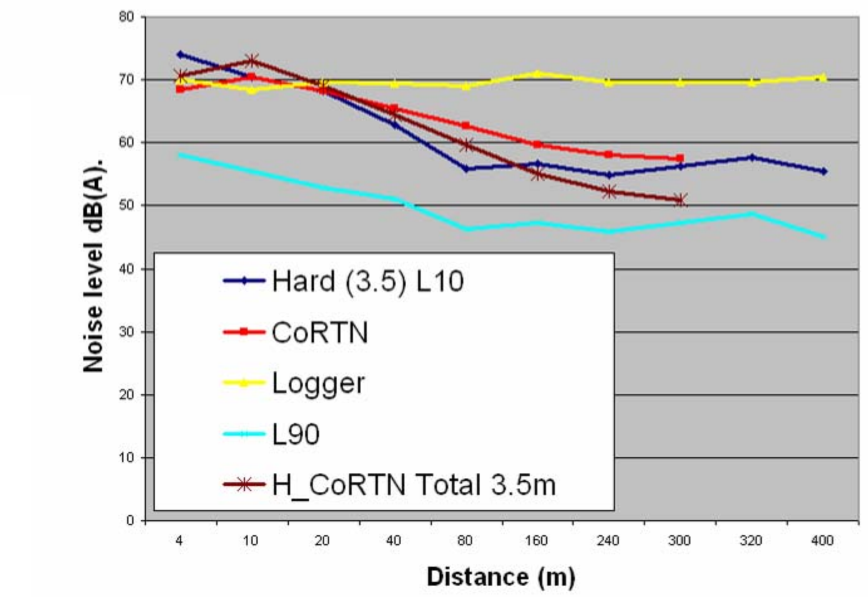


Figure 33: Noise levels verses distance for hard ground without vegetation at 3.5 m

The noise levels verses distance for the hard ground with vegetation at 1.5 metres. Figure 34 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

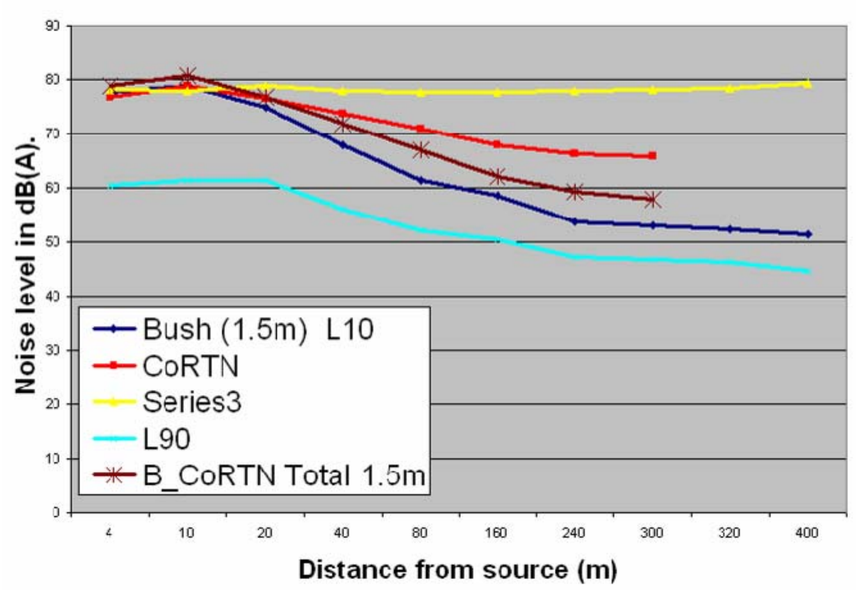


Figure 34: Noise levels verses distance for hard ground with vegetation at 3.5 m

The noise levels verses distance for the hard ground with vegetation at 3.5 metres. Figure 35 shows the corrected (S_CoRTN total) and uncorrected values of CoRTN in relation to the measured values.

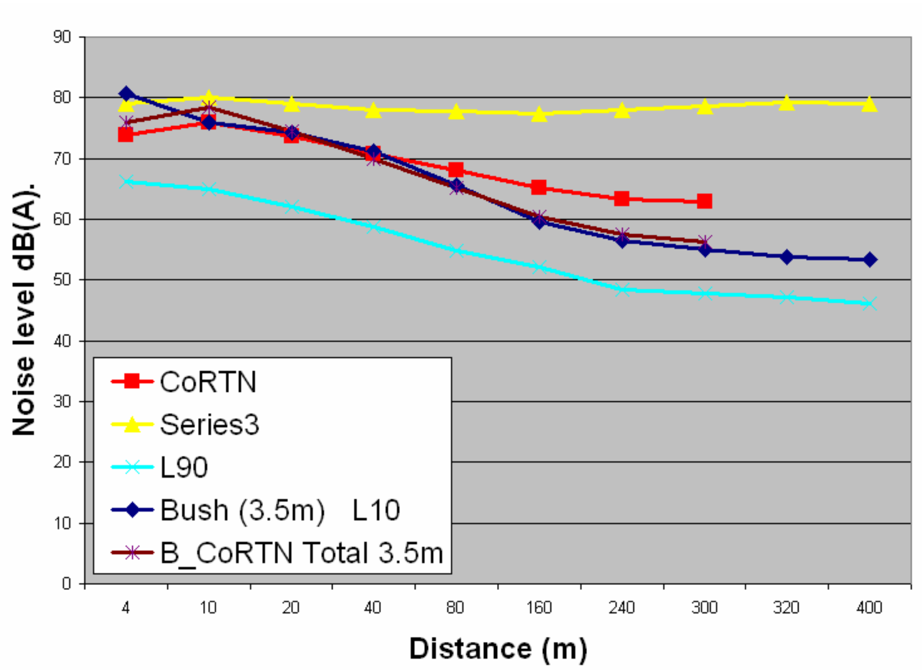


Figure 35: Noise levels verses distance for hard ground with vegetation at 3.5 m

Chapter 8 - Conclusions and Recommendations

Collected data on noise generating parameters was used to calculate the predicted noise level from the three locations of hard ground without vegetation, hard ground with vegetation and soft ground without vegetation. The comparison tests were made in order to examine the goodness of fit, between the predicted and measured noise levels from collected field data and to suggest a suitable correction factor for the predicted noise levels if needed. For the present study following conclusions are drawn.

- The summarized details showing the variation between observed and estimated noise levels for all locations.

Table 4: Summarized details between predicted and measured values

	CHITEST	CORREL	Range of difference between observed and estimated noise levels dB(A)	R^2
Soft (1.5)	0.979	0.929	1.15 - 5.63	0.8635
Soft (3.5)	0.992	0.965	0.27 - 4.6	0.9309
Hard (1.5)	0.598	0.7582	1.5 - 7.1	0.5748
Hard (3.5)	0.988	0.7582	0.5 - 6.5	0.8652
Bush (1.5)	0.963	0.996	1.6 – 9.8	0.991
Bush (3.5	0.999	0.976	0.9 - 5.3	0.9535

From **Table 4**, the R^2 value for all the models lie in the acceptable range, as the value of 1 indicates a very good correlation between the observed and the estimated values.

From the charts it can be determined that that all sites were within a range of $\pm$ 10 dB(A). Although this range of the noise levels is high it isn't representative of mean value which is 3.1 dB(A). The difference between the Predicted and Monitored levels of 3.1 dB(A) would be considered acceptable considering the differences vegetation, environmental and ground effects that occurred during the monitoring process, so I would consider that no further action is needed to prove the CoRTN model does predict accurately and there is no need to modify the CoRTN algorithms for any future areas that are similar to the three, above mentioned, locations.

Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project

PROJECT SPECIFICATION

FOR:	**ROBERT GRANT**
TOPIC:	A study of the ground and vegetation effects on the propagation of road traffic noise in south east Queensland.
SUPERVISORS:	Chris Snook Cedric Robert, Department of main roads.
ENROLMENT:	ENG 4111 - S1, EXT, 2005; ENG 4112 –S2, EXT, 2005
PROJECT AIM:	Main Roads uses a United Kingdom methodology known as CoRTN (Calculation of Road Traffic Noise) to calculate road traffic noise. This model considers attenuation due to distance. However, there may be significant differences in the level of road traffic noise attenuation between the physical environments of England's ground and vegetation types and Australia's ground and vegetation types. This research project will aim to identify whether a correction factor for the L10 noise descriptor is needed for CoRTN, helping to ensure the noise predictions and calculations undertaken by Main Roads are suited to south east Queensland conditions.
SPONSORSHIP:	Department of main roads.
PROGRAMME:	**Issue A, 21st March 2005**

1. Research the background information relating to road traffic noise. This will include the different phenomena that effect the propagation of road traffic noise and the equipment settings that will give the best representation of the noise levels at the monitoring sites.

2. Design a field monitoring program and collect the road traffic noise levels, weather and traffic volume data.

3. Set up data base for all the field data.

4. Analyse the data for statistical correlation.

5. Evaluate the measured data compared to CoRTN model.

As time permits:

6. Use the 1/3 octave frequency bands to see the changes of frequency compared with noise levels over distance.

7. Increase the number of monitoring locations to include an urban area.

AGREED:

_______________ (Student) _______________ (Supervisor)

2 / 11 / 05 2 / 11 / 05

Appendix B

DEFINITIONS:

Noise is simple part of a structure transformed into air pressure variations

Directivity is a measure of the difference in radiation with direction, and is usually stated as a function of angular position around the acoustical centre of the source, also as a function of frequency

Time weighting:	The time weight determines the speed at which the measuring instrument follows the input signal. The fast-time weighting follows the input signal more closely than the slow-weighting due to a faster response time in measuring noise pressure levels. (Bruel & Kjaer 2001).
Continuous noise:	Continuous noise is where the noise levels remain constant for long periods of time.

Figure 36: Continiuos noise (Bruel & Kjaer 2001)

Line source:	A line source is where the source shape is straight and long. The sound pressure from a line source drops by 3dB for a doubling of the distance from the source, because the sound spreads out from the source as a wavefront in a direction perpendicular to the line source. (Bruel & Kjaer Sound & Vibration Measurement A/S)
Distance from source:	The measured distance away from the noise source where the noise measurements were taken. (m)
Height above source:	The measured height above the source where the noise measurements were taken. (m)

Frequency content of the noise:	Frequency range showing the bands which have content (Hz)
Relative humidity	Relative humidity of air (%)
Ambient pressure:	Barometric pressure (hPa)
Ambient temperature:	Dry bulb temperature (°C).
Wind	Wind speed can bend the path of sound to "focus" it in different directions. Speed (m/s) Direction (North)
Temperature	Temperature affects noise, as does the wind, by changing the focal point. As the air temperature rises it causes a temperature inversion focusing the sound on the ground, and the opposite is true for a fall in temperature (Bruel & Kjaer Sound & Vibration Measurement A/S)
L_{Aeq} **:**	The equivalent sound pressure level L_{eq} is an electronically calculated mean RMS level which integrates all the energy in a signal measured over a certain time period, T. L_{eq} can be considered as the continuous noise which would have the same total energy as the real fluctuating noise measured over the same period of time. (dB) (Bruel & Kjaer Sound & Vibration Measurement A/S)
$L_{Aeq(1hr)}$	Is the highest tenth percentile hourly A-weighted L_{eq}
$\mathbf{L_W}$	Sound power level of source in dB
$\mathbf{A_{propagation}}$	Propagation attenuation in dB

A_{div}	The attenuation as a result of geometrical spreading describes the manner in which the sound wave fronts radiate outward from a source. For a line source, this "spreading" of wave fronts takes on a cylindrical form. The ever increasing area of the cylinder is proportional to the radial distance from the line source. The acoustical intensity (net energy flowing through a unit area) in decibels changes with distance.
A_{atm}	The attenuation as a result of air absorption
A_{gr}	The attenuation due to ground absorption
A_{misc}	The attenuation due to miscellaneous effects (weather)
A_{reflec}	The correction due to the contribution of reflections

Sound pressure levels

$$L_P = L_W + D_C + C_D - A_{Propagation}$$

L_P = Equivalent noise level at receiver point in dB

L_W = Sound power level of source in dB (ref = 1 pW)

D_C = Directivity correction in dB if the source does not emit sound equally in all directions

C_D = Correction in dB if the source is not always active. For example, the long-term level is reduced by 3dB if the source is active 12 hours a day

$A_{Propagation}$ = Propagation attenuation in dB

$$L_{p\theta} = L_w + DI_\theta - 20\log r - A_e - 11 \quad dB$$

$L_{p\theta} =$ sound-pressure level at a receiver located in the direction θ, a distance r (in m) from source, dB *re* 2×10^{-5}

$L_w =$ sound-power level of the source, dB *re* 10^{-12}

$DI_\theta =$ directivity index of source in the direction θ, dB (note:even if the source in nondirective, DI = 3 dB for hemispherical radiation)

$r =$ distance of receiver from source, m

$A_e =$ excell attenuation caused by environmental conditions, dB

$11 \approx$ 10 log 4π

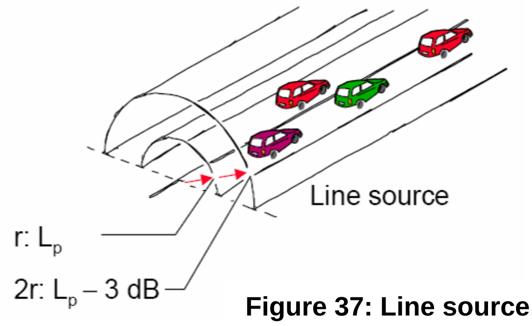


Figure 37: Line source (Bruel & Kjaer 2001)

Discrete sources on a line.

A Common line source is freely flowing automobile traffic on a flat highway. Let us assume *n point sources distance b apart* each radiating different (incoherent) sounds, but all of the same strength. The sound-pressure level L_p at an observer for loss-free air and ground is determined from

$$L_p = L_{W_1} + 10\log\left(\frac{\alpha_1 - \alpha_2}{r_0 b}\right) + \Delta L - 8 \quad dB$$

$L_p =$ sound-pressure level

$L_{W_1} =$ sound-power level of each of the incoherent sources,assumed equal in power, dBre 10^{-12} *watt*

$\alpha_1 - \alpha_2 =$ aspect angle of the n sources, radians (Note: α_1 and α_2 may take on both positive and negative values, but $\alpha_n > \alpha_1$.)

$r_0 =$ perpendicular distance from the line to the observer,m

$b =$ distance between two adjacent sources,m

$n =$ number of sources

Excess Attenuation

$A_{e1} =$ effect of the difference in value of ρc from 400mks rayls when the ambient temperature and barometric pressure differs appreciably from the values given in table 2.4 and figure 2.3

$A_{e2} =$ attenutation by absorption in the air, dB

$A_{e5} =$ attenuation by grass, shrubbery, and trees

$A_{e6} =$ attenuation and fluctuation, owin to wind and temperature gradients, to atmospheric turbulence, and the characteristics of the ground, dB

Free field grazing incidence

Care must be taken that a specific microphone is used at the appropriate angle, since there maybe 15 dB differences at frequencies above 10,000Hz between various types of membranes. Must have spirit level to make sure mic is at 90 degrees. All microphones have resonances, and in the best design these are either critically damped or exist beyond the frequency range of interest for the microphone which is the B&K 4189. Typical vibration sensitivities for condenser microphones are of the order of 85 to 90 dB L_P per g RMS. Condenser microphones have minimum mass consisting simply of the thin diaphragm itself, and they also have the minimum vibration sensitivity

The biggest increase in "sensitivity" is obtained when the sound wave comes from a direction perpendicular to the diaphragm (defined as 0° incidence). At other angles the increase will be less pronounced as shown here(Bruel & Kjaer 2001)

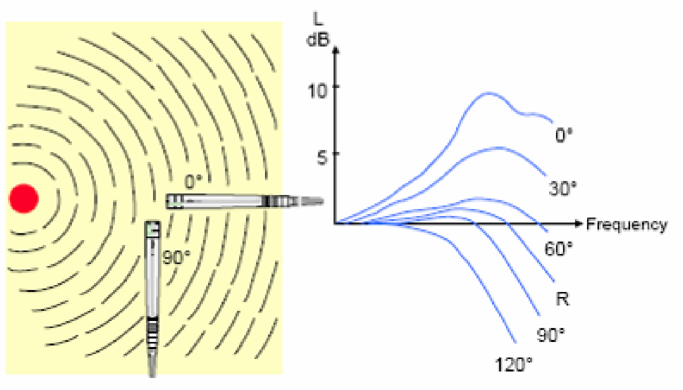


Figure 38: Free field correction (Bruel & Kjaer 2001)

Appendix C

Site Diagrams:

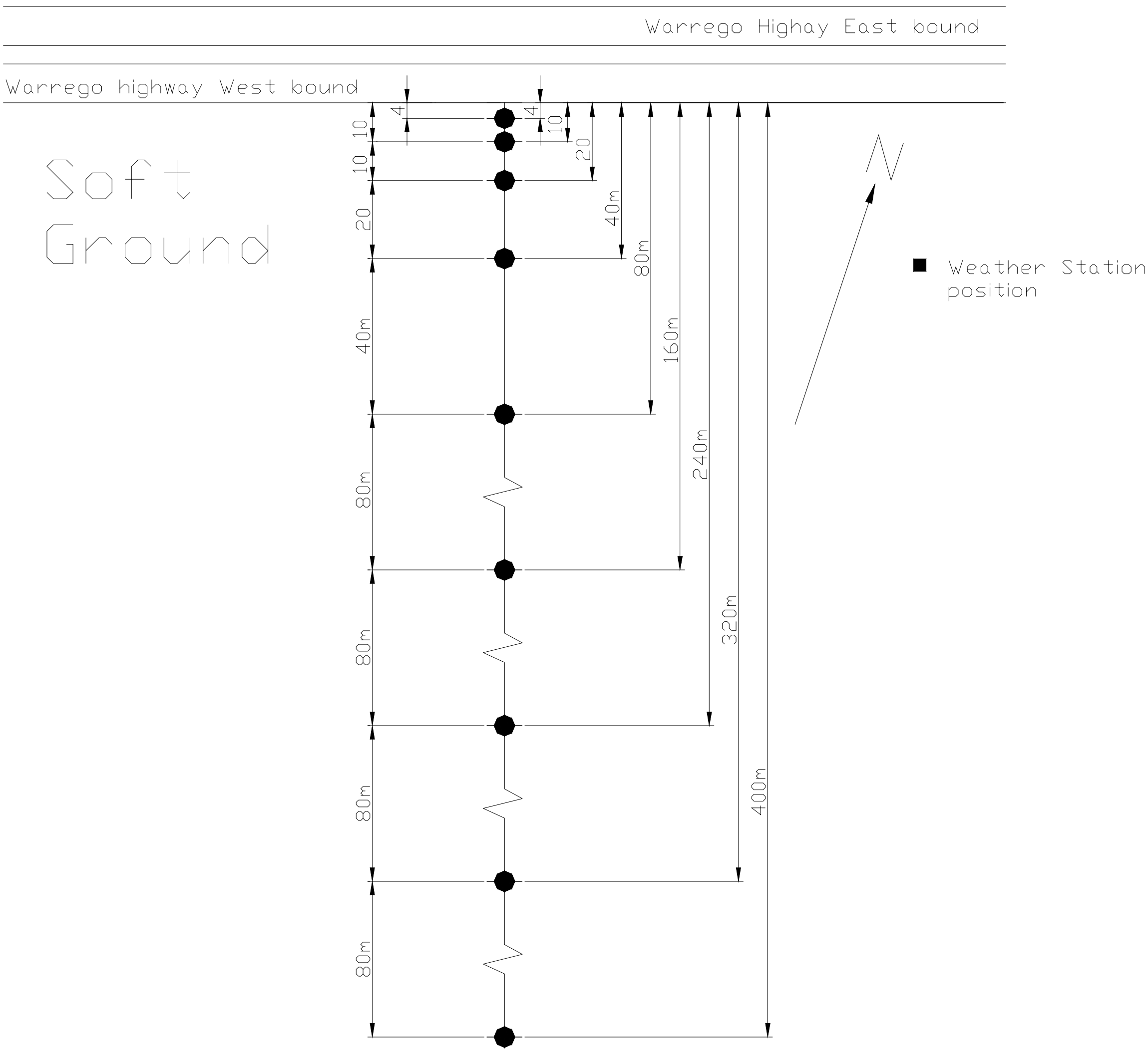


Figure 39: Site view (Drawn by Robert Grant)

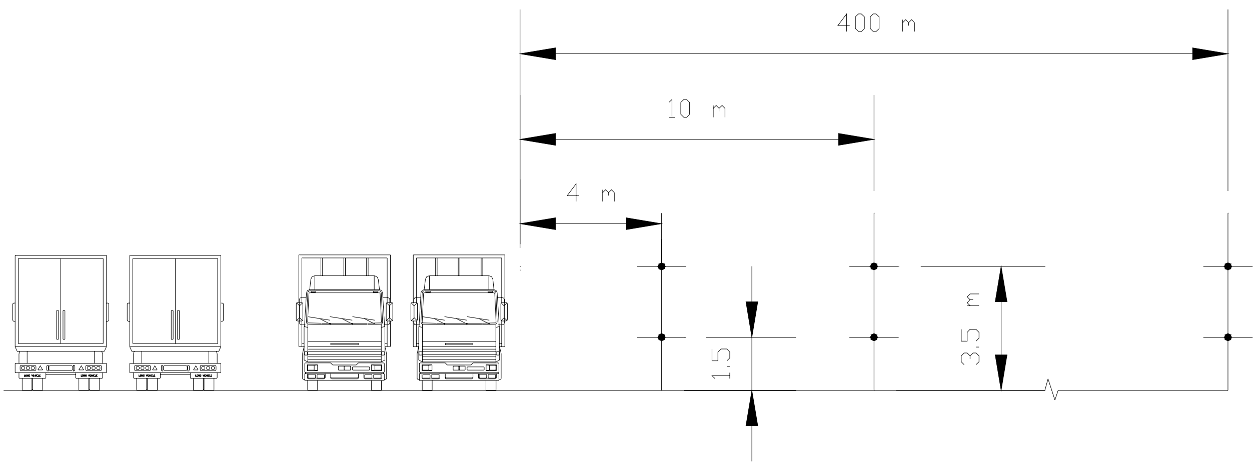


Figure 40: Side view (Drawn by Robert Grant)

Appendix D

CoRTN charts

CoRTN flow chart

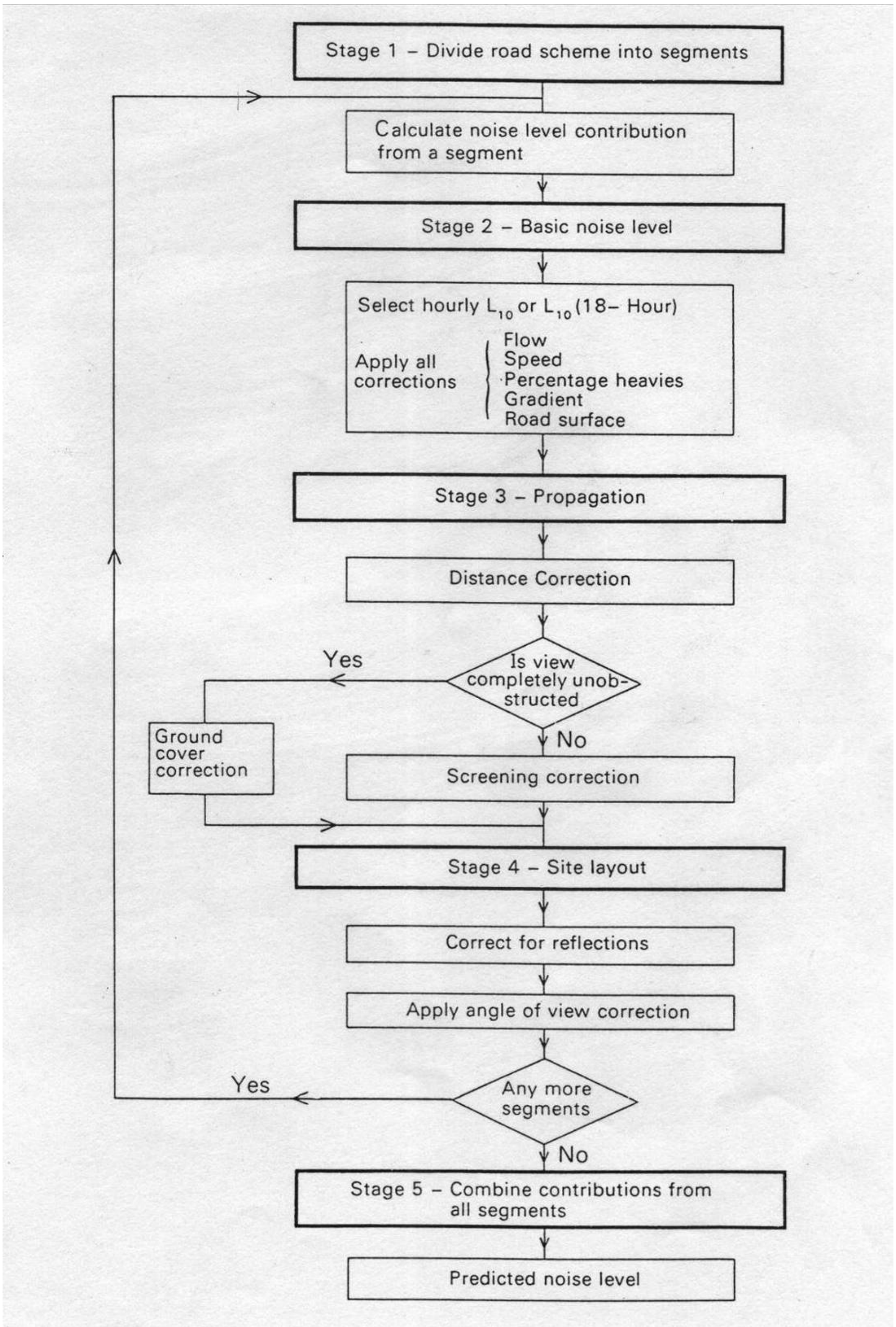
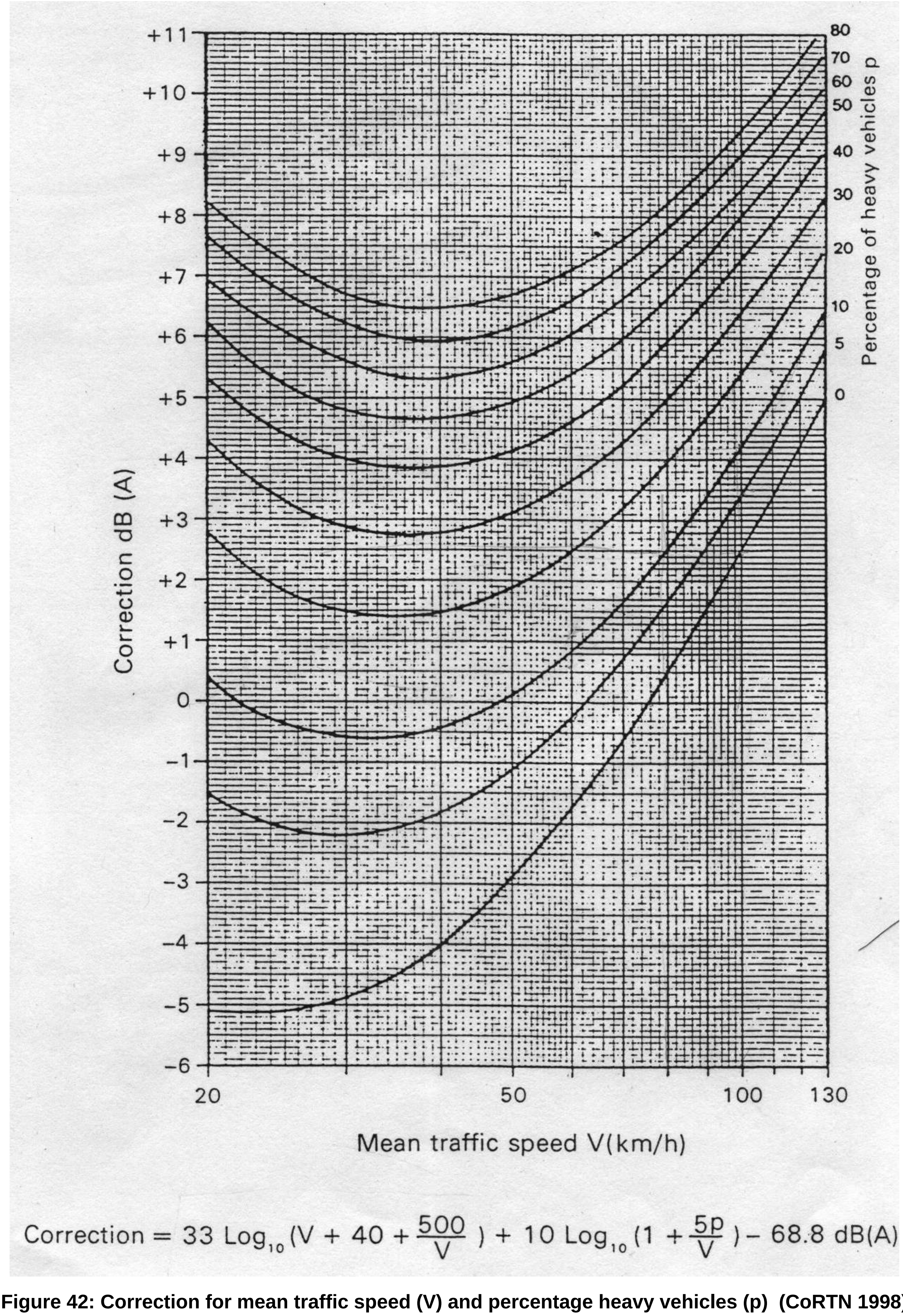


Figure 41: Flow chart for predicting noise from road schemes (CoRTN 1988)

Correction for mean traffic speed (V) and percentage heavy vehicles (p)



$$\text{Correction} = 33 \log_{10}\left(V + 40 + \frac{500}{V}\right) + 10 \log_{10}\left(1 + \frac{5p}{V}\right) - 68.8 \text{ dB(A)}$$

Figure 42: Correction for mean traffic speed (V) and percentage heavy vehicles (p) (CoRTN 1998)

Correction for low traffic flow

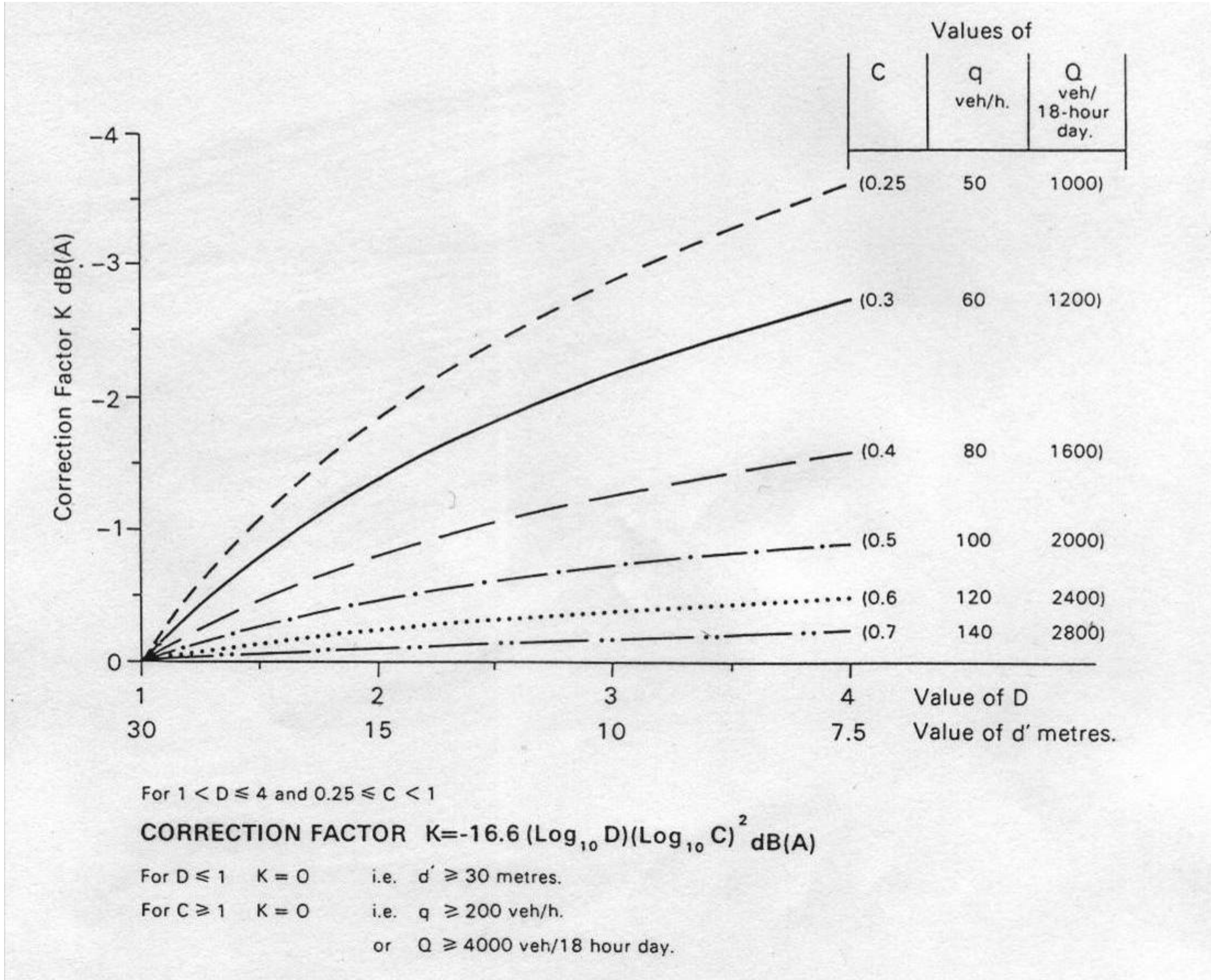


Figure 43: Correction for low traffic flow, K (CoRTN 1988)

Correction for ground absorption as a function of horizontal distance from edge of nearside carriageway (d), the average height of propagation (H) and the proportion of absorbent ground (I)

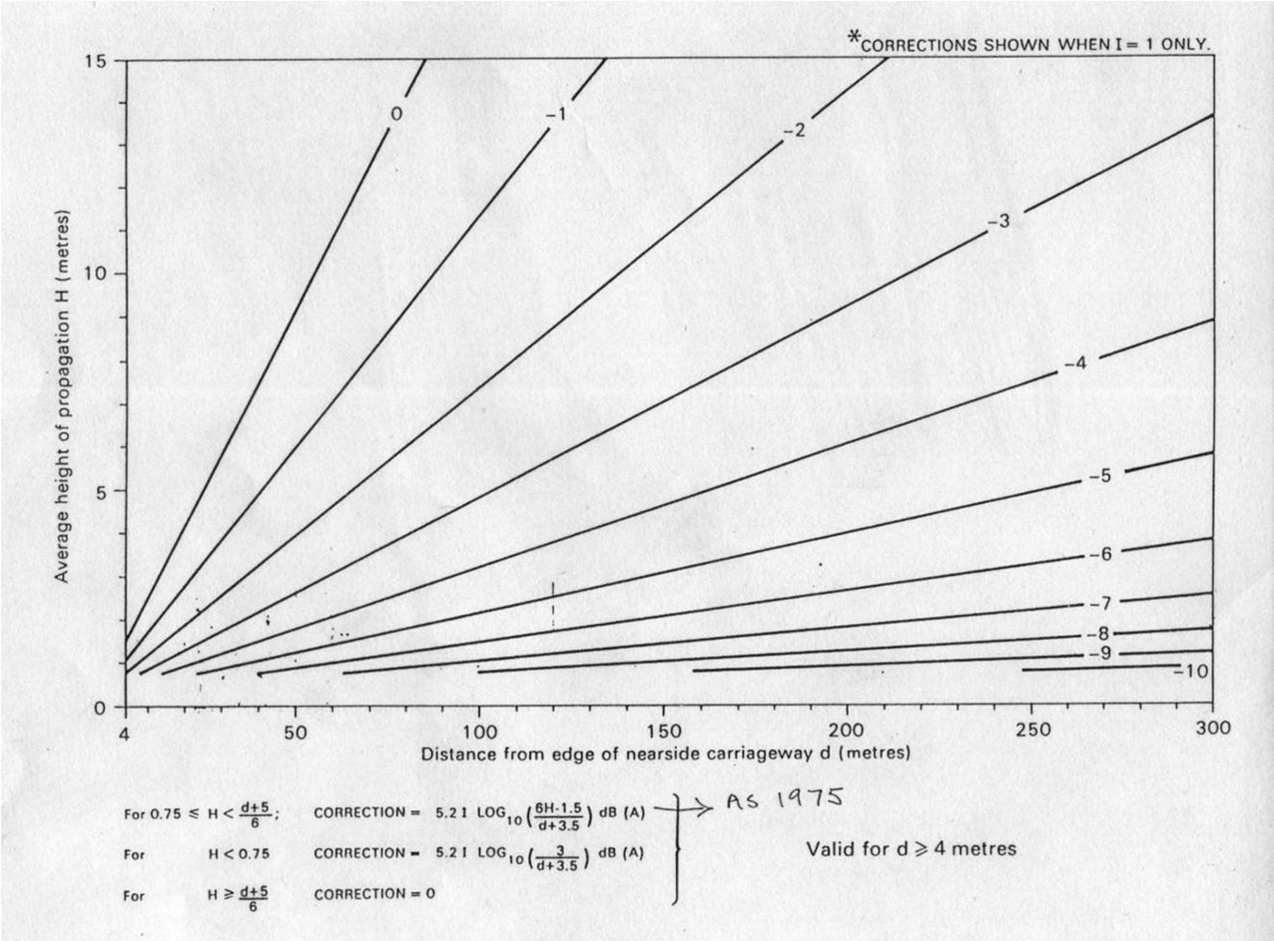


Figure 44: Correction for ground absorption as a function of horizontal distance from edge of nearside carriageway (d), the average height of propagation (H) and the proportion of absorbent ground (I)*. (CoRTN 1988)

Prediction of basic noise level hourly L10 in terms of total hourly flow (q)

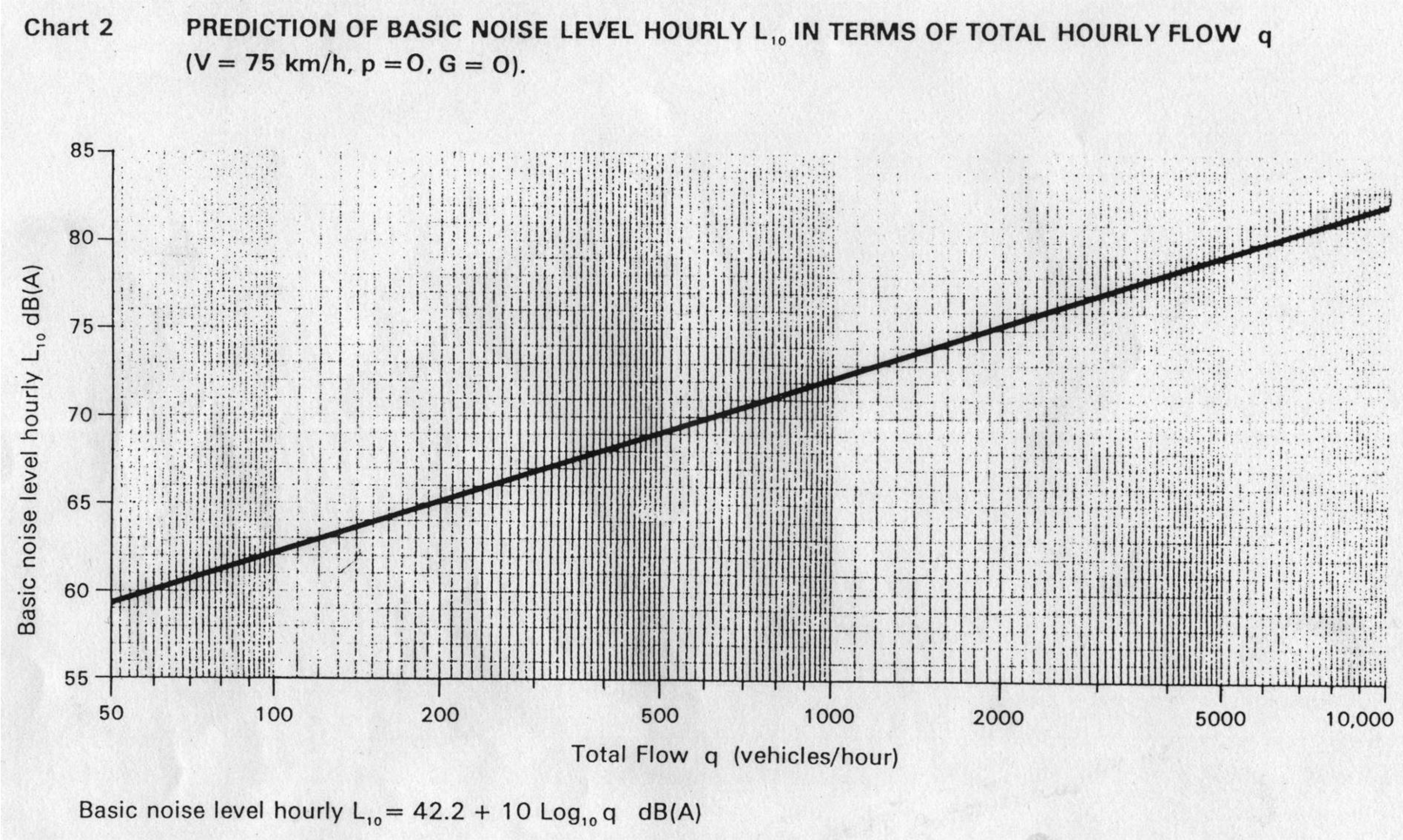


Figure 45: Prediction of basic noise level hourly L10 in terms of total hourly flow (q) (V=75km/h, p=0, G=0). (CoRTN 1988)

Correction for distance as a function of horizontal distance from edge of nearside carriageway (d) and the relative height between the reception point and the effective source position (h).

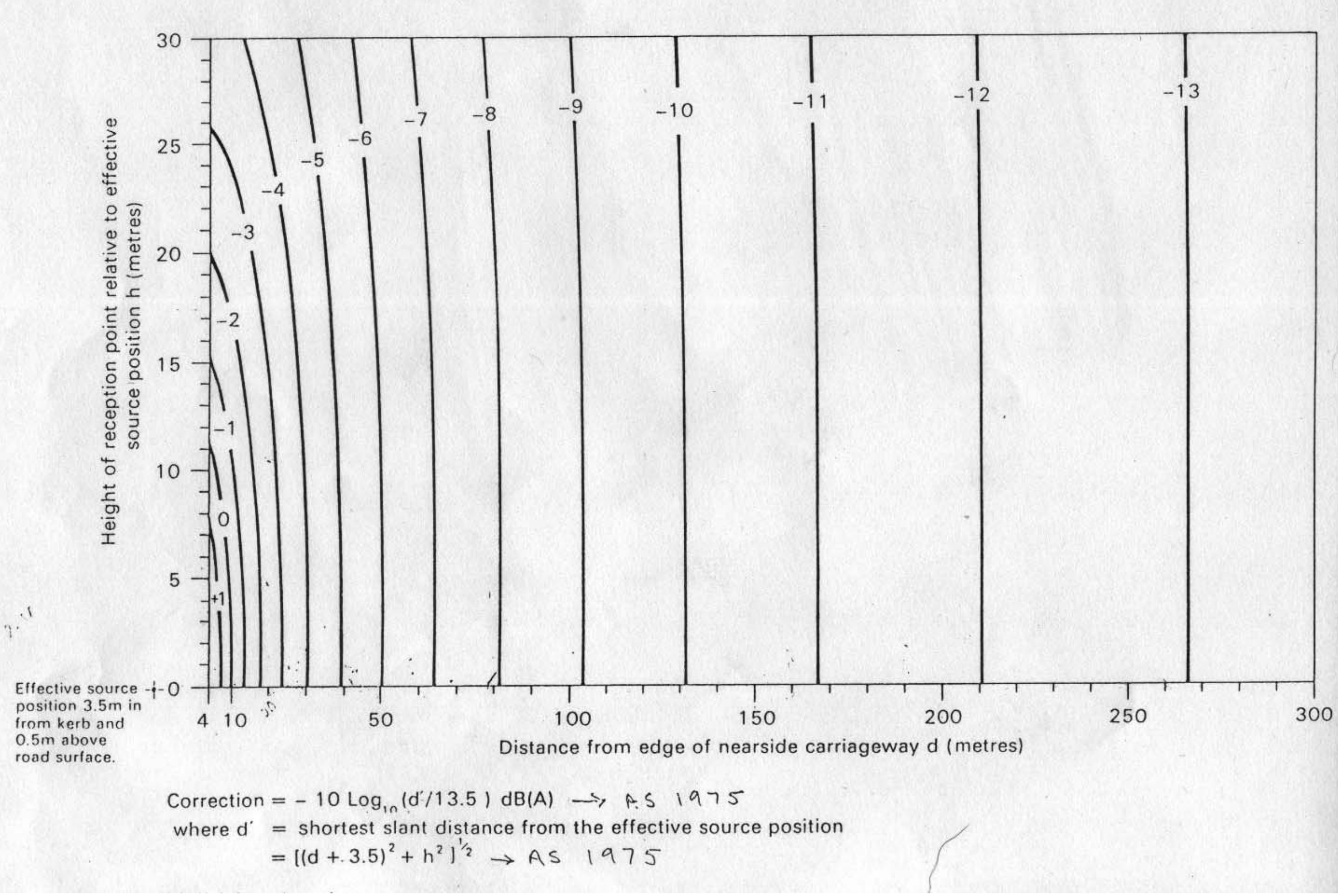


Figure 46: Correction for distance as a function of horizontal distance from edge of nearside carriageway (d) and the relative height between the reception point and the effective source position (h). (CoRTN 1988)

Appendix E

Table 1: Risk Management Chart

Discription of Hazards	People at risk	Number at risk	Parts of body	Risk level
Taking photos of the pavement type	All in area	1		Low (must face the traffic at all times and step away when the traffic nears)
Setting up of monitoring equipment near the road	All in area	1		Low (must face the traffic at all times and step away when the traffic nears)
Sun exposure	All in area	1		Low

Categories	Short term controls	Long term controls	Completion Details
Design Substitution Redesign	Always face the traffic when working near the road		Employer: Main Roads Noise and Vibration Branch Prepared by: Robert Grant Date 25/4/05

Separation Administration			Assented to by: Cedric Roberts Senior Engineer (technical services)
P.P.E	Reflective safety vest, sun screen, water, hat, and a long sleeve shirt		Signature Date

Appendix F

Equipment sheets

Check Lists for field measurements

Why are the measurements to be made –	Calibration of CoRTN
Where are they to be made –	Warrego highway
Are there and abnormal environmental conditions -	No
What are the sources of noise	Traffic
What are the operating characteristics of the source	
When are the noise sources operating	Continuously
What is the physical size of the source	1km
what is the characteristics of the source	Line
what is the character of the noise	Steady flow
What is the temporal of the noise	
Measurement techniques	comparison of noise levels over distance
Measurement procedure used	
Map showing position of sound sources, relevant objects, and observation points	

Operational checklist

Perform a visual inspection of the instrument to ascertain that it has not been damaged in transit	Done
Recheck batteries to ensure there is sufficient power for making accurate measurements	Done
Place the acoustic calibrator over the microphone and adjust the gain of the SLM	Done

to give the calibrated signal	

Equipment checklists

What is the principle of operation of the instrument	
Is there danger of damage to the instrument from signal overload, from to much heat, from twisting something to for or too hard	A fragile diaphragm and susceptibility to humidity <90% at $40^{\circ}C$, no condensation
What are the lowest and highest sound-pressure levels in each frequency band and what range of frequencies can be read correctly	Working on
Does using an extension cable with the system alter the	Not applicable
What is the inherent accuracy of the equipment	Frequency response. The response of a microphone at high frequencies is dependant upon the sound field and the geometry of the microphone. When the size of microphone exceeds about 1/20th of wavelength its presence disturbs the sound field Disturbance is dependant on wave length λ of the sound wave compared to the size of microphone For a cylindrical microphone with the diaphragm at one end, the disturbance is a maximum when λ is a little less than twice the radius
Calibration procedures should be followed meticulously	Done
Does the meter read RMS, average or peak levels of sound waves	RMS

Will adding equipment to the output of the instrument alter readings	Not applicable
Does the instrument take different readings when handheld or on a stand	Yes

Measurement records

Purpose of the measurement	
The standards used	AS…. ISO 1996 AS1055…
Types, models, serial numbers, or other identification characteristics for all instrumentation and equipment	Pre-polarized Free-field 1/2" microphone type 4189 B&K which perform better in humidity than other microphone types
Detailed description of the area in which measurements are made	See Site selection
Detailed description of primary noise source including dimensions, type of mounting, location within space, nameplate data, owner's tag number, and other pertinent facts such as speed and power rating at the time of measurement	See Site selection
Description of secondary noise sources including location, type, kinds of operation	Aeroplanes, irrigation sprinklers, birds, car horns
Location of engineers, observers (including names), worker, if any, during the measurements	Robert Grant, no observers
Measurement positions including the orientation of the microphone diaphragm relative to the direction to the source	1.5m and 3.5m
Barometric pressure, temperature, wind velocity (speed and direction), and humidity, if appropriate	Shown on Monitoring sheets
Results of calibration and operational tests	Shown on Monitoring sheets
Measured frequency-band levels at each microphone position	See appendix
measured frequency-band background noise levels	See appendix
Date time and location	See data table

Prevailing conditions	Fine
Nature/state of ground between source and receiver	Three sites – Hard, soft, and dense bush
Source variability	slightly
Measurement data, start and stop time	On data sheets
Number of measurements made	54

Appendix G

Addition and Subtraction of dB Levels

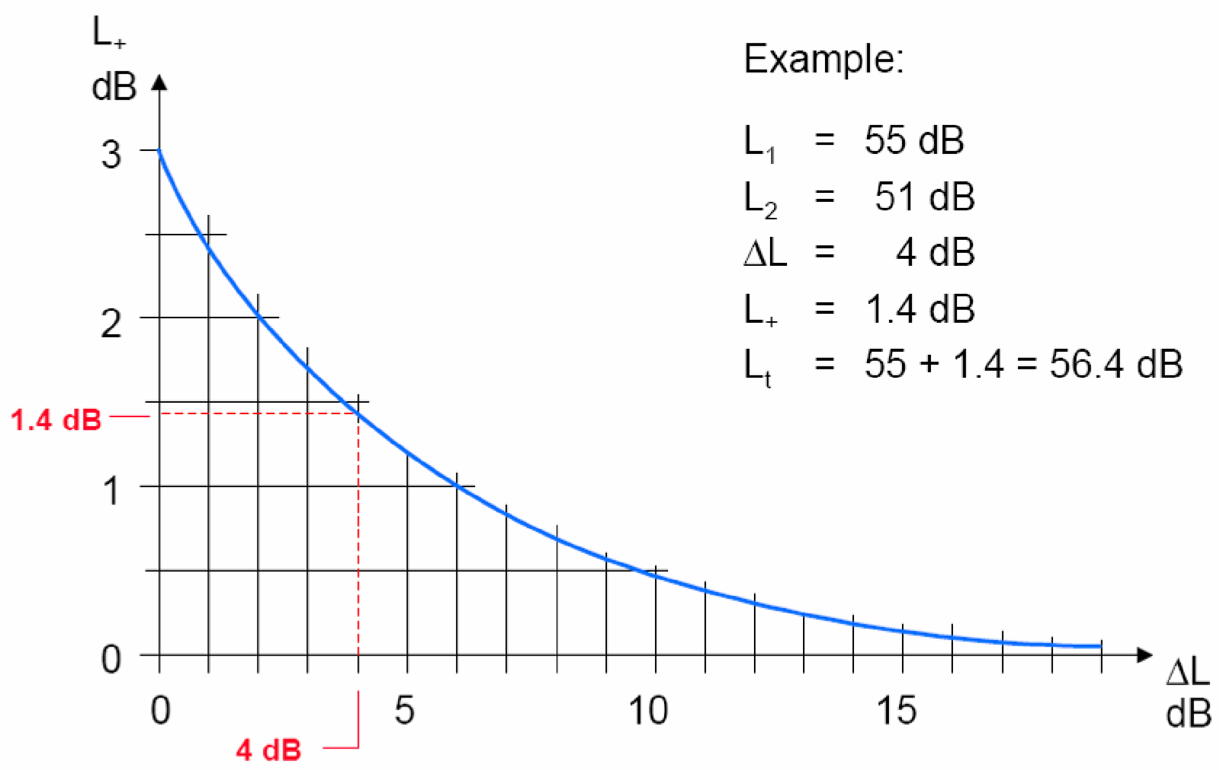


Figure 47: Addition of noise levels (Bruel & Kjaer 2001)

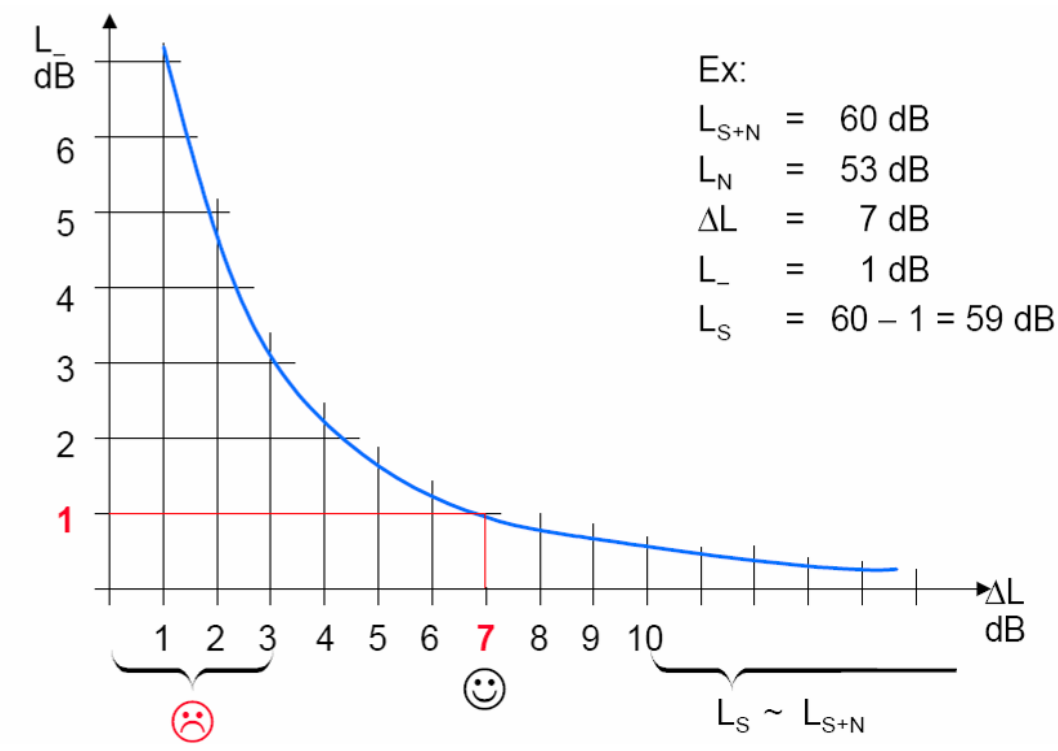


Figure 48: Subtraction of noise levels (Bruel and Kjaer 2001)

Table 5: CoRTN correction calculations and correlation calculations

	Bush 1.6m					Bush 3.6m				
Distance	CoRTN	B_CoRTN Total 1.6m	Bush (1.5m) LIO	LSD	Logger	CoRTN	B_CoRTN Total 3.6m	Bush (3.5m) LIO	LSD	Logger
4	768	78.749	77.6	60.5	78.2	73.9	75.977	80.6	66.2	79.1
10	788	80.771	788	61.4	77.8	75.9	78.431	75.9	64.9	80.15
20	765	76.630	75	61.3	78.9	73.6	74.467	74.2	62.1	79.075
40	737	71.849	67.8	56.1	77.9	70.8	69.832	71.2	58.8	78
80	709	67.034	61.4	52.1	77.6	68	65.146	65.6	54.9	77.75
160	68	62.148	58.5	50.5	77.65	65.1	60.374	59.5	52.2	77.35
240	66.3	59.313	53.8	47.3	77.85	63.4	57.598	56.4	48.5	77.9
300	65.8	58.021	53.1	46.9	78.13	62.9	56.345	55.1	47.85	78.525
320			52.4	46.2	78.4			53.8	47.2	79.15
400			51.4	44.6	79.4			53.3	46.1	79.1
Chi Test		0.96281138					0.99958			
Correlation		0.99574082					0.97647			

	Soft 1.6m					Soft 3.6m				
Distance	CoRTN	S_CoRTN Total 1.6m	Soft (1.5) LIO	LSD	Logger	CoRTN	S_CoRTN Total 3.6m	Soft (3.5) LIO	LSD	Logger
4	65.5	67.449	74.5	46.9	75.8	69	70.949	77.5	55	75.3
10	67.5	69.471	67.5	43.4	75.6	71	72.971	71	53.8	75.15
20	65.2	65.330	63	41	76.1	68.7	68.830	70.8	53.1	75.3
40	62.4	60.549	58.8	46.3	75.45	65.9	64.049	66.2	54.5	75.15
80	59.6	55.734	59.8	49.4	75.5	63.1	59.234	59.7	51.1	75.45
160	56.7	50.848	52.4	43.7	75.7	60.2	54.348	56.8	47.1	75.3
240	55	48.013	50.1	41.1	76	58.5	51.513	53.2	44.8	75.8
300	54.5	46.721	50	41.35	75.7	58	50.221	53.4	44.45	75.35
320			49.8	41.6	75.4			53.5	44.1	74.9
400			48.1	40.8	75.8			50.4	44	75
Chi Test		0.97925					Chi Test	0.99201		
Correlation		0.92925						0.964836		

	Hard 1.6m					Hard 3.6m				
Distance	CoRTN	H_CoRTN Total 1.6m	Hard (1.5) LIO	LSD	Logger	CoRTN	H_CoRTN Total 3.6m	Hard (3.5) LIO	LSD	Logger
4	64	65.949	696	55.4	69.3	685	70.577	74	58.1	6995
10	66	67.971	66	55.3	69.55	705	73.031	705	55.4	68.45
20	63.7	63.830	60.1	48.4	69.6	682	69.067	682	528	69.55
40	60.9	59.049	57.3	47.2	69.5	65.4	64.432	629	51.1	69.35
80	58.1	54.234	526	43.2	69.86	626	59.746	559	46.2	6905
160	55.2	49.348	47.2	40	69.55	597	54.974	567	47.2	71.1
240	53.5	46.513	57	45.8	69.1	58	52.198	549	45.9	69.7
300	53	45.221	558	44.95	70.575	57 5	50.945	56.25	47.3	6965
320			546	44.1	72.05			57 6	48.7	69.6
400			547	44	70			55.4	45.1	70.5
Chi Test			0.5979					0.9886		
Correlation			0.7582					0.9302		

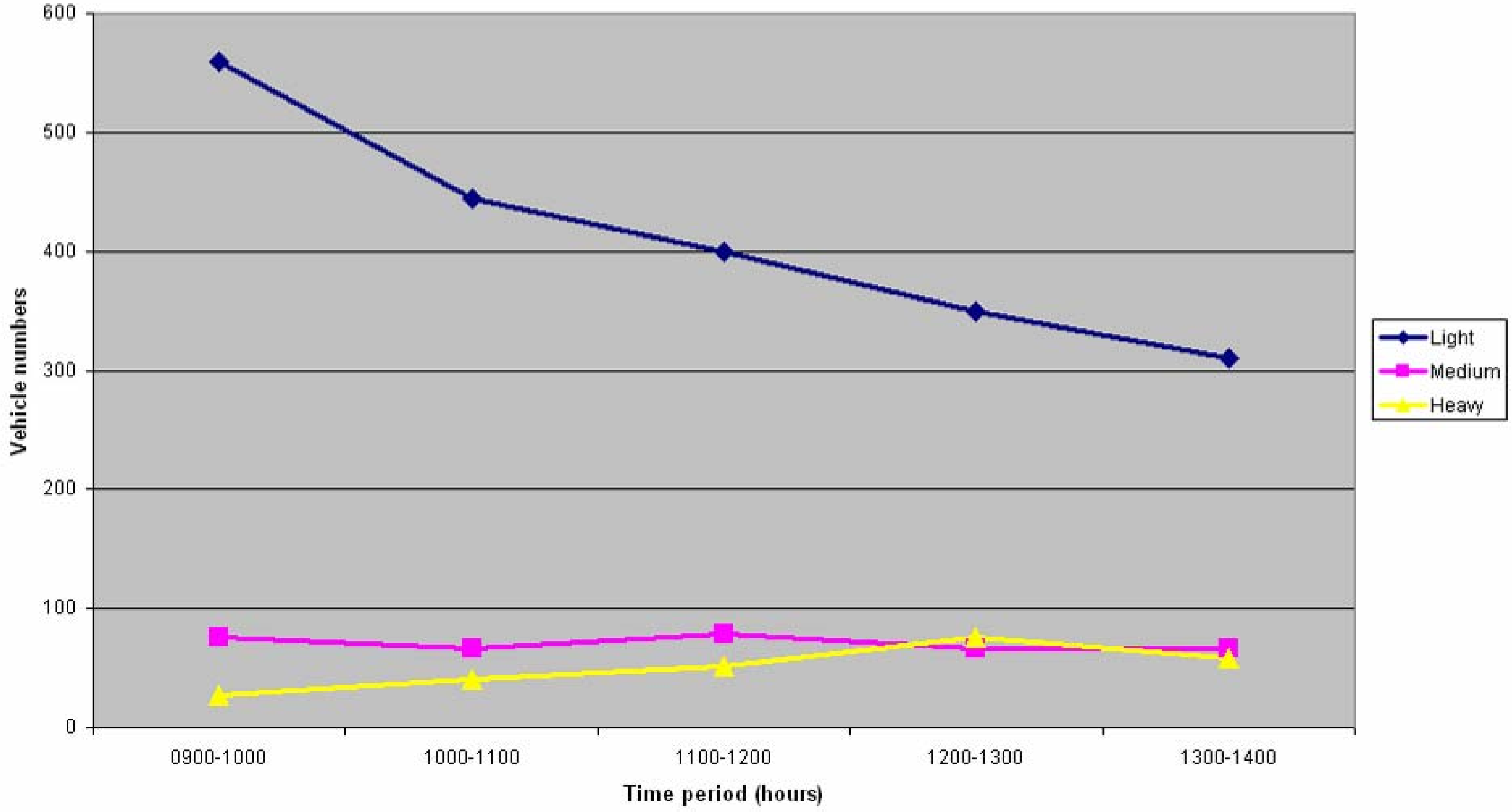
CoRTN Total 1.6m	CoRTN Total 3.6m
-1.949	-2.077
-1.971	-2.531
-0.130	-0.867
1.851	0.968
3.866	2.854
5.852	4.726
6.987	5.802
7.779	6.555
8.386	7.134

Hard Ground with vegetation

d	h1	h1	H1	H2	d'(1.6)	d'(3.6)	CoRTN (Dist) (1.6m)	CoRTN (Soft Ground) (1.6)	CoRTN Total 1.6m	CoRTN (Dist) (3.6m)	CoRTN (Ground) (3.6)	CoRTN Total 3.6m
4	1.5	3.5	1.25	2.25	7.649	8.276	2.468	0.000	-1.949	2.125	0.000	-2.077
10	1.5	3.5	1.25	2.25	13.583	13.946	0.027	2.363	-1.971	0.141	0.846	-2.531
20	1.5	3.5	1.25	2.25	23.548	23.759	2.416	3.401	-0.130	2.465	1.853	-0.867
40	1.5	3.5	1.25	2.25	43.526	43.641	5.084	4.650	1.851	5.096	3.050	0.968
80	1.5	3.5	1.25	2.25	83.513	83.573	7.914	6.039	3.866	7.917	4.476	2.854
160	1.5	3.5	1.25	2.25	163.507	163.537	10.832	7.512	5.852	10.833	5.947	4.726
240	1.5	3.5	1.25	2.25	243.505	243.525	12.962	8.396	6.987	12.962	6.831	5.802
320	1.5	3.5	1.25	2.25	323.503	323.519	13.795	9.029	7.779	13.796	7.464	6.555
400	1.5	3.5	1.25	2.25	403.503	403.515	14.755	9.524	8.386	14.755	7.958	7.134

Appendix H

Figure 49: Traffic chart for Thursday 13/8/2005 n the Warrego highway



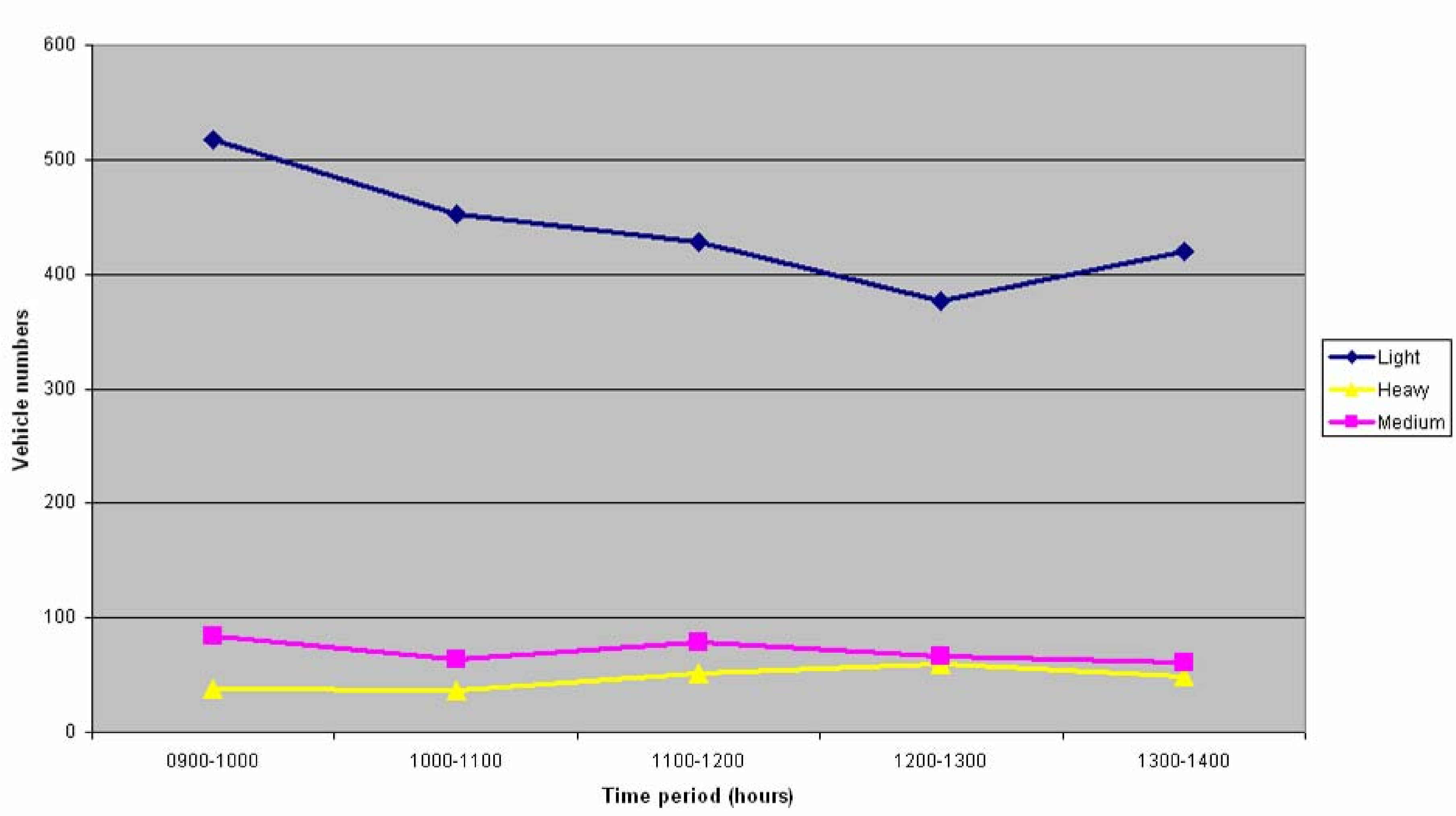


Figure 50: Traffic chart for Friday 14/8/2005 on the Warrego highway

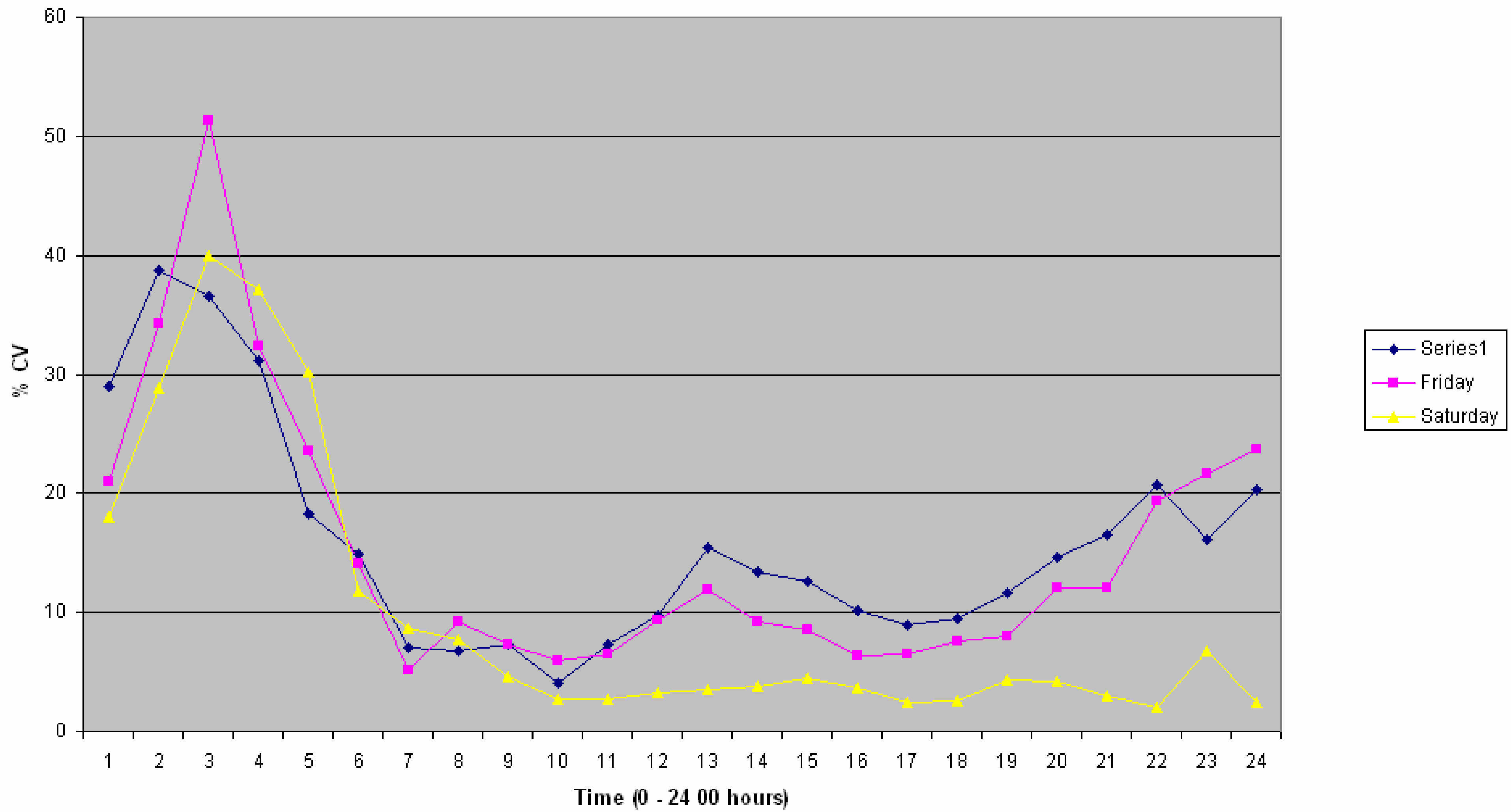


Figure 51: Percent commercial vehicle Vs time

Appendix I

Monitoring sheets

City	State Road	Owner	Equipment Used	Calibration Times	Stated Speed Limit	Measurement Dur.
Brisbane	Warrego Highway	Mrs Lorna Gunn	ARL-316	Start: 94.6 13/08/2005 8:54	100 km/h	10 minute
Operator	**Address**	**Date**	**Microphone Ht.**	Finish: 93.9	**Road Surface**	**Sample Interval**
Robert Grant	5000 Warrego Highway Gatton	13/08/2005 Thursday	1.5m	13/08/2005 14:24	Dense Graded Asphalt	10 minutes

Queensland Government
Department of Main Roads

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
13/08/2005	9:35	82.5	78.6	69.7	60.2	53.2	47.5	66.7	9:35 AM	0	12.4	45	1020.6	W	5.7	7.7
13/08/2005	9:40	81.7	73.3	68.9	60.6	48.4	43.5	65	9:40 AM	0	13	44	1020.6	W	5	7.5
13/08/2005	10:05	84.3	78.8	69.2	60.8	50.3	41.7	66.6	10:05 AM	0	14.7	40	1020.3	W	4.6	6.7
13/08/2005	10:10	80.3	79	69.9	60.9	50.3	47.5	66.9	10:10 AM	0	15	40	1020.3	W	4.6	6.5
13/08/2005	10:35	84	79.5	70.2	60.9	52.7	47.9	67.4	10:35 AM	0	16.6	37	1020.3	SW	4.5	6.5
13/08/2005	10:40	88.8	82.1	69	60.5	48.7	43.4	68.8	10:40 AM	0	16.8	37	1020.3	SW	4.5	6
13/08/2005	11:05	91.1	83.4	71.1	61.8	49.2	44.8	70.8	11:05 AM	0	16.5	43	1020.2	SW	4.1	5.7
13/08/2005	11:10	78.8	72.9	67.9	59	52.5	48.8	64	11:10 AM	0	16.7	42	1020.2	SW	4.1	6
13/08/2005	11:35	83.1	79.5	70.7	60.3	51.2	46.2	67.5	11:35 AM	0	18.1	40	1019.4	S	4.1	6.5
13/08/2005	11:40	85.2	79.3	69	57.2	48.6	45.9	66.5	11:40 AM	0	18.6	39	1019.4	S	4.1	6.5
13/08/2005	12:05	79.7	75.8	69.5	59.2	51.1	46	65.4	12:05 PM	0	19	38	1018.9	SE	4.1	6.7
13/08/2005	12:10	83.3	79.8	69.6	60.7	50.4	45.3	66.9	12:10 PM	0	19.2	38	1018.9	SE	4.5	6.5
13/08/2005	12:35	84	79.7	69.5	61.3	53	48.9	66.9	12:35 PM	0	19.7	37	1018.8	SE	4.5	6.8
13/08/2005	12:40	76.2	73.7	68.7	58.8	51.8	46	64.3	12:40 PM	0	19.8	37	1018.8	SE	5	9
13/08/2005	13:05	81.6	80.3	71.5	62.4	55.4	50.3	68.4	1:05 PM	0	20.5	36	1018.2	SE	5.7	9.3
13/08/2005	13:10	85.6	81.2	72.6	64.3	56	51.7	69.9	1:10 PM	0	20.1	39	1018.2	SE	6	9
13/08/2005	13:35	79	75.2	69	61.9	53.1	49.7	65.4	1:35 PM	0	19.8	37	1018.1	SE	6	8.8
13/08/2005	13:40	86	80.1	71	62.9	53.9	48.9	68.4	1:40 PM	0	19.8	38	1018.1	SE	6.7	8.7

Site Photos

Site Diagram

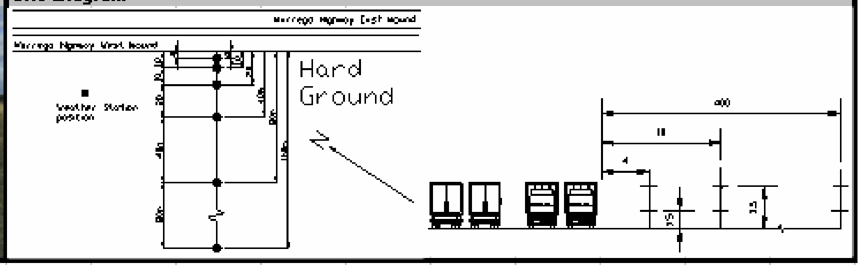


Figure 52: Monitoring sheet hard ground with out vegetation at 1.5 m

City	State Road	Owner	Equipment Used	Calibration Times		Stated Speed Limit	Measurement Dur.
Brisbane	Warrego Highway	Mrs Lorna Gunn	ARL-316	Start:	94.6	100 km/h	10 minute
				13/08/2005 8:54			
Operator	**Address**	**Date**	**Microphone Ht.**	Finish:	93.9	**Road Surface**	**Sample Interval**
Robert Grant	5000 Warrego Highway Gatton	13/08/2005 Thursday	3.5m	13/08/2005 14:24		Dense Graded Asphalt	10 minutes

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
13/08/2005	9:50	81.3	78.1	70.4	64.9	58	51.2	67.5	9:50 AM	0	17.1	52	1024.5	W	5.7	7.7
13/08/2005	9:55	81.3	74.2	69.5	62.7	56.4	53.5	66	9:55 AM	0	17.3	50	1024.5	W	5	7.5
13/08/2005	10:20	83.1	77.4	69.5	62.2	51.4	44.8	66.7	10:20 AM	0	18.5	46	1024.2	W	4.6	6.7
13/08/2005	10:25	81.9	72.2	67.4	59.7	50.6	46.5	64.3	10:25 AM	0	18.7	45	1024.2	W	4.6	6.5
13/08/2005	10:50	82.6	75.2	68.8	61.7	53.2	49	65.5	10:50 AM	0	20.4	45	1023.7	SW	4.5	6.5
13/08/2005	10:55	80	75.9	70.3	63.5	55.1	50.7	66.6	10:55 AM	0	20.6	44	1023.7	SW	4.5	6
13/08/2005	11:20	80.4	77.7	69.1	61	51.7	47.9	65.9	11:20 AM	0	19.2	48	1023.3	SW	4.1	5.7
13/08/2005	11:25	84.6	78.9	69.6	58.8	47.8	43.7	66.7	11:25 AM	0	19.3	47	1023.3	SW	4.1	6
13/08/2005	11:50	83	78.9	69.3	58.2	48.7	44.4	66.5	11:50 AM	0	20.9	43	1022.8	S	4.1	6.5
13/08/2005	11:55	82.5	73.4	68.8	59.3	47.3	44.2	65.2	11:55 AM	0	20.6	45	1022.8	S	4.1	6.5
13/08/2005	12:20	83.8	79.6	69.8	61.6	53.6	49.9	67.2	12:20 PM	0	20.5	44	1022	SE	4.1	6.7
13/08/2005	12:25	84.8	80.8	72.4	62.9	53	49.8	69.6	12:25 PM	0	20.6	45	1022	SE	4.5	6.5
13/08/2005	12:50	84.3	77.2	70.4	63.1	55.7	50.9	67.4	12:50 PM	0	19.8	44	1021.5	SE	4.5	6.8
13/08/2005	12:55	80.5	73.9	69	60.7	50.4	42.8	65	12:55 PM	0	19.9	47	1021.5	SE	5	9
13/08/2005	13:20	82.3	76.6	69.6	61.5	50.9	46.5	66.2	1:20 PM	0	21.1	41	1021	SE	5.7	9.3
13/08/2005	13:25	83.7	75.6	69.6	61	53.5	50.7	66.1	1:25 PM	0	21.3	43	1021	SE	6	9
13/08/2005	13:50	81.5	77.8	70.8	63.1	54.8	49.2	67.2	1:50 PM	0	21.4	41	1020.7	SE	6	8.8
13/08/2005	13:55	80.6	76.9	70.2	62.6	52.9	47.4	66.6	1:55 PM	0	20.8	43	1020.7	SE	6.7	8.7

Site Photos

Site Diagram

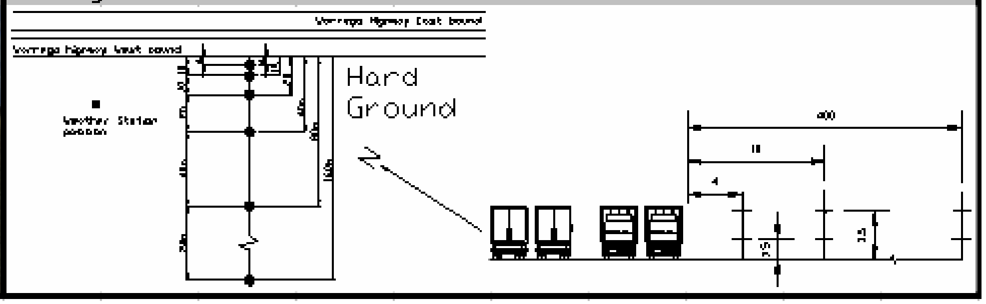


Figure 53: Monitoring sheet hard ground without vegetation at 3.5 m

City	State Road	Owner	Equipment Used	Calibration Times	Stated Speed Limit	Measurement Dur.
Brisbane	Warrego Highway	Brendon Clark	ARL-316	Start: 94.5 14/08/2005 8:38	100 km/h	10 minute
Operator	**Address**	**Date**	**Microphone Ht.**	Finish: 93.9 14/08/2005 13:53	**Road Surface**	**Sample Interval**
Robert Grant	5028 Warrego Highway Gatton	14/08/2005 Friday	1.5m		Dense Graded Asphalt	10 minutes

Queensland Government
Department of Main Roads

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
14/08/2005	9:10	88.4	81.3	76.2	62.3	49.9	38.6	71.4	9:10 AM	0	14.6	58	1025	W	3.6	4.6
14/08/2005	9:15	86.5	81.5	75.4	61.4	51.2	46.2	70.7	9:15 AM	0	15.1	56	1024.8	W	3	4.6
14/08/2005	9:35	88.1	83.5	76.3	61.2	46.4	38.1	71.9	9:35 AM	0	16.2	54	1024.7	SW	2.2	4.6
14/08/2005	9:40	83.1	79.9	74.9	60	44.5	38.5	69.4	9:40 AM	0	16.5	50	1024.7	S	1.8	4.6
14/08/2005	10:05	87	83.5	76.1	59.4	46.4	37.4	71.3	10:05 AM	0	17.8	49	1024.3	S	1.5	3.6
14/08/2005	10:10	91	86.5	76.1	62.2	50.3	44.6	73.1	10:10 AM	0	17.9	48	1024.3	S	3.7	3.6
14/08/2005	10:35	83.2	80	75.7	60.6	51.1	47.5	70.1	10:35 AM	0	18.7	48	1023.9	SE	3.7	3.6
14/08/2005	10:40	88.4	82.4	75.2	59.9	51.2	42.8	70.9	10:40 AM	0	19.1	49	1023.9	SE	3.6	3.6
14/08/2005	11:25	87.5	80.6	76.2	62	52.7	46.7	71	11:25 AM	0	19.3	47	1023.3	E	4.1	6.2
14/08/2005	11:30	80	78.7	74.8	60.6	52.3	49	68.9	11:30 AM	0	19.7	46	1022.9	E	4.1	6.2
14/08/2005	11:50	84.7	81.5	75.2	61.2	53.4	48.3	70.4	11:50 AM	0	20.9	43	1022.8	E	4.1	6.2
14/08/2005	11:55	85.5	80.6	76.2	63.7	56.9	53.3	71.3	11:55 AM	0	20.6	45	1022.8	E	4.1	6.2
14/08/2005	12:20	86.5	80	75.8	61.2	51.2	45.7	70.6	12:20 PM	0	20.5	44	1022	E	4.6	8.2
14/08/2005	12:25	88.8	83.4	76.2	61.8	50.3	41.3	72.1	12:25 PM	0	20.6	45	1022	E	4.6	8.2
14/08/2005	12:50	84.3	79.6	74.7	62	53.3	45.6	69.7	12:50 PM	0	19.8	44	1021.5	E	4.8	8.2
14/08/2005	12:55	86.4	81.4	76.1	60.9	47.2	42.3	70.9	12:55 PM	0	19.9	47	1021.5	E	4.6	8.2
14/08/2005	13:20	88.5	80.6	75.5	61.9	53.1	46.1	70.6	1:20 PM	0	21.1	41	1021	E	5.1	7.2
14/08/2005	13:25	85.8	80	76.1	62.2	52.7	47.2	70.8	1:25 PM	0	21.3	43	1021	E	4.6	9.3

Site Photos

Site Diagram

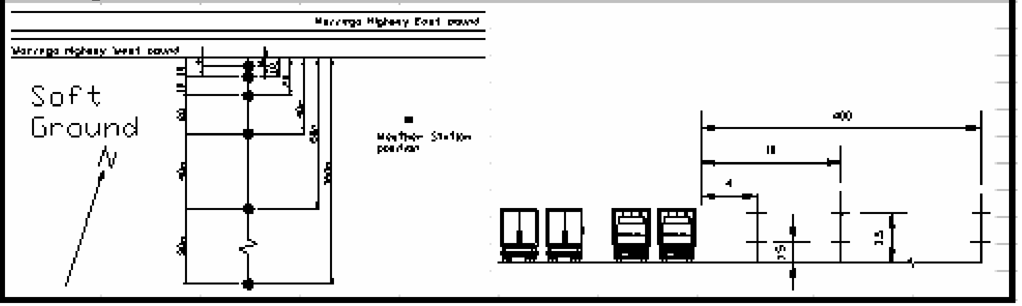


Figure 54: Monitoring sheet Soft ground at 1.5 m

City	State Road	Owner	Equipment Used	Calibration Times		Stated Speed Limit	Measurement Dur.	
Brisbane	Warrego Highway	Brendon Clark	ARL-316	Start:	94.5	100 km/h	10 minute	Queensland Government Department of Main Roads
				14/08/2005 8:38				
Operator	**Address**	**Date**	**Microphone Ht.**	Finish:	93.9	**Road Surface**	**Sample Interval**	
Robert Grant	5028 Warrego Highway Gatton	14/08/2005 Friday	3.5m	14/08/2005 13:53		Dense Graded Asphalt	10 minutes	

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
14/08/2005	9:20	89.6	80.8	75.3	60.3	45.7	40	70.5	9:20 AM	0	15.4	55	1024.8	W	3.6	4.6
14/08/2005	9:25	89.5	83.9	75.3	58.7	46.8	41.9	71.6	9:25 AM	0	15.7	53	1024.8	W	3	4.6
14/08/2005	9:50	92.4	83.6	75.1	58.5	48.1	45.5	71.6	9:50 AM	0	17.1	52	1024.5	SW	2.2	4.6
14/08/2005	9:55	83.3	79.7	75.2	57.2	40.6	36.7	69.5	9:55 AM	0	17.3	50	1024.5	S	1.8	4.6
14/08/2005	10:20	82.8	79.5	75.8	61.9	52.9	48	70.3	10:20 AM	0	18.5	46	1024.2	S	1.5	3.6
14/08/2005	10:25	81.2	79.4	74.8	60.2	48.2	43.4	69.2	10:25 AM	0	18.7	45	1024.2	S	3.7	3.6
14/08/2005	10:50	89.1	84.4	77.3	65.3	55.6	52.1	73	10:50 AM	0	20.4	45	1023.7	SE	3.7	3.6
14/08/2005	10:55	81.2	79.4	77	63	53.4	45.5	71.3	10:55 AM	0	20.6	44	1023.7	SE	3.6	3.6
14/08/2005	11:35	82	79.2	75.2	59.9	50	47	69.7	11:40 AM	0	20.9	43	1022.9	E	4.1	6.2
14/08/2005	11:40	89.6	81.3	75.7	59.3	50.7	43.9	71.3	11:45 AM	0	21.1	41	1022.8	E	4.1	6.2
14/08/2005	12:05	88.3	80.4	75.6	60.6	51.2	44.9	70.8	12:05 PM	0	19.7	46	1022.4	E	4.1	6.2
14/08/2005	12:10	82.3	79.4	75	58.7	51.8	44	69.2	12:10 PM	0	19.3	47	1022.4	E	4.1	6.2
14/08/2005	12:40	86.6	81.2	75.8	62.5	54.8	50.3	70.9	12:35 PM	0	20.7	42	1021.7	E	4.6	8.2
14/08/2005	12:45	81.5	79.7	75.8	60.5	51.8	48.1	70	12:40 PM	0	20.4	44	1021.7	E	4.6	8.2
14/08/2005	13:05	88	80.6	74.4	59.4	49.3	42.6	70	1:05 PM	0	19.9	45	1021.2	E	4.8	8.2
14/08/2005	13:10	93.9	79.8	75.4	61.2	50.1	44	71.3	1:10 PM	0	19.9	47	1021.2	E	4.6	8.2
14/08/2005	13:35	81.4	79.2	75.2	61	51.7	48.1	69.6	1:35 PM	0	21.4	42	1020.9	E	5.1	7.2
14/08/2005	13:40	87.2	79.8	74.8	61.7	53.4	48.6	70	1:40 PM	0	21.5	39	1020.9	E	4.6	9.3

Site Photos

Site Diagram

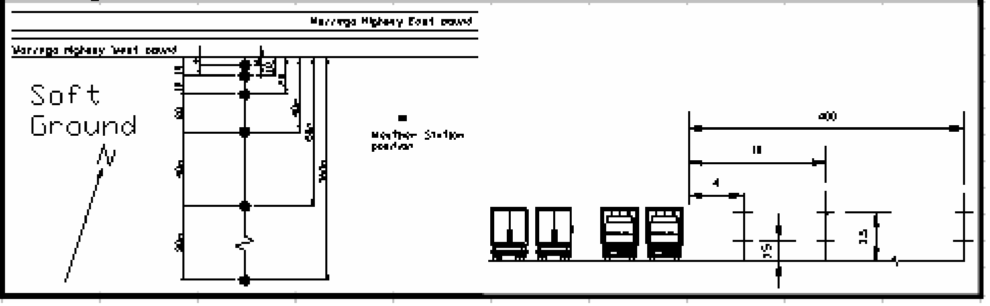


Figure 55: Monitoring sheet Soft ground at 3.5 m

City	State Road	Owner	Equipment Used	Calibration Times		Stated Speed Limit	Measurement Dur.
Brisbane	Warrego Highway	Main Roads Works Depot	ARL-316	Start:	94.5	100 km/h	10 minute
				15/08/2005 10:02			
Operator	**Address**	**Date**	**Microphone Ht.**	Finish:	93.9	**Road Surface**	**Sample Interval**
Robert Grant	Fotheringham Rd	15/08/2005	3.5m	15/08/2005 15:21		Dense Graded Asphalt	10 minutes
		Saturday					

Queensland Government
Department of Main Roads

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
15/08/2005	11:20	90.6	86.4	80.1	73.5	62.9	59.8	76.8	11:20 AM	0	21.4	35	1026.8	N	4.6	6.7
15/08/2005	11:25	87.8	85.9	78.1	69.9	60.9	51.8	74.9	11:25 AM	0	21.2	36	1026.8	N	4.6	6.7
15/08/2005	11:50	92.9	87.5	81.3	72.9	63.8	53.7	77.6	11:50 AM	0	21.4	32	1026	N	4.6	6.5
15/08/2005	11:55	88.4	86.5	79	71.5	64.3	58.9	75.9	11:55 AM	0	21.6	33	1026	NE	4.6	6.1
15/08/2005	12:20	87.9	84.9	77.9	69.6	61	54.8	74.4	12:20 PM	0	21.8	33	1025.5	E	2.6	4.6
15/08/2005	12:25	88.8	85.1	77.9	69.2	56.5	50.1	74.1	12:25 PM	0	22	34	1025.5	E	2.6	4.6
15/08/2005	12:35	88.9	84.8	77.9	70.1	61.4	52.4	74.3	12:35 PM	0	22	34	1025.3	N	2.6	4.6
15/08/2005	12:40	87.6	85.5	78.1	69.7	61.2	54.1	74.6	12:40 PM	0	21.9	34	1025.3	N	2.6	4.1
15/08/2005	13:05	88.2	85.5	77.7	69.6	62.3	59.3	74.7	1:05 PM	0	22.5	31	1024.9	N	1.5	3.6
15/08/2005	13:10	87.2	84.7	77.8	69.4	59.7	55	74.3	1:10 PM	0	22.6	31	1024.9	N	1.5	3.1
15/08/2005	13:35	88.8	86.8	77.7	69.9	61	56.2	74.9	1:35 PM	0	22.7	33	1024.4	N	1.5	3
15/08/2005	13:40	86.4	83	77	69.6	61.4	52.3	73.3	1:40 PM	0	22.9	33	1024.4	NE	1.5	7
15/08/2005	14:05	86.8	83	77.4	69.5	62.5	57.4	73.6	2:05 PM	0	22.6	33	1024	NE	2.6	4.1
15/08/2005	14:10	88.2	86.1	78.4	70.4	64.1	59.5	75.4	2:10 PM	0	22.4	34	1024	E	2.6	4.1
15/08/2005	14:35	90.9	85.6	79.7	72.9	65.3	60.6	76.1	2:35 PM	0	21.9	35	1023.7	E	2.6	4.1
15/08/2005	14:40	91.8	86.4	78.6	71.6	63.5	58.8	75.4	2:40 PM	0	22.1	35	1023.7	E	2.1	4.1
15/08/2005	15:05	88.1	85.5	79.3	74	66.3	61.6	76.1	3:05 PM	0	22.3	35	1023.3	SW	2.1	4.6
15/08/2005	15:10	90.7	86	78.9	73.6	66.6	62.9	76.1	3:10 PM	0	22.2	35	1023.3	S	2.1	4.6

Site Photos

Site Diagram

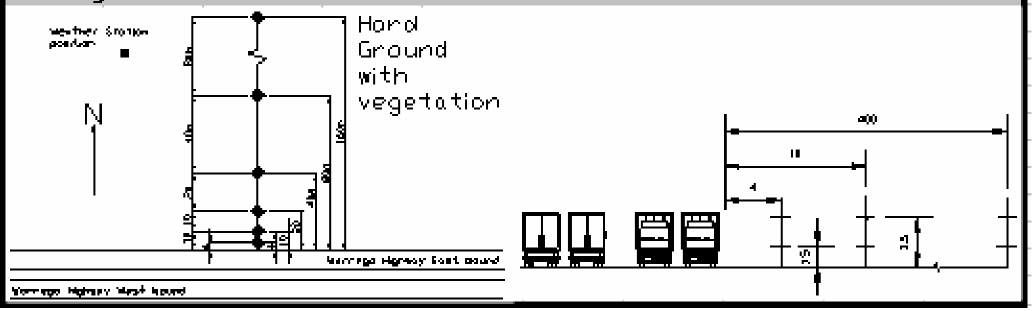


Figure 56: Monitoring sheet Hard ground with vegetation at 3.5 m

City	State Road	Owner	Equipment Used	Calibration Times		Stated Speed Limit	Measurement Dur.
Brisbane	Warrego Highway	Main Roads Works Depot	ARL-316	Start:	94.5	100 km/h	10 minute
				15/08/2005 10:02			
Operator	**Address**	**Date**	**Microphone Ht.**	Finish:	93.9	**Road Surface**	**Sample Interval**
Robert Grant	Fotheringham Rd	15/08/2005 Saturday	1.5m	15/08/2005 15:21		Dense Graded Asphalt	10 minutes

Date	End Time	Lmax	L1	L10	L50	L90	L99	Leq	End Time	Rain mm	Dry Bulb Temp	Relative Humidity %	Air Pressure hPa	Wind Direction	Av Wind Speed m/s	Wind Speed max m/s
15/08/2005	11:10	88.2	85.3	78.3	70.3	62.5	58	74.9	11:10 AM	0	21.7	37	1026.9	N	4.6	6.7
15/08/2005	11:15	88.6	85.5	78.1	69.6	61.9	56.1	74.5	11:15 AM	0	21.5	35	1026.8	N	4.6	6.7
15/08/2005	11:35	86.2	82.5	76.8	69.5	62.5	56.7	73	11:35 AM	0	21.6	34	1026.4	N	4.6	6.5
15/08/2005	11:40	88.1	85.3	78.8	70.5	64	59	75.2	11:40 AM	0	21.7	34	1026.4	NE	4.6	6.1
15/08/2005	12:05	89.6	87.5	78.8	71.3	63.3	57.6	76.1	12:05 PM	0	21.3	33	1025.8	E	2.6	4.6
15/08/2005	12:10	88.4	85.9	79	70.2	62.1	57.2	75.5	12:10 PM	0	21.3	35	1025.8	E	2.6	4.6
15/08/2005	12:20	87.9	84.9	77.9	69.6	61	54.8	74.4	12:20 PM	0	21.8	33	1025.5	N	2.6	4.6
15/08/2005	12:25	88.8	85.1	77.9	69.2	56.5	50.1	74.1	12:25 PM	0	22	34	1025.5	N	2.6	4.1
15/08/2005	12:50	86.3	83.7	77.3	69.5	59.2	48.3	73.6	12:50 PM	0	21.5	35	1025.2	N	1.5	3.6
15/08/2005	12:55	88.3	85.9	77.9	70	59.1	53.8	74.8	12:55 PM	0	21.8	34	1025.2	N	1.5	3.1
15/08/2005	13:20	87.9	83.4	77.2	70.6	63.2	59.6	73.7	1:20 PM	0	22.1	33	1024.8	N	1.5	3
15/08/2005	13:25	88.1	83.9	78.1	70.2	63.1	58.7	74.4	1:25 PM	0	22.3	33	1024.8	NE	1.5	7
15/08/2005	13:50	88.3	85.6	77.6	69.3	60.1	55	74.3	1:50 PM	0	23.2	32	1024.3	NE	2.6	4.1
15/08/2005	13:55	87.8	84.3	78.1	69.9	61.9	56	74.4	1:55 PM	0	23.2	32	1024.3	E	2.6	4.1
15/08/2005	14:20	87.4	85.1	77.7	70.6	62.7	59.2	74.4	2:20 PM	0	22.2	34	1023.8	E	2.6	4.1
15/08/2005	14:25	87.6	85.8	79.1	71.2	63.7	57.1	75.7	2:25 PM	0	22.1	35	1023.8	E	2.1	4.1
15/08/2005	14:50	86.8	85.2	78.5	71.6	64.3	57.2	74.9	2:50 PM	0	22.1	36	1023.5	SW	2.1	4.6
15/08/2005	14:55	88.7	86	80.3	71.4	64.3	56.1	76.3	2:55 PM	0	22.1	35	1023.5	S	2.1	4.6

Site Photos

Site Diagram

Figure 57: Monitoring sheet Hard ground with vegetation at 1.5 m

Appendix J

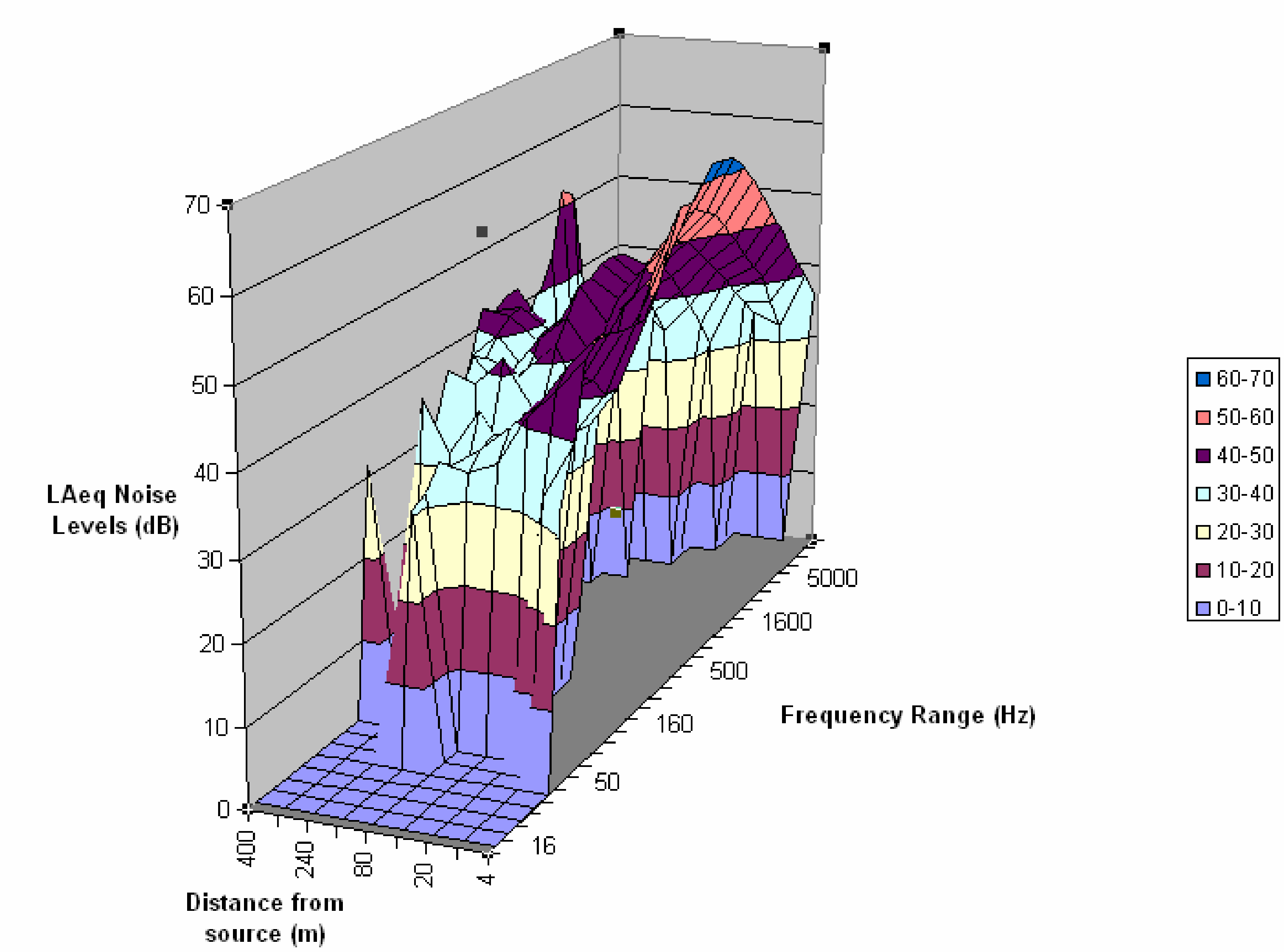
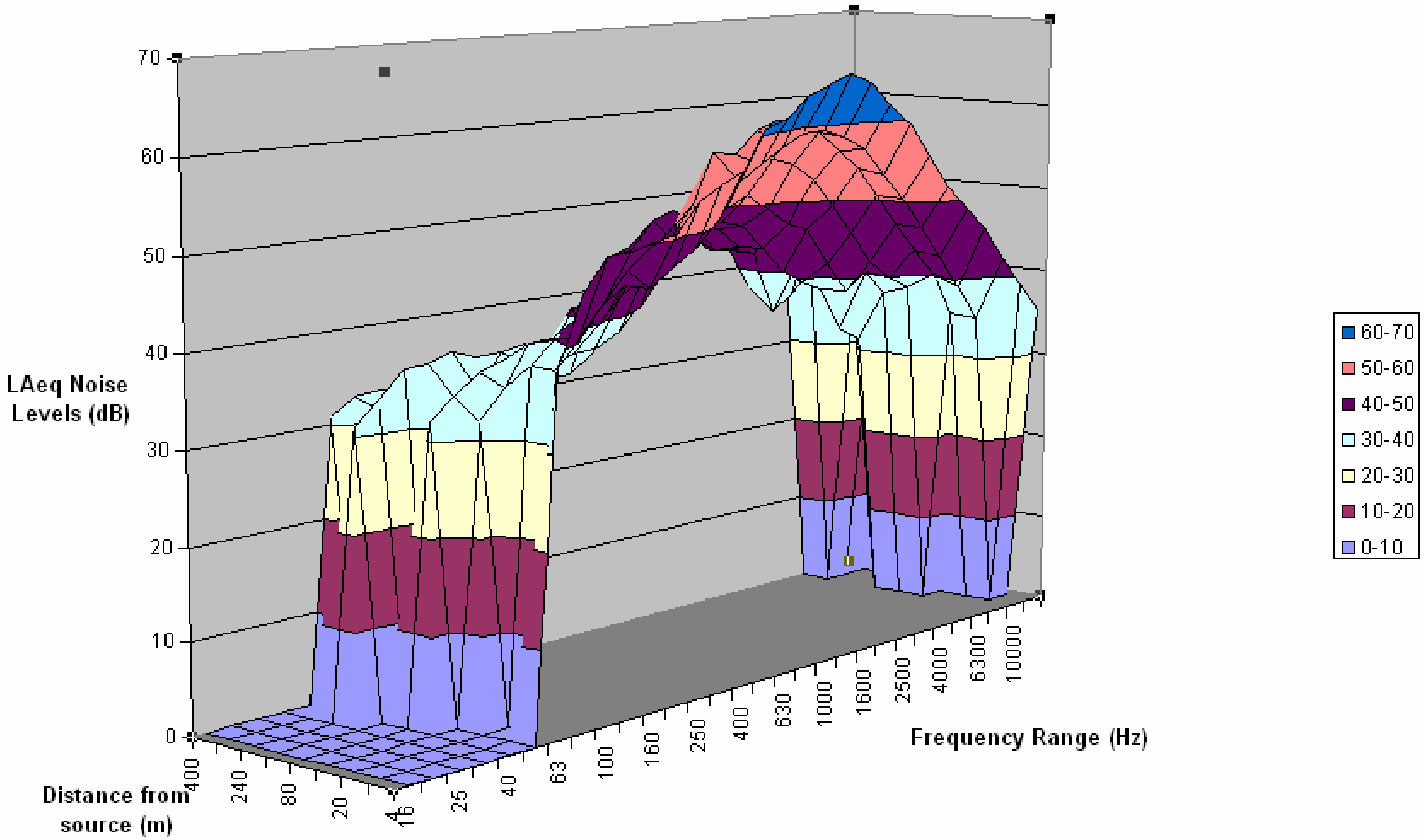


Figure 58: 3D plot of LAeq Vs Dist Vs Frequency for Soft ground at 1.5 m

Figure 59: 3D plot of LAeq Vs Dist Vs Frequency for Soft ground at 3.5m



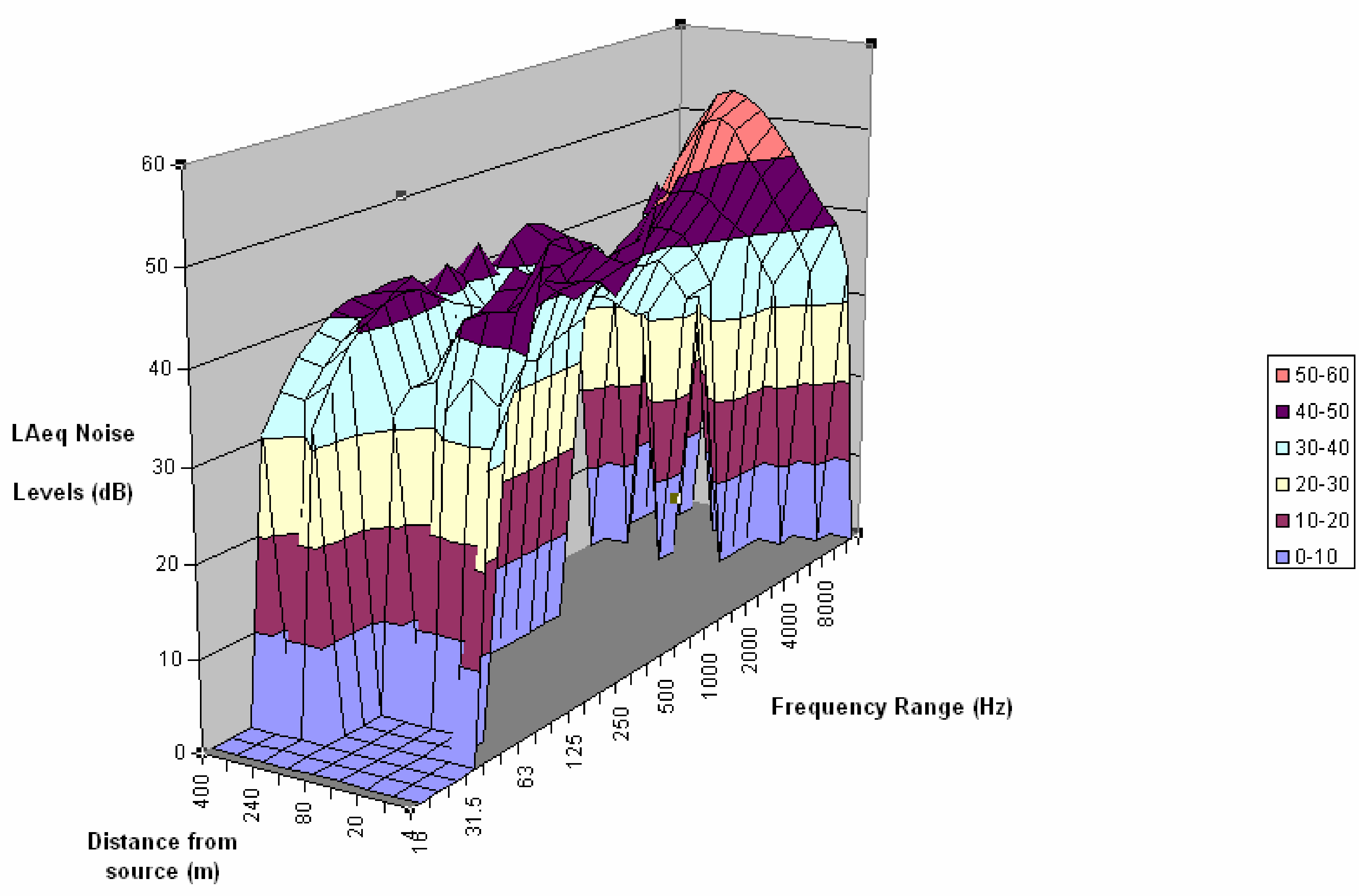


Figure 60: 3D plot of LAeq Vs Dist Vs Frequency for Hard ground at 1.5 m

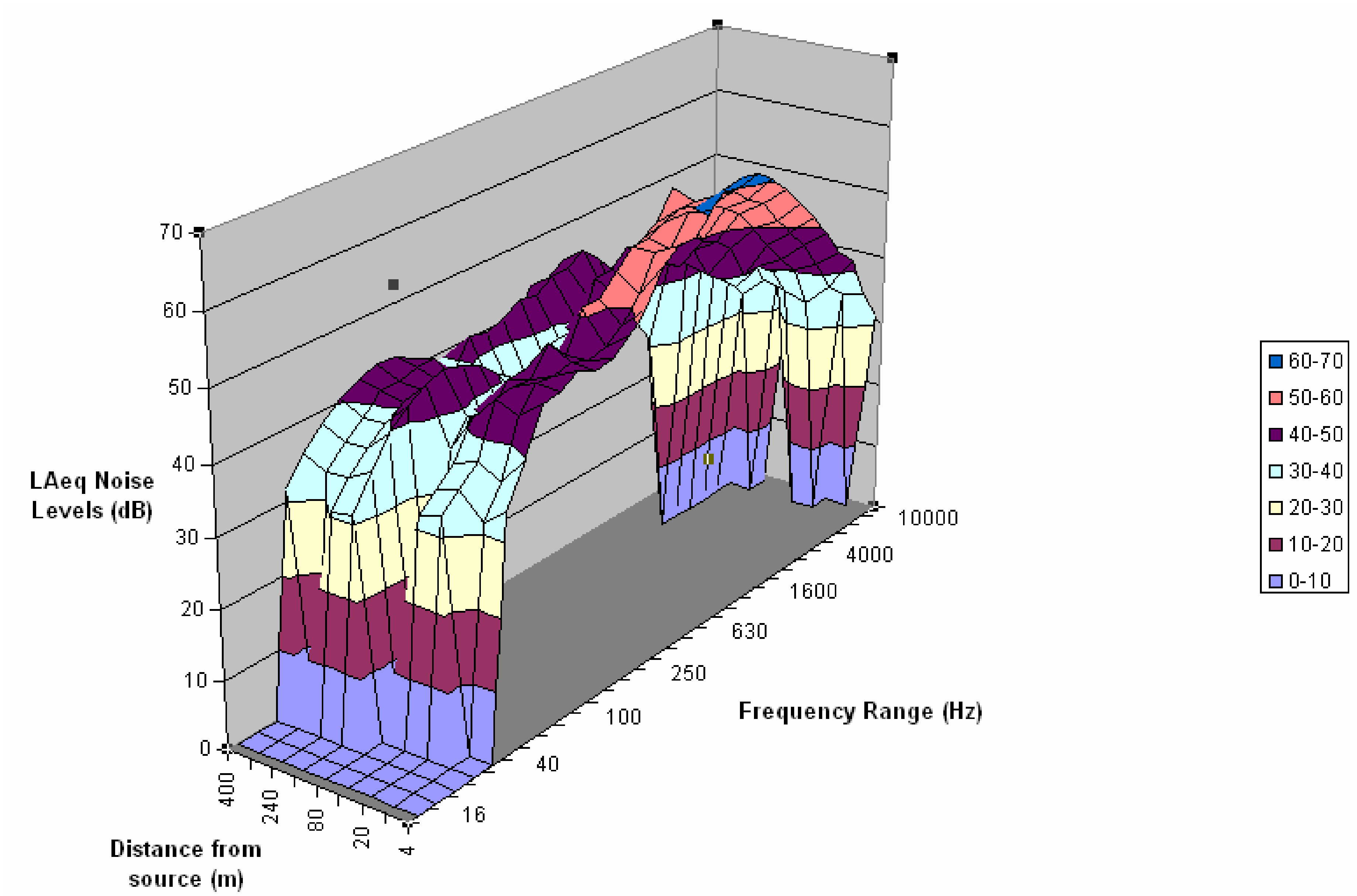


Figure 61: 3D plot of LAeq Vs Dist Vs Frequency for Hard ground at 3.5 m

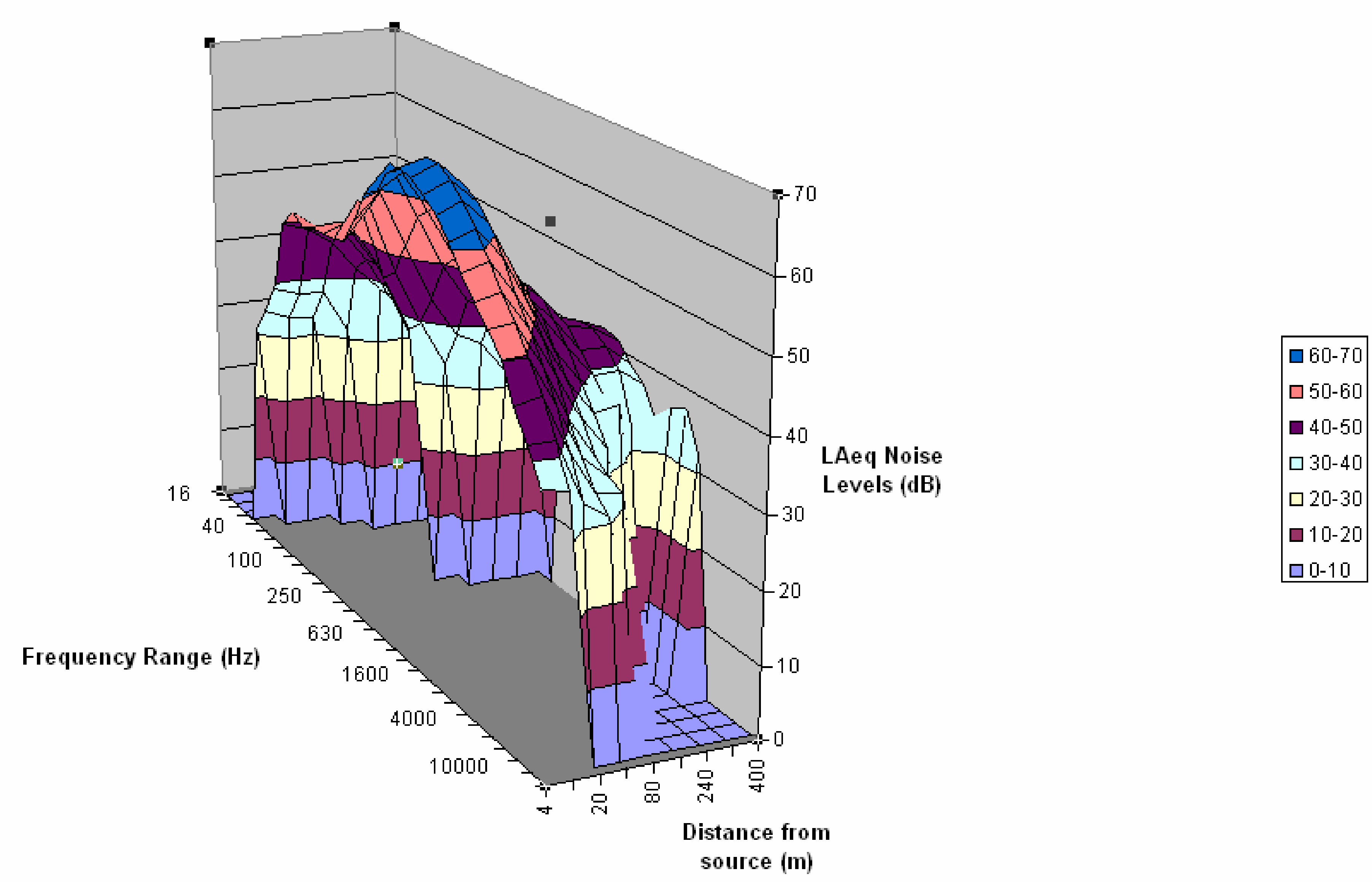


Figure 62: 3D plot of LAeq Vs Dist Vs Frequency for Hard ground with vegetation at 1.5 m

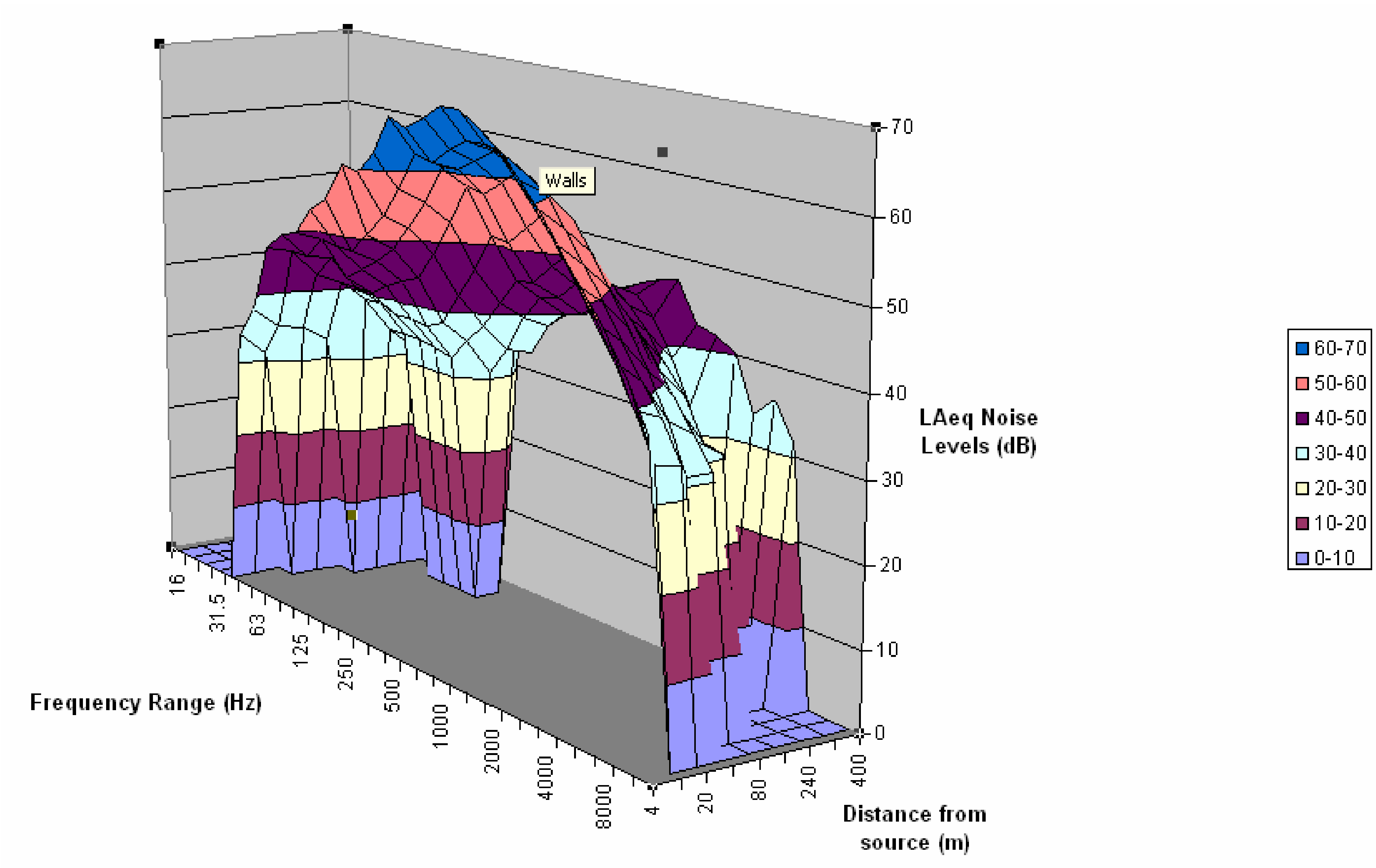


Figure 63: 3D plot of LAeq Vs Dist Vs Frequency for Hard ground with vegetation at 1.5 m

Appendix K

Traffic data sheets

Table 6: Medium vehicle traffic data

Main	Roads	Southern	District			
Weekly	Vehicle	Counts	(Virtual	Week)		
VirtWeeklyVehicle-336	--	English	(ENA)			
Datasets:						
Site:	WESTBOUND	TRAFFIC	AT	BIG	ORANGE	MEDIUM
Profile:						
Filter	time:	12:00	Wednesday,	10	August	2005
Included	classes:	3,	4,	5,	6,	7,
Speed	range:	10	-	160	km/h.	
Direction:	West	(bound)				
Separation:	All	-	(Headway)			
Name:	Main	Roads	Southern	District		
Scheme:	Vehicle	classification	(AustRoads94)			
Units:	Metric	(meter,	kilometer,	m/s,	km/h,	kg,
In	profile:	5359	VehiclesWeekly	Vehicle	Counts	(Virtual

Hour	Mon	Tue	Wed	Medium Thu	Medium Fri	Medium Sat
0000-0100	5	11	9	10	9	4
0100-0200	11	9	7	7	8	5
0200-0300	5	5	8	11	8	4
0300-0400	9	8	11	13	8	3
0400-0500	14	12	18	17	18	3
0500-0600	26	37	27	33	35	15
0600-0700	47	47	56	54	52	21
0700-0800	56	52	71	59	52	28
0800-0900	52	58	53	59	69	34
0900-1000	68	62	64	76	84	44
1000-1100	67	60	45	66	63	42
1100-1200	60	70	62	78	78	42
1200-1300	57	63	65	67	66	27
1300-1400	55	59	59	66	61	34
1400-1500	52	55	75	64	90	27
1500-1600	52	60	70	71	70	24
1600-1700	47	36	36	52	52	25
1700-1800	40	35	43	44	35	30

Table 7: Heavy vehicle numbers

	Hour |	1-May Mon	Tue	Wed	Heavy Thu	Heavy Fri	Heavy Sat	Sun
1	0000-0100	8	9	14	18	9	9	10
2	0100-0200	2	12	20	12	12	19	3
3	0200-0300	7	17	18	15	20	14	4
4	0300-0400	8	13	10	14	12	13	5
5	0400-0500	10	11	15	13	16	16	8
6	0500-0600	19	24	18	24	23	12	8
7	0600-0700	19	24	26	24	16	18	10
8	0700-0800	30	46	33	41	46	33	7
9	0800-0900	43	39	36	55	49	26	15
10	0900-1000	56	38	34	27	38	20	15
11	1000-1100	51	45	51	40	36	23	11
12	1100-1200	74	51	56	52	52	29	5
13	1200-1300	74	68	63	76	60	24	11
14	1300-1400	72	60	70	58	49	25	8
15	1400-1500	51	52	77	59	57	25	12
16	1500-1600	57	68	46	52	48	20	4
17	1600-1700	59	60	63	47	51	14	9
18	1700-1800	56	60	39	46	57	13	11
19	1800-1900	50	46	53	49	50	18	12
20	1900-2000	40	51	38	41	49	9	15
21	2000-2100	46	43	40	31	35	5	15
22	2100-2200	28	35	43	31	41	3	10
23	2200-2300	27	23	35	18	29	9	5
24	2300-2400	19	27	15	15	23	2	3

Table 8: Light vehicle traffic data

Main	Roads	Southern	District				
Weekly	Vehicle	Counts	(Virtual	Week)			
VirtWeeklyVehicle-336	--	English	(ENA)				
Datasets:							
Site:	[30068]	30068	on	18A	LN	1	WESTBOUND
LIGHT	VEHICLES	ONLY	(Classes	1	&	2)	
Profile:							
Filter	time:	12:00	Wednesday,	10	August	2005	=>
Included	classes:	1,	2				
Speed	range:	10	-	160	km/h.		
Direction:	North,	East,	South,	West	(bound)		
Separation:	All	-	(Headway)				
Name:	Main	Roads	Southern	District			
Scheme:	Vehicle	classification	(AustRoads94)				
Units:	Metric	(meter,	kilometer,	m/s,	km/h,	kg,	tonne)
In	profile:	49505	Vehicles				
Weekly	Vehicle	Counts	(Virtual	Week)			

Hour	Mon	Tue	Wed	Light Thu	Light Fri	Light Sat	Sun
0000-0100	28	21	31	34	25	37	71
0100-0200	14	9	13	12	15	42	23
0200-0300	9	9	11	15	11	17	14
0300-0400	14	17	18	18	17	19	17
0400-0500	38	37	31	41	34	34	41
0500-0600	126	128	108	104	105	75	43
0600-0700	297	259	273	261	246	169	75
0700-0800	509	490	524	510	398	368	228
0800-0900	491	624	641	638	549	513	360
0900-1000	516	583	654	559	517	691	434
1000-1100	506	450	667	444	453	779	612
1100-1200	486	417	543	400	428	813	612
1200-1300	398	340	327	349	377	638	569
1300-1400	337	303	335	310	420	590	544
1400-1500	378	362	336	344	525	504	633
1500-1600	381	432	432	387	637	509	750
1600-1700	455	469	431	424	688	526	653
1700-1800	404	433	359	394	653	468	668
1800-1900	304	342	375	328	537	377	806
1900-2000	177	217	208	213	337	193	459
2000-2100	127	147	147	139	226	156	303
2100-2200	120	112	99	101	157	141	185
2200-2300	87	110	108	81	98	121	118
2300-2400	59	58	53	43	67	77	44
0700-1900	5165	5245	5624	5087	6182	6776	6869
0600-2200	5886	5980	6351	5801	7148	7435	7891
0600-0000	6032	6148	6512	5925	7313	7633	8053
0000-0000	6261	6369	6724	6149	7520	7857	8262
AM Peak	900	800	1000	800	800	1100	1100
	516	624	667	638	549	813	612
PM Peak	1600	1600	1500	1600	1600	1200	1800
	455	469	432	424	688	638	806

Time line

Project time lines	3d	Mon 28/02/05	Wed 2/03/05
Risk Assessment Chart	2d	Mon 28/02/05	Tue 1/03/05
Literature review	0d	Thu 5/05/05	Thu 5/05/05
Progress assessment	48.5d	Mon 28/02/05	Thu 5/05/05

Need to put literature into my own words and site specific.

Progress Assessment DUE 13th - JUNE

Check lists	5d	Mon 28/02/05	Fri 4/03/05
Training	1d	Wed 27/07/05	Wed 27/07/05
Noise Monitoring	7d	Thu 28/07/05	Fri 5/08/05
Data Analysis	30d	Mon 8/08/05	Fri 16/09/05
Dissertation	177days	Mon 28/02/05	Tue 1/11/05

Chapter 9 References

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