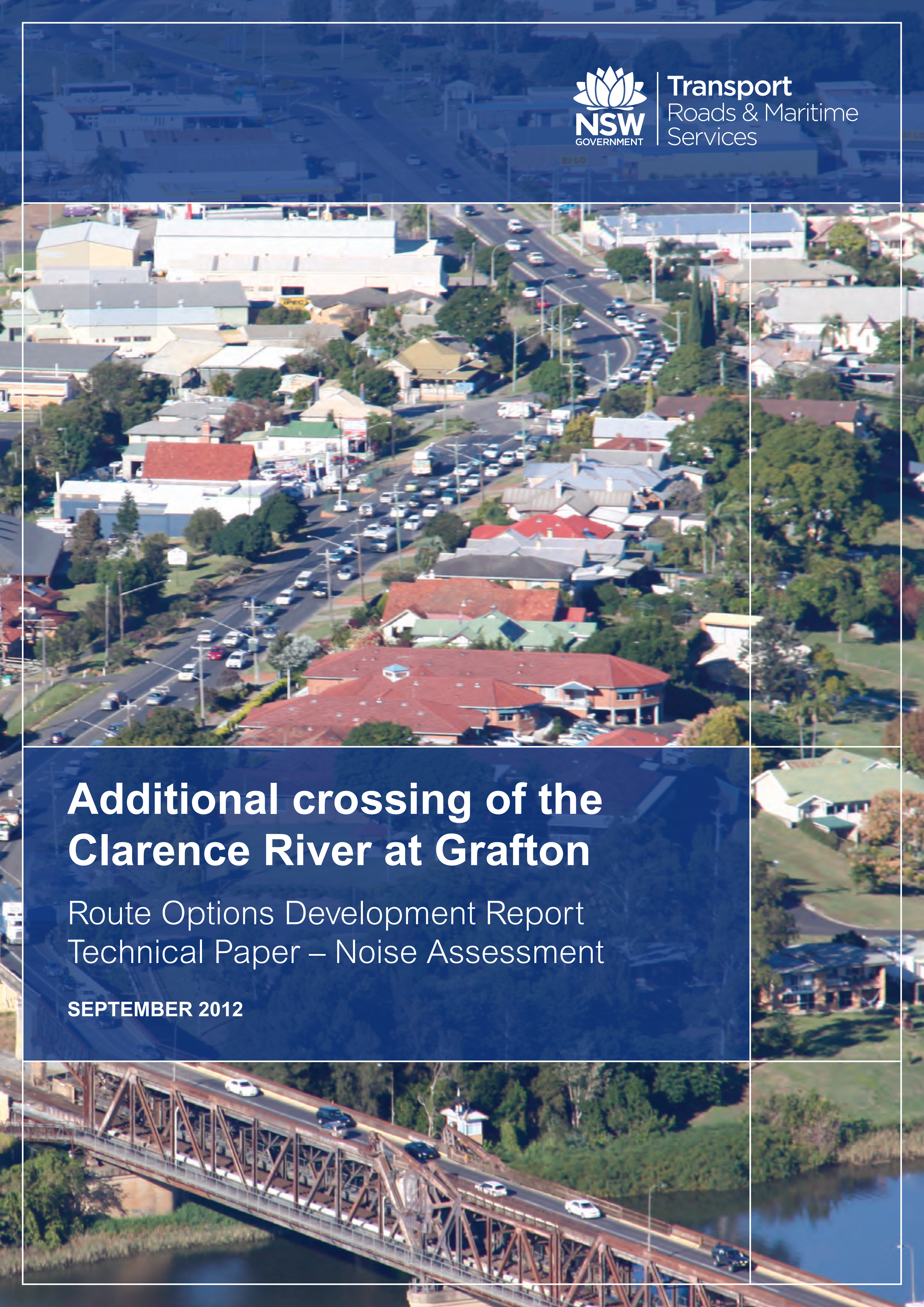

Transport
Roads & Maritime
Services

Additional crossing of the Clarence River at Grafton

Route Options Development Report
Technical Paper – Noise Assessment

SEPTEMBER 2012

Roads and Maritime Services

Main Road 83 Summerland Way - Additional Crossing of the Clarence River at Grafton

Noise Assessment

August 2012

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 220422

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Executive Summary

Arup Acoustics was commissioned by Roads and Maritime Services (RMS), to investigate potential noise impacts in relation to an additional crossing of the Clarence River at Grafton.

This report details an assessment of the comparative acoustic impacts of each of the six short-listed options. Two main assessment methodologies have been employed based on statutory guidelines (NSW Road Noise Policy, RNP) and international best practice (DETR Community Noise Burden) to aid in this comparison. Properties near to each of the route options and existing arterial roads have been considered in the analysis. This allows the focus to be on those properties where the noise levels would be most likely to exceed the adopted RNP criteria and where the greatest increase in noise levels would be likely to occur.

Noise surveys were conducted over a period of seven consecutive days in September 2011 at locations across Grafton and South Grafton. Noise monitoring locations were selected based on their proximity to short-listed route alignments and as being representative of the various different acoustic environments throughout Grafton and South Grafton. In addition, noise surveys were also previously conducted in August 2010 in closer proximity to the existing bridge. Noise survey data was validated against traffic count data obtained at the time of noise monitoring.

An acoustic model was developed for the road network across Grafton and South Grafton. Traffic count and noise survey data was used to calibrate and verify the acoustic model. Projected traffic flows were input into the acoustic model for each route option as well as the scenario of no new option being built (i.e. ‗No-Build'). For all options, noise predictions were made for both daytime and night-time periods for the proposed design year (2019) and 10 years thereafter (2029).

The same number of receiver locations was used for each of the route options to form a consistent basis for comparison. Property acquisitions and approved development applications were also considered in the noise modelling and included as appropriate.

In summary, route options closer to the current river crossing (i.e. Options A, C & E) were found to have the lowest acoustic impact on the community. This is largely due to their location close to areas where traffic noise currently exists, hence affecting little change to the existing noise environment. Route alignments that are further away from existing thoroughfares (i.e. Options 11, 14 & 15) introduce additional receiver locations that would otherwise remain relatively unaffected. For this reason Option E is predicted to impact upon more receivers than A & C due to its alignment being slightly further from the existing bridge.

Option 11 is predicted to have the greatest acoustic impact upon the community for all acoustic indicators used. This is due to its proposed alignment on Fry Street being densely populated with residential receivers that are not currently exposed to high levels of road traffic. Similarly, Option 14 is predicted to significantly increase road traffic noise exposure on residential receivers aligning North Street.

It is noted that the relative acoustic impact between the various options is often quite close (i.e. little difference). General advice for potential noise mitigation options are provided for reference. Predicted noise levels are not indicative of eligibility for noise mitigation. This will need to be assessed during the detailed design phase once a preferred route option has been selected.

1 Introduction

Roads and Maritime Services (RMS) is currently undertaking investigations to identify an additional crossing of the Clarence River at Grafton to address short-term and long-term transport needs. Arup is undertaking acoustic investigations.

Since the early 1970s there have been various discussions and studies into an additional crossing of the Clarence River near Grafton. A number of these studies have been carried out during the past ten years and provide the background to the current investigation.

In December 2010, RMS commenced a revised process to work more closely with the community to determine the preferred location for an additional crossing. As part of this revised process, a series of public surveys, community forums and meetings with residents and community groups have been held and various studies and project documents released for public viewing and comment.

In June 2011, RMS released the *Feasibility Assessment Report*, which describes the assessment undertaken by RMS on the 41 route suggestions identified by the community following the announcement of the revised process in December 2010. The report identifies 25 preliminary options within five strategic corridors to go forward for further engineering and environmental investigation.

Between June 2011 and January 2012, RMS carried out investigations in the Grafton area and surrounds to identify constraints relevant to an additional crossing of the Clarence River. The outcomes of these investigations, community comment and a community and stakeholder evaluation workshop provided the inputs to the selection of the short-list of route options.

In January 2012, six route options to be investigated further as part of the process to identify a location for the crossing were announced (as shown in Figure 1). The short-listed options were identified in the *Preliminary Route Options Report – Final* (RMS, January 2012) which also provided details of the technical investigations undertaken on the 25 preliminary options and the process to select the short-listed options.

This technical paper is an attachment to the Route Options Development Report and will be used to define the broad acoustic impacts for these six route options. The findings of these investigations will be used as part of the selection of a recommended preferred option.

Figure 1: Short-list of route options for an additional crossing of the Clarence River at Grafton

1.1 Acoustic Assessment

Arup Acoustics has been commissioned to model and assess the potential road traffic noise impacts for the six short-listed route options. To undertake noise modelling, the following process has been adopted in accordance with industry best practice and statutory requirements:

- Measure existing noise environment in Grafton and South Grafton.
- Undertake traffic counts at the same time as the noise monitoring to correlate measured noise data with traffic, (vehicle type and volume) and the surrounding environment (e.g. birds, industrial noise, machinery etc.).
- Undertake computer modelling of the six route options to identify the predicted noise environment as a result of each of the route options. The modelling was undertaken for the anticipated year of opening and for 10 years after opening.

This technical paper summarises the noise impact assessment of the six route options. It contains:

- The results of attended and unattended noise measurements undertaken in August 2010 and September 2011 at several locations throughout Grafton and South Grafton. This was undertaken in order to assess the existing noise environment.
- The description and the results of the computer modelling used to predict the noise environment for the existing bridge and the six options for future situations. The computer models were constructed in SoundPLAN noise modelling and prediction software. The computer model was validated using the results of noise measurements taken on site in Grafton and South Grafton. The results of the modelling are used to assess and compare the noise impact of the various route options.
- A traffic noise assessment undertaken in general accordance with the NSW Office of Environment and Heritage (OEH) Road Noise Policy (RNP, July 2011) and the Road and Maritime Services (RMS) Environmental Noise Management Manual (ENMM, December 2001).
- A glossary of terms is provided in Appendix A.

The noise impacts have been assessed against relevant noise criteria from the RNP as well as the Community Noise Burden[1] (CNB) of each option. These assessment parameters are an input to the selection process for a recommended preferred route option for an additional crossing of the Clarence River at Grafton.

1.1.1 Assumptions and Suitability of Assessment

The following is a summary of assumptions made during assessment. Justification for each is made within the report.

- RNP criteria selection (refer Section 3.1.1)
- Traffic modelling figures (refer Section 4.1)
- Selection of receiver locations (refer Section 4.4)

Despite the above assumptions, the methodology is suitable for a route option selection process. It should be noted that results herein are not suitable for mitigation eligibility.

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[1] Burgemeister, K.A. ‗*A Community Noise Burden Approach to Highway Route Selection*', Proc. Australian Acoustic Society Conference, 13-15 November 2002.

1.2 Social Impacts of Noise

The following information in Section 1.2 was provided by BBC Consulting Planners. It is generally accepted that there are groups within the community who are more vulnerable to noise than the general population (World Health Organisation, 2001). However, different groups are vulnerable to different effects (eg sleep disturbance, general annoyance, physiological effects) as identified in Table 1.

In high doses, noise can affect sleep or disturb rest and relaxation, generate stress and annoyance, affect educational achievement, interfere with speech or job performance, and contribute to a number of physiological and mental health effects. At the individual level, these impacts affect quality of life.

There is evidence that noise may have an effect on community cohesion, with some research suggesting, for example, that it can reduce helping behaviour (Berglund & Lindvall 1995). It is not considered likely, however, that changes in noise exposure due to the project would engender population segregation or a general deterioration of those residential areas affected. There should be little or no effect on the sense of community or the ―vitality" of adjoining suburbs.

Effect	Susceptible or sensitive groups
Annoyance	Self-reported noise-sensitive individuals (IEH 97) Noise sensitive people, people with fear of certain sources, those feeling they have no control over the situation have an increased risk of severe annoyance (Netherlands 97) Those concerned with health effects of noise, those who report interference with activities, self-reported noise sensitive individuals (Morrel 97)
Sleep disturbance	Ill people, older people, people with sleeping difficulties (Netherlands 97) Elderly people, shift workers, those with physical or mental disorders people with sleeping difficulties (Berglund 96) Shift workers (Job 96) Sensitive groups e.g. anxious/depressed (IEH 97) Children appear less susceptible to sleep disturbance caused by noise.
Speech disturbance	Elderly and hearing impaired
Performance by school children	Pupils with learning difficulties, hearing impairment, English as a second language. (IEH 97)

Table 1: Vulnerable, susceptible or sensitive groups by Noise Effect[2]

Common to all options, construction activities have the potential to impact upon the amenity and lifestyle of localised areas, such as changes to air quality (ie dust, plant and vehicle pollutants), noise (on-site from plant and vehicles, and off-site from vehicles), vibration, visual pollution, increases in traffic levels and truck movements or changes to access and movement patterns and safety concerns.

[2] Department for Environment, Food & Rural Affairs Noise and Nuisance Policy - Health Effect Based Noise Assessment Methods: A Review and Feasibility Study (1998)

2 Existing Ambient Noise Environment

There is a range of ambient noise environments in the Grafton area including rural and urban environments depending on proximity to the town centres. The main contributors to ambient noise in the Grafton area are:

- Road traffic noise, including heavy vehicles, along the main arterial roads in and around Grafton.
- General road traffic in and around the city centre.
- Passenger and freight rail activity along the Northern Railway Line.
- Rural industry and machinery.
- Local insect and animal noise.

2.1 Noise Surveys

An extensive noise survey of the Grafton area has been undertaken in order to benchmark the existing acoustic environment. This survey incorporates noise data collected during two stages of the project and is discussed further below.

A map of noise monitoring locations for both survey periods is provided in Appendix B for reference.

2.1.1 August 2010

A noise survey was conducted by Arup between 9 and 19 August 2010 as part of the first stage of the project, prior to the December 2010 announcement of a change in project direction. Noise monitoring during this survey was concentrated in the areas near to the existing bridge. Data obtained during this noise survey has been validated against road traffic data obtained at the time.

2.1.2 September 2011

In preparation for the next phase of the project, additional noise monitoring was required for the wider Grafton area to supplement the previous noise investigations undertaken around the existing bridge. Noise survey areas were selected based on the different characteristic acoustic environments that exist in the Grafton and South Grafton areas.

Representative locations were selected for noise monitoring as follows:

- ‗Rural' ambient noise environment: characterised as being remote from urban centres and existing road traffic noise.
- ‗Urban' ambient noise environment: characterised by proximity to the town centre. Expected to have local traffic flows with low percentage of heavy vehicles.
- Existing arterial road noise affected: locations aligning existing arterial roads. Expected to have a higher percentage of heavy vehicles than local roads.

Based on this methodology, a total of 15 noise monitoring locations were selected, to supplement the data collected in 2010. Unattended environmental noise monitoring was conducted at these locations between 13 and 22 September 2011. This is discussed further in Section 2.1.3. Representative noise monitoring locations as discussed above are shown in Appendix B for reference.

2.1.3 Unattended Noise Nonitoring

2.1.3.1 Noise Monitoring Locations

A total of 19 locations have been used for this study and these are discussed in the following sections. Noise loggers were placed at a height of 1.5 m above the ground at the receiver location. Wherever appropriate and possible, noise loggers were located within 1 m of the building facade, in accordance with best practice and RMS guidelines[3].

A brief description of each logger location along with site photographs identifying the noise logger position is provided in Appendix C.

2.1.3.2 Instrumentation

Equipment used for the continuous unattended noise surveys included RTA Technology Type 1 Noise Loggers and ARL Ngara and EL-31X Type 1 noise loggers carrying current calibration certificates. Details of logger types and serial numbers can be found below in Table 2.

Calibration of the loggers was checked prior to and following measurements using a Brüel & Kjær Sound Level Calibrator Type 4231 with no significant drift in calibration being recorded. The sample time interval was set at 15 minutes and the meter time constant set to ―Fast”.

	Reference Location	Address	Logger Type	Serial Number
2011 Noise Survey	1	245 Lawrence Road, Great Marlow	RTA -02	050
	2	86 Great Marlow Road, Great Marlow	RTA -02	049
	3	591 Summerland Way, Carrs Creek	RTA -02	009
	4	Cnr Hoof and Clarence Streets, Grafton	Ngara	87809E
	5	94 Dobie Street, Grafton	RTA -04	010
	6	81 Edward Ogilvie Drive, Clarenza	Ngara	87802E
	7	Pacific Highway near Alipou Creek	Ngara	87807F
	8	326 Centenary Drive, Clarenza	Ngara	878079
	9	Cnr Iolanthe Street & Butters Lane, South Grafton	Ngara	878060
	10	146-148 Ryan Street, South Grafton	Ngara	878000
	11	5 School Drive, Swan Creek	Ngara	878080
	12	Riverbank at end of Meona Lane, off Pacific Highway.	Ngara	878007
2010 Noise Survey	13	Villiers Street, near TAFE, Grafton	RTA-04	008
	14	Gummyaney Pre-School, 30 Pound Street, Grafton	RTA-02	050
	15	8 Fitzroy Street, Grafton	RTA-04	010
	16	St. Mary‘s Church, Clarence Street	EL-316	15-299-419

[3] RMS Procedure: Preparing an Operational Traffic and Construction Noise and Vibration Assessment Report – July 2011

	Reference Location	Address	Logger Type	Serial Number
	17	12 Bent Street, Grafton Aged Care Home, South Grafton	EL-315	15-299-422
	18	8 Beatson Street, South Grafton	RTA-04	009
	19	España Hotel, Schwinghammer Street, South Grafton	RTA-02	049

Table 2: Unattended noise logger locations, types and serial numbers

2.1.3.3 Weather Data

Continuous weather data was obtained from the Bureau of Meteorology‘s (BOM) nearby weather stations at Grafton Airport and Grafton Agricultural Research Station. This data was reviewed to identify periods of adverse weather during the unattended noise logging surveys. Adverse weather has the potential to influence recorded noise levels and provide inaccurate results.

Where appropriate, periods of high winds and/or rain were excluded from the analysis. Other extraneous noise events were also excluded from the analysis as required (e.g. farm machinery, local animal noise, etc).

2.1.3.4 Road Traffic Counts

Road traffic counting was undertaken by Austraffic at noise logging locations aligning existing road corridors. Traffic counting was conducted concurrently with noise logging throughout the entire noise monitoring period. Traffic modelling parameters are discussed further in Section 4.1.

This data was recorded in order to correlate measured ambient noise data with the expected contribution from road traffic based on recorded traffic volumes. This validation process is discussed further in Section 4.3.

2.1.3.5 Results

Unattended noise logging results have been processed in accordance with the provisions of the Office of Environment and Heritage (OEH) Road Noise Policy (RNP) to derive the day-time and night-time average ($L_{Aeq,\ 15\ hour}$) and ($L_{Aeq,\ 9\ hour}$) noise levels against project specific criteria discussed in Section 3.

A summary of the measured day-time and night-time average noise levels for each logger location is provided in Table 3. Instances where logger data returned erroneous or spurious results have been identified and omitted from the data presented. 24 hour graphs of measured acoustic metrics are also provided for reference in Appendix D for the entire monitoring period.

	Reference Location	Address	Measured Noise Level (dB)	
			Day-time average $L_{Aeq, 15 hour}$	Night-time average $L_{Aeq, 9 hour}$
2011 Noise Survey	1	245 Lawrence Road, Great Marlow	58	51
	2	86 Great Marlow Road, Great Marlow	50	43
	3	591 Summerland Way, Carrs Creek	65	59
	4	Cnr Hoof and Clarence Streets, Grafton	49	45
	5	94 Dobie Street, Grafton	58	51
	6	81 Edward Ogilvie Drive, Clarenza	60	56
	7	Pacific Highway near Alipou Creek	71	70
	8	326 Centenary Drive, Clarenza	50	49
	9	Cnr Iolanthe Street & Butters Lane, South Grafton	52	49
	10	146-148 Ryan Street, South Grafton	63	56
	11	5 School Drive, Swan Creek	69	68
	12	Riverbank at end of Meona Lane, off Pacific Highway.	48	47
2010 Noise Survey	13	Villiers Street, near TAFE, Grafton	66*	58*
	14	Gummyaney Aboriginal Pre School, 30 Pound Street, Grafton	53*	43
	15	8 Fitzroy Street, Grafton	59*	53
	16	St. Mary‘s Church, Clarence Street, Grafton	53	47
	17	12 Bent Street, Grafton Aged Care Home, South Grafton	68	59
	18	8 Beatson Street, South Grafton	56	49
	19	España Hotel, Schwinghammer Street, South Grafton	66	66

Table 3: Unattended noise logger results

* Fifteen minute attended measurements employed

2.1.4 Attended Noise Measurements

Operator attended noise monitoring was also conducted at each noise logger location during both the day and night-time periods. This was undertaken in order to record more detailed spectral noise data that assists in observing and analysing the prevailing ambient noise environment. Noise spectrum measurements break the overall noise level down into its individual frequency components, this assists in identifying the different types of noise sources within a measurement. For example, an aeroplane fly over is dominated by low frequency noise and may appear different to a train passing by or mechanical machinery.

A summary of measured noise spectra is provided in Appendix E. Comments on the noise environment at each measurement location are provided in Appendix C.

3 Noise Criteria

In accordance with the principles of the ENMM, it should be noted that this stage of works corresponds to a ―network analysis” phase. Its objective is to strategically identify and broadly ―scope” and prioritise possible road options within an area. The following sections discuss the criteria and indicators employed to perform this network analysis.

3.1 Road Noise Policy (RNP)

The RNP has been considered in developing the assessment methodology, acknowledging that the primary aim of the RNP is to aid the selection of appropriate noise mitigation measures for road projects once a route has been selected. The RNP was not developed to guide the selection of a preferred option but has nevertheless been used as a reference for developing an appropriate noise assessment methodology, including the noise levels and the identification of receivers. This is considered suitable for this stage of the project.

The RNP provides noise criteria for both residential and other non-residential noise sensitive receivers. The RNP provides both absolute noise level limits, dependent upon road category, and limits to control the relative increase in road traffic noise.

The following sections provide a summary of project specific acoustic criteria for noise sensitive receiver types and land uses as stipulated in the RNP.

3.1.1 Residential Receivers

Table 4 is an excerpt from the RNP Section 2.3.1 Noise assessment criteria – residential land uses, summarising noise criteria for residential receivers relevant to this project.

Road Category	**Type of Project/Land Use**	**Assessment Criteria (dB)**	
		Day 0700 – 2200 hours	**Night 2200 – 0700 hours**
Freeway / arterial / sub-arterial roads	1. Existing residences affected by noise from new freeway / arterial / sub-arterial road corridors	$L_{Aeq, 15 hour}$ 55 (external)	$L_{Aeq, 9 hour}$ 50 (external)
Freeway / arterial / sub-arterial roads	2. Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads	$L_{Aeq, 15 hour}$ 60 (external)	$L_{Aeq, 9 hour}$ 55 (external)

Table 4: Road traffic noise assessment criteria for residential land uses

For the purpose of this study, a comparative assessment of all roads has been made against the criteria for new road corridors (i.e. 55 $dBL_{Aeq, 15 hour}$ and 50 $dBL_{Aeq, 9 hour}$). This represents a conservative assessment of exceedances and a uniform methodology for all route options.

The results of the assessment against these criteria should not be interpreted as indicating requirements for the provision of noise mitigation measures.

3.1.1.1 Relative Increase Criteria

Table 5 is an excerpt from the RNP Section 2.4 Relative increase criteria, stipulating the allowable increase above existing traffic noise for residential receivers. These criteria are to be assessed in addition to those mentioned above.

Road Category	**Type of Project/Land Use**	**Assessment Criteria (dB)**	
		Day 0700 – 2200 hours	Night 2200 – 0700 hours
Freeway / arterial / sub-arterial roads	New road corridor / redevelopment of existing road / land use development with the potential to generate additional traffic on existing road	Existing Traffic $L_{Aeq, 15\ hour}$ + 12 (external)	Existing Traffic $L_{Aeq, 9\ hour}$ + 12 (external)

Table 5: Relative increase criteria for residential land uses

As defined in the Section 2.5.3 of the RNP, the ‗existing' traffic noise level refers to the level from all road categories which would occur for the relevant ‗no build' option. (‗No build' refers to the scenario where no additional crossing or approach roads are constructed). Where the existing $L_{Aeq,\ period}$ road traffic noise level is found to be less than 30 dB(A), it is deemed to be 30 dB(A).

3.1.2 Sensitive Land Uses

Table 6 is an excerpt from the RNP Section 2.3.2 Noise assessment criteria – other non-residential land uses, summarising noise criteria for other noise sensitive receivers relevant to this project.

Existing Sensitive Land Use	**Assessment Criteria (dB)**		**Additional Considerations**
	Day 0700 – 2200 hours	**Night 2200 – 0700 hours**	
1. School Classrooms	$L_{Aeq, 1\ hour}$ 40 (internal)	-	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the ‗maximum' levels shown in Australian Standard 2107:2000 (Standards Australia 2000)
2. Hospital Wards	$L_{Aeq, 1\ hour}$ 35 (internal)	$L_{Aeq, 1\ hour}$ 35 (internal)	
3. Places of Worship	$L_{Aeq, 1\ hour}$ 40 (internal)	$L_{Aeq, 1\ hour}$ 40 (internal)	The criteria for places of worship are internal, i.e. the inside of the building. Areas outside the place of worship, such as a churchyard or cemetery, may also be a place of worship. Therefore, in determining appropriate criteria for such external areas, it should be established what in these areas may be affected by road traffic noise. For example, if there is a church car park between a church and the road, compliance with the internal criteria inside the church may be sufficient. If, however, there are areas between the church and the road where outdoor services may take place such as weddings and funerals, external criteria for these areas are appropriate. As issues such as speech intelligibility may be a consideration in these cases, the passive recreation criteria (see point 5) may be applied.

Existing Sensitive Land Use	Assessment Criteria (dB)		Additional Considerations
	Day **0700 – 2200 hours**	**Night** **2200 – 0700 hours**	
4. Open Space (Active Use)	$L_{Aeq,\ 15\ hour}$ 60 (external) When in Use	-	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion. Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. playing chess, reading. In determining whether areas are used for active or passive recreation the type of activity that occurs in that area and its sensitivity to noise intrusion should be established. For areas where there may be a mix of passive and active recreation, e.g. school playgrounds, the more stringent criteria apply. Open space may also be used as a buffer zone for more sensitive land uses.
5. Open Space (Passive Use)	$L_{Aeq,\ 15\ hour}$ 55 (external) When in Use	-	
8. Childcare Facilities	Sleeping Rooms $L_{Aeq,\ 1\ hour}$ 35 (internal) Indoor Play Areas $L_{Aeq,\ 1\ hour}$ 40 (internal) Outdoor Play Areas $L_{Aeq,\ 1\ hour}$ 55 (external)	-	Multi-purpose spaces, e.g. shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
9. Aged Care Facilities	-	-	Residential land use noise assessment criteria should be applied to these facilities.

Table 6: Road traffic noise assessment criteria for non-residential land uses

The RNP stipulates internal noise objectives for the majority of sensitive land uses (e.g. schools, hospitals, churches, etc). Given the variability of building construction, it is not practical to accurately assess the impact on internal noise levels.

Corresponding external criteria for sensitive land uses were used for the assessment, defined as being 10 dB above those stipulated as internal noise criteria. This is considered to be representative of expected attenuation through a typical open window.

3.2 Community Noise Burden

A Community Noise Burden (CNB) approach has been used to further interpret and complement the assessment made against the prescriptive noise criteria summarised above. This approach provides an alternative view of the potential noise impacts of the route options, and has been successfully implemented in previous large scale road projects by Arup. It is a good measure for a comparative assessment of route options and is suitable for this stage of the project.

This procedure is derived from guidance for undertaking studies of the environmental effects of transport options published by the UK DETR[4]. Here, a portion of the guidance (relating to UK studies of typical annoyance response to road traffic noise) is used to help differentiate the impact of each of the routes.

The CNB is a quantitative evaluation of the overall noise impact of each route option made by summing the noise impact at all of the individual residences over the length of the route option.

For this project, the absolute and relative noise burdens have been used on the project as follows:

- Absolute CNB: This is a quantitative evaluation of potential annoyance caused by *absolute* traffic noise levels on residential receivers.
- Relative CNB: This is a quantitative evaluation of potential annoyance caused by *change* in noise levels at residential receivers (i.e., the additional noise created by a route option).

The noise impact resulting from each of the proposed routes has been determined based on the product of the number of residences exposed to a specific noise level and a weighting based on the subjective annoyance factor of that noise level.

For the Relative CNB, the noise impact is based on the product of the number of residences exposed to a change in noise level caused by a route option, and weighted based on the subjective annoyance factor of that change in noise level and the absolute level from which the change has occurred. This is explained in more detail in Sections 3.2.1 and 3.2.2.

3.2.1 Absolute CNB

For this project, the Absolute Community Noise Burden was based on a continuous annoyance function derived from Figure 2 in the UK Design Manual for Roads and Bridges[5] (DMRB) as follows;

$$\%\ \text{bothered} = \frac{100}{(1+e^{-\mu})} \quad \text{where } \mu = 0.12(L_{A10,18hr}dB) - 9.08$$

This factor can be used to weight the impact of higher noise levels on residences closer to the road. The function is shown graphically in Figure 2.

A threshold limit of 40 $dBL_{A10,\ 18\ hour}$ was used as a lower limit for annoyance. Based on the DMRB function, percent annoyance below 40 $dBL_{A10,\ 18\ hour}$ approaches zero. Having no threshold of annoyance had a negligible effect on the Absolute Community Noise Burden results.

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[4] Guidance on the Methodology for Multi-Modal Studies (GoMMS), UK Department of the Environment, Transport and the Regions, http://www.dft.gov.uk./webtag/documents/overview/unit1.2.php.
[5] *Design Manual for Roads and Bridges*, ―Volume 11 Section 3 Part 7: Traffic Noise and Vibration", August 1994.

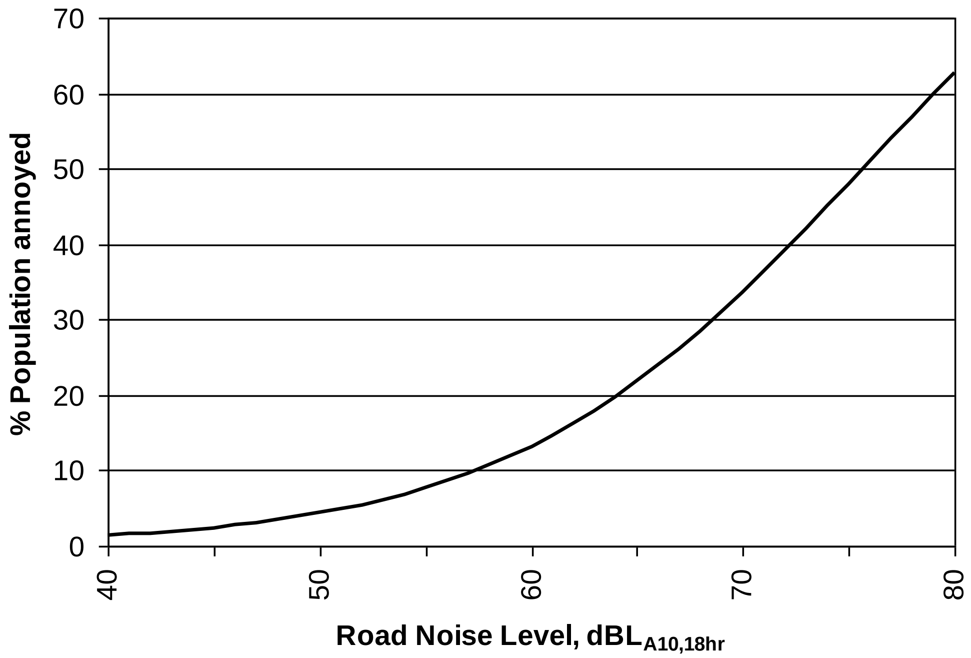


Figure 2: Absolute Community Noise Burden annoyance function

As an example, based on the above, for residential receivers experiencing a road traffic noise level in the order of 60 dBL$_{A10,\ 18\ hour}$, the studies have estimated that approximately 13% of people in those properties are likely to be annoyed by the noise.

3.2.2 Relative CNB

The Relative Community Noise Burden has also been calculated based on the following function. This function is related to the change in dBL$_{A10,\ 18\ hour}$, and is defined as:

$$\text{Change of \% bothered} = \quad 21(\Delta L_{A10,18hr} dB)^{0.33}$$

The function is shown graphically in Figure 3.

The Relative CNB value quantifies the change in annoyance levels due to increases or decreases in traffic noise created by a route option. The noise impact is based on the product of the number of residences exposed to a change in noise level, and weighted based on both the subjective annoyance factor of that change in noise level, and on the absolute level from which the change has occurred.

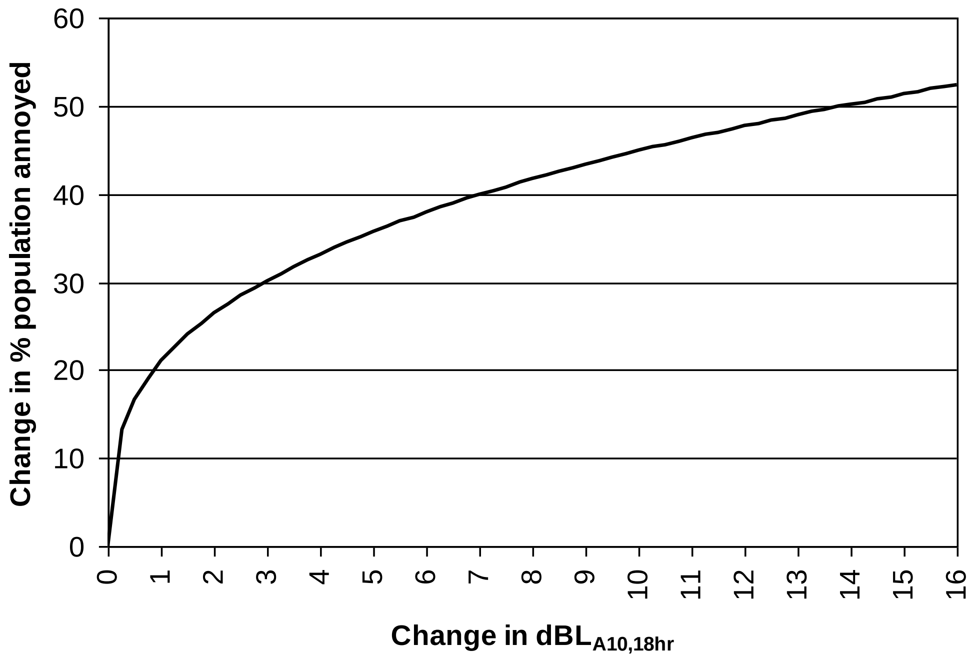


Figure 3: Relative Community Noise Burden annoyance function

For example, from Figure 3, a 5 dB change in traffic noise levels is likely to increase percent annoyance in the population by 36%. From Figure 2, if existing traffic noise levels are 45 $dBL_{A10,\ 18\ hour}$, then approximately 2% of the population is likely to be annoyed by traffic noise. However, approximately 8% of the population is likely to be annoyed by existing traffic levels of 55 $dBL_{A10,\ 18\ hour.}$ Therefore a 5 dB increase in traffic noise levels for the two examples would be:

Increase from 45 $dBL_{A10,\ 18\ hour}$ to 50 $dBL_{A10,\ 18hour}$
$\Rightarrow$ Expected increase in annoyance = 36% of 2% = 0.72%

Increase from 55 $dBL_{A10,\ 18\ hour}$ to 60 $dBL_{A10,\ 18\ hour}$
$\Rightarrow$ Expected increase in annoyance = 36% of 8% = 2.88%

4 Operational Noise Assessment

4.1 Traffic Modelling Parameters

Traffic modelling parameters and figures are discussed in detail in the *Technical Paper: Traffic Assessment*, in Volume 2 of the *Route Options Development Report*. All indices and parameters used in the acoustic study are based on the current traffic modelling and monitoring for the project.

Traffic flow data is presented for the ―design year". In accordance with ENMM, the Design Year is taken as being 10 years after the assumed date of opening.

The methodology for the noise assessment uses traffic modelling forecasts to predict noise levels for comparison between the options in 2029 with a no build scenario for 2029. However, it was not possible to effectively model traffic forecasts for the ‗no build' scenario at 10 years after opening (2029) in the detailed traffic network simulation. This is because the existing bridge and road network approaches are unable to cater for the estimated future traffic demand and the system becomes congested without a second bridge being built. As reported in the *Technical Paper: Traffic Assessment* and also the *Technical Paper: Economic Evaluation*, an indicative ‗no build' case for the future year 2029 was generated. This acknowledges that the existing road network would continue to function beyond 2019 with similar traffic growth to the options but with increased delays. Comparison to this indicative ‗no build' case has been employed for all options.

Traffic flows throughout the entire Grafton road network have been used for the acoustic assessment. A summary of annual average flows for both the existing (Table 7) and proposed (Table 8) bridges for each route option is presented here for reference. Composition has been broken down into light and heavy vehicle classifications as required for acoustic assessment.

Option	Design Year (2029)			
	Light		Heavy	
	Day 0700 – 2200 hours	Night 2200 – 0700 hours	Day 0700 – 2200 hours	Night 2200 – 0700 hours
E	12,958	835	1,091	60
A	11,745	758	989	54
C	14,160	912	1,192	66
11	16,526	810	1,345	75
14	27,197	748	2,353	1,136
15	27,496	865	2,315	126

Table 7: Annual average traffic flows: Existing Grafton Bridge

Option	Design Year (2029)			
	Light		Heavy	
	Day 0700 – 2200 hours	Night 2200 – 0700 hours	Day 0700 – 2200 hours	Night 2200 – 0700 hours
E	24,851	1,603	2,092	115
A	26,150	1,686	2,201	121
C	23,747	1,532	1,999	109
11	26,282	588	1,821	1,233
14	9,352	603	788	43
15	9,467	612	797	43

Table 8: Annual average traffic flows: Future Bridge / Route Option

4.2 Acoustic Modelling Methodology

Acoustic modelling has been undertaken in accordance with RMS guidelines[3,6] as well as international best practice[8]. To summarise, predictions have been made using the Calculation of Road Traffic Noise[7] (CoRTN) model within the SoundPLAN software suite. Guidance on acoustic modelling best practice has been obtained from the WG-AEN[8] position paper as appropriate.

CoRTN predicts an L_{A10} single number value (either $L_{A10,\ 1\ hour}$ or $L_{A10,\ 18\ hour}$) at a distance of 10 m from the edge of the road. For continuous traffic flows, based on past project experience and baseline measurements conducted for this study, L_{A10} has been found to be approximately 3 dB(A) higher than L_{Aeq}, and therefore the predicted L_{A10} values have been corrected to L_{Aeq} values using this correlation.

Given the nature of this stage of assessment, being a broad comparison between route options, a single height model has been adopted. This approach employs a single source height for all vehicle classifications. Single point receiver calculations have been made at a height of 1.5 m above the worst affected storey on the most exposed facade of the receiver.

4.3 Acoustic Modelling Validation

Road traffic noise level calculations were performed based on the hourly traffic count data measured at each respective noise logger location. As per standard practice, only noise logging locations where road traffic was the dominant noise source were used for validation purposes in order to accurately validate the road traffic noise levels. A visual inspection of each respective data set was undertaken. Locations where data that is not representative of road traffic noise, measured by either the noise logger or road traffic counter have been excluded from the analysis.

It should be noted that, notwithstanding this excluded data, a sufficient amount of information was collected to develop an accurate noise model in order to adequately predict road traffic noise.

Measured traffic flow data was input into existing road alignments at road segments immediately affecting noise loggers. The $L_{Aeq,\ 15\ hour}$ and $L_{Aeq,\ 9\ hour}$ road traffic noise level

[6] Roads and Traffic Authority – *Environmental Noise Management Manual* (Dec 2001)
[7] UK Department of Transport – *Calculation of Road Traffic Noise* (1988).
[8] WG-AEN Position Paper – *Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure* (January, 2006).

predictions were compared to measured noise levels at each noise logging location. All analysed locations were found to be accurate to within 2 dB during the day-time period. This is within the requirements of RMS procedure guidelines[3].

The SoundPLAN model was generally found to under-predict noise levels during the night-time period. These discrepancies are discussed further below. In general, with regard to assessment, it is noted that the day-time traffic data governs exceedances and assessment criteria. This is discussed further in Section 4.4.

Results of this validation are presented in Table 9. Discrepancies greater than 2 dB have been identified in bold. A justification for each discrepancy greater than 2 dB is provided below the table.

Measurement Location	**$L_{Aeq, 15 hour}$ dB Day Time (0700 – 2200 Hours)**		**Change dB**	**$L_{Aeq, 9 hour}$ dB Night Time (2200 – 0700 hours)**		**Change dB**
	Modelled	Measured		Modelled	Measured	
245 Lawrence Road, Great Marlow	60	58	2	51	51	0
591 Summerland Way, Carrs Creek	67	65	2	60	59	1
Cnr Hoof and Clarence Streets, Grafton	50	49	1	40	45	**5**
94 Dobie Street, Grafton	59	58	1	49	51	2
81 Edward Ogilvie Drive, Clarenza	59	60	1	52	56	**4**
Pacific Highway near Alipou Creek	72	71	1	66	70	**4**
326 Centenary Drive, Clarenza	49	50	1	42	49	**7**
146-148 Ryan Street, South Grafton	62	63	1	54	56	2
5 School Drive, Swan Creek	67	69	2	62	68	**6**

Table 9: Measured data validation analysis during night-time period

Corner of Hoof and Clarence Streets and 81 Edward Ogilvie Drive: Vehicle flows at these locations were recorded to be between 1 and 10 vehicles per hour during the night-time period. At such low vehicle flows, road traffic noise ceases to dominate ambient noise levels. It is therefore expected that predicted road traffic noise levels at the monitoring location will not account for other noise sources associated with rural ambience (e.g. birds, insects, humans, etc).

Pacific Highway near Alipou Creek: The percentage heavy vehicles along the Pacific Highway during the night-time period exceeds 50%. The relatively transient nature of this dominant noise source is such that the relationship between L_{eq} and L_{10} metrics converges (refer Appendix D). Analysis of the measured difference between these metrics during the night-time period at this location yields a discrepancy in the order of 1 dB as opposed to the standard assumed 3 dB discussed in Section 4.2. Taking this feature into account, correlation between modelled and measured noise levels is within 2 dB.

5 School Drive, Swan Creek: As above, significant heavy vehicle percentage during the night-time period is likely to influence the difference between measured L_{eq} and L_{10} metrics. Notwithstanding this, review of measured data shows little correlation between different days of the survey.

During attended measurements, it was noted that trucks used compression braking on approach to this corner of the Pacific Highway. Further, the noise logger was elevated to a height approximately 2.5 m above road level due to the topography of the area. This feature of being exposed to loud, irregular compression braking events at exhaust height would account for the erratic relationship between the L_{eq} and L_{10} metrics at this location (refer Appendix D).

326 Centenary Drive, Clarenza: This noise logging location was approximately 70 m from the road side with intervening grass cover and at a slightly lower RL than the road. Whilst calculations for this receiver compensated for these topographical features, it is likely that the contribution from local ambient noise sources (e.g. people, animals, insects, etc) dominated measured noise data given the significant distance to the roadside.

On the basis of the good correlation between modelled and measured levels during the daytime period and the reasoning presented above for discrepancies during the night-time period, the SoundPLAN model created is considered robust in accordance with RMS guidelines[3].

4.4 Noise Sensitive Receiver Locations

Properties near to each of the route options and existing arterial roads have been considered in the analysis and are generally limited to properties that are:

- within the first two rows of properties adjacent to the route options or existing arterial roads, and
- within 300 m of the route options or existing arterial roads

This allows the focus to be on those properties where the noise levels would be most likely to exceed the adopted RNP criteria and where the greatest increase in noise levels would be likely to occur.

A preliminary computer noise model was created for each of the route options using the preliminary alignment information, traffic flow rate predictions and property locations. Analysis was undertaken and confirmed that the criteria for selection of residential receivers to be used in the analysis was appropriate. Due to distance attenuation and shielding from intervening structures, residential receivers beyond this would generally not be exposed to levels of noise above the adopted criteria. While road traffic noise levels beyond these receivers locations may be audible this is not significant in discriminating between alternative route options.

Properties that are subject to approved Development Applications have also been included as part of the noise modelling where appropriate. Generally, Development Application approvals are valid for five years from the date of approval. Based on this, properties subject to approved Development Applications from 2007 to the announcement of the short-list of route options on 18 January 2012 were taken into consideration. Only approved Development Applications that related to potentially noise sensitive receivers were included in the modelling.

4.5 Predicted Noise Levels

Road traffic noise levels were predicted for all potentially noise sensitive receivers for the following:

- Assumed year of opening - 2019
- Design Year, 10 years after assumed year of opening - 2029

For the purpose of this assessment, only the 2029 data is presented here as being representative of the worst case impact. Assessment has been made for both the day (7am-10pm, 15hr) and night (10pm-7am, 9hr) periods as appropriate.

In order to provide direct comparison between options, identical receiver locations were used for each assessment. Where dwellings were identified for acquisition, those receivers have been removed from the assessment.

The following sections summarise the assessment parameters calculated from predicted noise levels for all receiver locations in order to provide indicators for comparison between route options.

It should be noted that predicted noise levels have been used as the basis for route option comparison only, as appropriate to this stage of development. Predictions made herein are not appropriate for use in determining eligibility for mitigation measures. This will be undertaken as part of the detailed design once the preferred route has been selected.

Interpretation of the data is used to feed into acoustic indicators used for the project as described in Table 10 below.

Indicator	Description
Number of residential properties where noise levels exceed 55 dB(A) during the day or 50 dB(A) during the night, at 10 years after opening (2029) (No.)	This is an indicator of the comparative impacts on residential properties adjacent to existing or new arterial roads. It also includes aged care facilities which are assessed using the same noise criteria as residential properties. This indicator is calculated using the noise model that was developed for the project. For each option the number of residential properties that in 2029 would exceed the NSW Road Noise Policy (NSW OEH, 2011) criterion for new arterial/sub-arterial road corridors, 55 dB(A) during the day or 50 dB(A) during the night is identified. The number of residential properties where noise levels exceed these levels in the ‗no build' (ie if a new bridge were not to be built) for 2029 is also shown. The noise levels have been set approximately at the point at which 10% of residents are highly annoyed by the noise. Comparatively, the greater the number, the greater the potential impact. Note: • No mitigation measures have been included in the assessment. • The noise model takes into account the influence of the number and speed of heavy vehicles (on traffic noise levels). • Some of the residences counted in this indicator would also experience an increase of at least 12 dBA, and would also be counted in the following indicator.
Number of residential properties where noise levels increase by 12 dB or more, at 10 years after opening (2029) (No.)	This is an indicator of the comparative impacts on residential properties adjacent to existing or new arterial roads. It also includes aged care facilities which are assessed using the same noise criteria as residential properties. This indicator is calculated using the noise model that was developed for the project. For each option the number of residential properties that in 2029 would exceed the NSW Road Noise Policy (NSW OEH, 2011) criterion for new road corridor/redevelopment, an increase of 12 dB or more is identified. A relative increase of 12 dB represents slightly more than an approximate doubling of perceived loudness (AS2659.1-1988) and is likely to trigger community reaction, particularly in environments where there is a low existing level of traffic noise (NSW Road Noise Policy (NSW OEH, 2011)). Comparatively, the greater the number, the greater the potential impact. Note: • No mitigation measures have been included in the assessment. • The noise model takes into account the influence of the number and speed of heavy vehicles (on traffic noise levels). • Some of the residences counted in this indicator would also experience noise levels that are above the 55 dB(A) or 50 dB(A) criteria in the NSW Road Noise Policy (NSW OEH, 2011) and would also be counted in the above indicator.
Number of other sensitive land uses where noise levels exceed the criteria in the NSW Road Noise Policy (NSW OEH, 2011), at 10 years after opening (2029) (No.)	This is an indicator of the comparative impacts on sensitive land uses other than residential and aged care facilities adjacent to existing or new arterial roads. These include schools, hospitals, places of worship (eg churches), open spaces (when occupied eg parks) and childcare facilities. This indicator is calculated using the noise model that was developed for the project. For each option the numbers of facilities that in 2029 exceed the NSW Road Noise Policy (NSW OEH, 2011) criterion have been estimated. Comparatively, the greater the number, the greater the potential impact. Note: • No mitigation measures have been included in the assessment. • The noise model takes into account the influence of the number and speed of heavy vehicles (on traffic noise levels).

Table 10: Acoustic indicators

4.5.1 Residential Receivers

The following parameters have been calculated for all residential receiver locations:

- Number of receivers above RNP criteria for both day and night periods (refer to Figure 4 and Figure 5).
- Number of receivers with relative noise increase above ‗No Build' (2029) scenario for each route option in excess of RNP criteria (refer to Figure 6 and Figure 7).
- Absolute Community Noise Burden for each route option (refer to Figure 8).
- Relative Community Noise Burden above ‗No Build' (2029) scenario for each route option (refer to Figure 9).

Figure 4 to Figure 9 show the relative comparison between route options per parameter calculated. For reference, the locations of receivers above each of the RNP daytime criteria (i.e. 55 dBA and +12 dB) are provided in Appendix F.

A discussion of the results is included in Section 4.6. Note that aged care facilities are included in the analysis of residential receivers as per the RNP.

RNP Exceedances - Absolute

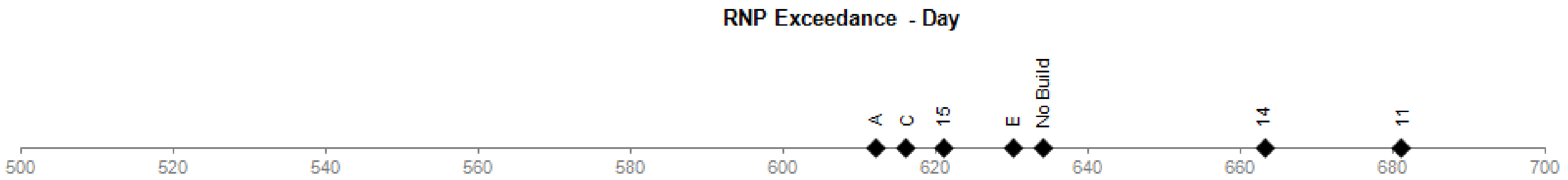


Figure 4: Number of residential receivers above day-time RNP criterion of 55 $dBL_{Aeq, 15\ hour}$

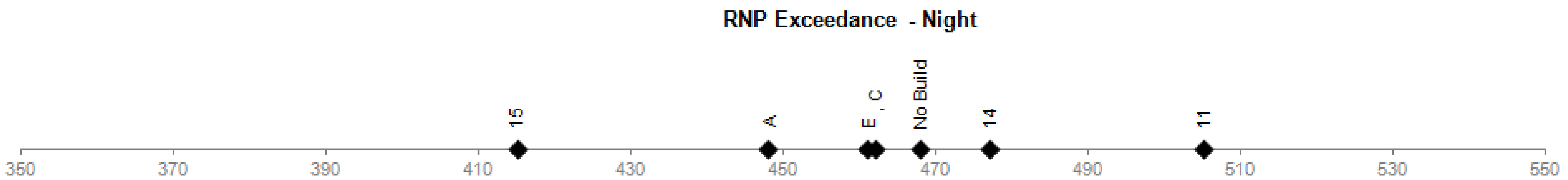


Figure 5: Number of residential receivers above night-time RNP criterion of 50 $dBL_{Aeq, 9\ hour}$

RNP Exceedances - Relative

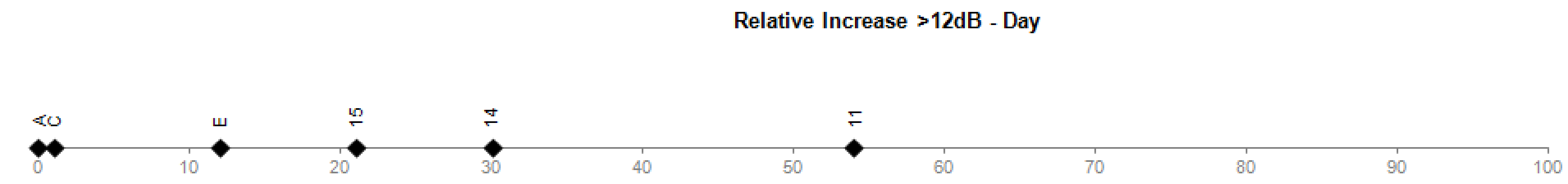


Figure 6: Number of residential receivers with relative noise increase >12 dB during day

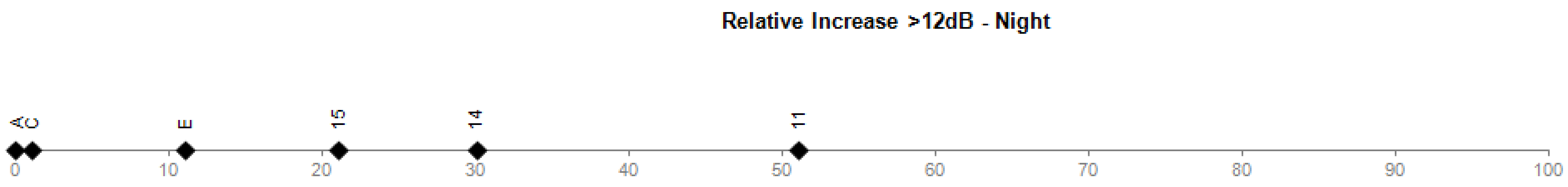


Figure 7: Number of residential receivers with relative noise increase >12 dB during night

Community Noise Burden

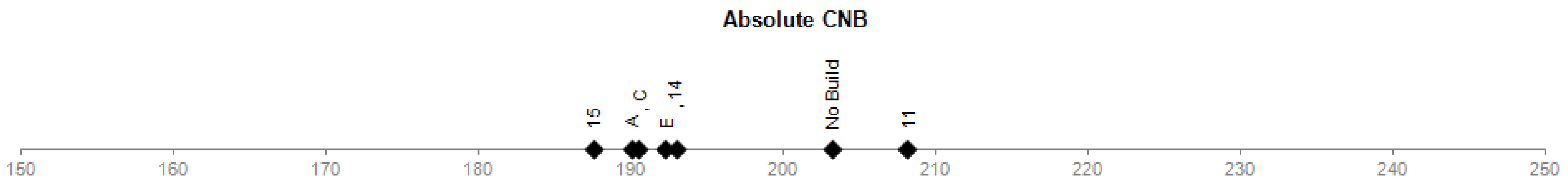


Figure 8: Absolute Community Noise Burden

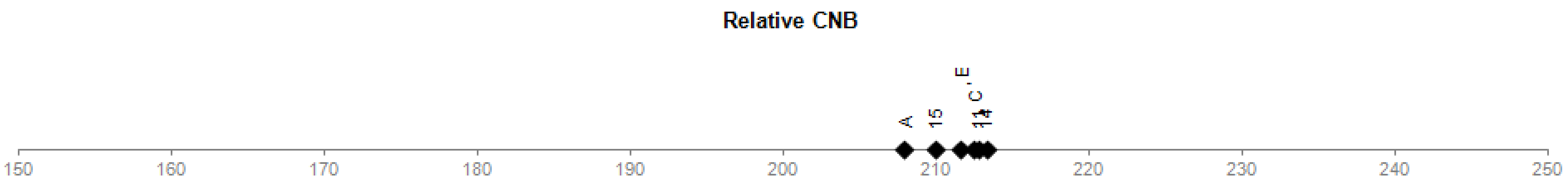


Figure 9: Relative Community Noise Burden

4.5.2 Sensitive Land Uses

There are other land uses that may be adversely affected by road traffic noise in addition to those residential receivers discussed above. These are defined in the RNP and include churches, educational buildings (schools), childcare facilities and hospitals. RNP criteria as discussed in Section 3.1.2 are used here to compare road traffic noise impacts on these types of receiver for each option.

Sensitive land use receiver locations were identified using the same selection criteria as residential receivers (i.e. first two rows within 300 m of route or arterial road). On this basis, the total number of receiver locations per sensitive land use classification remains consistent for all options and is presented in Table 11 below.

Ranges of predicted road traffic noise levels at identified non-residential sensitive land use receiver locations are provided in Table 11. The figures presented represent the range of noise levels from the least to worst affected locations for each route option. Results have been rounded to the nearest decibel. A comparison against ‗equivalent' external noise criteria as discussed in Section 3.1.2 (i.e. 10 dB higher than internal criteria on the basis that typical sound insulation provided through an open window is approximately 10dB) is also provided.

Receiver Classification	Number of Receiver Locations	Equivalent External Noise Criteria[1]	Predicted road traffic noise levels – dB$L_{Aeq, 1 hour}$ Day					
			Option A	Option C	Option E	Option 11	Option 14	Option 15
Church	6	50	53-72	53-71	53-77	53-71	52-72	52-72
Education	8	50	50-70	51-70	55-71	51-70	51-69	51-69
Childcare	2	45	50-66	50-66	50-66	50-66	57-65	57-65
Hospital	1	45	51	51	51	51	51	52
Open Space	34	55-60	Up to 77	Up to 73	Up to 73	Up to 71	Up to 71	Up to 73

Table 11: Non-residential noise-sensitive receiver road traffic noise levels - 2029

[1]Critera derived for external road traffic noise level as explained in Section 3.1.2.

N.B. In accordance with the RNP, aged care homes are considered residential and are therefore not shown here.

Data presented in Table 11 shows that road traffic noise criteria at all non-residential sensitive land use receiver locations are significantly exceeded for all options. Whilst these exceedances change slightly depending on the introduction of the various route options and flow on effects of road traffic flows throughout Grafton, these fluctuations are not significantly altered (1-3 dB).

There is one exception to this for Option E where one receiver location experiences noise levels of up to 6 dB higher than for other route options. The current use of this facility is unknown. It was previously the McAuley Catholic College which has since moved to Clarenza. The property is still owned by the Sisters of Mercy so it has been assumed to be a church facility as it may be used for convent purposes such as prayer meetings.

It should also be noted that the Clarence Valley Conservatorium at 6-8 Villiers Street is affected by Option E by up to 3 dB more than other options.

For open space areas used for active and passive recreation, given the nature of these spaces, the extent of affectation varies considerably depending upon proximity to the roadway. This is due to the often large area which they encompass. For Options 14 & 15, two recreational spaces have been significantly more impacted upon due to their alignment being remote from the existing arterial roads. These extra areas align the Clarence River and are directly impacted upon by the new alignments. The maximum exceedances observed for all options are once again within 1-2 dB of each other. Option A is an exception to this where the new route alignment dissects two parks located on both river banks.

In light of the above comparison between route options for non-residential sensitive land uses yielding little discrepancy, the analysis of residential receiver locations presented in the previous section will form the primary basis for comparison between route options in this report. The only clear indicator that may be appropriate for inclusion in the route selection process is the significant impact (up to 6 dB above) of Option E on the church facility.

It should be noted that, once a preferred route option is selected, detailed design of that option will include investigation into appropriate mitigation measures for adversely affected non-residential noise sensitive receivers on a case by case basis.

4.6 Discussion

In general, based on the interpretation of data presented in the sliding scales shown in Figure 4 to Figure 9, Options A, C & E result in a similar road traffic noise impact for all indicators. This is to be expected due to their comparable geographic location to each other. Option E tends to affect slightly more receivers due to its more remote alignment from the existing bridge. It also affects two non-residential receivers that are otherwise less affected by the other options as discussed in Section 4.5.2.

These three route options generally represent those with the lowest road traffic noise impact overall. This is largely due to their location close to the existing bridge and the Grafton urban centre (i.e. the area where the traffic noise currently exists) hence affecting little change to the existing noise environment. Route alignments that are further removed from existing thoroughfares introduce extra receiver locations that would otherwise remain relatively unaffected.

In this respect, Option 11 is a clear outlier for all indicators, receiving the greatest impact from road traffic noise overall. This is due to the dense concentration of residential receivers aligning the proposed route that currently experience very little road traffic noise due to Fry Street being a local road with low traffic volumes. Similarly, receivers along North Street experience an increase in traffic flows under the introduction of the Option 14 alignment.

Whilst the majority of the Option 14 alignment is shared by Option 15, the realignment to the north that redirects traffic away from receivers aligning North Street significantly reduces the overall impact. This redirection into largely green field areas, coupled with the alleviation of some traffic from the existing bridge and the proximity of the receivers to the road alignment reduces the relative impact of Option 15 overall, particularly during the night-time period.

The number of properties that exceed the RNP criteria in the no build scenario is higher than some options and lower than others. This is a result of the varying redistributions of traffic that occur within the options and the possibility of property acquisitions that are unique to each route alignment.

When interpreting the data, it should be noted that exceedances of RNP criteria are relative to a single criterion value. There is no discrimination as to how far above or below the criteria receivers fall. As such, small changes in road traffic noise level may change the number of exceedances greatly or not at all. The CNB assessment approach aims to address this issue by providing a weighting based on the actual predicted noise level, regardless of its relationship to a criterion value.

It can be seen from the comparison between RNP and CNB indicator analysis that the relative impact of each option is more closely spaced when basing assessment on CNB. This is largely due to the relationship between a few receivers experiencing a relatively high level of road traffic noise when compared against many receivers receiving a relatively low level of road traffic noise. The resultant effect is that the corresponding overall community impact due to increases in road traffic noise exposure is regarded as being similar for both scenarios, and is also similar for each route option. Within the relative CNB, the differences between the route alignments are comparatively small and as such, insignificant rounding errors can result in slight deviation to the order of the alignment options.

The RNP assessment of road traffic noise impacts is relative to statutory criteria whilst the CNB assessment provides a good insight into comparative impacts across the whole community and serves to highlight the similarity between all options.

4.7 Noise Mitigation Options

As discussed, the assessment of traffic noise impact has been undertaken with no mitigation measures in place. In reality, for the preferred route option, where practical, noise exceedances would be addressed through noise mitigation measures.

As operational noise levels are predicted to exceed the RNP noise criteria, all reasonable and feasible mitigation measures must be considered and applied to control road traffic noise levels during the detailed design of the preferred route option.

Practice Note IV (PN-IV) of the Environmental Noise Management Manual[6] (ENMM) provides a detailed procedure for *„sdecting and designing "feasible and reasonable" treatment options for road traffic noise"*that is aimed at providing a consistent approach to the evaluation, selection and design of appropriate noise control options. Note that not all properties above the criteria will qualify for noise mitigation measures.

This section explores some of the mitigation measures that could potentially be implemented and is separated into ~~–at~~ road" and ~~–at~~ dwelling" categories.

4.7.1 At Road Mitigation

4.7.1.1 Noise Barriers

By introducing a barrier between the noise source and the receiver, the amount of sound reaching the receiver can be significantly reduced. In principle it is most effectively located as close to the source of sound (i.e. the road) as possible, except where the road is in a cutting when it is better to place the barrier at the top of the cutting where it will have greater effect.

On multi-lane roads the noise from the furthest traffic lanes will not be reduced as much as that from the near lanes of the different path angles. Where barriers are located on both sides of a road, the internal finish of the barriers should be considered. An absorptive treatment may be appropriate to reduce the impact of reflected noise.

The height of the barrier is also significant — as a general rule a barrier should at least be high enough to dissect the line between a point anywhere 1m above the road surface (on both carriageways) and a point 1.5m above the floor of an adjacent residence.

In general, the higher the barrier, the greater the level of noise reduction. This is due to path length difference and is not a linear relationship. Potential barrier correction as a function of path difference is defined in CoRTN, a graph of which is reproduced in Figure 10 below. It can be seen that the effectiveness of the noise barrier reduces with increasing height.

The ENMM states that noise barriers more than 8 m high are generally considered visually unacceptable. This provides a practical limit to achieving path length difference. It would therefore, generally speaking, be unlikely that a reduction of more than 15 dB(A) be achieved from implementation of a noise barrier.

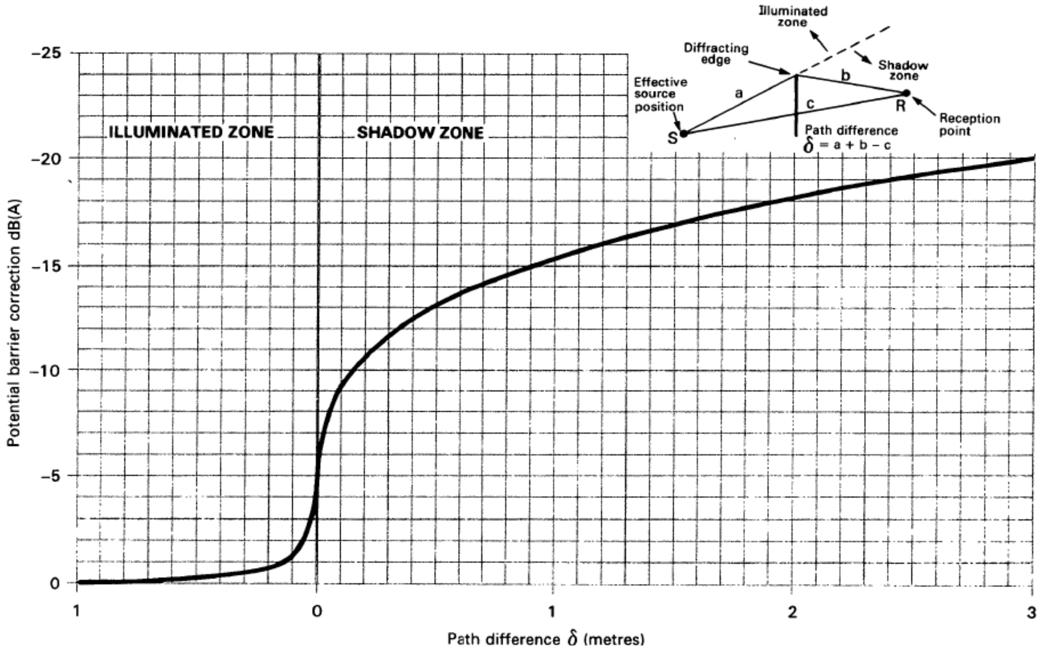


Figure 10: Potential Barrier Correction as a Function of Path Difference (CoRTN)

Practice Note-IV Part (a) of the ENMM provides a detailed procedure for the analysis of the cost/benefit of noise barrier options, including the level of noise reduction achieved, the number of residences protected and the typical installed cost of noise barriers. Given the built-up nature of the existing route, noise barriers are unlikely to be a practical mitigation measure due to access requirements (i.e. driveways).

4.7.1.2 Reducing the Speed Limit

In general, reducing the speed limit can reduce noise levels, particularly if it is reduced from speeds greater than 70 km/hr. CoRTN defines the correction to propagated road traffic noise as follows:

$$\text{Correction} = 33\ Log10\left(V + 40 + \frac{500}{V}\right) - 68.8\ dB(A)$$

Very generally speaking, this reduction approximately equates to a reduction in the order of 1 dB per 10 km/hr reduction in speed. It is unlikely that speed limits will be able to be reduced by more than 10 km/hr. This therefore limits the effectiveness of this mitigation measure to the order of 1 dB(A).

4.7.1.3 Use of Low-Noise Pavement

Section 3 of the ENMM discusses the effectiveness of low-noise pavements with traffic speed, and states that tyre noise is generally dominant for cars and light vehicles above ~30–50 km/h, and is generally dominant for heavy vehicles above 40–80 km/h, with the pavement surface being most effective above 70 km/h.

For free-flowing traffic at 80 km/h, low-noise pavements are expected to produce tangible benefits. However, when traffic is starting or stopping (e.g. at an intersection or corner) the effect of low-noise pavement on the noise levels would be reduced. Further, it is more suitable for higher speed roads. It does not have suitable strength for turning movements or stop-start movement.

It should also be noted that existing residences are predicted to exceed the RNP by greater than 5 dB. As such, the use of low-noise pavement alone will not adequately reduce noise levels to within the recommended limits.

4.7.2 At Dwelling Mitigation

4.7.2.1 Architectural Treatments

Treatments of individual properties using measures such as double glazing, increased sound insulation and / or installation of mechanical ventilation systems may result in significant noise reductions inside residences.

Table 8.1 of the ENMM provides indicative noise reduction values for architectural acoustic treatments. Generally the effectiveness of architectural treatments is greater for masonry construction buildings than light construction (e.g. fibreboard). Table 8.1 of the ENMM is reproduced in Table 11 below:

Building Type	Treatment	Noise Reduction
Light frame	Fresh air ventilation system	10 dB(A)
	Fresh air ventilation system Upgraded window and door seals	12 dB(A)

Masonry	Fresh air ventilation system	15 dB(A)
	Fresh air ventilation system Upgraded window and door seals Sealed wall vents	20 dB(A)
	Fresh air ventilation system Upgraded window and door seals Sealed wall vents Upgraded Glazing Solid-Core Doors	25 dB(A)

Table 12: Indicative noise reductions provided by architectural treatments (Table 8.1 ENMM)

However there are limitations to the effectiveness of architectural treatments, including:

- No acoustic benefit is provided for outdoor living areas.
- Opening of windows for ventilation in summer, especially at night, can negate any benefits.
- For some houses such as fibro structures, the building construction itself limits the amount of practical noise reduction possible.

Selection of appropriate architectural treatments will be made during the detailed design of the preferred option, using the methodology of Practice Note IV(b) of the ENMM, and considering the cost and benefit provided by architectural treatments compared to other noise-mitigation measures.

4.7.3 Summary of Operational Noise Control Measures

A summary of the noise control measures considered for this project is presented below in Table 13.

Mitigation Measure	Predicted Maximum Noise Reduction
Noise Barrier	Up to 15 dB(A)
Reducing Traffic Speed	1 dB(A)
Low-Noise Pavement	Up to 5 dB(A)
Architectural Treatments	12 dB(A) (light construction) 25 dB(A) (masonry)

Table 13: Traffic Noise Control Measures considered for the Summerland Way River Crossing Concept Options

Architectural treatments of individual properties generally provide greater scope for noise reduction than other mitigation measurements, but may not be able to reduce noise levels to the RNP criteria at all receivers, particularly if receivers are of lightweight construction.

Appendix A

Glossary

Ambient Noise Level

The noise level in a space measured in the absence of the noise being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans.

Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time.

dB(A)

dB(A) is a single number to describe a sound pressure level and includes a frequency weighting to reflect the subjective loudness level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB. Some typical dB(A) levels are shown below.

Noise Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street

dBL_{eq}

The ‗equivalent continuous sound level', L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

dBL_{eq} is often used as the ―average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time. When the dB(A) weighting is applied, the level is denoted dBL_{Aeq}. Often the measurement duration is quoted, thus $dBL_{Aeq,\ 15\ minute}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

dBL$_{10}$

The dBL$_{10}$ statistical level is often used as the “average maximum” level of a sound level that varies with time.

Mathematically, the dBL$_{10}$ level is the sound level exceeded for 10% of the measurement duration. dBL$_{10}$ is often used for road traffic noise assessment. As an example, 63 dBL$_{A10,\ 18\ hour}$ is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

dBL$_{90}$

The dBL90 statistical level is often used as the “average minimum” or “background” level of a sound level that varies with time.

Mathematically, dBL$_{90}$ is the sound level exceeded for 90% of the measurement duration. As an example, 45 dBL$_{A90,\ 15\ minute}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear, which allows hearing over a large range of sound pressure levels. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

Frequency

Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as “pitch”. Sounds towards the lower end of the human hearing frequency range are perceived as “bass” and sounds with a higher frequency are perceived as “high pitched”.

‘No-Build’

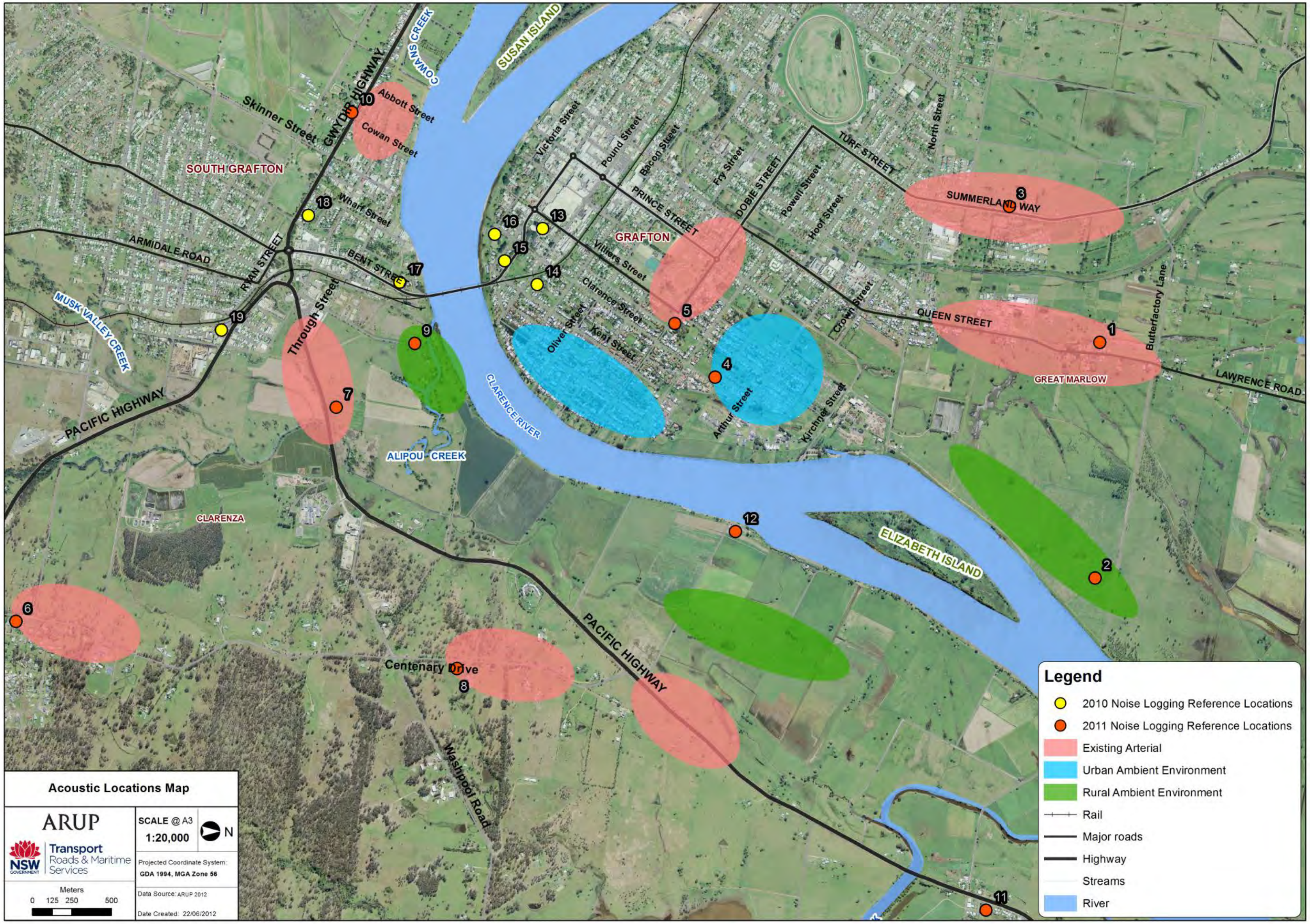
This term refers to the scenario if no additional crossing were to be built. The no build scenario includes some road works that would be necessary to address localised congestion and capacity restraints as they arise to reasonably cater for expected demand in 2029. The impacts of projected road traffic flows with no development form the point of comparison against those of route option alignments.

Appendix B

Acoustic Locations Map

For reference, noise monitoring locations referenced in the aerial photograph over leaf correspond to those listed in the table below.

	Reference Location	Address	Logger Type	Serial Number
2011 Noise Survey	1	245 Lawrence Road, Great Marlow	RTA -02	050
	2	86 Great Marlow Road, Great Marlow	RTA -02	049
	3	591 Summerland Way, Carrs Creek	RTA -02	009
	4	Cnr Hoof and Clarence Streets, Grafton	Ngara	87809E
	5	94 Dobie Street, Grafton	RTA -04	010
	6	81 Edward Ogilvie Drive, Clarenza	Ngara	87802E
	7	Pacific Highway near Alipou Creek	Ngara	87807F
	8	326 Centenary Drive, Clarenza	Ngara	878079
	9	Cnr Iolanthe Street & Butters Lane, South Grafton	Ngara	878060
	10	146-148 Ryan Street, South Grafton	Ngara	878000
	11	5 School Drive, Swan Creek	Ngara	878080
	12	Riverbank at end of Meona Lane, off Pacific Highway.	Ngara	878007
2010 Noise Survey	13	Villiers Street, near TAFE, Grafton	RTA-04	008
	14	Gummyaney Pre-School, 30 Pound Street, Grafton	RTA-02	050
	15	8 Fitzroy Street, Grafton	RTA-04	010
	16	St. Mary‘s Church, Clarence Street	EL-316	15-299-419
	17	12 Bent Street, Grafton Aged Care Home, South Grafton	EL-315	15-299-422
	18	8 Beatson Street, South Grafton	RTA-04	009
	19	España Hotel, Schwinghammer Street, South Grafton	RTA-02	049


SUSAN ISLAND
COWANS CREEK
GWYDIR HIGHWAY
Skinner Street
Abbott Street
Cowan Street
SOUTH GRAFTON
Wharf Street
ARMIDALE ROAD
RYAN STREET
BENT STREET
Through Street
MUSK VALLEY CREEK
PACIFIC HIGHWAY
ALIPOU CREEK
CLARENZA
Victoria Street
Pound Street
Bacon Street
Fry Street
DOBIE STREET
TURF STREET
North Street
PRINCE STREET
GRAFTON
Villiers Street
Clarence Street
Oliver Street
Kent Street
Powell Street
Hoof Street
Crown Street
Arthur Street
Kirchner Street
SUMMERLAND WAY
QUEEN STREET
Butterfactory Lane
GREAT MARLOW
LAWRENCE ROAD
CLARENCE RIVER
ELIZABETH ISLAND
Centenary Drive
Washpool Road
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Legend
2010 Noise Logging Reference Locations
2011 Noise Logging Reference Locations
Existing Arterial
Urban Ambient Environment
Rural Ambient Environment
Rail
Major roads
Highway
Streams
River
Acoustic Locations Map
ARUP
Transport Roads & Maritime Services
NSW GOVERNMENT
SCALE @ A3
1:20,000
N
Meters
0 125 250 500
Projected Coordinate System:
GDA 1994, MGA Zone 56
Data Source: ARUP 2012
Date Created: 22/06/2012

Appendix C

Unattended Noise Logging Locations

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
1	245 Lawrence Road, Great Marlow	Arterial Road	Single-storey residence with receiver at building facade, approximately 16.2 m to the edge of Lawrence Rd. House located on large acreage and surrounded by farmland. Main contribution from Lawrence Road. Some local agriculture during day-time period.	
2	86 Great Marlow Road, Great Marlow	Rural	Receiver located along paddock fence line on rural road serving 15 semi-rural residences along the Clarence River. Noise environment generally governed by farm machinery, road traffic on Great Marlow Road and livestock/wildlife. Receiver is positioned approximately 16.3m from roadside.	

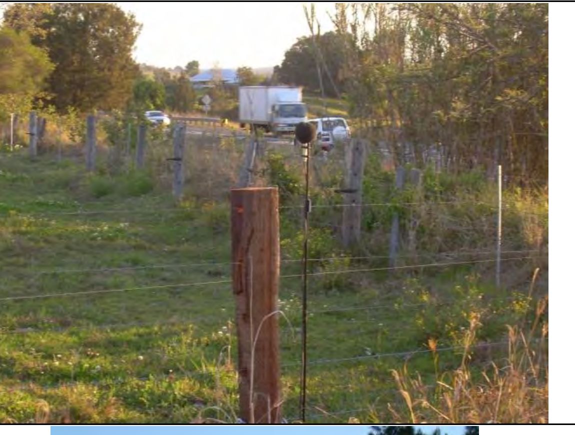
[9] N.B. Colour coding can be referenced to Appendix B colour scheme

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
3	591 Summerland Way, Carrs Creek	Arterial Road	Single-storey residence with receiver placed in tree line at front of property, approximately 4.6 m from facade due to access restrictions. Approximately 12.2m to the edge of Summerland Way, separated by a wide grassed verge. Road traffic along Summerland Way noted as the dominant noise source.	
4	Cnr Hoof and Clarence Streets, Grafton	Urban	Receiver located along fence line in an uninhabited paddock surrounded by single and double storey residences. Located approximately 11.3m from the roadside. The relative level of the property was noted as being slightly below the level of the road surface. Local traffic flows and community noise governs ambient noise environment.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
5	94 Dobie Street, Grafton	Urban	Single-storey residence with receiver placed at building facade, approximately 16.8m from Dobie Street roadside. Road traffic noise, including some heavy vehicles from further north along Dobie Street, noted as dominant noise source.	
6	81 Edward Ogilvie Drive, Clarenza	Arterial Road	Receiver placed in large front garden of single storey residence in semi-rural suburb approximately 10.7m from Centenary Drive roadside. Grass verge and light shrubbery separates receiver from road. Centenary Drive receives significant use by both cars and heavy vehicles.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
7	Pacific Highway near Alipou Creek	Arterial Road	Receiver positioned directly adjacent to Pacific Highway northbound approximately 6.6m to guard to roadside. The noise environment at this location is significantly dominated by road traffic flows including high percentage of heavy vehicles.	
8	326 Centenary Drive, Clarenza	Arterial Road	Single storey semi-rural residence with receiver positioned approximately 67.7m from Centenary Drive and a further 2m from the facade outside front porch canopy. Receiver separated from Centenary Drive by considerable grassed expanse. Predominantly affected by road traffic along Centenary Drive and local farm industry.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
9	Cnr Iolanthe Street & Butters Lane, South Grafton	Rural	Semi-rural property located relatively close to South Grafton urban area, existing Grafton Bridge and Clarence Riverbank. Receiver positioned in empty paddock surrounded by livestock and semi-rural residences. Butters lane is a no thoroughfare road that services 3 residences that is fed by Iolanthe Street. Primary noise sources in the area include livestock, local residential activity, rail movements along the nearby Northern Line and road traffic noise predominantly along the existing Grafton Bridge.	
10	146-148 Ryan Street, South Grafton	Arterial Road	Receiver located along fence line within a community garden owned by Clarence Valley Council. Receiver is located approximately 10.2m from Ryan St roadside. Acoustic environment governed by significant road traffic flows along Ryan Street during the day-time period.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
11	5 School Drive, Swan Creek	Arterial Road	Receiver located adjacent to community hall within roadside overgrowth approximately 21.1m from the Pacific Highway and 18.7m to School Drive. Receiver is positioned approximately 2.5m above road level. Primary source of noise is heavy vehicle flow along the Pacific Highway. Compression braking noted during attended noise surveys, especially during night-time period.	
12	Riverbank at end of Meona Lane, off Pacific Highway.	Rural	Receiver located in rural paddock occupied by livestock along the bank of the Clarence River and approximately 660m from the Pacific Highway. Due to the gradient of the riverbank the receiver was partially acoustically shielded from road traffic noise although the Pacific Highway was still identified as being the primary noise source.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
13	29 Villiers Street, in front of TAFE College, Grafton	Urban	Single-storey residence with floor raised approximately 1m on brick columns with TAFE college at back fence by tree. Residential facade approximately 15m back from kerbside. Main noise contribution from traffic on Villiers Street that includes some through traffic and traffic using the shopping mall directly opposite.	
14	Gummyaney Aboriginal Pre School, 30 Pound Street, Grafton	Urban	Noise logger set up on school boundary with school building approximately 25m back from logger and logger approximately 15m back from Pound Street. The school is located in a residential area with an elevated train line running across Pound Street within 50-60m of the School facade. The noise environment is generally quiet except for occasional residential car traffic and trains.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
15	8 Fitzroy Street, Grafton	Arterial Road	Two storey residence at rear and one at the front. Rear of residence faces elevated section of Bent Street. The elevated road has an approximately 1.5-2m solid concrete barrier along both sides. The roofs of some passing traffic, particularly trucks can be seen from the receiver and logging location. The elevated rail line is also in direct line of sight of the rear of the receiver. The dominant noise source is from traffic on the elevated Bent Street. Freight trains are also audible when passing.	
16	St. Mary's Church, Clarence Street, Grafton	Urban	Receiver located close to edge of the river and in the corner of a park adjacent to a 90 degree bend on Clarence Street/Victoria Street. The noise environment is generally dominated by the heavy traffic on Bent Street as it crosses the river for the south and eastern facades (approximately 320m), and at the end of Clarence Street for the north facade (approximately 150m). There is some additional noise from traffic on the less busy local Fitzroy and Clarence Streets.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
17	12 Bent Street, Grafton Aged Care Home, South Grafton	Arterial Road	Elevated single storey brick building located approximately 20-30m from nearside carriageway. The land rises by approximately 1-2m from the carriageway level and looks directly onto it. Both car and commercial traffic noise from Bent Street dominates the noise environment.	
18	8 Beatson Street, South Grafton	Urban	Noise logger placed on second storey balcony at the rear of a two storey house set back approximately 50m back from Ryan Street/Gwydir Highway. It was not possible to set up the noise logger at houses directly overlooking the road. The dominant noise source was from a mix of traffic including cars and commercial traffic using Ryan Street/Gwydir Highway. Beatson Street is a local street with a low volume of traffic use.	

Reference Location	Address	Acoustic Locale[9]	Notes	Site Photo
19	España Hotel, Schwinghammer Street, South Grafton	Arterial Road	This receiver is a single storey brick building located adjacent the Pacific Highway/Schwinghammer Street in South Grafton. The noise logger was set up a few meters from the facade in a free-field position and the facade is approximately 30m back from the kerb side of the road. Car traffic and particularly commercial traffic at night are the dominant noise sources at this location.	

Appendix D

Unattended Noise Logging Graphs

D1 Noise Logger Location 1 – 245 Lawrence Road, Great Marlow

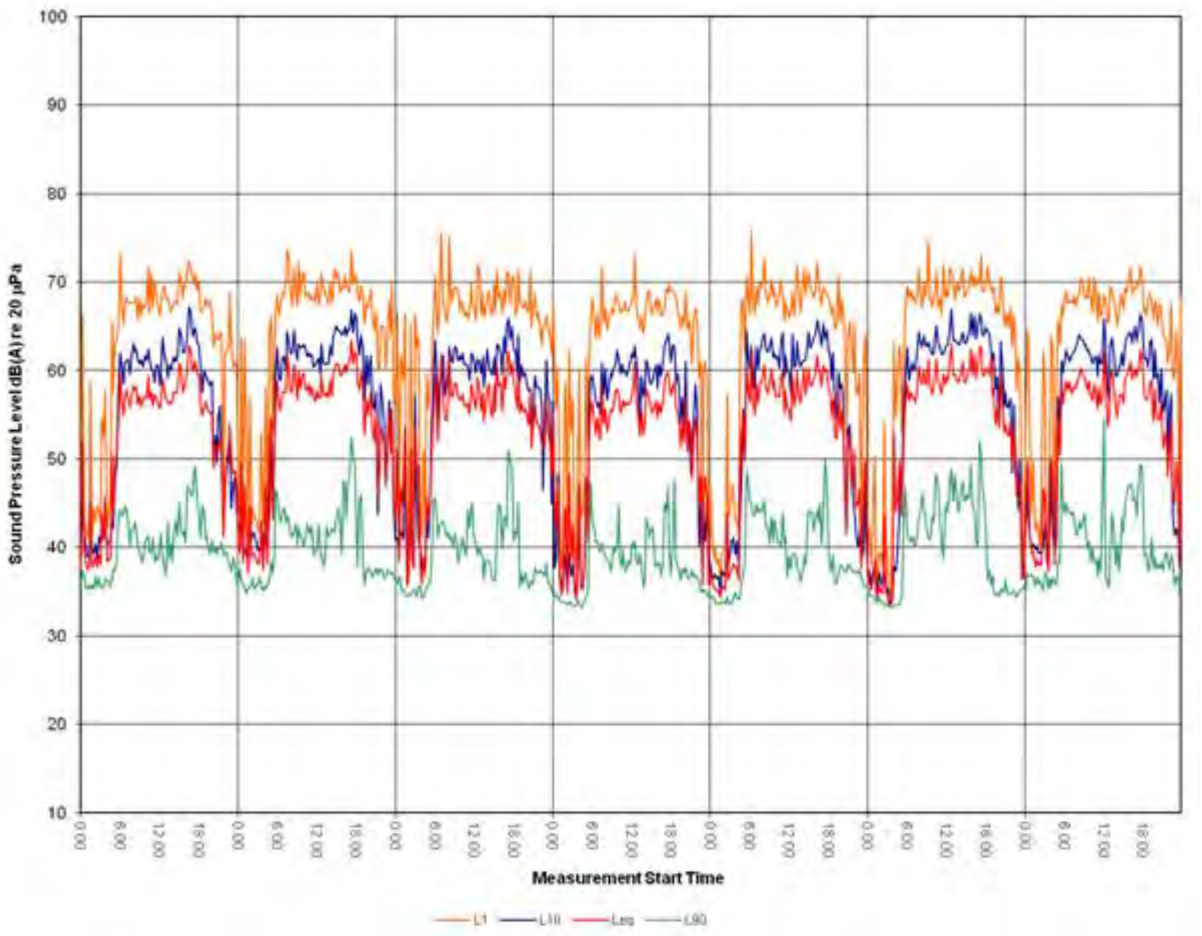


Figure 11: Measured Noise Levels – Logger Location 1 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D2 Noise Logger Location 2 – 86 Great Marlow Road, Great Marlow

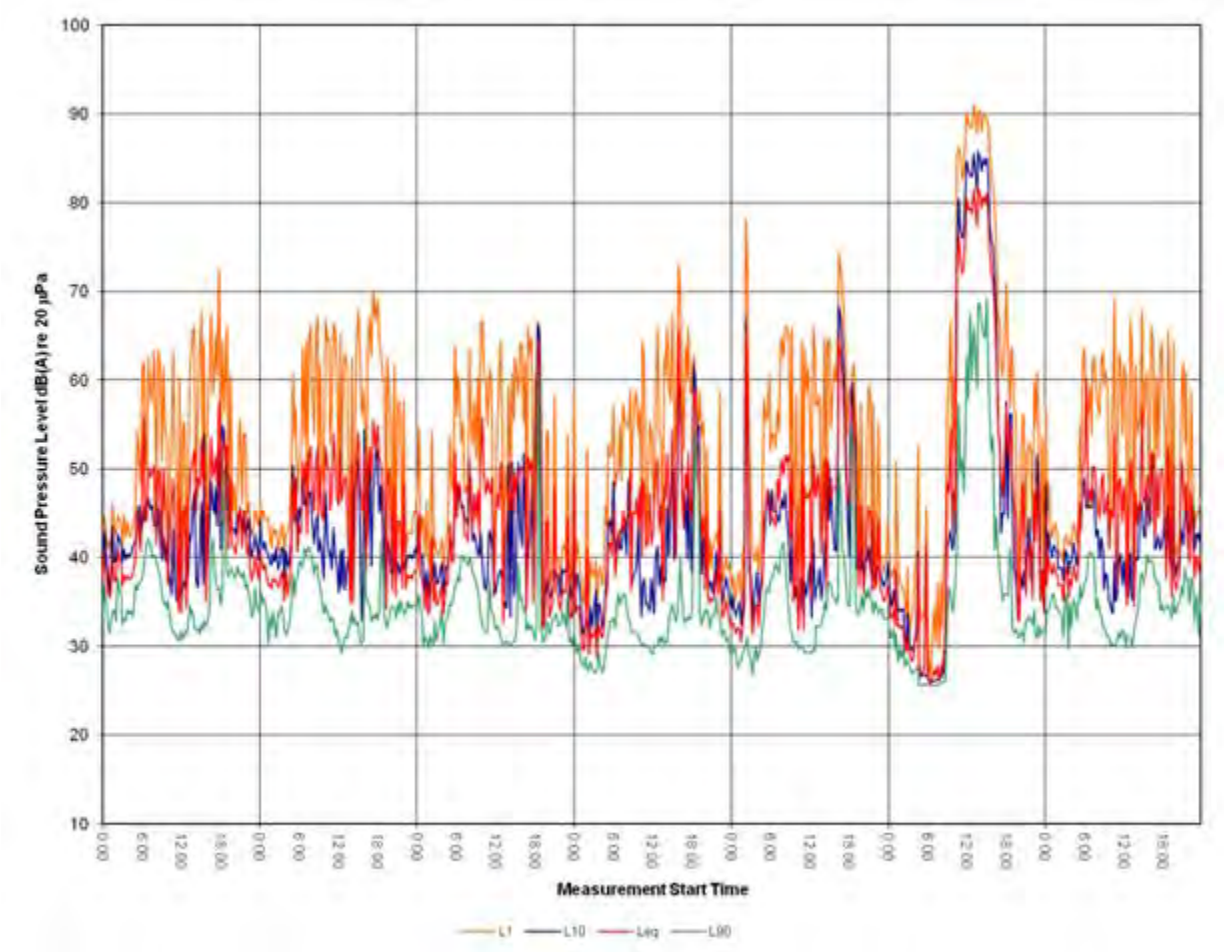


Figure 12: Measured Noise Levels – Logger Location 2 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 μPa.

D3 Noise Logger Location 3 – 591 Summerland Way, Carrs Creek

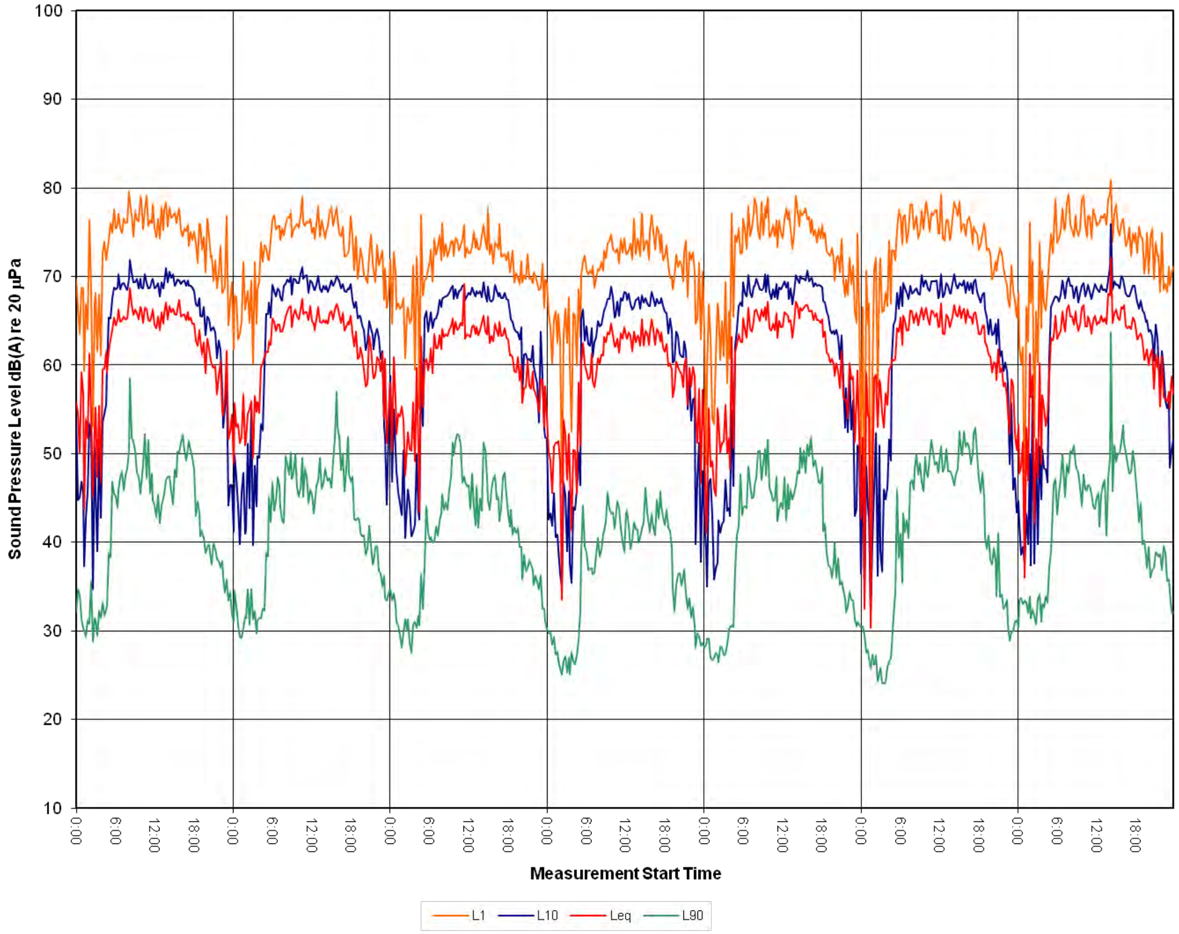


Figure 13: Measured Noise Levels – Logger Location 3 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D4 Noise Logger Location 4 – Cnr Hoof & Clarence Sts, Grafton

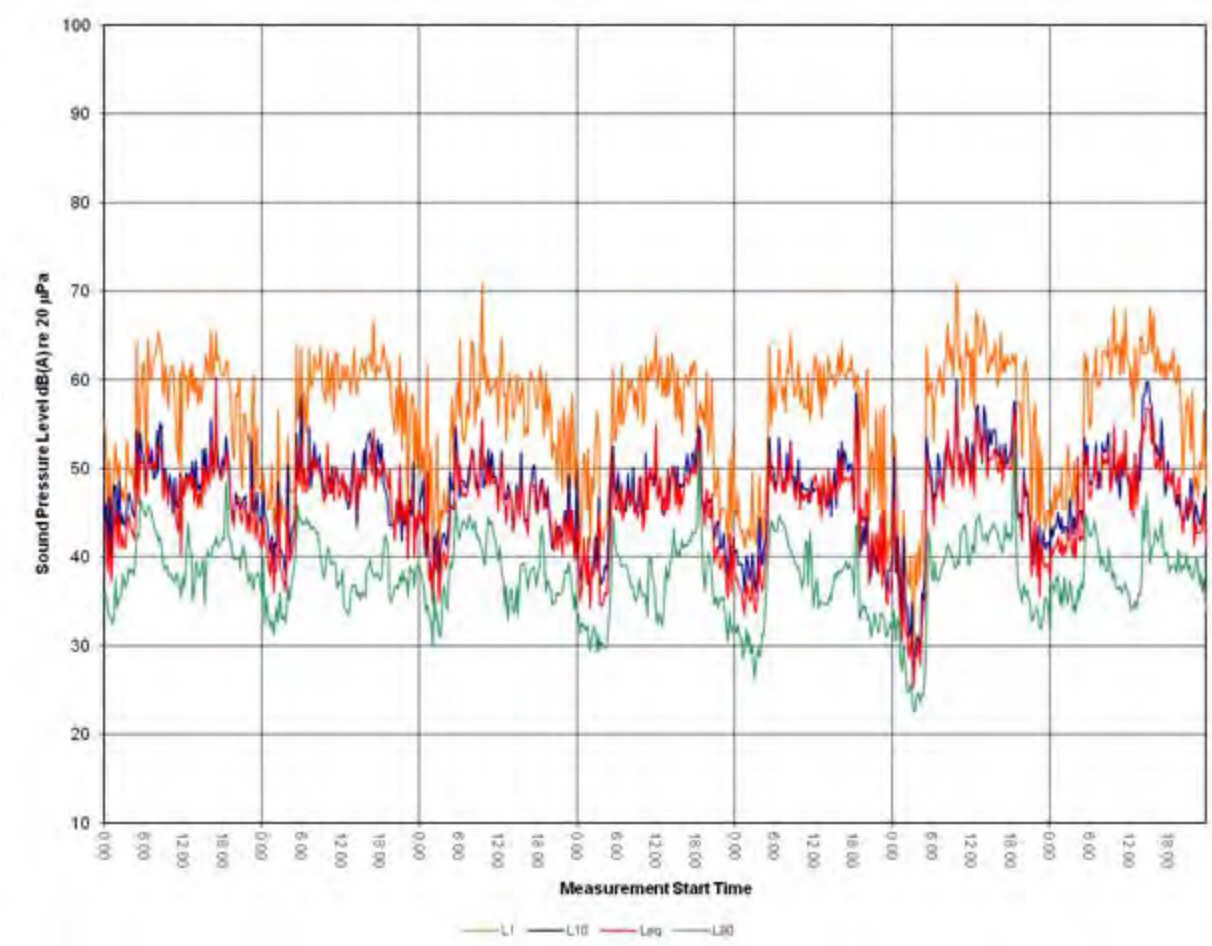


Figure 14: Measured Noise Levels – Logger Location 4 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D5 Noise Logger Location 5 – 94 Dobie Street, Grafton

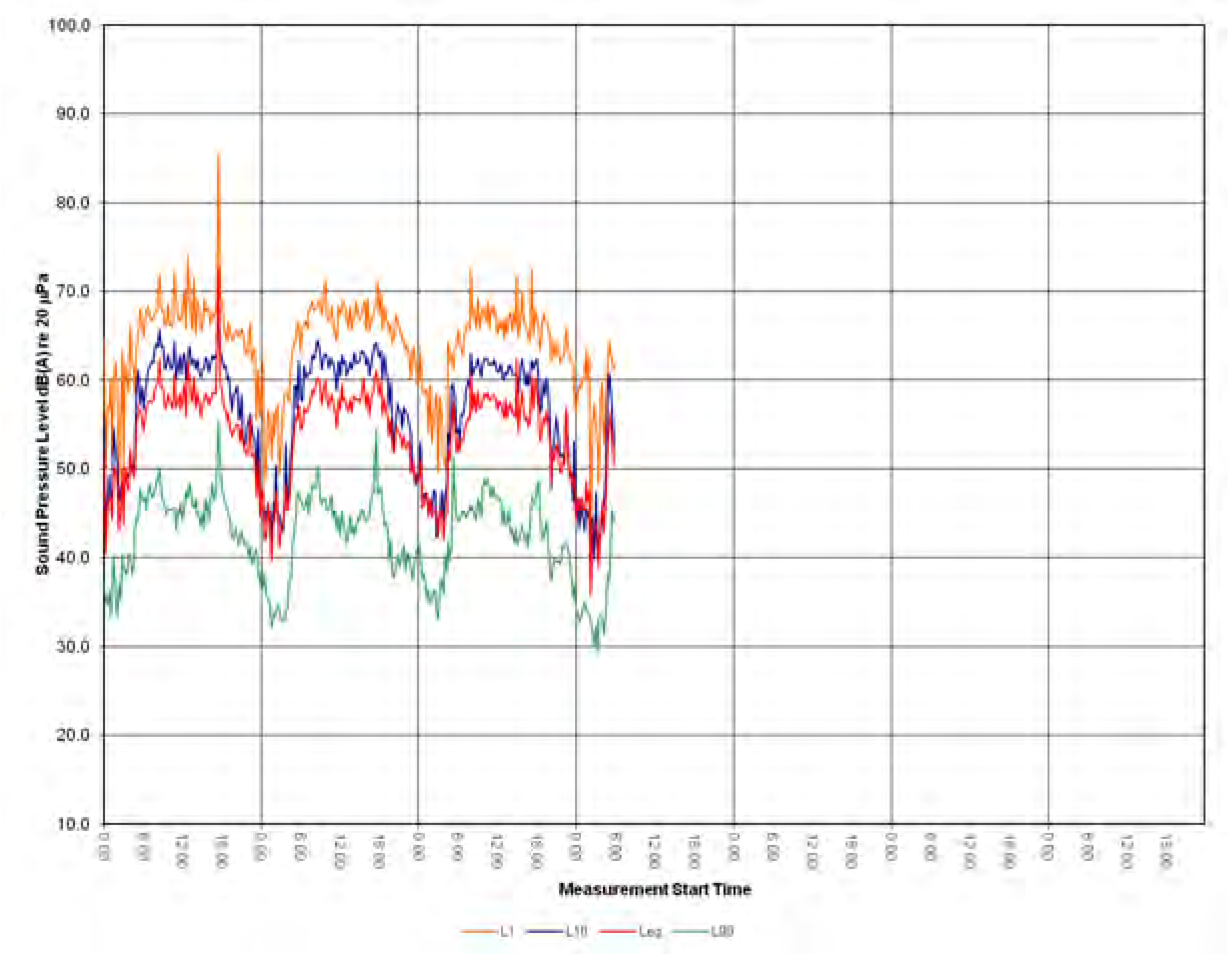


Figure 15: Measured Noise Levels – Logger Location 5 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D6 Noise Logger Location 6 – 4 Bacon Street, Grafton

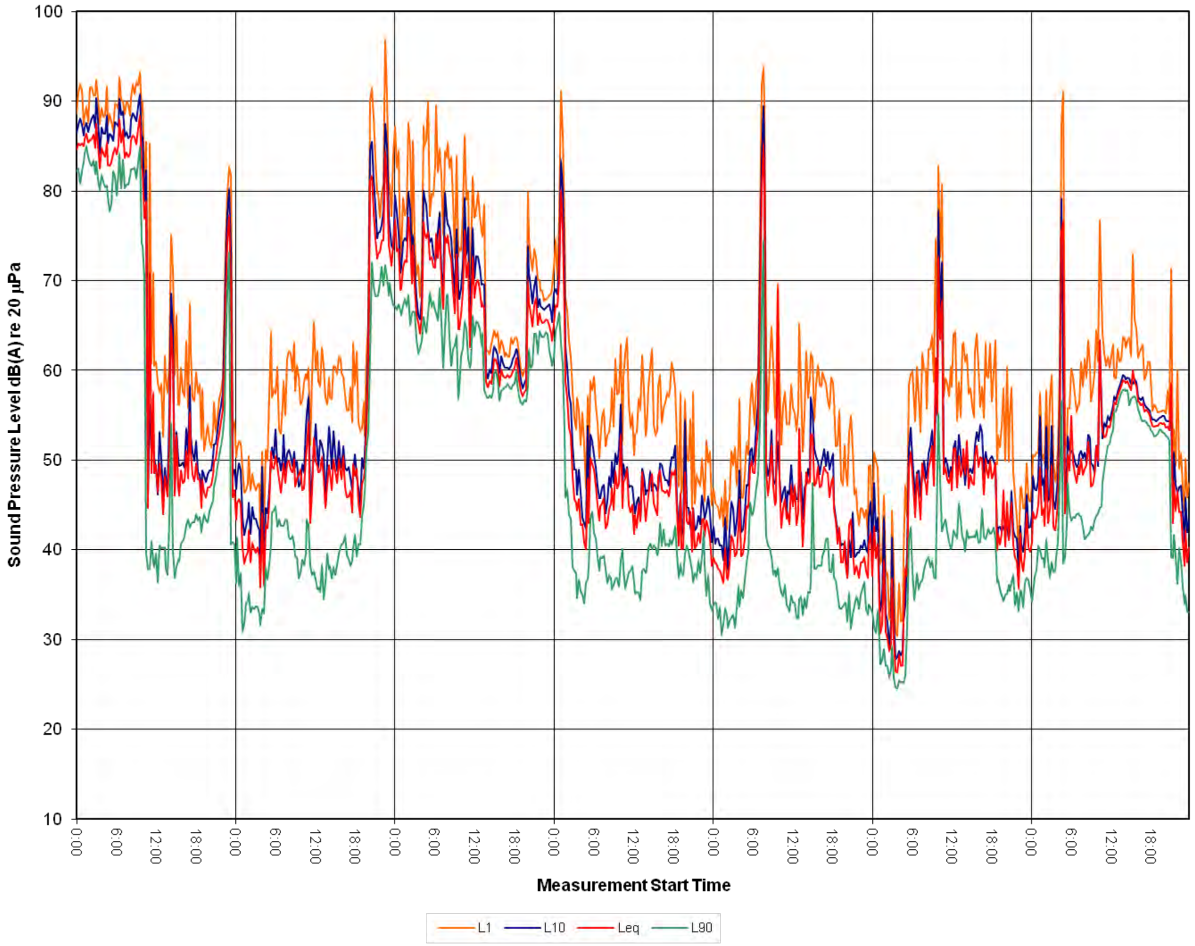


Figure 16: Measured Noise Levels – Logger Location 6 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D7 Noise Logger Location 7 – 81 Edward Ogilvie Drive, Grafton

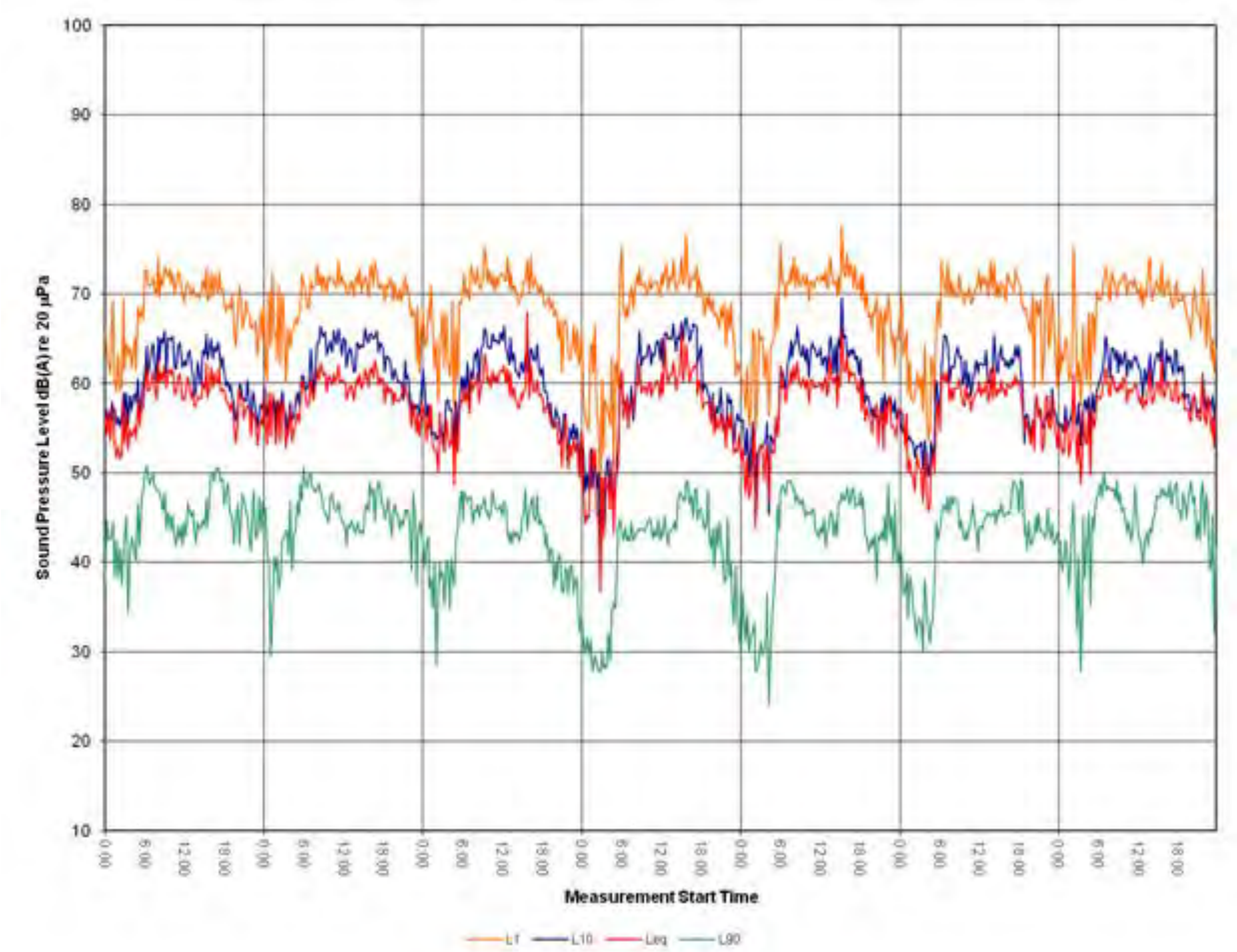


Figure 17: Measured Noise Levels – Logger Location 7 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D8 Noise Logger Location 8 – Pacific Highway, Grafton

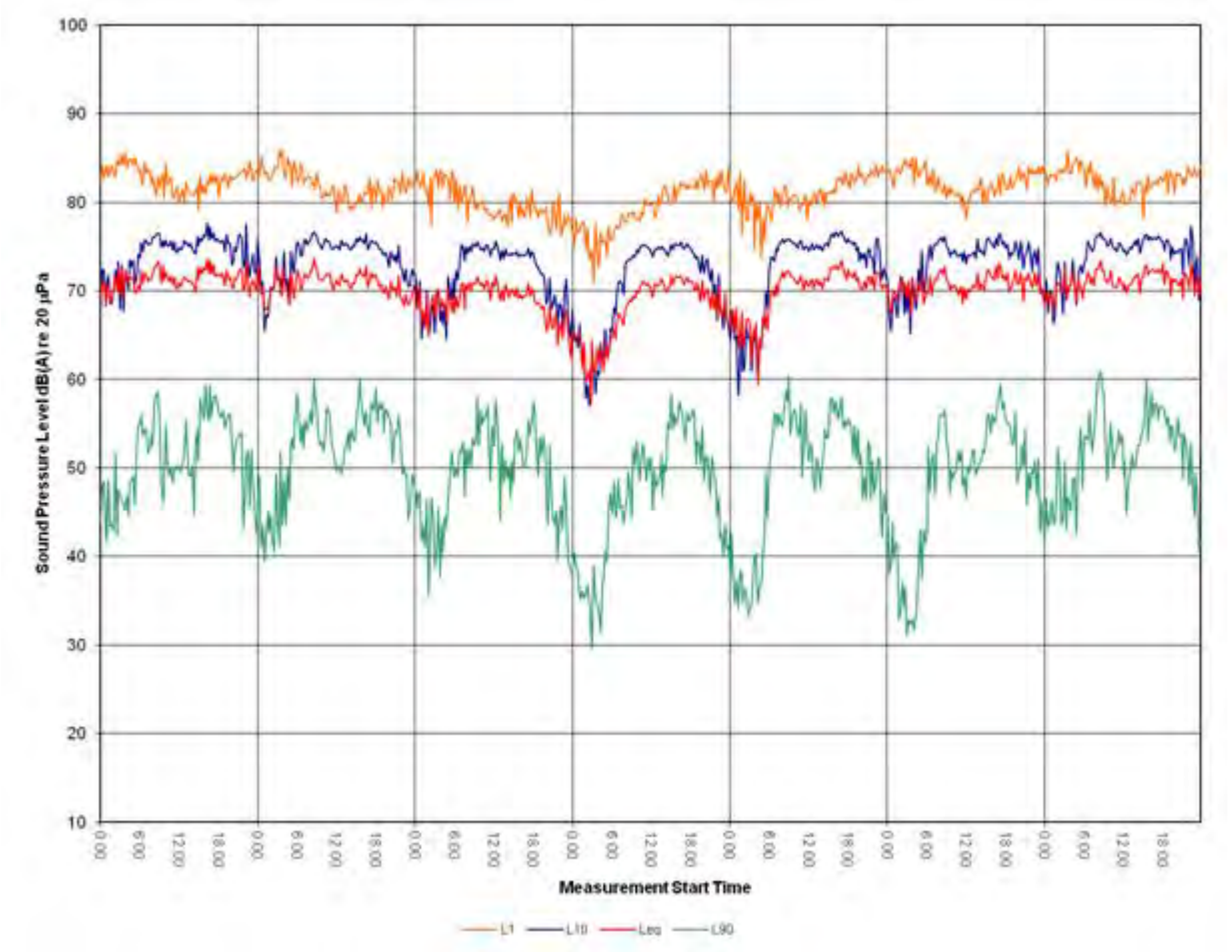


Figure 18: Measured Noise Levels – Logger Location 8 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D9 Noise Logger Location 9 – 326 Centenary Drive, Clarenza

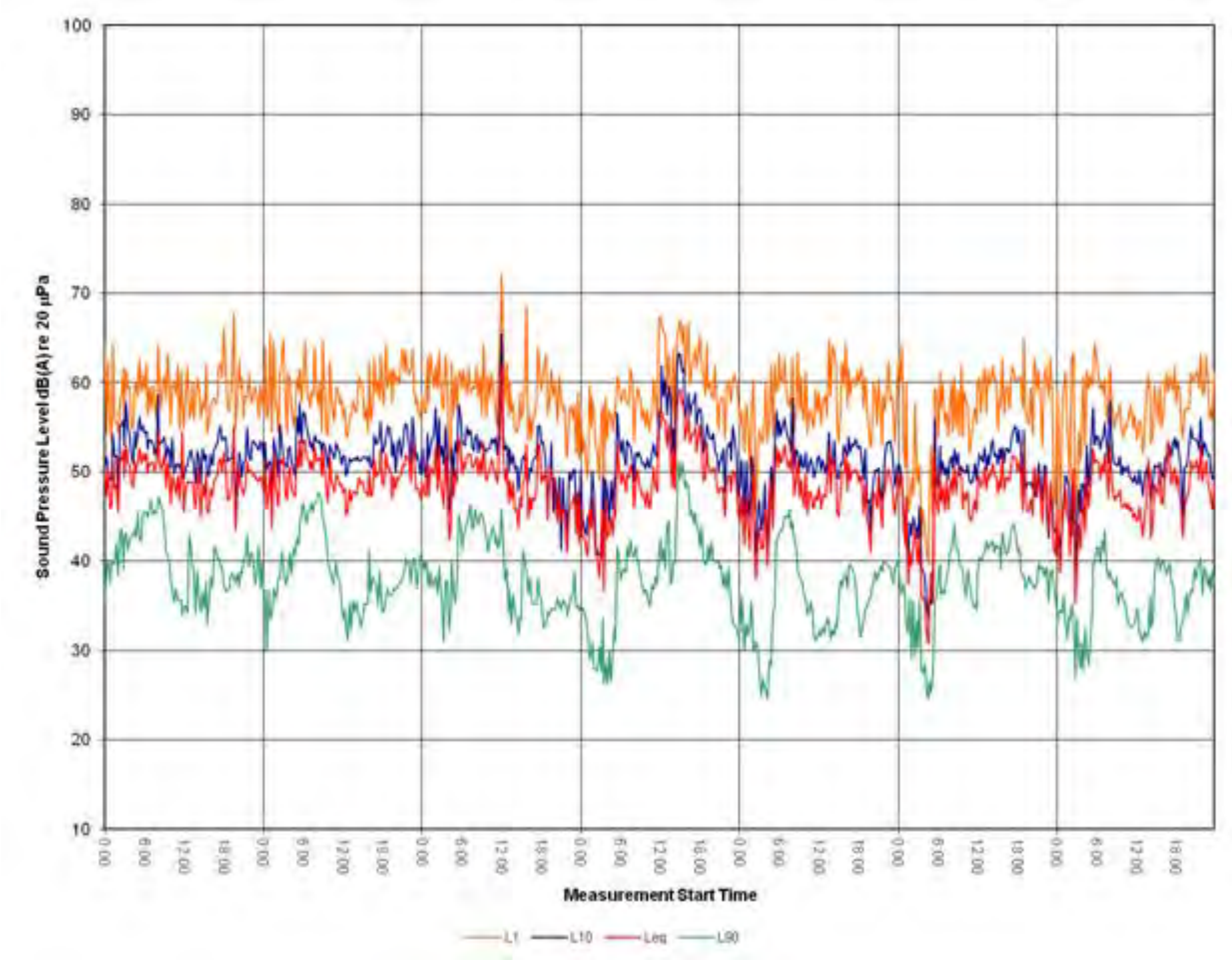


Figure 19: Measured Noise Levels – Logger Location 9 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D10 Noise Logger Location 10 – Cnr Iolanthe St & Butters Lane, Grafton

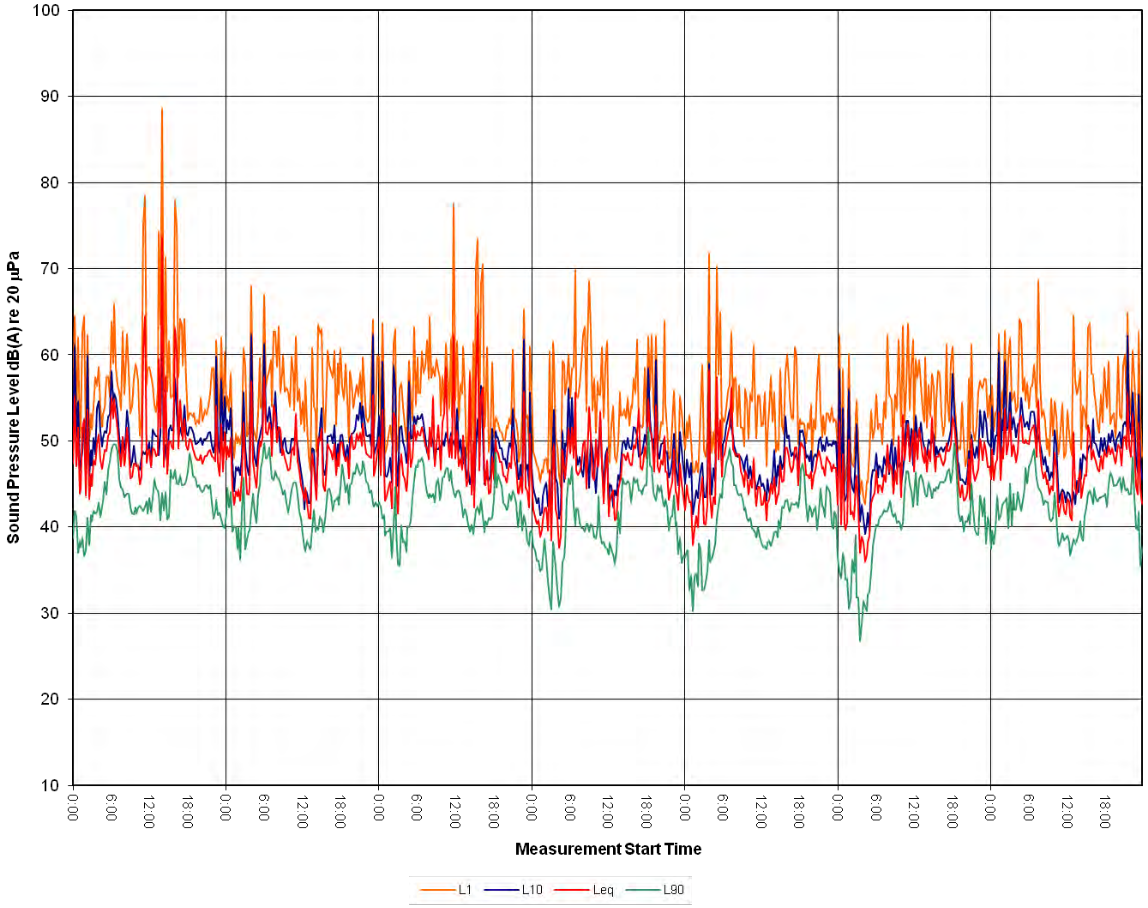


Figure 20: Measured Noise Levels – Logger Location 10 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D11 Noise Logger Location 11 – 146-148 Ryan St, Grafton

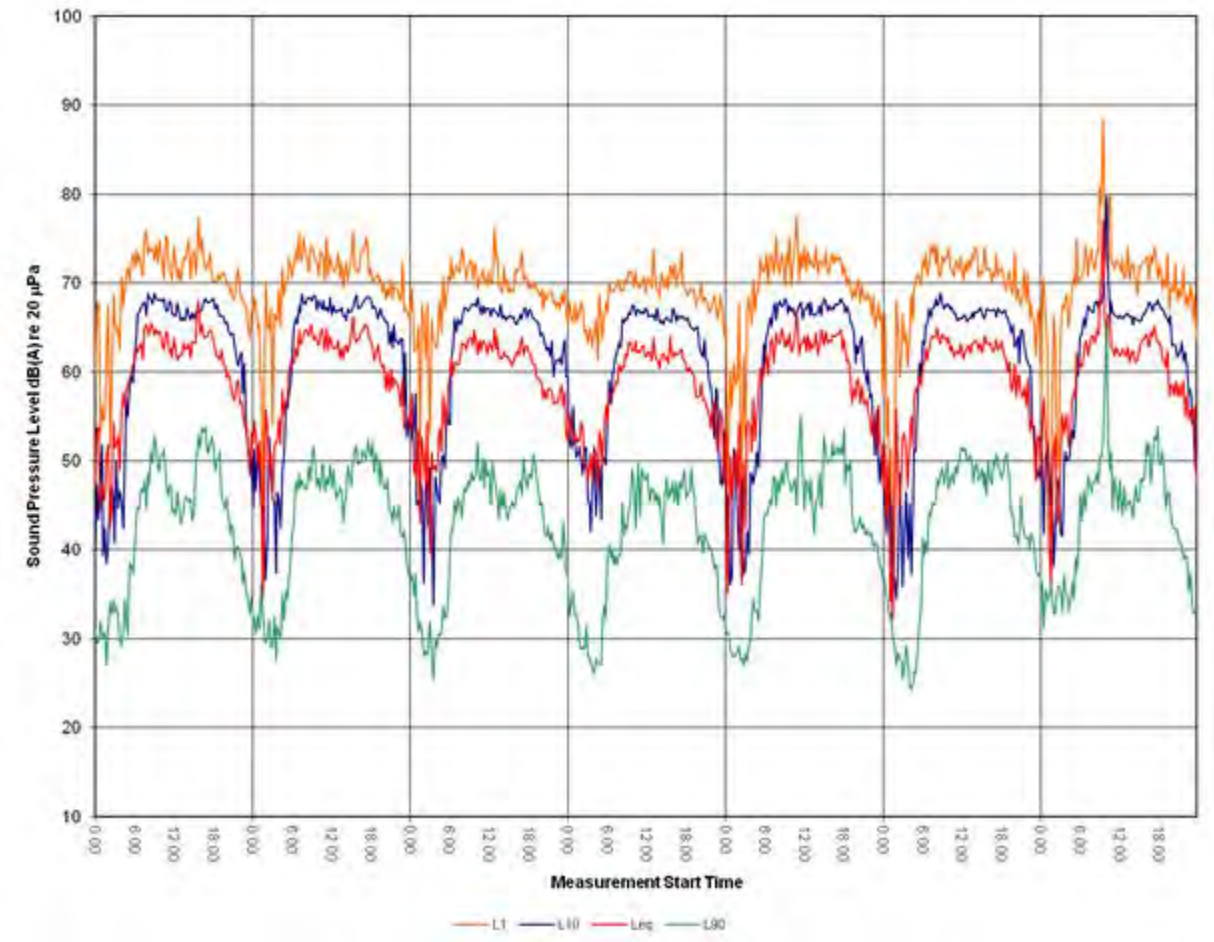


Figure 21: Measured Noise Levels – Logger Location 11 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D12 Noise Logger Location 12 – 5 School Drive, Grafton

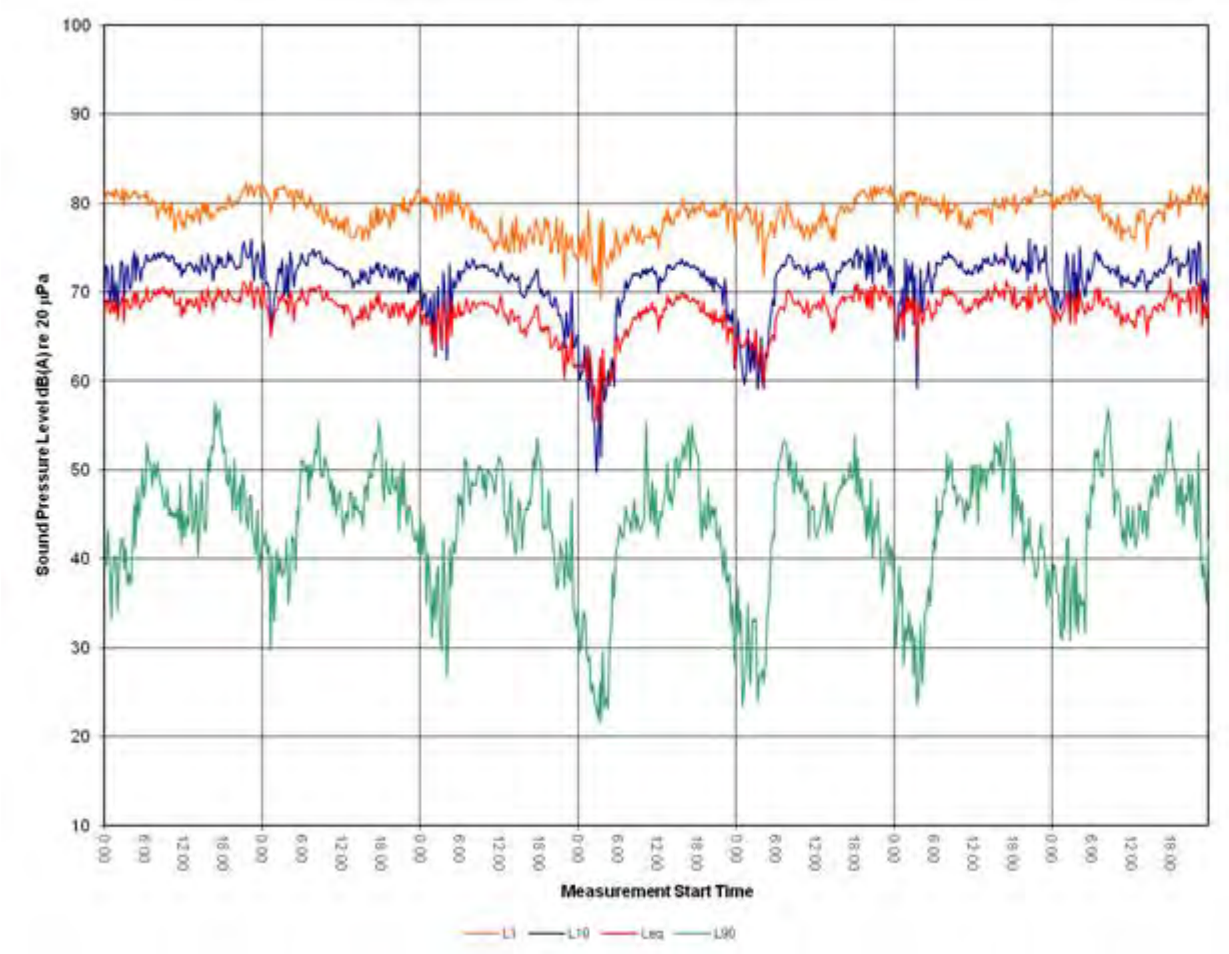


Figure 22: Measured Noise Levels – Logger Location 12 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa.

D13 Noise Logger Location 13 – Riverbank at end of Meona Lane, Grafton

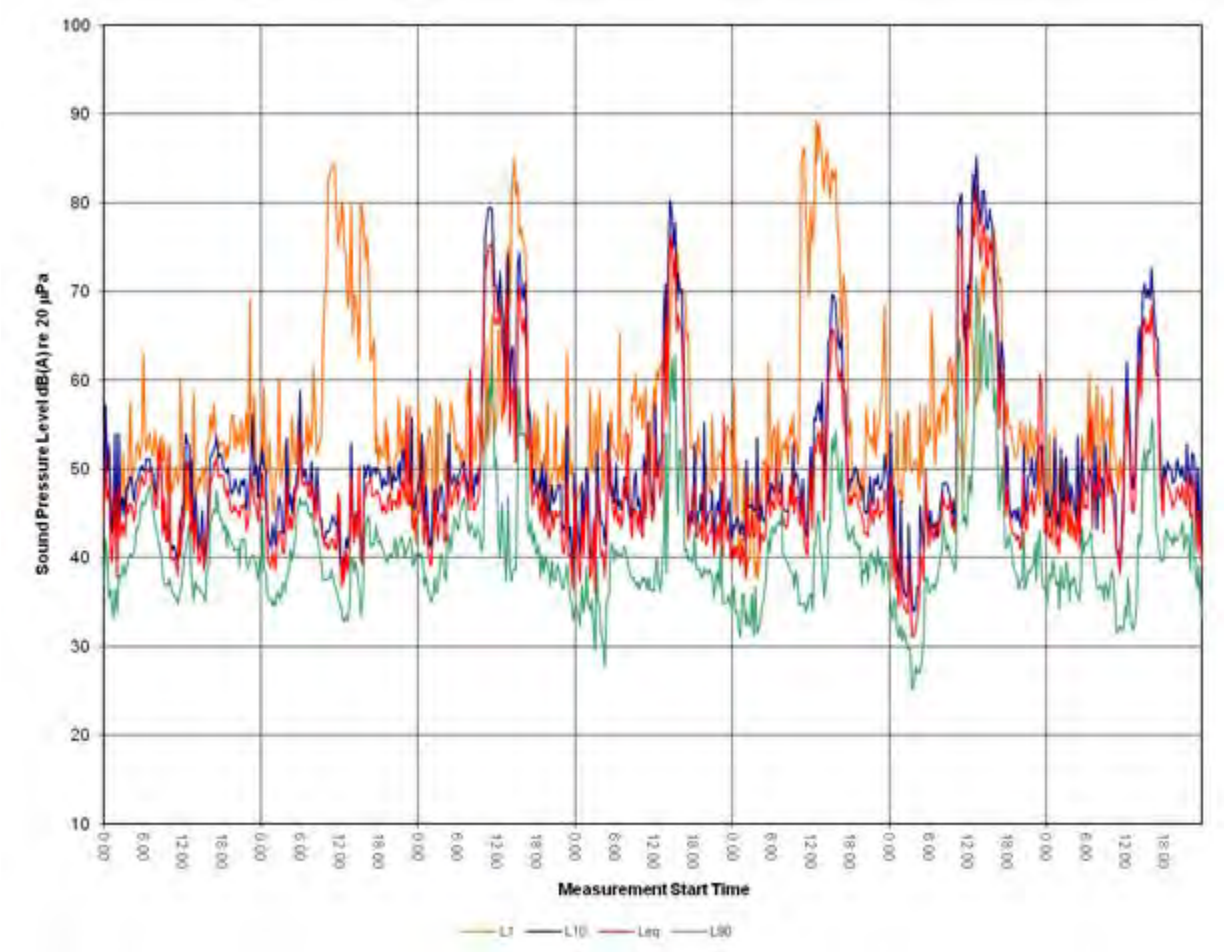


Figure 23: Measured Noise Levels – Logger Location 13 – Thursday 15 September to Wednesday 21 September 2011, dB re 20 µPa

Appendix E

Attended Noise Monitoring Spectra

Reference Location	Address	Period	Octave Band									
			31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz	dB(A)
1	245 Lawrence Rd, Great Marlow	Day	68	68	67	65	65	66	60	51	44	69
		Night	46	49	45	31	32	30	26	31	15	37
2	86 Great Marlow Rd, Great Marlow	Day	74	70	63	55	43	31	26	23	18	51
		Night	55	61	60	47	48	50	39	42	41	53
3	591 Summerland Way, Carrs Creek	Day	68	72	68	63	62	63	60	52	45	67
		Night	84	64	58	56	52	57	55	44	32	60
4	Cnr Hoof & Clarence St, Grafton	Day	66	69	59	54	53	54	47	41	32	57
		Night	68	54	50	40	36	38	32	21	15	42
5	94 Dobie St, Grafton	Day	71	73	67	63	60	61	57	52	45	65
		Night	68	57	55	47	45	45	42	32	19	49
6	4 Bacon St, Grafton	Day	64	59	53	48	47	45	38	38	29	50
		Night	74	51	49	46	44	40	28	14	14	45
7	40 Dobie St, Grafton	Day	64	62	57	56	57	58	51	45	38	60
		Night	73	55	51	44	41	38	30	20	14	44
8	81 Edward Ogilvie Drive, Clarenza	Day	83	63	58	49	40	44	40	34	24	50
		Night	83	70	61	53	54	55	48	38	24	58
9	Pacific Hwy nr Alipou Creek	Day	86	74	68	57	45	38	34	34	27	55
		Night	102	76	73	71	67	65	57	47	37	70
10	326 Centenary Drive, Clarenza	Day	83	75	73	74	75	77	68	60	51	79
		Night	70	61	54	47	50	49	40	29	17	52
11	Cnr Iolanthe Street & Butter Lane, South Grafton	Day	77	63	53	42	38	41	39	35	27	47
		Night	64	60	54	49	51	48	38	22	13	52
12	146-148 Ryan Street, South Grafton	Day	78	70	69	64	63	65	60	51	42	68
		Night	68	61	59	57	54	59	54	44	35	62

13	5 School Drive, Swan Creek	Day	85	69	64	61	60	64	58	51	43	66
		Night	84	76	75	67	69	71	66	57	48	74
14	22 Fry Street, Grafton	Day	76	60	50	44	39	40	42	44	34	49
		Night	43	50	47	38	38	33	21	14	14	39
15	Riverbank at end of Meona Lane, Grafton	Day	88	73	66	55	44	40	32	28	20	54
		Day*	102	76	73	71	67	65	57	47	37	70
		Night	67	61	49	45	49	46	35	21	13	50

* Measurement location closer to Pacific Highway with no shielding from intervening terrain.

Appendix F

Residential Receiver Locations above RNP Criteria

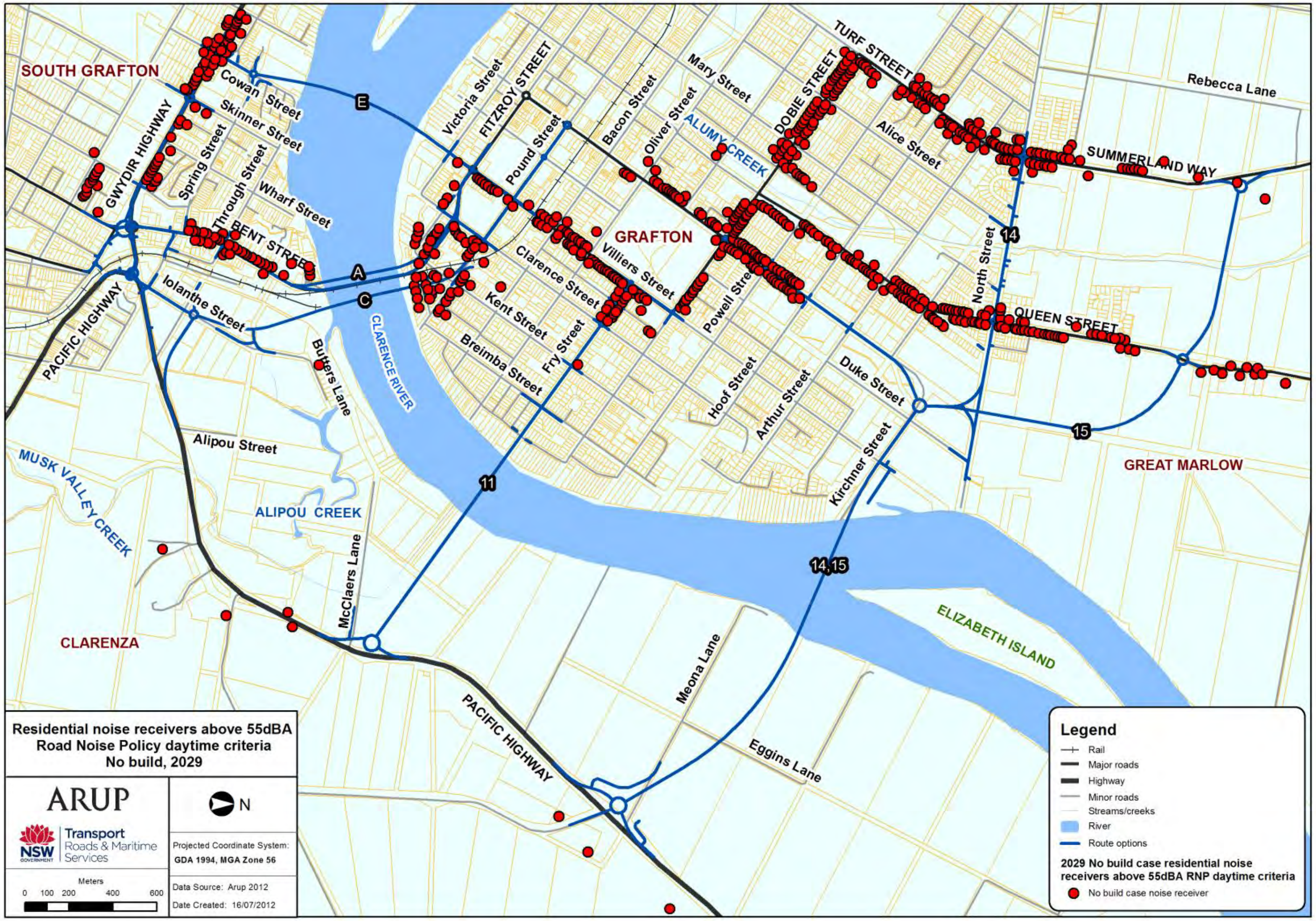


Figure 24: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – No Build (2019)

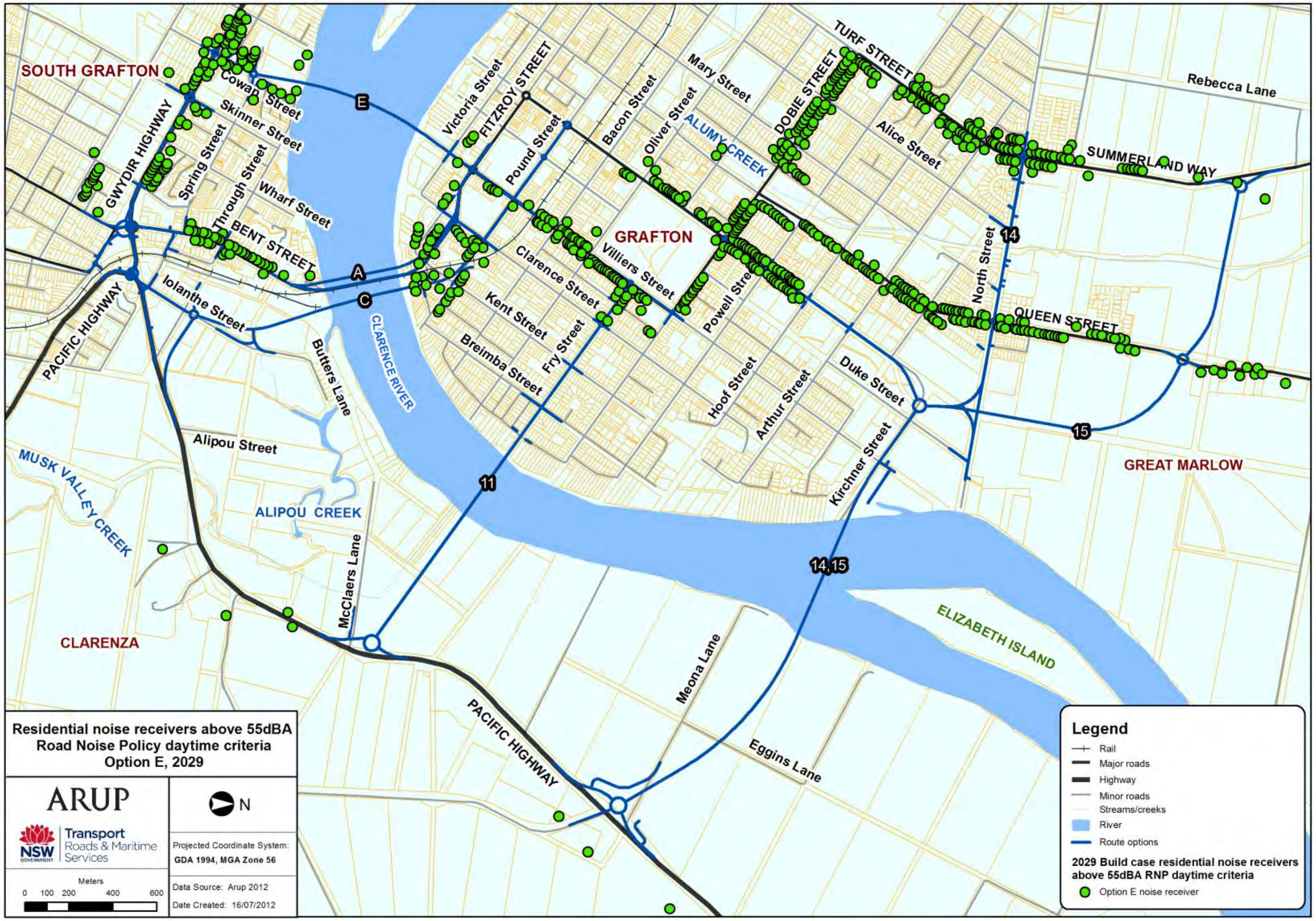


Figure 25: Residential receiver locations above 55 $dBL_{Aeq, 15 hour}$ – Option E (2029)

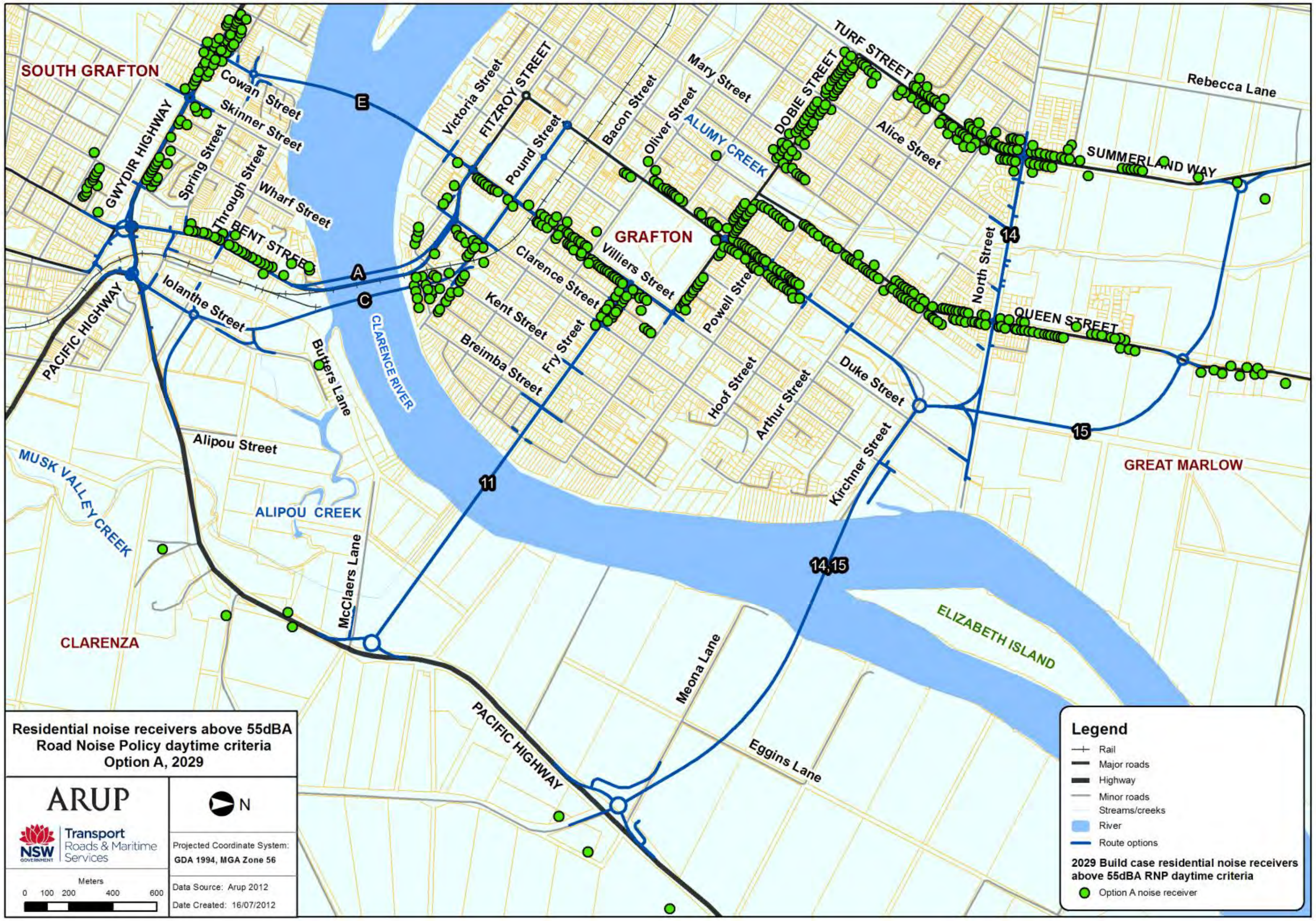


Figure 26: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – Option A (2029)

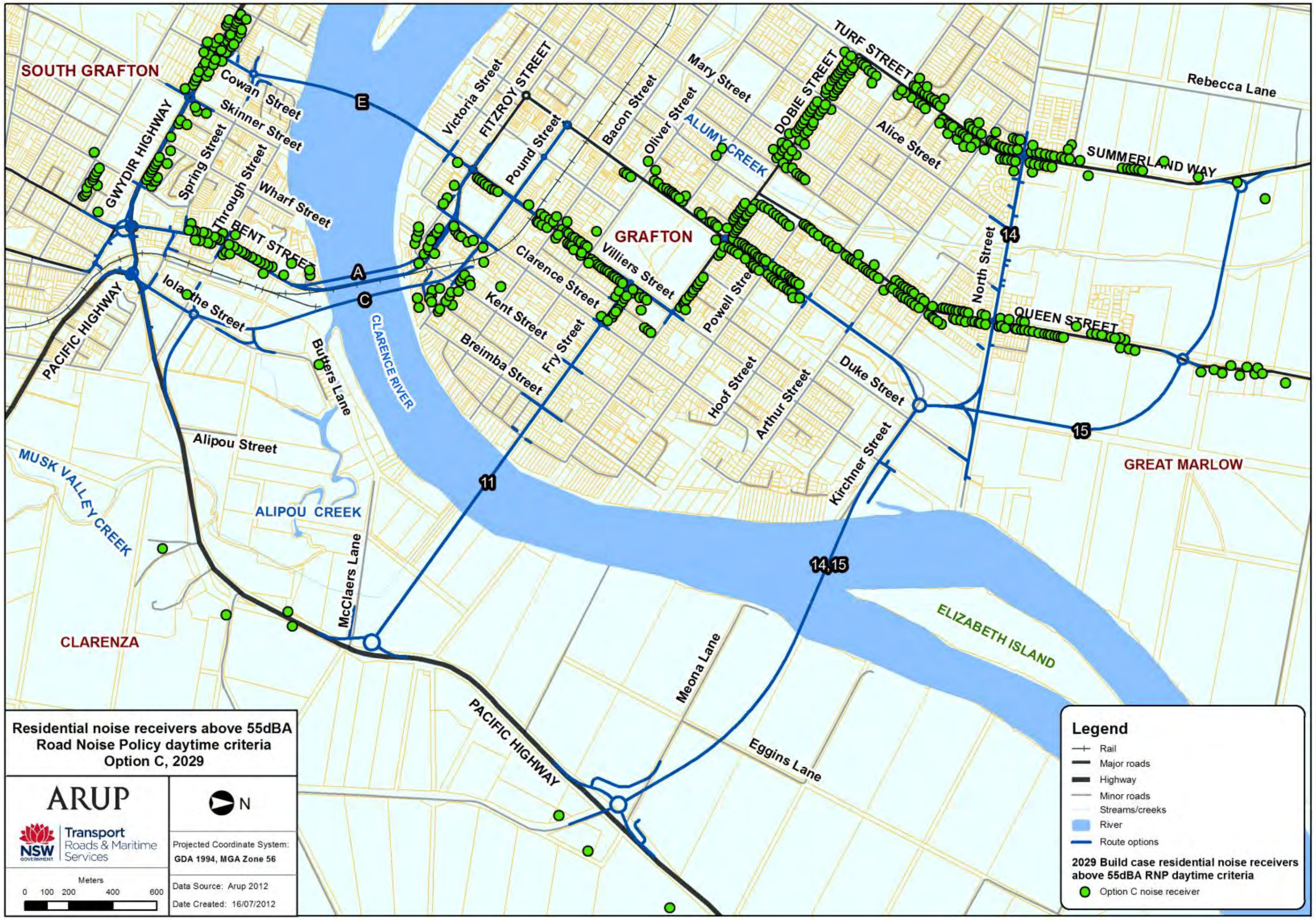


Figure 27: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – Option C (2029)

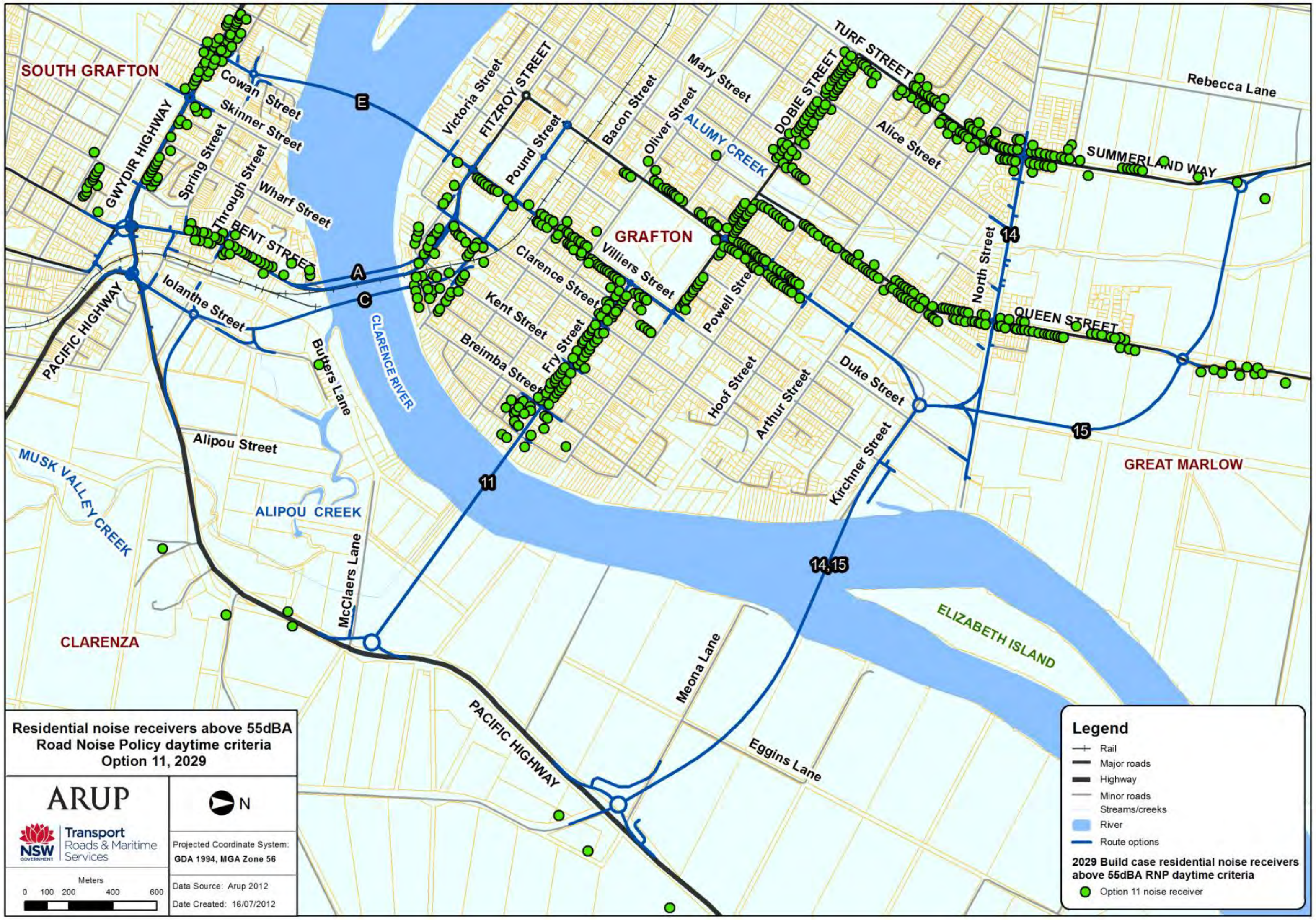


Figure 28: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – Option 11 (2029)

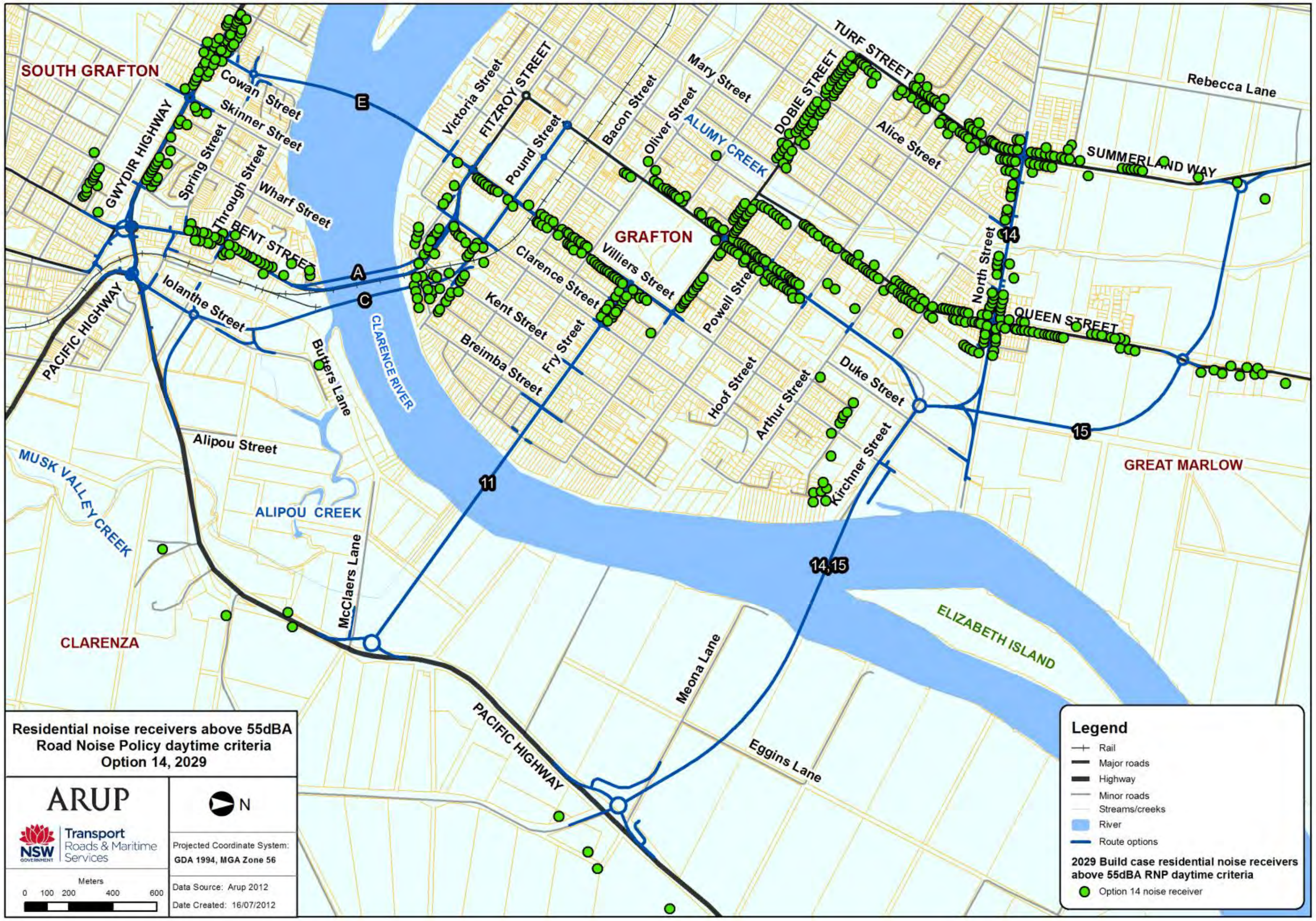


Figure 29: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – Option 14 (2029)

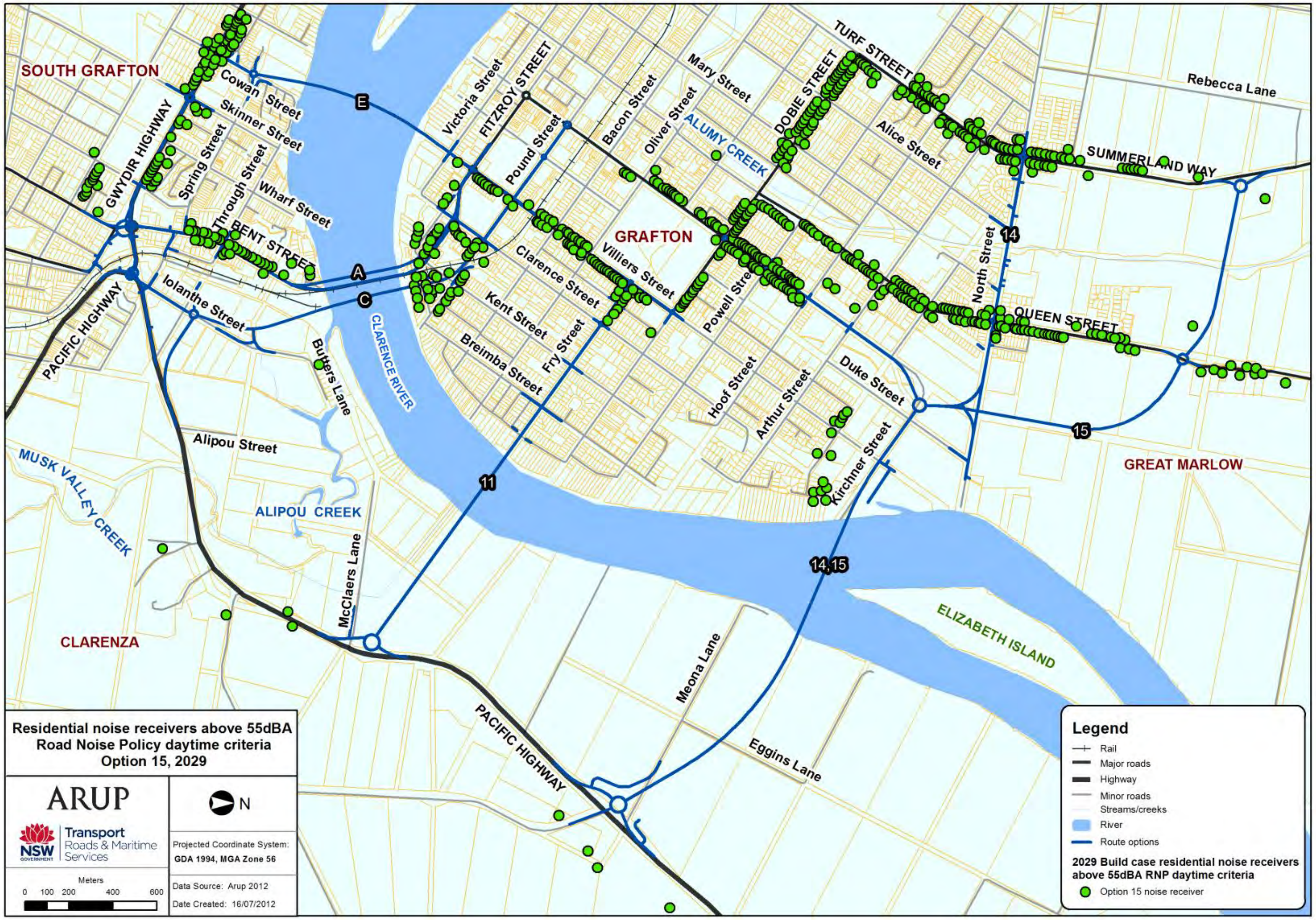


Figure 30: Residential receiver locations above 55 $dBL_{Aeq,\ 15\ hour}$ – Option 15 (2029)

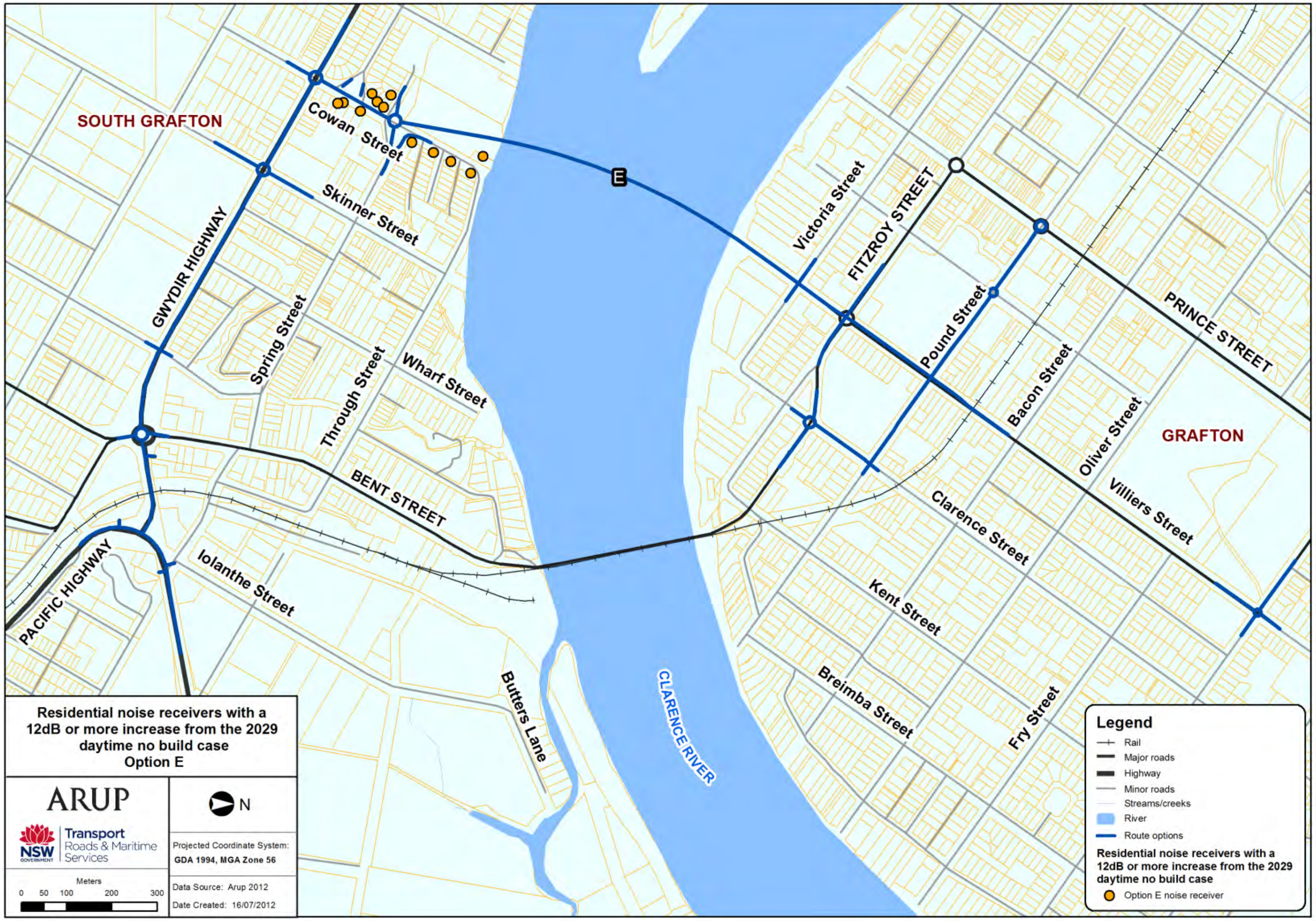


Figure 31: Residential receiver locations with daytime increase above No Build of greater than +12 dB – Option E (2029)
N.B. Option A has no receivers that exceed the RNP relative increase criterion. No map is therefore reproduced here.

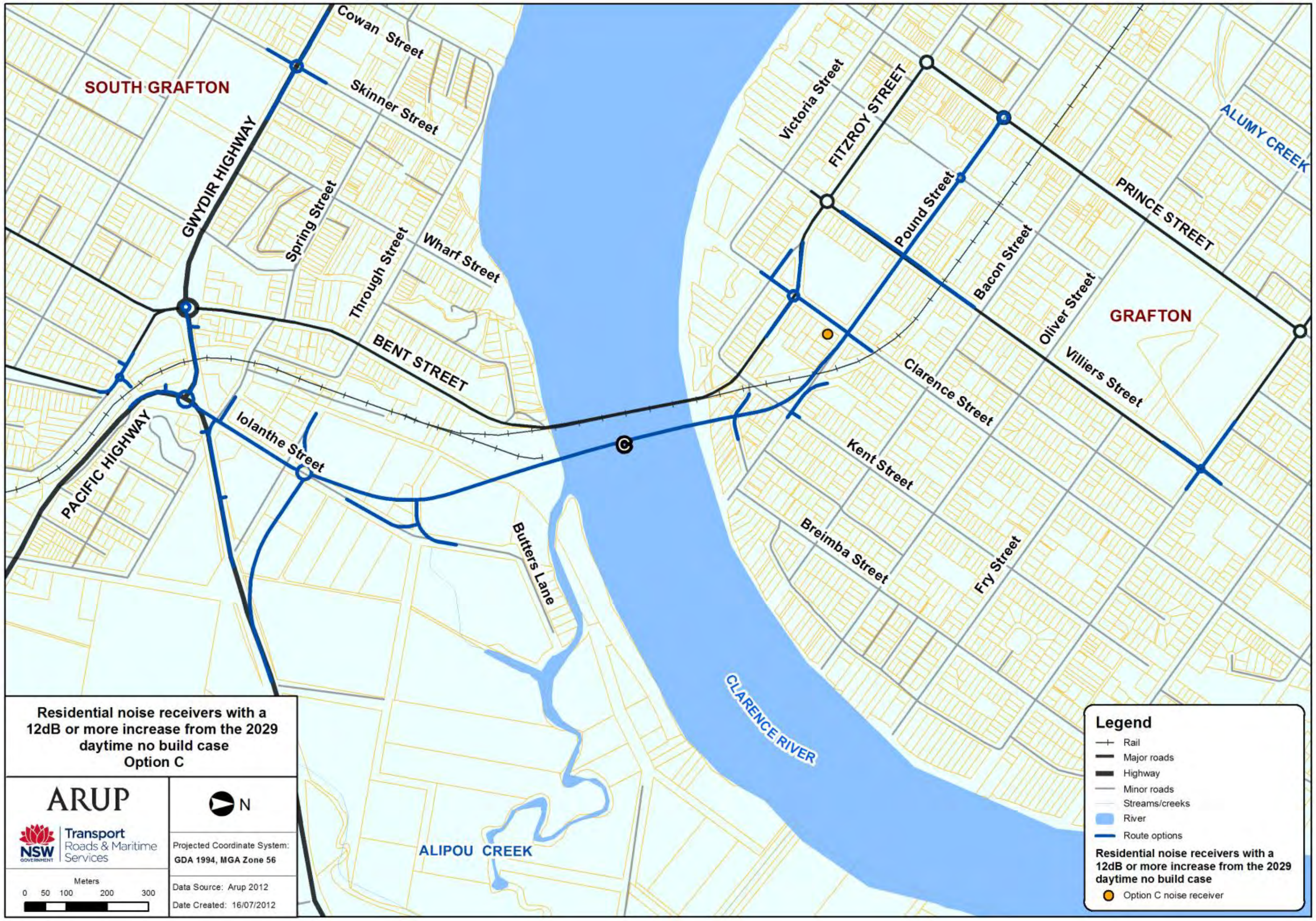


Figure 32: Residential receiver locations with daytime increase above No Build of greater than +12 dB – Option C (2029)

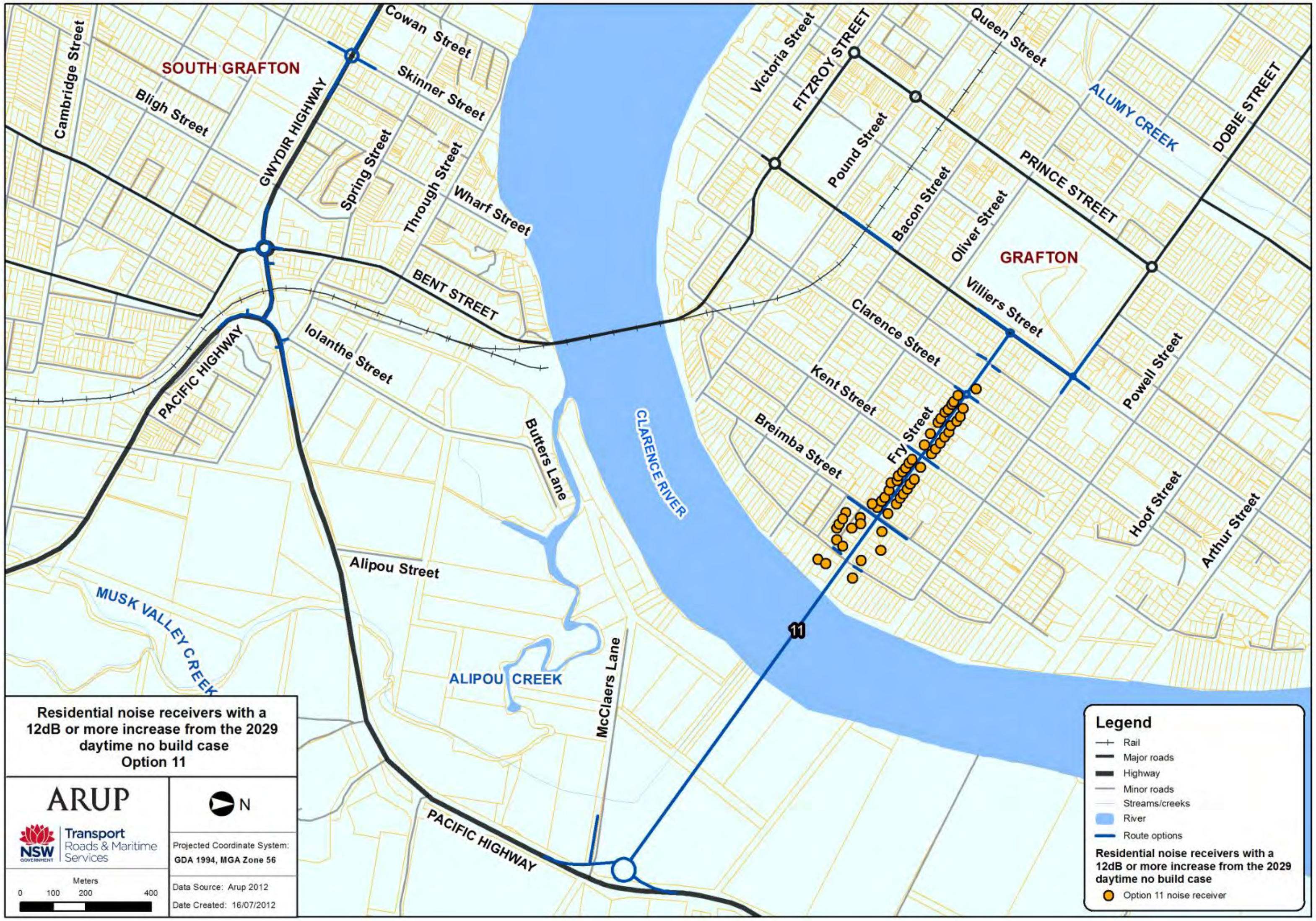


Figure 33: Residential receiver locations with daytime increase above No Build of greater than +12 dB – Option 11 (2029)

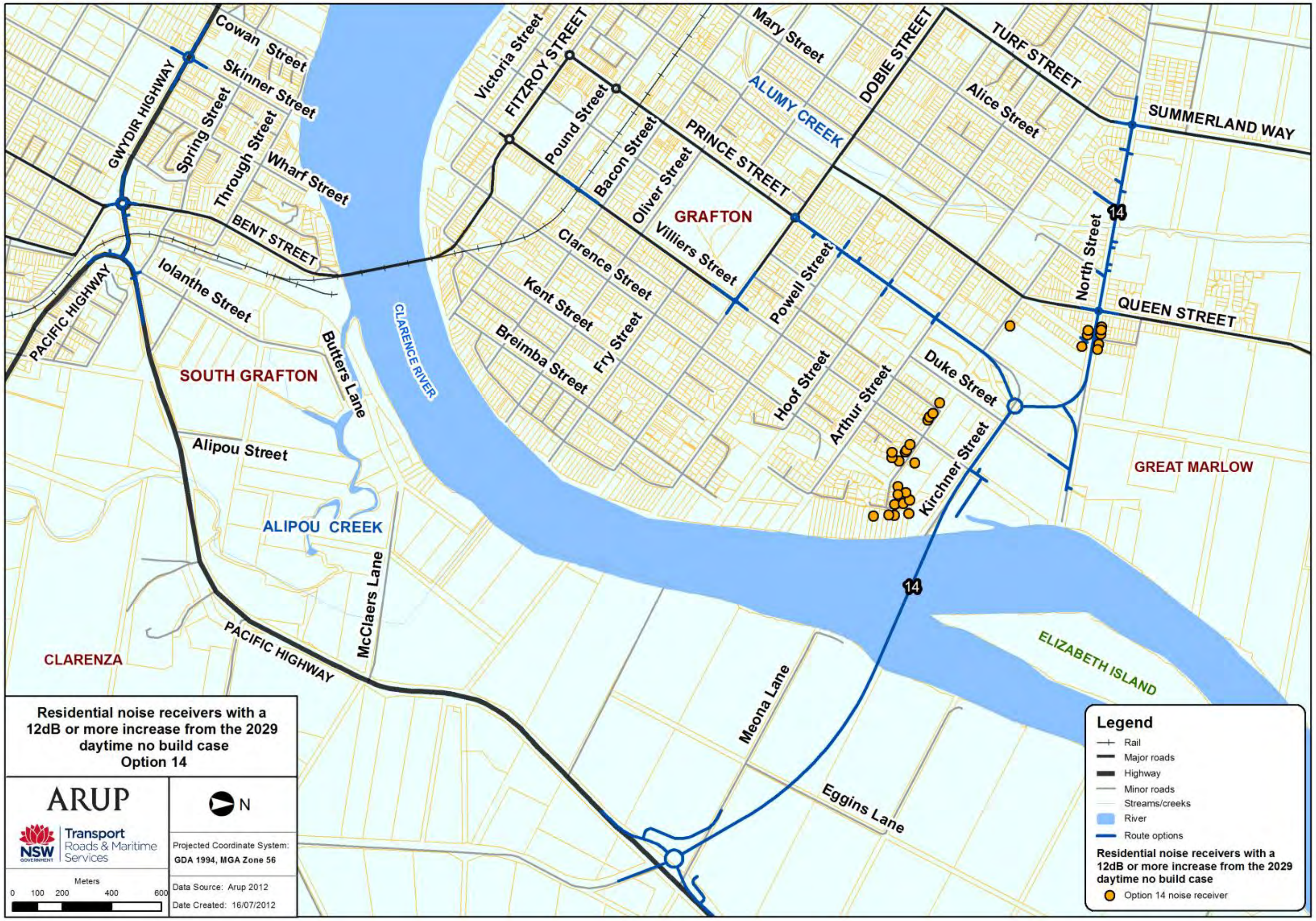


Figure 34: Residential receiver locations with daytime increase above No Build of greater than +12 dB – Option 14 (2029)

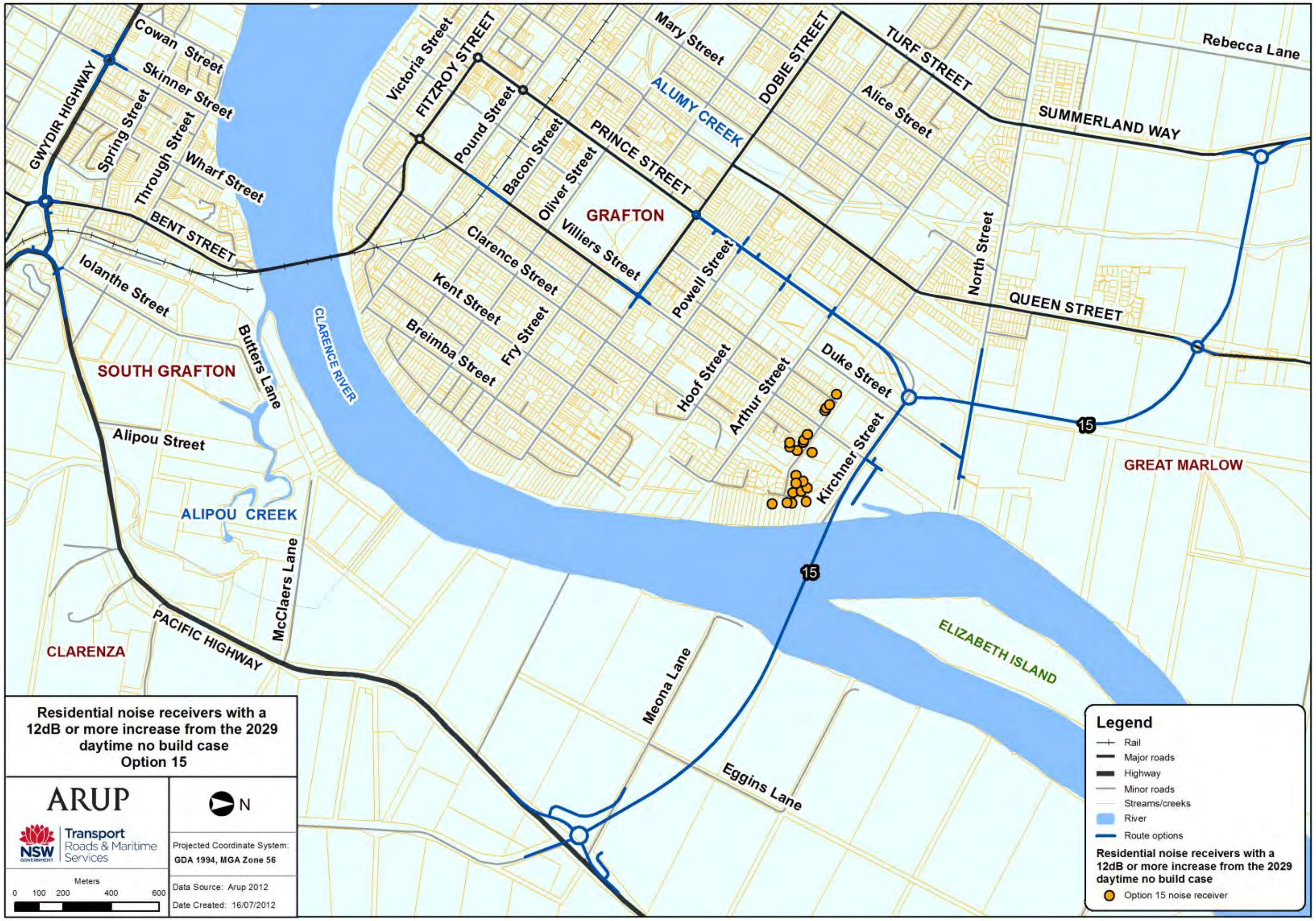


Figure 35: Residential receiver locations with daytime increase above No Build of greater than +12 dB – Option 15 (2029)