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Environmental Impact Statement – Appendix L: Noise and Vibration Impact Assessment

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

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Glossary of terms and abbreviations

TERM	DESCRIPTION
Adverse weather	Weather conditions that affect noise measurements (wind, rain and temperature inversions) that occur at a particular site for a significant period of time. The maximum wind speed allowed during acoustics measurements is 5m/s. No rain is allowed.
Ambient noise	The all-encompassing noise environment at a given location, comprising sources in the near and far field.
Assessment period	The period in a day over which assessments are made.
A-weighting	Adjustment made to a noise level based on international standards. Approximates a human's hearing response to frequency at lower sound levels.
Background noise	Background noise is the term used to describe the underlying level of noise present in an area, measured in the absence of any extraneous noise. Typically when measured with a sound level meter is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period ($L_{A90,T}$).
dB	Decibel, the logarithmic ratio of a given sound pressure to a reference pressure.
dB(A)	A-weighted decibels.
Free-field	A sound field where the effects of reflection are negligible in the region of interest.
Frequency	The number of cycles per unit of time. It is measured with cycles per second (cps) or the interchangeable Hertz (Hz). Frequency can be associated as a synonymous to pitch.
Intermittent noise	Level that drops to the background noise level several times during the period of observation.
Heavy vehicle	Trucks and buses (defined by Ausroads vehicles classifications, class 3 and higher).
Light vehicle	Passenger vehicles, cars, vans, utilities, motorcycles (defined by Ausroads vehicles classifications as class 1 and class 2).
$L_{A1,T}$	The noise level exceeded for 1% of the time period, T.
$L_{A10,T}$	The noise level exceeded for 10% of the time period, T.
$L_{A90,T}$	The noise level exceeded for 90% of the time period, T. Commonly referred to as the background noise level.
$L_{Aeq,T}$	The equivalent average noise level of the time period, T. It represents in a single number, the energy of the actual fluctuating noise level over the period.
$L_{Amax,T}$	The maximum noise level measured during the period, T.
RBL	Rating Background Level. The background noise level as defined by the NSW Industrial Noise Policy (EPA, 2000). It is calculated by the taking the median value of the lowest 10th percentile L_{A90} measurements in any day, evening or night period.
Sound Pressure Level (SPL)	Is the difference between the pressure produced by a sound wave and the barometric (ambient) pressure at the same point in space. Typically expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound Power Levels (Lw)	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power. Typically associated with noise sources.

1 Introduction

ERM has been engaged by SMEC Australia Pty Ltd (SMEC) to undertake a noise and vibration assessment of the potential impacts for the Warragamba Dam Raising Project (the project) at Warragamba Dam (the dam).

This assessment forms part of the environmental impact statement (EIS), pursuant to Part 5, Division 5.2 (section 5.12) (State Significant Infrastructure, SSI) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1 Objectives

The objective of this assessment has been to assess construction and operational noise impacts from the project.

Noise and vibration impacts from operation of the raised dam wall post construction are expected to be consistent with the existing dam operations. Current operation of Warragamba Dam does not generate significant noise or vibration impacts on the community, and are not expected to change significantly following completion of the dam wall raising. As such the assessment scope has primarily focused on construction impacts.

This assessment has been conducted with consideration to the following documents:

- Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration (ANZEC, 1990)
- *Interim Construction Noise Guideline* (ICNG) DECC 2009
- *Assessing Vibration, A Technical Guideline* (Vibration Guideline) DEC 2004
- *Industrial Noise Policy* (INP) EPA 2000
- *Noise Policy for Industry* (NPfI) EPA 2017
- *Road Noise Policy* (RNP) EPA 2011
- Roads and Maritime Services (2016) Construction Noise and Vibration Guideline
- Transport for New South Wales (2017) Construction Noise Strategy

The objectives of the noise and vibration assessment are to:

- Quantify the existing background and ambient acoustic environment at sensitive noise receivers in the project area
- Assess noise and vibration impacts from construction and operation
- Recommend reasonable and feasible noise and vibration mitigation measures.

1.2 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (SEARs) were issued by the former Department of Planning and Environment (now the Department of Planning, Industry and Environment, DPIE) on 30 June 2017. Revised SEARs were issued on 13 March 2018.

SEARs relevant to the noise and vibration assessment are provided in Table 1-1.

Table 1-1: SEARs relevant to noise and vibration

DESIRED PERFORMANCE OUTCOME	SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS	WHERE ADDRESSED
11. Noise and Vibration - Amenity Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity. Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community.	1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers including small businesses, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Section 5
	2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required	Section 5.5
12. Noise and Vibration – Structural Desired performance outcome: Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage. Increases in noise emissions and vibration affecting environmental heritage as defined in the Heritage Act 1977 during operation of the project are effectively managed.	1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	Section 5.3
	2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Section 5.5

2 Project description

2.1 The Project

Warragamba Dam Raising is a project to provide flood storage capacity in the Lake Burragorang catchment (Warragamba catchment) to facilitate flood mitigation and to provide environmental flows downstream of Warragamba Dam.

The Project would:

- enable the dam to capture and temporarily hold back inflows coming from the Warragamba catchment behind the wall
- provide capacity to facilitate flood mitigation by increasing the central spillway by approximately 12 metres and increasing the dam abutments (including access road) by 17 metres, which includes approximately three metres to be resilient to the future impacts of climate change
- provide infrastructure to allow for environmental flows to be released from Warragamba Dam.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots for discharge of water from the flood mitigation zone (FMZ)
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flows infrastructure.

2.1.1 Location

Figure 2-1 shows the local and regional context of the Project. The Project site is located approximately 65 kilometres west of the Sydney Central Business District in the Wollondilly Local Government Area (LGA). To the west of the Project site are the Blue Mountains and various National Parks and State Conservation Areas which make up the catchment of Lake Burragorang which is the water storage formed by Warragamba Dam. To the east of the Project site are the Warragamba and Silverdale townships and surrounding rural residential areas.

2.1.2 Construction area

Figure 2-2 shows the construction area for the Project including:

- ancillary facilities such as coffer dams, batch plants, material storage areas and worker facilities
- areas which require clearing of vegetation to allow for construction and access
- areas directly impacted by construction works
- areas that would be used for construction activities but would not be modified by the Project (e.g. existing roads, Lake Burragorang).

2.2 Main activities and elements

Figure 2-2 shows the existing dam and proposed construction areas. Figure 2-3 shows the modified dam after the Project works have been completed. The Project works include:

- demolition
- thickening and raising of dam abutments
- thickening and raising of central spillway
- modifications to the auxiliary spillway
- other infrastructure and elements
- environmental flow infrastructure

These are described in greater detail in the following sections.

Figure 2-1: Location of project

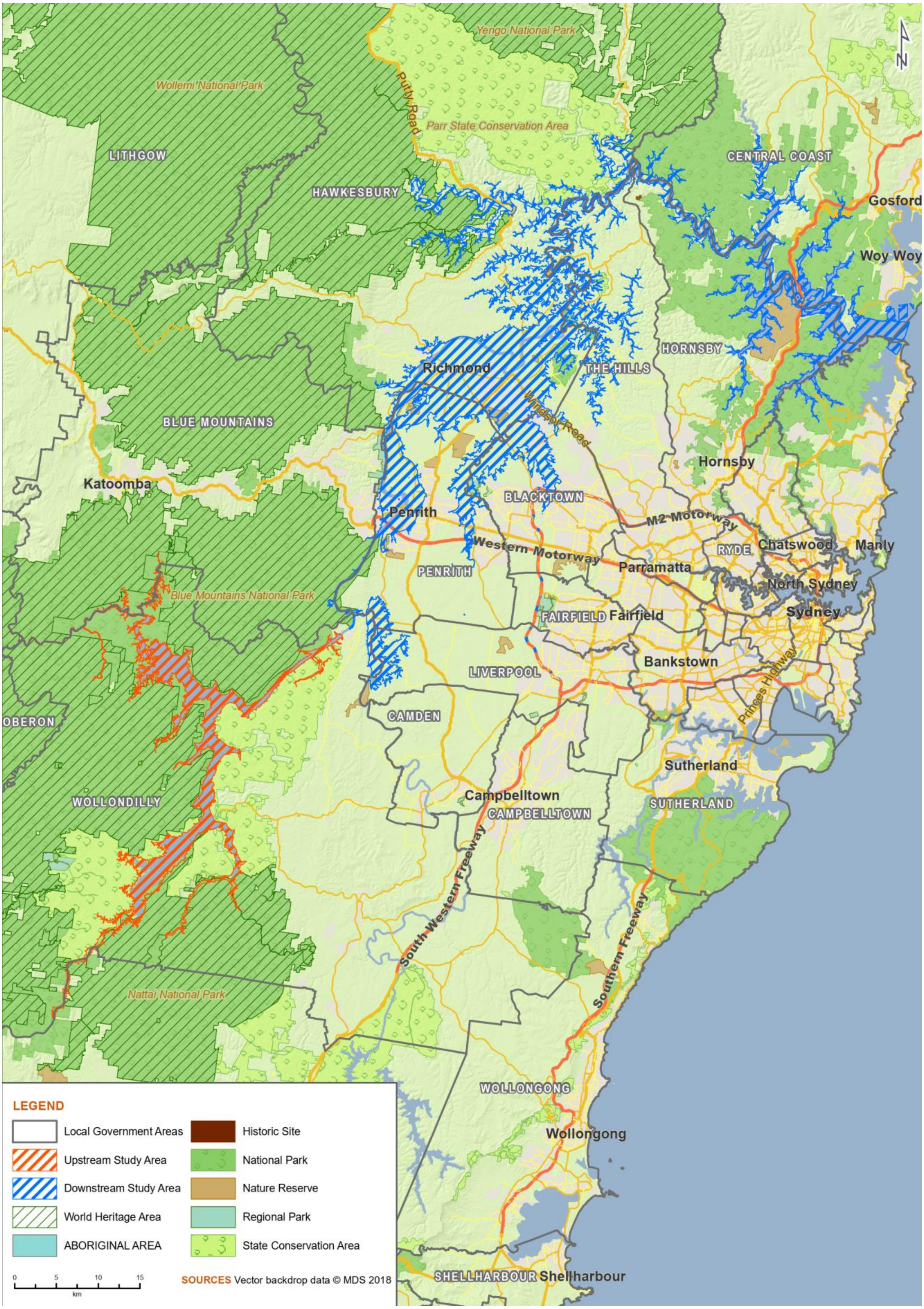
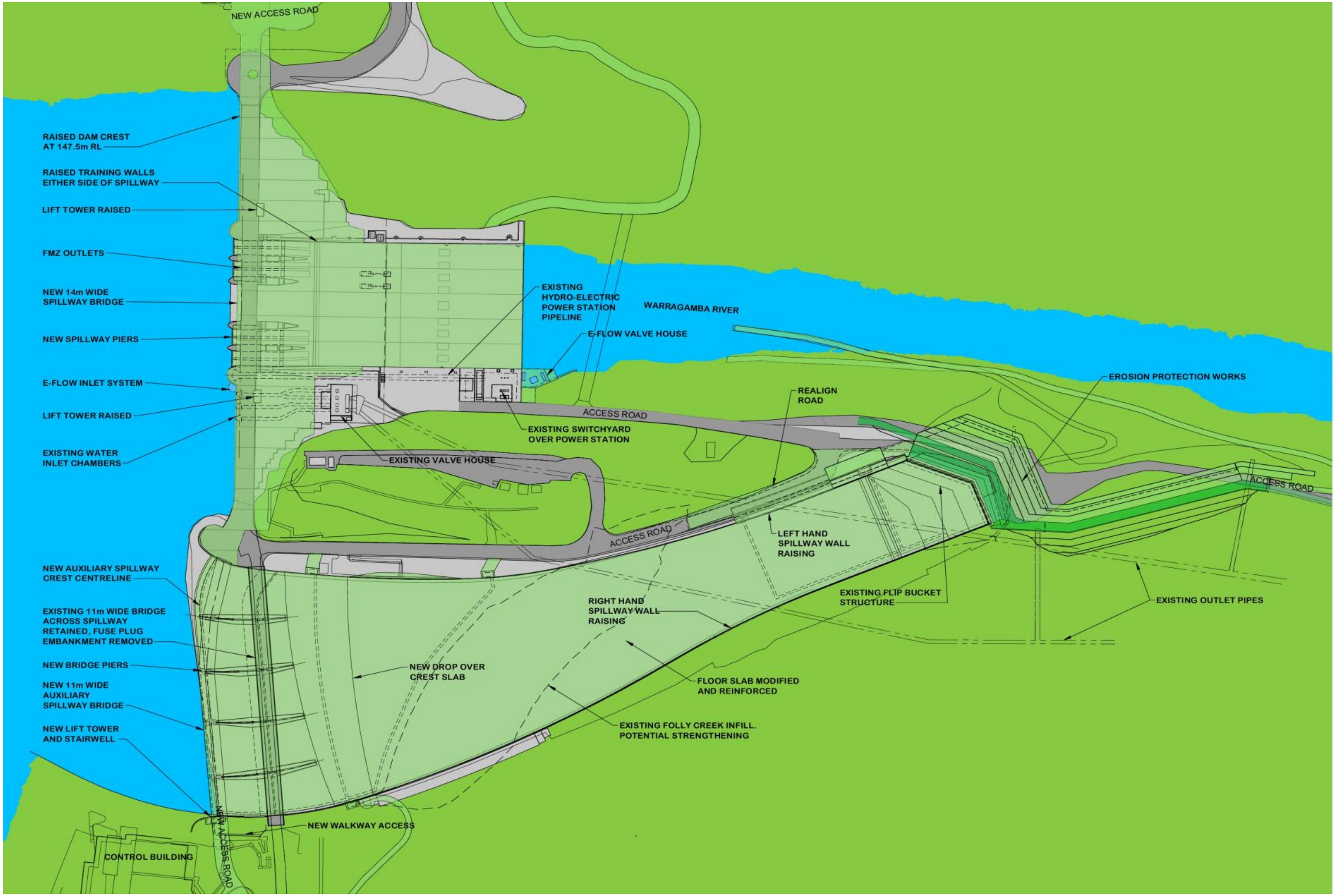


Figure 2-2: Construction area

Figure 2-3: Modified dam from the Project works



2.2.1 Demolition

Elements of the existing Warragamba Dam would require demolition or removal to enable dam raising construction to proceed. These include:

- the existing road and main spillway bridge across the top of the dam
- the drum and radial gates, and associated mechanical and electrical infrastructure, and portions of the piers within the central spillway
- minor concrete structures to allow the tie-in of the new dam and spillway
- the valve house control room building located at the rear of the valve house
- areas of roads, operational laydown areas, drainage systems and other infrastructure external to but associated with the dam
- the existing gantry crane and associated equipment
- the existing hydroelectric power station equipment to allow for new environmental flow infrastructure
- miscellaneous dam crest services and equipment.

2.2.2 Thickening and raising of the dam abutments

The dam abutments, located either side of the central spillway (see Figure 2-3), would be modified:

- the dam abutments would be thickened on the downstream side with additional concrete. The face of the abutments would be smooth as with the existing dam
- the abutment height would be increased by around 17 m
- the left abutment would extend into the surrounding rock to suit the thickening and raising.

2.2.3 Thickening and raising of the central spillway

The existing central spillway would be modified as follows (see Figures Appendix A):

- the spillway would be thickened on the downstream face with concrete and it would have a smooth surface
- the spillway crest would be raised to create the Flood Mitigation Zone, including the use of post tensioned anchors within the wall for stability
- gated conduits would be constructed within the central spillway to allow for the controlled discharge of floodwaters. These openings would be located so the flood mitigation zone could be drawn back down to the full supply level
- potentially slots would be constructed within the central spillway crest to allow for the discharge of floodwaters.

2.2.4 Modifications to the auxiliary spillway

The following modifications would be undertaken on the auxiliary spillway (Figure 2-3):

- removal of the existing fuse plugs (earth/rock embankments designed to wash away in a major flood) and replacement with a concrete spillway crest
- the spillway floor slabs and walls would be modified and reinforced to suit discharging of flood water from the raised dam
- erosion protection would be provided downstream from the auxiliary spillway.

The existing bridge across the auxiliary spillway would be retained for access to the valve house and the base of the dam and spillway.

2.2.5 Other infrastructure and elements

Other infrastructure and elements would include:

- A new bridge would be built above the auxiliary spillway crest to provide access to the raised dam
- The raised abutments and central spillway bridge would allow for vehicle and pedestrian access across the top of the dam. These would connect with the approaches and road network on either side of the dam
- New control and instrumentation equipment including mechanical, electrical and communications elements
- New landscaping and urban design features would be provided for areas disturbed by construction and for other areas which require improved integration to the new dam structure

- Ancillary works to tie existing services into the raised dam
- The existing two lift towers would be modified to suit the raised dam
- The eel passageway on the left bank would be modified to continue to allow the migration of eels from the river to Lake Burragorang.

2.2.6 Environmental flows infrastructure

In 2017, the NSW Government released the 2017 Metropolitan Water Plan (www.planning.nsw.gov.au/about-us/Sydney-Metropolitan-Water) which included the introduction of new variable environmental flows from Warragamba Dam to improve the health of the Hawkesbury-Nepean River.

The Project would provide the infrastructure to enable environmental flows to be released from the Dam. Operational procedures would be developed as part of the implementation of the Metropolitan Water Plan. These would be subject to a separate approval process.

The environmental flows infrastructure would include:

- a multi-level offtake concrete tower on the upstream face of the dam wall to draw water from Lake Burragorang
- the use of existing pipeline, formerly for the hydro-electric power station, to transfer the water to a valve house
- a new valve house, downstream of the existing hydro-electric power station, to discharge the water into the river.

2.2.7 Operation of the dam for flood mitigation

There would be two different modes of operation for the raised Warragamba Dam; normal and flood operations. In both modes Warragamba Dam would continue to store and supply up to 80% of Sydney’s drinking water. The storage capacity, which is the dam’s Full Supply Level, would not change.

2.3 Project construction

This section describes the proposed approach to construction. If the project is approved, further detailed construction planning would take place prior to commencement to inform a Construction Environmental Management Plan (CEMP). This plan would consider methods and the scheduling of activities to minimise impacts on the community and the environment such as noise, access and amenity, and would detail mitigation and management measures.

2.3.1 Construction area

The proposed construction area is shown in Figure 2-2. This area may be refined as part of detailed design and construction planning.

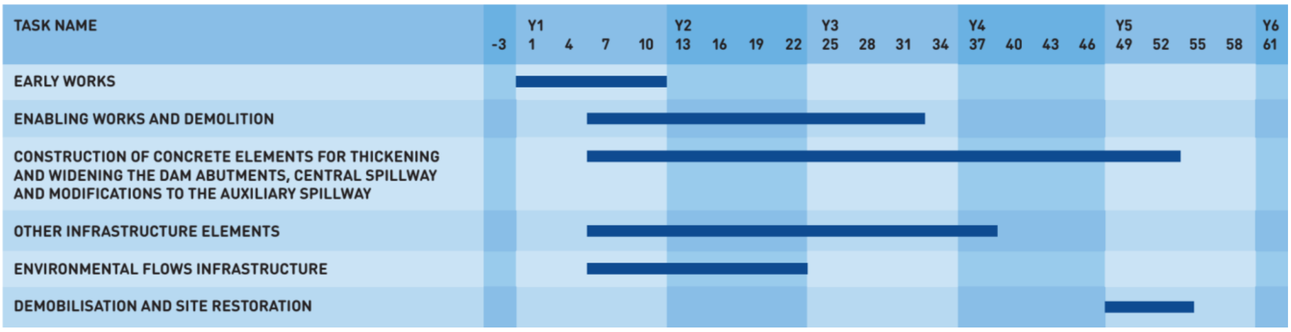
This includes:

- areas directly impacted by construction
- areas where access for construction is required
- concrete batch plants and material laydown and storage areas
- offices and worker amenities
- visitors and education centre
- other ancillary sites.

2.3.2 Construction program

A preliminary construction program is presented in Figure 2-4 with the project anticipated to be completed between four to five years from commencement.

Figure 2-4: Preliminary construction program



2.3.3 Construction workforce

The number of workers would vary over the program. Up to 300 workers would undertake establishment activities including setting up offices and compounds, assembling the concrete batch plants and beginning early and enabling works. The number of workers on site would increase during construction to around 500 during peak construction periods.

2.3.4 Construction hours

The majority of works would take place during standard construction hours for NSW which are:

- 7am to 6pm – Monday to Friday
- 8am to 1pm – Saturday
- no work on Sundays and Public Holidays

This includes the majority of high noise generating activities such as:

- deliveries of materials including concrete, sand and aggregates for concrete production
- demolition work including hydro-blasting (a concrete removal technique that uses high pressure water)
- earthworks, excavations, drilling and blasting

Some activities would need to take place outside of standard construction hours. These activities may include:

- Operation of chilled water plants for cooling and curing of concrete. Continuous cooling of the concrete is required to ensure that heat does not become excessive, and cause cracking and loss of strength of the concrete, during curing
- Operation of the batching plants for the delivery and pouring of concrete. In warmer periods, concrete pours may not be able to take place in normal working hours. High temperatures may cause thermal issues and cracking during the curing process. Concrete pours may be required at night-time when temperatures are lower
- Preparatory or emergency works for a flood during the construction period including removing equipment and materials from the construction area, minor earthworks and other activities
- Work outside the nominated working hours may need to occur in the case of emergencies or unexpected issues
- The local community would be notified of construction activities including any activities taking place outside of standard construction hours in accordance with the Community Consultation Plan developed by the construction.

2.3.5 Construction methodology

2.3.5.1 Early works

Early works are activities that may be able to commence before main construction works and would include:

- further investigations including surveying, geotechnical studies, building and utility condition and location surveys and other studies as required to assist in the design and construction of the project
- installation of security fencing and site environmental controls including water management, soil management and noise management measures
- establishment of temporary site offices and worker facilities
- procuring of concrete batching facilities, cranes, conveyors and other infrastructure

- clearing of vegetation
- adjustment and provision of utilities for construction facilities
- minor road works and establishment of site access roads including a temporary access bridge downstream of the dam
- establishment of areas for stockpiling of materials such as aggregate and flyash.

2.3.5.2 Enabling works and demolition

Enabling and demolition works are required to be undertaken before commencement of concrete placement to raise and thicken the dam wall. These would include:

- Upgrading the existing boat ramp, pontoon and access road upstream of the dam to allow for water access to the dam wall
- Establishment of batching plants on site so concrete can be poured almost immediately after batching to maintain adequate concrete placement temperatures. Potential on-site locations are Haviland Park or the terraced gardens (Figure 2-2). The facilities would consist of:
  - hardstand area with drainage to environmental control ponds
  - concrete testing and geotechnical laboratory
  - weighbridge and office
  - materials storage bins and sheds (for aggregates, sand, fly ash and other materials)
  - silos, mixers, conveyors, above ground tanks, control facilities and dust control facilities
  - water and material chilling plant
  - connections to communication, power and water supply services
  - other environmental controls if required (e.g. noise walls)
- Releasing water from the dam until the water is 5 m below full supply level. This is required to provide a buffer for floods during construction and allow construction of the new crest in the auxiliary spillway
- Emptying (dewatering) the dissipator pool at the base of the dam to enable works to be undertaken
- Construction of coffer dams at multiple locations around the dam wall to manage the impact of works on the Warragamba River and protect the site from river backflows. Indicative locations are shown in Figure 2-2 and include at the end of the existing central spillway dissipator, immediately upstream of the auxiliary spillway and downstream of the auxiliary spillway. The number and size of the coffer dams would be confirmed by the detailed design
- Construction of the raised dam would require demolition of a number of existing structures and removal of machinery, pipes and operational equipment. These are outlined in Chapter 5 of the EIS. The methodology and scheduling would be determined by the construction stages and the need to maintain safe operations of the dam.

2.3.5.3 Construction of concrete elements for thickening and widening the dam abutments, central spillway and modifications to the auxiliary spillway

Warragamba Dam is a concrete gravity dam which uses the weight of the concrete to resist the horizontal pressure of water. The same design and construction approach would be used for raising the dam wall. Mass concrete would provide the strength to enable the dam height to be increased. Reinforced concrete would be used to construct elements such as bridges, walls, piers, conduits, chambers, etc.

Work would include:

- Installing formwork to create concrete blocks. The blocks have been sized to match the existing dam block dimensions and for structural performance. Generally, the formwork would be lifted into place by a crane
- Where cooling of the concrete is required after the pour, small pipes may be cast into the concrete to allow chilled water to be pumped through the concrete during curing
- Pouring concrete into the formwork and allowing the concrete to set and start to cure. The concrete would be delivered from the on-site batch plants by a crane or cableway with a concrete bucket and/or a conveyor
- Chilled water may be pumped through the installed pipe systems to assist in curing if required
- Removing the formwork and repeating the process for the next concrete block.

Although the majority of the concrete works for the project would involve mass concrete, certain parts would require reinforced concrete. Work would include:

- Installing formwork to allow concrete placement as determined by the design. Generally, the formwork would be lifted into place by a crane
- Placing reinforcing steel in the formwork in the required locations and patterns. Reinforcement would be either lifted into place by a crane or would be placed by hand
- Pouring concrete into the formwork and allowing the concrete to set. The concrete would be delivered from the on-site batch plants by a truck, a crane, a cableway and/or a conveyor
- Removing the formwork and repeating the process for the next concrete element.

2.3.5.4 Thickening and raising dam abutments

Work would include:

- Excavation and earthworks at the base of the dam wall to provide a key for the concrete buttress used to increase the thickness of the dam wall
- Excavation and removal of material for about 30 m east of the left abutment at the raised dam crest location
- Grouting of foundations for the raised dam crest on the left abutment
- Controlled blasting may also be used to excavate material
- Hydro blasting the existing concrete wall. Between 20 and 50mm of the existing concrete surface of the dam wall would be removed to facilitate the bond between the existing concrete and the new concrete
- Thickening the abutments on the downstream face using the placement methodology described in Chapter 5 of the EIS
- Raising the abutments about 17 m higher than the existing dam crest level
- Raising of the two lift towers including installation of two new lifts.

The profile of the new abutment would be constructed to mirror the existing profile.

2.3.5.5 Thickening and raising of the central spillway

Work would include:

- Excavating the foundations to allow the tie in of the new works
- Hydro blasting the existing concrete wall. Between 20 and 50 mm of the existing concrete surface of the dam wall would be removed to facilitate the bond between the existing concrete and the new concrete
- Installing stress bars in the base of the thickened dam. Holes for the stress bars would be drilled and the stress bars inserted and then grouted
- Thickening the central spillway wall on the downstream face using the placement methodology described in Chapter 5 of the EIS
- Raising the central spillway crest about 12 m higher than the existing full supply level
- Extending the existing training walls downstream on either side of the spillway which would tie in with the existing dissipater walls
- Constructing two new reinforced concrete bridge piers within the central spillway crest
- Constructing eight 4.5 m by 4.5 m conduits through the new central spillway
- Installing hydraulically controlled gates in each the conduits and their control systems
- Installing a new maintenance gate including guides for each conduit
- Commissioning and testing electrical and mechanical elements for operating the gates.

2.3.5.6 Auxiliary spillway modifications

Work would include:

- Removal of the existing earth/rock embankments (fuse plugs) in the crest of the auxiliary spillway
- Preparation of the existing bedrock for the foundations of the new auxiliary spillway crest including grouting
- Constructing a new uncontrolled concrete spillway crest across the width of the auxiliary spillway. The majority of the spillway would consist of mass concrete however reinforced concrete sections would be required on the top of the crest of the spillway
- Constructing of four new reinforced concrete bridge piers within the spillway crest
- Installation of additional anchor bars from the spillway floor into the underlying rock. Holes for the anchor bars would be drilled, the anchor bars inserted and then grouted in place

- Constructing a 30 to 50 m long reinforced concrete drop-over slab across the width of the spillway about 130 m downstream of the new spillway crest to allow for changed spillway flows
- Increasing the height and/or strength of the existing spillway chute walls in various locations. Construction would be either mass or reinforced concrete depending on the degree of heightening or strengthening required and the location of the wall
- Raising and/or replacing of shotcrete wall lining with reinforced concrete or new shotcrete in various locations
- Additional scour protection would be required downstream of the auxiliary spillway . Activities would include removing soil, excavation of rock to the required level (including blasting if needed) and installation of rock scour protection, concrete and anchor bars.

2.3.5.7 Other Infrastructure and elements

Work would include:

- A new road and pedestrian access would be built along the top of the abutments, the auxiliary and central spillway. These would connect with the approaches and road network on either side of the dam to provide access and provision of services across the dam crest. Timing of construction of the new access will be linked to raising of the auxiliary, central and abutment crests
- Areas for spoil emplacement may be used for disposal of some natural excavated materials on-site. Material from the earth/rock embankments removal, the temporary coffer dams and other excess spoil from other excavations may be emplaced into these areas. Activities would include site preparation, emplacing material, site stabilisation and landscaping.

2.3.5.8 Environmental flows infrastructure

Work would include:

- Underwater construction of a concrete base for multi-level water intake tower on the upstream face of the dam
- Underwater and above water construction of the new tower using precast concrete units connected to the upstream face of the dam
- Underwater excavation of a section of the existing hydro-electric power station intake tower to allow water to pass between the new tower and the existing tower
- Installation of hydraulically operated gates into the intake tower
- Installation of concrete panels to block off the existing hydro-electric power station intake tower openings
- Relining of the existing 4.2m diameter hydro-electric power station pipe with epoxy or a new pipe grouted in place
- Removal of existing generating equipment within the existing downstream hydro-electric power station including hazardous materials
- Construction of a new valve house building, downstream of the existing downstream hydro-electric power station, using reinforced concrete
- Installation of new steel pipes within the existing hydro-electric power station and new valve house including new valves.

2.3.5.9 Demobilisation and site restoration

Demobilising and restoration of the construction site would be undertaken progressively, as work in an area is completed, and include activities such as:

- removing temporary construction infrastructure, plant and equipment
- earthworks
- site stabilisation and landscaping.

3 Existing environment

3.1 Noise and vibration sensitive land uses

The nearest residential sensitive receivers are located to the east of the proposal. The closest residence is located approximately 600 metres north east of the wall in Warragamba.

Within Warragamba are schools, and a number of community and businesses, summarised as follows:

- Visitor Centre
- Warragamba Dam Lookout
- Warragamba Public School
- Neighbourhood Centre
- Warragamba Workers Club
- Sacred Heart Catholic Church
- Saint Paul's Anglican Church
- Preschool
- Town Hall
- Commercial, Police Station, Fire and Rescue
- Sporting ovals and swimming pool

The nearest road accessible point in the Blue Mountains National Park is the Nepean River Lookout which is located approximately 4km to the north west of the Dam Wall.

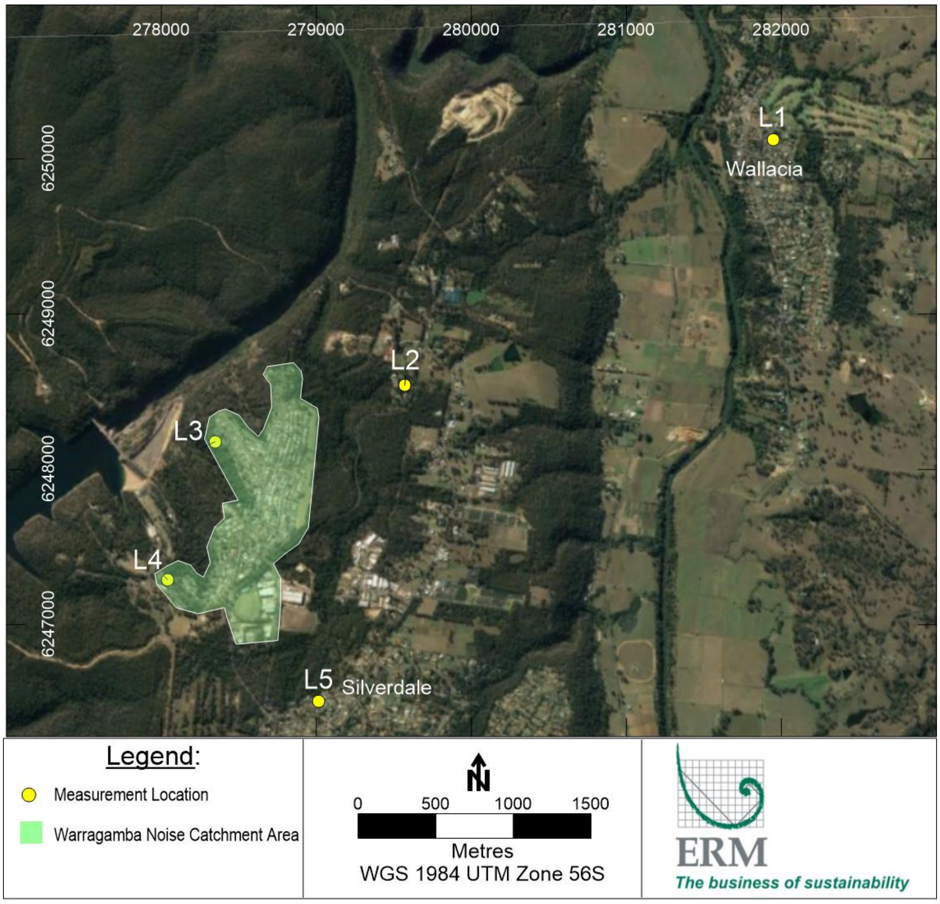
There are a number of vibration sensitive heritage receivers near the proposed construction works including;

- Warragamba Supply Scheme dam infrastructure
- Visitor centre
- Haviland Park
- Aboriginal heritage sites.

The Project area measurement locations, and the Warragamba noise catchment area (i.e. the nearest potentially impacted receivers in Warragamba) are presented in *Figure 3-1*. Noise monitoring location in Warragamba and on the project access routes in Wallacia and Silverdale are also included in this figure.

The assessment of construction impacts on noise sensitive receivers in Warragamba has summarised results into groups of sensitive receivers. These groups of receivers are discussed further in Section 5.2, assessment of construction noise.

Figure 3-1: Noise Catchment Areas and Noise Monitoring Locations



3.2 Existing acoustic environment

The existing acoustic environment was characterised by a combination of short term (attended) and long term (unattended) noise monitoring. The nearest residential areas are suburban residential areas and larger rural residential blocks. During attended noise monitoring the primary influence on ambient noise profiles included local community activity, fauna (birds and insects) and discontinuous traffic on Farnsworth Road and Silverdale Road.

No industrial noise sources or dam operations sources were audible during attended noise monitoring.

3.3 Monitoring methodology

Unattended noise monitoring was undertaken in the suburbs of Wallacia, Warragamba and Silverdale on two occasions between 12-19 March 2018 and 22-29 June 2018. Unattended monitoring was carried out at the five locations shown in *Figure 3-1*and detailed in Table 3-1.

Table 3-1: Noise Monitoring Locations

LOCATION ID	ADDRESS	SUBURB	EASTING (M)	NORTHING (M)
L1	11 Green Street	Wallacia	281949	6250125
L2	20 Farnsworth Avenue	Wallacia	279571	6248543
L3	37 Thirteenth Avenue	Warragamba	278354	6248177
L4	South West end of Farnsworth Road (Near 2 19th Street)	Warragamba	278041	6247289
L5	15 Warradale Road	Silverdale	279016	6246505

Noise loggers were installed to quantify the existing acoustic environment in residential areas potentially impacted by construction activity and construction traffic. Loggers were set to record A-weighted noise levels every 15 minutes and set to 'fast' response time.

Short term (attended) noise measurements were also carried out at the background monitoring locations. Measurements were undertaken over 15 minute intervals with consideration to AS1055:1997 Description and Measurement of Environmental Noise. Field calibration was checked before and after each measurement occasion with no significant drift (±0.5 dB) observed.

Details of monitoring equipment used are as presented in *Table 3-2*.

Table 3-2: Noise Monitoring Equipment

NOISE MONITORING TYPE	LOCATION USED	MODEL	SERIAL NUMBER
Attended Sound Level Meter	All	NTi XL2	A2A-06981-E0
Unattended Noise Loggers	L1	EL 215	194525
	L2	EL 215	194447
	L3	EL 215	194637
	L4	RION NL 31	603874
	L5	EL 215	194637

Weather conditions recorded at the nearest bureau of meteorology automatic weather station (Badgerys Creek – no. 67109) were reviewed to identify periods of potentially adverse weather conditions. Observations were also made of onsite weather conditions to assist in identifying likely periods of unsuitable weather data. Review of the weather station data found some adverse conditions likely to influence noise measurements. Periods excluded from the collected noise data are shown in the noise monitoring results data in Appendix B.

3.4 Monitoring results

Attended monitoring indicated the noise environment at all the monitoring locations was influenced by occasional vehicle passbys. Background noise levels were observed to range from 30 to 40 dB(A) with no industrial influences audible or affecting the measurements. No operational noise was observed to be audible at any point during attended monitoring. Attended monitoring indicated noise levels consistent at monitoring locations across the project area. A summary of the attended noise measurements is shown in *Table 3-3* below.

Unattended noise monitoring has been summarised in *Table 3-4*. Background noise levels were found to be typical of a rural area, ranging between 26 dBA and 37 dBA. Daily graphs for the noise monitoring results are included in Appendix B. The unattended noise logger at L4 was tampered with, hence logging data from this location has been excluded from the data set.

Table 3-3: Attended Monitoring Results

DATE AND TIME	LOCATION	MEASURED NOISE LEVEL DB(A)				NOISE SOURCES IDENTIFIED DURING MONITORING
		LA1	L_{A10}	L_{A90}	L_{Aeq}	
09/03/18 14:10	L3 - 37 Thirteenth Street, Warragamba	58	49	33	47	Plane overhead 65 dB(A), bird 64-74 dB(A), ambient, distant traffic, insects, birds 34-37 dB(A), distant people talking 40 dB
09/03/18 15:15	L4 - 2 Nineteenth Street, Warragamba*	53	47	36	45	Ambient – insects, distant traffic, birds 38-41 dB(A), Bird 50-60 dB(A), Dog barking 52 dB(A)
12/03/18 15:23	L3 - 37 Thirteenth Street, Warragamba	56	51	39	48	Distant birds – constant 46-52 dB(A), Distant airplane 44 dB(A), Ambient – trees, birds, traffic 43-46 dB(A), Bird nearby 58 dB(A), Distant airplane 53 dB(A),Plane overhead 43 dB(A)
19/03/18 12:29	L4 2 Nineteenth Street, Warragamba*	44	44	39	42	Dog bark neighbour's air conditioner, birds, insects 39-41 dB(A), Dog barking louder 41-53 dB(A), Birds, car passing 45-47 dB(A), Distant airplane 49 dB(A), Bird screech 52 dB(A)
19/03/18 12:59	L3 - 37 Thirteenth Street, Warragamba	52	40	31	44	Constant birds 50-60 dB(A), lull – only insects 34-36 dB(A), Car takeoff 44 dB(A).
22/06/18 11:58	L1 - 11 Green Street, Wallacia	58	49	37	48	Birds 45dB(A), Trucks (Distant) 50-60dB(A), Airplane flyover 45-48dB(A), Dog barking 55-60dB(A)
22/06/18 12:31	L2 - 20 Farnsworth Avenue, Wallacia	60	53	35	50	Cars passing 60dB(A), Airplane flyover 40dB(A), Alarm siren (distant), 38dB(A), Birds 35dB(A), Truck passing (distant) 45 dB(A), Distant traffic/birds 35-38dB(A)
22/06/18 14:10	L4 - Farnsworth Avenue (Closest to 2 19th Street, Warragamba)	50	44	41	43	Intermittent music from construction activities 40-45 dB(A), Birds 40 dB(A), Construction noise hammering) 45dB(A), Airplane flyover 50-55dB(A)
22/06/18 14:41	L5 - 15 Warradale Road, Silverdale	59	54	34	48	Cars passing 50-55dB(A), Background ambience/birds 35dB(A), Cars passing 40-45dB(A), Airplane flyover 35-42dB(A), Distant traffic 36-38dB(A)

Note: 2 Nineteenth Street is an attended only monitoring location.

Table 3-4: Long Term Noise Monitoring Results

LOCATION	MEASURED NOISE LEVEL, DB(A)								
	Day			Evening			Night		
	L_{10}	RBL	L_{eq}	L_{10}	RBL	L_{eq}	L_{10}	RBL	L_{eq}
L1	53	35	50	48	35	43	49	30	42
L2	59	37	53	56	34	50	56	30	48
L3	58	31	55	56	33	48	51	32	46
L5	55	32	50	53	31	47	46	26	43

Note: The noise logger at L4 had noticeable signs of tampering, and was excluded from the dataset.

3.4.1 Background noise summary

Background noise levels were identified as being consistent with a quiet suburban or rural residential area with low levels of transportation noise. Intermittent traffic noise, occasional aircraft noise, occasional community noise and local fauna were also observed. No industrial noise sources were noted during attended noise measurements. Background levels were typically between 31 to 37 dB(A) in daytime periods, 31 to 35 dB(A) during the evening periods and 26 to 32 dB(A) during the night-time period.

Noise levels followed diurnal patterns with the ambient noise levels dropped from day to night time. L3 was an exception to this, however as this logger was deployed during a warmer part of the year and was potentially impacted by insect noise during the night time.

Noise monitoring data is included in Appendix B.

4 Criteria

4.1 Operational noise

The Noise Policy for Industry (EPA 2017) provides guidance on assessing noise from industrial sources in NSW. The policy is applied to premises which generate noise including; "utility generation/reticulation services premises" and has been applied to set noise targets from potential operational noise sources associated with the project.

Field survey of the existing acoustic environment did not identify any significant industrial noise associated with current dam operations or from other sources in the project area. Based on the monitoring results, intrusive noise levels are set based on background plus 5 dB(A). Noise criteria equivalent to the minimum project intrusiveness noise levels of 40 dB for the day time, 36 dB for the evening and 35 dB for the night time period would apply. A summary of the intrusive noise levels are reproduced in *Table 4-1* for receivers potentially impacted by dam operations in noise catchment area.

Table 4-1: Intrusive noise criteria (Warragamba)

TIME OF DAY	BACKGROUND NOISE LEVEL	Minimum project intrusiveness noise Levels (LAeq,15min dB(a))
Day	31	40
Evening	31	36
Night	30	35

Amenity noise levels are also applied to limit continuous increase in industrial noise when only an intrusive criteria is applied. Noise levels for sensitive receivers located within a suburban area range from 55 dBA for the day time period to 40 dB(A) during the night time. In this situation the intrusive limit is the controlling level for the project.

4.2 Construction noise

The *Interim Construction Noise Guideline* (ICNG) (DECCW, 2009) provides noise management levels for the control of noise from construction. In general, these criteria state that the construction noise should not exceed the background noise level by more than 10 dB during standard hours, and by more than five dB outside of standard hours. The criteria for residential receivers are reproduced in *Table 4-2*.

Table 4-2: Construction Noise Targets at Residences using Quantitative Assessment

TIME OF DAY	MANAGEMENT LEVEL $L_{AEQ,15MIN}$	HOW TO APPLY
Recommended Standard Hours: Monday to Friday 7.00am to 6.00pm Saturday 8.00am to 1.00pm No work on Sundays or Public Holidays	Noise affected RBL + 10 dB(A)	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq,(15min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences

TIME OF DAY	MANAGEMENT LEVEL $L_{AEQ,15MIN}$	HOW TO APPLY
		2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dBA	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community.

Source: ICNG (DECCW 2009).

The proposed construction activity would generally be limited to day period and as such a noise goal of RBL + 10dB(A) would apply at residential receivers. It is anticipated that some concrete pours during the warmer months may occur into the night time period, and would therefore be assessed using out of hours (OOH) noise criteria. Operation of chilling plant for concrete curing may also occur 24hrs per day during warmer months.

There are several noise sensitive commercial receivers located in the project area, including commercial activities, a sporting centre, a community centre, and several restaurants, however residential receivers are the nearest potentially impacted receivers to construction activities, and management of noise impacts for residential receivers will ensure noise impacts are managed for other receivers.

Noise Criteria (L_{Aeq} 15 minute) for other land uses are applied as follows in the ICNG (DECCW, 2009):

- School classrooms – 45 dB(A) internal noise level
- Places of worship – 45 dB(A) internal noise level
- Active recreation areas – 65 dB(A) external noise level
- Commercial premises – 70 dB(A) external noise level

The project specific construction noise management levels for sensitive receivers are presented in *Table 4-3*. These levels are based on the background noise levels described in 3.2

Sleep Disturbance

The Noise Policy for Industry (EPA, 2017) states that *"the potential for sleep disturbance from maximum noise level events from premises during the night-time period needs to be considered. Sleep disturbance is considered to be both awakenings and disturbance to sleep stages."*

This policy presents the following limits for sleep disturbance impacts prior to triggering the need for a detailed maximum noise level event assessment. These limits are applied to the night time noise levels from the subject development at the nearest residential location:

- $L_{Aeq,15min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, and/or
- L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is the greater.

Thus for the proposal the sleep disturbance criterion for residential receivers based on a background of 30dB(A) would be $L_{Aeq,15min}$ 45 dB(A) and L_{AFmax} 52 dB(A) which is the greater L_{AMax} limit.

Summary of Construction Noise management Levels

Table 4-3: Construction Noise Management Levels

LOCATION	WARRAGAMBA
	Management Level dB(A) $L_{Aeq\ 15minute}$
Background Noise Level	
RBL standard hours	31
RBL Day (OOH)	31
RBL Evening (OOH)	31
RBL Night (OOH)	30
Construction Noise Management Levels	
Standard Hours	41
RBL Day (OOH)	36
RBL Evening (OOH)	36
RBL Night (OOH)	35
Sleep Disturbance, L_{Aeq} (L_{Amax})	45 (52)

Notes:
1. Construction noise criteria calculated as Leq,15min = RBL+ 10 dB for day and Leq,15min = RBL + 5 dB for evening and night.
2. Standard hours: Monday to Friday 7.00am to 6.00pm Saturday 8.00am to 1.00pm. OOH day: Saturday 1.00 pm to 6.00 pm Saturday, 7 .00 am to 6.00 pm Sunday. OOH evening: Monday to Sunday 6.00pm to 10.00pm. OOH Night time: Monday to Saturday 10.00pm to 7.00am Sunday & Public Holidays 10.00pm to 8.00am.
3. Night time noise criteria for NCA1 has adopted the NCA2 background noise level as NCA 1 data was collected during warmer months with potentially greater insect activity.

4.3 Road noise

The NSW Road Noise Policy (RNP)(DECCW 2011) provides guidance on noise criteria for road upgrade projects and projects which result in additional traffic generating noise impacts at sensitive receivers.

The RNP provides guidance, criteria and procedures for assessing noise impacts from existing, new and redeveloped roads and traffic generating developments. The assessment of road traffic noise impacts on public roads is assessed under the RNP.

The Project is a traffic generating development as construction worker car movements and delivery and construction vehicle movements will be generated on the surrounding public roads as a result of the Project construction. Once construction is complete, project traffic is expected to return to levels similar to the current situation

The RNP details a number of noise assessment criteria for various road categories and land uses. Road access to the project will be via Park Road, Silverdale Road and Farnsworth Avenue and Production Avenue. These roads have been classed as collector or sub arterial roads due to their function of providing connections between local roads and carrying through traffic.

The assessment criteria for external noise levels apply at 1 m from the façade of the affected residential receiver. The criteria for residential land uses and receivers impacted by additional construction and operational traffic for the Project are presented in Table 4-4.

Table 4-4: RNP Residential Road Traffic Noise Criteria

ROAD CATEGORY	TYPE OF PROJECT/LAND USE	ASSESSMENT CRITERIA – DB(A)	
		Day 7am to 10pm	Night 10pm to 7am
Freeway/arterial/ sub-arterial roads	Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments.	$L_{Aeq,15hr}$ 60 (external)	$L_{Aeq,9hr}$ 55 (external)

For existing residences and other sensitive land uses affected by additional traffic on existing roads generated by land use developments, the RNP states that any increase in the total traffic level should be limited to 2 dB above the road traffic noise level without the development. The RNP application notes states that this limit should be applied wherever the noise level without the development is with 2 dB of or exceeds the noise assessment criterion.

Where existing noise levels are more than 2 dB below the criteria, any increase due to the Project should be limited to 12 dB above the existing noise level with the criteria as the upper limit. Where existing noise levels are either within 2 dB of or above the absolute criteria, any increase due to the Project should be limited to 2 dB above the existing noise level.

4.4 Vibration

Impacts from vibration can be considered both in terms of effects on building occupants (human comfort) and the effects on the building structure (building damage). Of these considerations, the human comfort limits are the most stringent. Therefore, for occupied buildings, if compliance with human comfort limits is achieved, it will follow that compliance will be achieved with the building damage objectives.

4.4.1 Human comfort

The EPA's Assessing Vibration: A Technical Guideline provides acceptable values for continuous and impulsive vibration in the range 1-80Hz.

Where vibration is intermittent, such as for construction sources, a vibration dose is calculated and acceptable values are shown in *Table 4-5* below.

Table 4-5: Acceptable Vibration Does Values for Intermittent Vibration (m/s1.75)

LOCATION	DAYTIME[1]		NIGHT TIME[1]	
	Preferred Value	Maximum Values	Preferred Value	Maximum Value
Critical areas [2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Notes:
1. Daytime is 7.00am to 10.00pm and night time is 10.00pm to 7.00am.
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source BS 6472-1992.

4.4.2 Building damage

German Standard DIN 4150-3-1999 Structural Vibration – Part 3 Effects of vibration on structures provides methods for evaluating the effects of vibration on structures in the absence of an Australian Standard.

The recommended limits (guide values) from DIN 4150 for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented in Table 4-6. Sensitivity of structure is dependent on the type of construction and the frequency of the vibration source. With structures being more sensitive to lower frequency vibration, requiring a lower criteria level.

Table 4-6: Guideline Vibration Values for Short Term Vibration on Structures (mm/s)

TYPE OF BUILDING	GUIDELINE VALUES FOR PEAK PARTICLE VELOCITY (MM/S)			
	1 to 10 Hz	10 to 50 Hz	50 to 100 Hz	Vibration at horizontal plane of highest floor at all frequencies
Commercial and Industrial Building	20	20-40	40-50	40
Dwellings and buildings of similar occupancy or design	5	5-15	15-20	15
Structures that, because of their particular sensitivity to vibration cannot be classified under lines 1 and 2 and are of great intrinsic value	3	3-8	8-10	8

4.5 Blasting overpressure and vibration

Blasting overpressure and ground vibration is assessed using the ANZEC guidelines (ANZEC, 1990). These guidelines set limits for overpressure and ground vibration levels (shown in *Table 4-7*). Where compliance is achieved, the risk of annoyance is minimised.

The guidelines recommend that blasting is carried out between 9.00am to 5.00pm Monday to Saturday and should not be carried out outside of these times, including on Sundays and Public Holidays.

Table 4-7: ANZEC Guideline Blasting Limits

CRITERION	OVERPRESSURE DB (LINEAR PEAK)	GROUND VIBRATION PPV (MM/S)
Recommended Maximum (95% of all blasts)	115	5
Level not to be exceeded	120	10
Long term goal for ground vibration	-	2

Notes:
1. Overpressure limits apply where measurement equipment has a cut-off frequency of 2 Hz or less. Where equipment has a high cut-off frequency, 5 dB should be added to all levels.
2. PPV – peak particle velocity.

Information provided by WaterNSW sets the following project specific limits for ground vibration on the nearby dam infrastructure during construction. This is shown in *Table 4-8*. Although the dam infrastructure has been identified as a heritage item, it is not considered vibration sensitive structure as per Table 4-6 or *Table 4-7*.

Table 4-8 Ground Vibration Limits Dam Infrastructure during construction

STRUCTURE	PPV (MM/S)
Concrete less than 7 days old	10
Concrete after 7 days	25
Concrete after 28 days (including existing concrete structures or concrete placed as part of the works).	50
Pressure grouted foundations	20
Pipelines	50
Power pylon near spillway crest	100

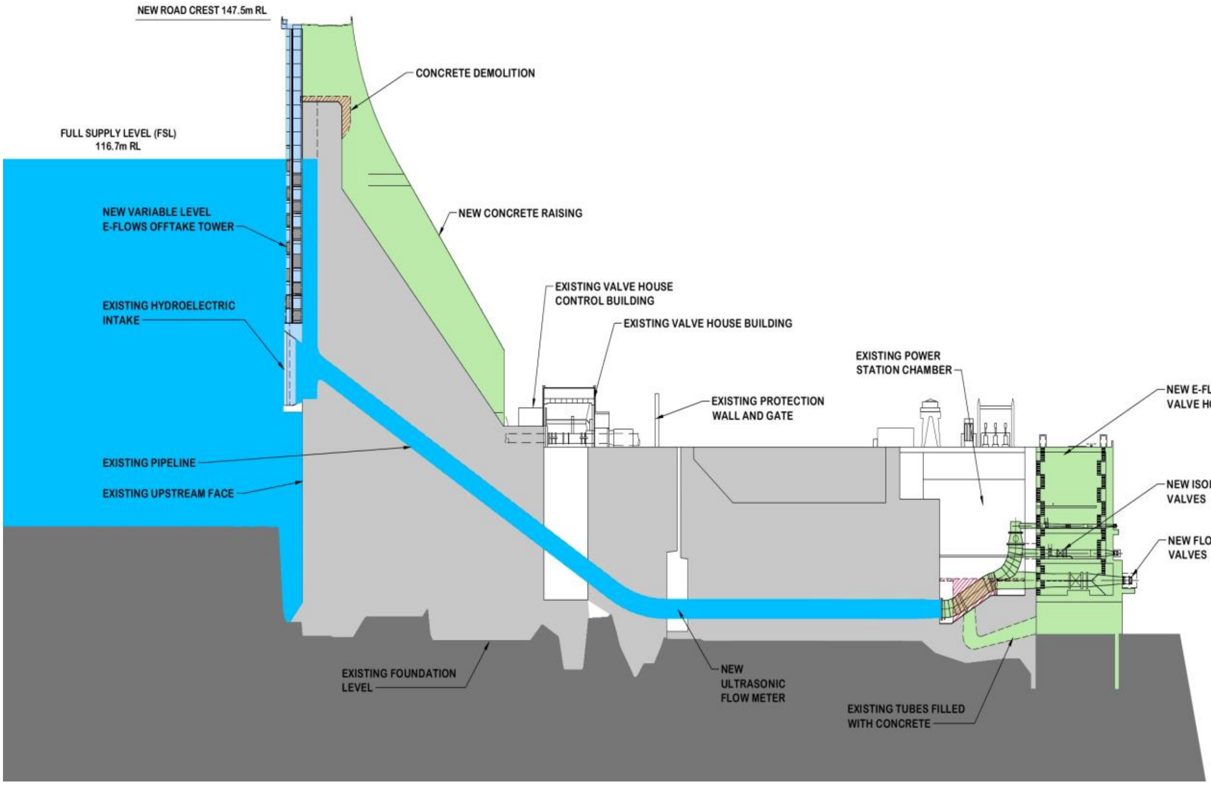
5 Assessment

5.1 Operational noise

Based on the existing environment noise survey, dam noise emissions were not identified as an audible noise source at locations representative of the nearest residential areas. There is no change to audibility expected after the dam wall has been upgraded. Extended releases from the FMZ are rare and cannot be practically mitigated for noise and vibration. As the impact is short term and unlikely to cause substantial annoyance to surrounding residences, an assessment has not been undertaken.

Project components with potential to generate water flow noise during normal operation are expected to be limited to the upgraded inflow infrastructure located within the wall structure and the outlet downstream of the wall. A cross section of this infrastructure is shown in Figure 5-1.

Figure 5-1: Environmental Flow Infrastructure



The environmental flow control infrastructure is housed within the existing infrastructure and within a new valve box.

Water flow noise from the upgraded inlet and outlets are not expected to result in significant noise emissions at typical environmental flow rates and would not be expected to generate annoying characteristics as described in the NPfI.

Based on the existing environment noise survey, which did not identify noise from the dam at the nearest sensitive receivers, and the similar arrangement of upgraded environmental flow infrastructure. Significant additional noise emissions from the environmental flow infrastructure are not expected, and have not been assessed further.

5.2 Construction noise

It is anticipated that construction activities would occur over a period of four to five years. The construction has been assessed in stages representative of the construction program, as shown in Figure 2-4 and Table 5-1.

Table 5-1: Construction Stages Modelled

CONSTRUCTION STAGE	WORKS
Early works	Laydown area clearing Minor roadworks Utilities
Enabling works and demolition (including environmental flow infrastructure)	Batching plants installation Coffer dam installation Minor structures demolition
Main construction works	Spillway and abutments widening and thickening preparation and construction works Auxiliary spillway works Other infrastructure Environmental flow infrastructure
Demobilisation and site restoration	Batch plant decommissioning, landscaping, minor works

It is anticipated that construction would generally be limited to standard hours in accordance with the ICNG however, it is anticipated that some concrete pours during warmer periods may occur into the night time period, as described in section 2.3.4. Operation of chilling plant for concrete curing may also occur 24hrs per day during warmer periods.

Project construction areas are shown in Figure 2-2.

5.2.1 Modelling methodology

Noise modelling has been undertaken using the ISO 9613 *Acoustics – Attenuation of sound during propagation outdoors* (ISO, 1996) algorithms, as implemented within the CadnaA 4.5 acoustic modelling package. The noise modelling takes into consideration the sound power level (SWL) of the proposed site operations, activities and equipment, and applies adjustments for attenuation from geometric spreading, acoustic shielding from intervening ground topography, ground effect, meteorological effects and atmospheric absorption.

As the project is located in a forested gorge and the landscape between the project and Warragamba township is also forested, noise modelling has assumed these areas are non-reflective of sound. The lake surface and dam was assumed to be 100 % reflective.

A model sensitivity test for a more reflective ground conditions (50%) and ground absorption, for example if the surrounding landscape was cleared or burnt off in a bushfire, indicated noise levels approximately 1dB higher than presented in this assessment at the nearest residential areas ranging to approximately 2dB higher at the most distant receivers in Warragamba.

SWL for plant used in each construction phase have been adopted based on UK DEFRA construction noise database (frequency spectrums) adjusted in line with typical construction plant SWLs as described in the Construction Noise Strategy (TfNSW, 2017) and Construction Noise and Vibration Guideline (RMS, 2016). SWLs for individual plant items and equipment used per construction stage are presented in Appendix C.

5.2.2 Results

Table 5-3 presents the noise modelling predictions during each construction phase. Construction plant and equipment has been modelled assuming that plant would be operational at full utilisation for the modelled period.

Out of hours works have been presented in *Table 5-4*.

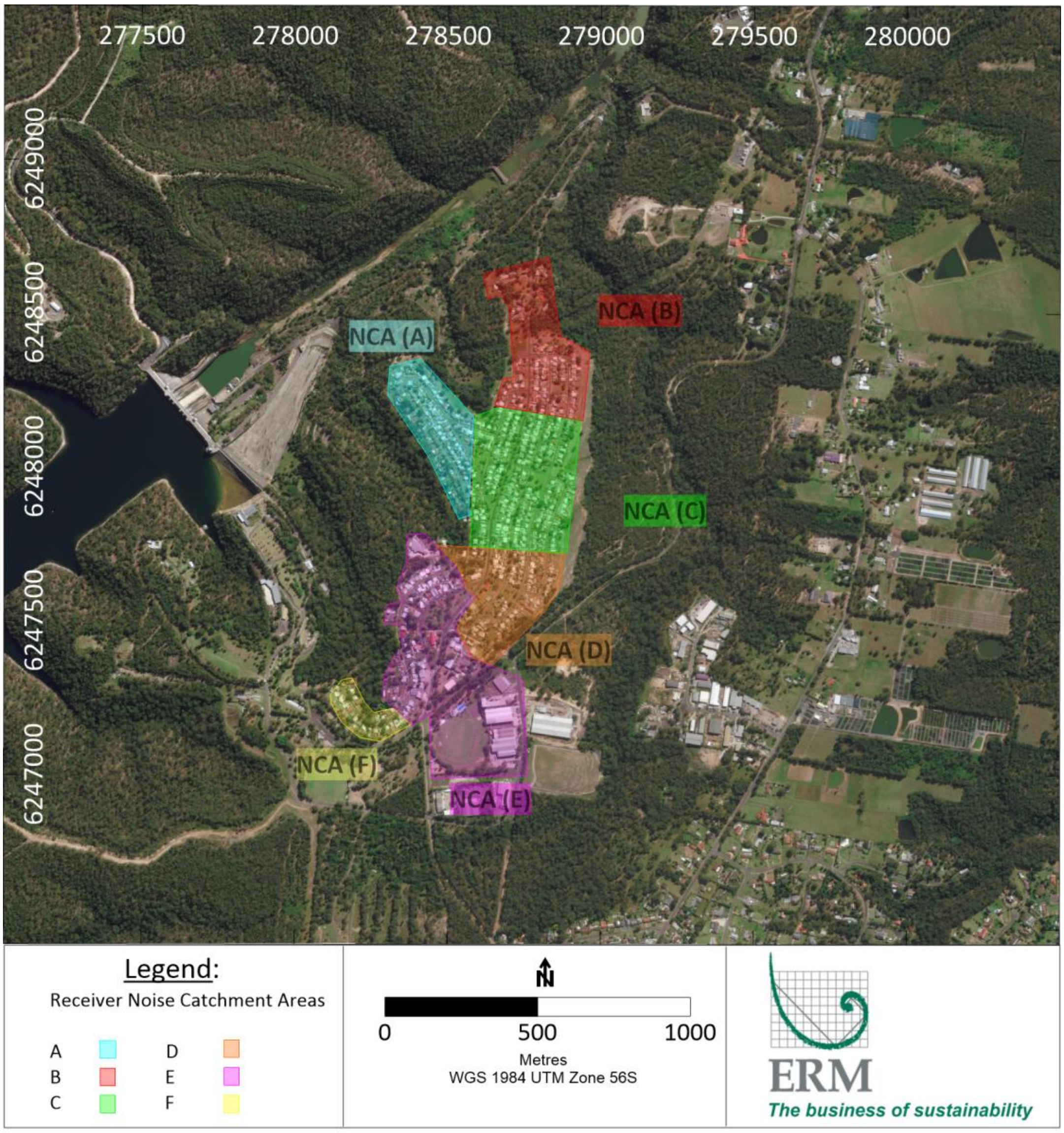
Noise sensitive receivers in Warragamba have been grouped into sensitive receiver noise catchments (A-F) in order to create areas that are in similar in location and are anticipated to receive similar impacts construction works.

Results have been presented as a range from minimum to maximum noise levels in each NCA (refer *Figure 5-2*) to show the range of impacts from each scenario at residential receivers.

Construction equipment noise emissions can vary significantly depending equipment location, orientation, mode of operation and variability in noise emissions between different makes of equipment. Construction noise impacts can be considered indicative only and may vary from the predicted noise levels.

Noise contours for each of the assessed construction scenarios are also included in Appendix C.

Figure 5-2: Noise Catchment Area Groups



Predicted noise levels have been presented with the magnitude of noise exceedances as per Table 5-2. Noise modelling inputs and results is provided in Appendix B.

Table 5-2: Impact Rating Colour Scheme

DESCRIPTION	EXCEEDANCE ABOVE RBL, DB(A)	PREDICTED NOISE LEVEL, DB(A)	COLOUR SCHEME
Noticeable	0 – 10 dB(A)	-	
Clearly audible	10 – 20 dB(A)	-	
Moderately intrusive	20 – 30 dB(A)	-	
Highly intrusive	> 30 dB(A)	-	
Highly Noise Affected	-	> 75 dB(A)	

Table 5-3: Predicted Construction Noise (Day time Works)

RECEIVER GROUP	CRITERIA $L_{AEQ,15MIN}$ DB(A)		NOISE LEVEL (DECIBELS A WEIGHTED) FOR EACH CONSTRUCTION STAGE			
			EARLY WORKS	ESTABLISHING WORKS AND DEMOLITION	MAIN WORKS	DEMOBILISATION AND SITE RESTORATION
NCA (A)	41	Min	**44**	**48**	**47**	**47**
		Max	**48**	**53**	**54**	**52**
NCA (B)	41	Min	39	**42**	41	**42**
		Max	**48**	**48**	**48**	**47**
NCA (C)	41	Min	40	**43**	**42**	**43**
		Max	**46**	**49**	**49**	**49**
NCA (D)	41	Min	**43**	**44**	**44**	**44**
		Max	**49**	**49**	**49**	**49**
NCA (E)	41	Min	**45**	**45**	**45**	**45**
		Max	**53**	**57**	**56**	**57**
NCA (F)	41	Min	**52**	**49**	**51**	**49**
		Max	**58**	**52**	**57**	**53**

Notes:
1. All levels presented as LAeq 15minute dB(A) Values denoted in **Bold** exceed the noise management level. Colour coding indicates predicted noise level above the RBL. Blue 0-10 dB, green 10-20dB, yellow 20-30dB.
2. Where highly annoying noise sources such as rock breaking are undertaken as part of the construction works, a 5dB penalty would be applied to the predicted levels presented in this table when these works are underway.

Table 5-4: Predicted Construction Noise (outside of standard hours)

RECEIVER GROUP	OOH CRITERIA $L_{AEQ, 15MIN}$ (DBA)				NOISE LEVEL (DECIBELS A WEIGHTED LEQ)					L_{MAX}
	Day/ Evening	Night	Sleep Disturbance		Batch Plant 1	Batch Plant 2	Dam Wall Construction	Cooling Plant 24hr operation	Sum	Night time max
NCA (A)	36	35	40 (52 LMax)	Min	**41**	**43**	**38**	26	**46**	47
				Max	**47**	**47**	**43**	33	**50**	52
NCA (B)	36	35	40 (52 LMax)	Min	35	**37**	33	20	**40**	42
				Max	**41**	**43**	**39**	28	**46**	48
NCA (C)	36	35	40 (52 LMax)	Min	34	**38**	34	20	**41**	42
				Max	**42**	**46**	**42**	28	**49**	49
NCA (D)	36	35	40 (52 LMax)	Min	35	**40**	35	22	**42**	43
				Max	**41**	**45**	**40**	26	**47**	48
NCA (E)	36	35	40 (52 LMax)	Min	**36**	**42**	**36**	21	**44**	44
				Max	**47**	**53**	**47**	33	**55**	**55**
NCA (F)	36	35	40 (52 LMax)	Min	**42**	**46**	**41**	24	**49**	49
				Max	**46**	**50**	**45**	27	**53**	**53**

Note: Values denoted in **Bold** exceed the noise management level. Colour coding indicates predicted noise level above the RBL. Blue 0-10 dB, green 10-20dB, yellow 20-30dB based on the day/evening for construction works and night time Lmax criteria.

5.2.3 Discussion of results

Works in Standard Hours

In each construction stage, the results show that noise levels are predicted to exceed construction noise criteria.

Predicted construction noise levels are expected to range from noticeable to clearly audible in each of the noise catchment areas assessed in Warragamba. The nearest residential receivers on the western edge of NCA (E) and NCA (F) are predicted to experience noise levels up to 57-58 dB during each construction phase.

Throughout the construction works program it is anticipated that there will be periods where rock breaking/jack hammering and drilling would be undertaken. When these activities are in use, a 5 dB penalty is applied to the predicted noise levels to take into account additional annoyance from these sources. That is a noise impact up to 62-63 dB at the nearest receivers.

Noise levels are not predicted to exceed the highly noise affected noise level of 75 dB(A) at any receiver for any of the construction scenarios modelled.

Based on the results of this assessment, noise management and mitigation measures have been recommended as presented in Section 7.

Out of Hours Works

Works outside normal hours may be required due to the construction methodology and concrete pour requirements. This may occur where concrete pours are required to continue into the out of hours periods. Operation of the chilled water plants may also be required 24hrs per day during warmer months.

As summarised in *Table 5-4* activities occurring outside standard hours will potentially result in noise exceedances of NMLs. As a result specific out of hours works management and mitigation measures would be required, as discussed in Section 7.4.

Operation of chilled water plants are not expected to result in noise exceedances when operated overnight.

Potential sleep disturbance impacts were identified at receivers closest to night time construction.

It is recommended that an out of hours works protocol be developed for the works. To reduce potential impacts during these periods, it is recommended that high noise generating activities be limited during more sensitive periods.

5.3 Construction vibration

Plant used during construction activities which are anticipated to generate vibration impacts at nearby receivers include a vibratory roller and hydraulic hammer. Locations within the project area and approximate distances to receivers are shown in *Table 5-5*.

Table 5-5: Location of Vibration Equipment and Distances to Receivers

ITEM	LOCATIONS	APPROXIMATE DISTANCE TO NEAREST RECEIVER
Vibratory Roller (15t)	Batch Plants	350m (NCA E)
	Auxiliary spillway	540m (NCA E)
	Upstream coffer dam	450m (NCA E)
	Downstream coffer dam	550m (NCA A)
Hydraulic Hammer	Batch plants	350m (NCA E)
	Dam wall	600m (NCA E)
	Auxiliary spillway	540m (NCA E)

As vibration inducing equipment is generally located at significant distance from the nearest receivers, it is not anticipated that vibration will be an issue. Although it is not expected, if vibration equipment is to be used closer to receivers for minor works such as pavement roadworks or utilities works, *Table 5-6* outlines safe working distances for the use of this equipment.

No buildings are located within the minimum safe working distance for jackhammers. No buildings are located within the minimum safe working distances for structural damage for each of the construction scenarios presented in *Table 5-1*.

The Construction Noise and Vibration Guideline (Roads and Maritime 2016) provides recommended minimum safe working distances for a range of construction activities. These are presented in *Table 5-6* and provide for minimum safe working distances to prevent cosmetic damage and human response, and must be complied with at all times, unless additional assessment or monitoring is completed to determine site specific safe working distances.

Table 5-6: Recommended minimum safe working distances for vibration intensive plant

ITEM	RATING/DESCRIPTION	SAFE WORKING DISTANCE	
		Cosmetic Damage (BS 7385)	Human Response (OH&E Vibration Guideline)
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg – 12 to 18t excavator)	7 m	23 m
Large Hydraulic Hammer	(1600 kg – 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Note: Construction Noise and Vibration Guideline (Roads and Maritime 2016).

It is recommended that vibration testing be completed where vibratory rollers and hammers are proposed to be used within 20 metres of structures, depending on the rating of equipment to be used. There are no currently identified heritage items within the safe working distance for the project, except for the dam infrastructure, which although a heritage item is not considered a vibration sensitive structure as defined in section 4.4 and 4.5.

In order to reduce the potential risk of impact, it is recommended that construction vibration mitigation measures are considered as part of the construction noise and vibration management plan.

5.4 Construction road traffic

This section assesses noise impacts from additional traffic generating noise from the project construction.

Calculations were made to estimate the impact of additional proposal-related traffic on roads using the Calculation of Road Traffic Noise (CoRTN).

Based on information presented in the *Warragamba Dam Raising Transport and Traffic Report* (SMEC, 2018), up to 208 heavy vehicle movements may occur over the day time construction period and up to 250 light vehicle movements may occur during the morning and afternoon peak hours during the peak construction phase from workers traveling to and from the project. Additional traffic movements anticipated during construction of the proposal would generally be limited to day time working hours.

Access via the public road network would include Silverdale Road, Park Road and Farnsworth Road. The proposed transport routes are shown in Appendix A. An assessment of road noise impact was completed at the nearest receivers to the project roads, at locations representative of nearest receivers; Park Road (17m set back), Silverdale Road(23m setback) and Farnsworth Road (24m setback).

5.4.1 Traffic modelling parameters

Traffic noise modelling was completed using predicted traffic volume data for the following transport routes:

- Park Road
- Silverdale Road
- Farnsworth Avenue

These roads have been classed as collector or sub arterial roads due to their function of providing connections between local roads and carrying through traffic.

Day/night splits and heavy vehicle classifications for existing traffic flows were sourced from measured traffic count data completed as part of the Traffic Assessment for the Project. These splits were applied to overall Annual average daily traffic (AADT) predictions for the proposal roads.

Posted speeds are currently 80 km/h on Park Road and 60km/h on Silverdale Road and Farnsworth Avenue, which will remain unchanged during the project.

A description of the expected transport routes are presented in *Table 5-7*.

Table 5-7: Road Traffic Scenarios

SCENARIO	DESCRIPTION AND ASSUMPTIONS
100% Northern Route	The Northern Route includes the following roads: • The Northern Road • Park Road from The Northern Road to Wallacia • Silverdale Road from Wallacia to Farnsworth Avenue • Farnsworth Avenue between intersections with Silverdale Road and Production Avenue • Production Avenue between intersections with Silverdale Road and the construction access. It is assumed that 100% of heavy traffic and 80% of light traffic will use Park Road and Farnsworth Avenue in this scenario and the remaining traffic will use Silverdale Road.
50% Northern Route and 50% Southern Route	The Southern Route includes the following roads: • Silverdale Road from the Oaks to Warradale Road • Warradale Road to Production Avenue • Production Avenue between intersections with Warradale Road and the construction access. It is assumed that 50% of heavy traffic and 20% of light traffic will use Silverdale Road in this scenario and the remaining project traffic will use Farnsworth Avenue and Park Road.

A summary of the modelled traffic volumes is provided in Table 5-8.

Table 5-8: Modelled Traffic Volumes

PROJECT ROAD	PERIOD	EXISTING		100% NORTH ROUTE		50/50 NORTH AND SOUTH ROUTE	
		Total	Heavy	Total	Heavy	Total	Heavy
Park Road	Day	5279	875	5687	1083	5583	973
	Night	1228	217	1428	217	1428	217
Farnsworth Avenue	Day	2290	284	2698	492	2594	388
	Night	410	57	610	57	610	57
Silverdale Road	Day	2955	486	3005	486	3109	590
	Night	552	106	602	106	602	106

Notes:
1. Average day night splits based on 1 week of traffic count data collected for traffic assessment
2. Day = 7am-10pm, Night = 10pm – 7am

Predicted traffic noise levels are presented in *Table 5-9*. Based on existing traffic flows and estimated construction traffic volumes for the Project.

Table 5-9: Predicted Noise from Existing Traffic and Project Traffic

ADDRESS	SEGMENT	DISTANCE TO RECEIVER, M[1]	PERIOD	CRITERIA, L_{AEQ}	EXISTING	100% NORTH	50/50 ROUTE
						Noise Level L_{Aeq}	Noise Level L_{Aeq}
24 Park Road, Wallacia	Park Road	17	Day	60	64.9	65.5	65.3
			Night	55	58.5	59.2	59.2
16 Farnsworth Avenue, Wallacia	Farnsworth Avenue	24	Day	60	58.9	60.6	60.1
			Night	55	51.4	52.9	52.9
15 Warradale Road, Silverdale	Silverdale Road	11	Day	60	59.4	59.9	60.4
			Night	55	52.1	53.9	53.9

Notes:
1. Day (7.00am – 10.00pm), night (10.00pm – 7.00am).
2. Receiver distances measured from centreline of road.

5.4.2 Results

Comparison of the predicted noise levels with the RNP (DECCW 2011) criteria indicated existing traffic noise levels are potentially above traffic noise criteria for the nearest receivers to Park Road, Wallacia during the day time and night time periods. Existing traffic noise levels were below the criteria for the nearest receivers to Farnsworth Road and Silverdale Road.

The addition of project traffic did not result in a noise level increase of greater than 2 dB, and as such would not result in a noticeable increase in traffic noise. The greatest noise increase is expected for Warradale Road Residents where traffic noise levels will increase by 1.8 dB during the night time period (early morning construction traffic) from additional passenger vehicle traffic.

As per the RNP (DECCW 2011)

"an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person."

Mitigation measures for construction traffic are not expected to be required.

5.5 Construction blasting assessment

It is anticipated that rock at the toe of the dam spillway and left abutment will be required to be blasted. Approximately 58,000 m^3 of excavation at the toe of the dam and on the left abutment , which is majority rock, may require blasting. Approximately 2,500 m^3 will be on the left abutment, with the reminder at the toe of the dam. The extent of the required excavation varies from about 20 m deep and 20 m width to only a few metres deep. Given the proximity to the dam blasting will need to be controlled to meet vibration criteria for the existing structures.

5.5.1 Methodology

Blasting overpressure and vibration have been calculated at the nearest sensitive receivers with consideration to Australian Standard AS 2187: Part 2-2006 "Explosives – Storage and Use – Part 2: Use of Explosives" and the US Bureau of Mines.

The air blast overpressure levels (OP) are predicted from the equation below:

$$OP\ = 164.35 - 24\left(\log D - \frac{1}{3} logQ\right)$$

The PPV for average ground type are predicted from the equation below:

$$PPV = K * \left(\frac{D}{\sqrt{Q}}\right)^{-1.6}$$

For both equations, D is distance in metres from the blast to the assessment point, Q is the weight in kg of explosive per delay or MIC (maximum instantaneous charge).

The K factor is site specific and is usually defined empirically after a series of trial blasting. In this instance, K factor of 1140 was adopted consistent with AS 2187: Part 2 2006 to predict the 50 per cent chance of exceedance in "average conditions."

Representative MIC values have been estimated with consideration of likely hole diameter, column height, powder factor and number of holes fired instantaneously. It is expected that blast design to minimise risk of damage to dam structures will be the limiting factor on MIC.

5.5.2 Results

Blast vibration and overpressure have been predicted for the following MIC values

- 40kg
- 100kg
- 350kg

Overpressure and vibration levels have been presented in *Table 5-10* below at the nearest residential receivers in each noise catchment area. An indicative level is also provided for the Warragamba Dam Visitor's Centre.

Table 5-10: Predicted Blasting Vibration and Overpressure Levels

NEAREST RECEIVER	DISTANCE	VIBRATION (MM/S)				OVERPRESSURE (DBL)			
	m	Criteria	MIC-40KG	MIC-100KG	MIC-350KG	Criteria	MIC-40KG	MIC-100KG	MIC-350KG
NCA 1A	600	5	0.8	1.6	4.4	115	110	114	**118**
NCA 1B	940	5	0.4	0.8	2.1	115	106	109	113
NCA 1C	940	5	0.4	0.8	2.1	115	106	109	113

NEAREST RECEIVER	DISTANCE	VIBRATION (MM/S)				OVERPRESSURE (DBL)			
	m	Criteria	MIC-40KG	MIC-100KG	MIC-350KG	Criteria	MIC-40KG	MIC-100KG	MIC-350KG
NCA 1D	1085	5	0.3	0.6	1.7	115	104	107	112
NCA 1E	820	5	0.5	1.0	2.7	115	107	110	115
NCA 1F	1030	5	0.3	0.7	1.9	115	105	108	112
NCA 2	1800	5	0.1	0.3	0.8	115	99	102	107
Warragamba Dam Visitor's Centre	390	5	1.5	3.2	**8.8**	115	115	**118**	**123**
Haviland Park	450	5	1.2	2.6	**7.1**	115	114	**117**	**121**
Heritage – Warragamba[1] 135	580	5	0.8	1.7	4.7	115	111	114	**118**
Heritage – Warragamba[1] 136	470	5	1.2	2.4	**6.6**	115	113	116	**121**

Note: Distance is approximate. Levels exceeding the criteria are shown in bold. 1 indicates indigenous heritage receivers.

The above results show that a MIC of 100kg and above is expected to exceed criteria at Warragamba Dam Visitor's Centre, Haviland park and both of the closest indigenous heritage receivers. An MIC of less than 40kg is expected to meet criteria at the nearest receivers.

Due to the proximity of the wall to blasting (directly adjacent) blast impacts will need to be confirmed utilising test blasts to confirm impacts do not exceed vibration and overpressure criteria at the dam infrastructure.

6 Conclusions

This report has assessed the potential for noise and vibration assessment associated with the construction of the Warragamba Dam Raising. The assessment has considered existing noise levels, terrain and meteorology in the prediction and assessment of noise levels and has been completed with consideration to NSW EPA guidelines, assessment methods and relevant noise standards.

A construction noise assessment was completed for each major phase of construction including site establishment, early works, main construction works and demobilisation. It is anticipated that construction would generally be limited to the daytime period only, except for occasional night time works for specific concrete pour requirements.

The results of this assessment have found that construction noise impacts associated with the proposal are predicted to exceed construction noise management level criteria at the majority of receivers in Warragamba throughout the construction program. Predicted noise levels were identified as noticeable to clearly audible for the majority of receivers. The nearest residences to the works are anticipated to experience moderately intrusive levels of construction noise. It is anticipated that these exceedances can be effectively managed and mitigated by the implementation of the recommendations provided in this report.

The predicted noise levels presented in Section 5 are typical of construction works and activities undertaken in the vicinity of residential and commercial land use precincts. These predicted values do not represent a constant noise emission that would be experienced by the community on a daily basis throughout the project’s construction schedule. The predicted noise levels will only be experienced for limited periods of time when works are occurring; they will not be experienced over whole daytime, evening or night time periods. Construction noise emissions will be temporary and do not represent a permanent impact on the community and surrounding environment.

Some noise from construction sites is inevitable, such that the ICNG focuses on minimising construction noise impacts, rather than only on achieving numeric noise levels. These results and noted exceedance of Noise Management Levels identify that best-practice construction noise management and control techniques will be required to reduce noise levels as far as practicable. These will need to be implemented in conjunction with community and stakeholder consultation and notification processes outlined in Section 7.

Construction noise levels are not expected to exceed the highly noise affected noise level of 75 dB(A) at any receiver for any of the construction scenarios modelled.

Vibration levels during construction activities are not expected to result in significant impact at the nearest sensitive receivers.

Construction traffic is not expected to result in significant increases (greater than 2 dB) in traffic noise levels on the proposed access routes to the project.

Construction blasting is anticipated to be required for the removal of rock from the toe of the spillway and the left abutment. Overpressure and vibration levels were predicted for MIC charge masses of 40kg, 100kg and 350kg at noise and vibration sensitive receivers. Results indicated that MIC of 40kg would not be expected to exceed ANZEC Blasting criteria of 115 dB and a peak particle velocity of 5mm/s at residential receivers.

It is anticipated that a construction noise and vibration management plan will be required to be developed to manage noise emissions during construction of the project. A blast management plan would also be developed to manage construction blasting.

7 Mitigation measures

7.1 Construction noise

Construction noise should be managed by a detailed Construction Noise and Vibration Management Plan (CNVMP) to be prepared by the successful construction contractor prior to commencement of works on site. This would utilise more detailed information in relation to the proposed construction methodology, activities, durations and equipment type and numbers. The CNVMP would consider the following as a minimum:

- Identify nearby residences and other sensitive land uses
- Develop noise management levels consistent with the ICNG
- Assess the potential impact from the proposed construction methods
- Where management levels are exceeded examine feasible and reasonable noise mitigation and develop associated noise monitoring program
- Develop a community engagement protocol for providing affected community appropriate notification for out of hours work (refer community management below)
- Develop an out of hours works protocol for managing noise impacts during these periods
- Develop reactive and proactive strategies for dealing with any noise complaints
- Identify a site contact person to follow up complaints.

The predicted noise levels indicate that the primary contributors to large exceedances are combined noise impacts when all plant are operating concurrently such as concrete batching, dozers and heavy vehicles. The noise management plan should develop measures to schedule these activities appropriately to reduce potential for noise impacts.

Source controls:

- Mitigation of specific noise sources using portable temporary screens, on site structures or other items, where possible
- Maximising the offset distance between noisy plant items and sensitive receivers
- Orienting equipment away from sensitive receivers
- Using noise source controls, such as the use of residential class mufflers, to reduce noise from all plant and equipment including cranes, excavators and trucks
- Using lower powered or reduced size equipment where noise benefits are available, where practical
- Using spotters, “smart” reversing alarms, or broadband reversing alarms in place of traditional beeper reversing alarms
- Operating machinery in a manner which reduces maximum noise level events including shaking excavator bucket, loading trucks
- Turning off machinery when not in use
- Specific controls for concrete trucks and site trucks including scheduling activities to avoid numerous concrete trucks operating on site simultaneously.

Administration controls:

- Limiting work to standard construction hours where possible
- Minimise the number of noisy plant operating at once and schedule high noise generating activities to the middle of the day away from more sensitive early morning and late afternoon periods
- Selecting plant and equipment based on noise emission levels
- Using alternative construction methods to minimise noise levels
- Site awareness training / environmental inductions that include a section on noise mitigation techniques / measures to be implemented throughout the proposal when on site and accessing the site
- Ensuring plant and equipment is well maintained and not generating excessive noise
- Avoid dropping materials and tools or dragging materials across hard surfaces.

Community management:

- Notifying receivers potentially affected by the works. This should be completed at least five days prior to works starting
- Keeping the community informed in relation to noise intensive activities in the immediate area
- Providing consultation where prolonged or consecutive periods of construction works are planned
- Noise monitoring at the nearest receivers for comparison against the noise management levels.

7.2 Construction vibration

Where activities using significant sources of vibration (i.e hydraulic hammers and vibratory rollers) occur within close proximity to structures and identified receivers, potential impacts are likely to be increased. In this case, the following mitigation measures are recommended for consideration:

- Substitution of methods of high vibration/impact emission to lower vibration/impact methods i.e use smaller machine or lower mode
- Preparation and implementation of a CNVMP to identify detailed assessment methods for high risk works, identify affected receivers, complaints handling and consultation protocols
- Undertaking trial measurements to establish the site specific vibration propagation from high risk activities to establish site specific offset distances required
- Alternatives to high vibration source plant and equipment should be used where reasonable and feasible.

Where vibration monitoring is undertaken and criteria exceedances are identified, management measures should be implemented immediately to ensure vibration compliance is achieved.

7.3 Construction traffic

Construction traffic noise management should also be included in the Construction Noise and Vibration Management Plan (CNVMP) to be prepared by the successful construction contractor prior to commencement of works on site. It is anticipated this may include as a minimum:

- Site awareness training / environmental inductions for construction staff that include a section on travelling to site/from the site to minimise traffic noise impacts on the surrounding community.

7.4 Additional mitigation measures/OOHW

Where exceedances are expected to occur, the Construction Noise and Vibration Guideline (Roads and Maritime 2016) provides example recommendations for the implementation of additional mitigation measures. These mitigation measures are presented in *Table 7-1*.

The guideline (RMS 2016) states that these mitigation measures are more applicable to short term construction activities, as these measures may become less effective with increasing durations of works whoever given the intermittent requirement for OOHW works, it is expected that this approach to noise mitigation measures will be appropriate.

Table 7-1: Triggers for Additional Mitigation Measures – Airborne Noise

PERCEPTION	DB(A) ABOVE RBL	DB(A) ABOVE NML	ADDITIONAL MITIGATION MEASURES TYPE [1]	MITIGATION LEVELS [2]
All Hours				
75dBA or greater			N, V, PC, RO	HA
Standard Hours: Mon - Fri (7am – 6pm), Sat (8am – 1pm), Sun/Pub Hol (Nil)				
Noticeable	5 to 10	0	-	NML
Clearly Audible	10 to 20	<10	-	NML
Moderate Intrusive	20 to 30	20 to 30	N/V	NML+10
Highly Intrusive	>30	>20	N/V	NML+20
OOHW Period 1: Mon – Fri (6pm – 10pm), Sat (7am – 8am & 1pm – 10pm), Sun/Pub Hol (8am – 6pm)				
Noticeable	5 to 10	<5	-	NML
Clearly Audible	10 to 20	5 to 15	N, R1, DR	NML+5
Moderate Intrusive	20 to 30	15 to 25	V, N, R1, DR	NML+15
Highly Intrusive	>30	>25	V, IB, N, R1, DR, PC, SN	NML+25
OOHW Period 2: Mon – Fri (10pm – 7am), Sat (10pm – 8am), Sun/Pub Hol (6pm – 7am)				
Noticeable	5 to 10	<5	N	NML
Clearly Audible	10 to 20	5 to 15	V, N, R2, DR	NML+5
Moderate Intrusive	20 to 30	15 to 25	V, IB, N, PC, SN, R2, DR	NML+15
Highly Intrusive	>30	>25	V, IB, N, PC, SN, R2, DR	NML+25

Notes:

1. R1 = Respite Period 1; V = Verification; PC = Phone calls; IB = Individual briefings; SN = Specific notifications; N = Notification; R2 = Respite Period 2;
2. DR = Duration Respite; Perception = relates to level above RBL
3. NML = Noise Management Level (see Appendix B)
4. HA = Highly Affected (> 75 dB(A) - applies to residences only), Source: Construction Noise and Vibration Guideline (Roads and Maritime 2016).

7.5 Blast management

A Blast Management Plan (BMP) should be developed for the Project. Further, trial blasts should be designed and monitored to confirm site specific conditions and validate local propagation characteristics (develop site specific "site laws") and confirm the MICs and blast designs to meet vibration and overpressure limits.

The blast management plan would include:

- Limiting criteria
- Identified blast sensitive receivers (community and onsite structures)
- Performance indicators
- Monitoring protocols
- Roles and responsibilities
- Blasting controls
- Protocols for community consultation, incidents and complaints
- Contingency protocols
- Reporting requirements.

The blast management plan would consider the following with regard to overpressure and ground vibration:

- Consideration of blast timing:
  – Restriction of blasting to within standard construction hours and between the hours of 9.00am to 5.00pm Monday to Saturday with no blasting outside of these times, including on Sundays and Public Holidays.
- Blast monitoring and inspection including:
  – Blast monitoring at key sensitive sites.
  – Trial blasts to assist in the development of "site laws" based on monitoring data.
  – Regular condition surveys and blast monitoring at heritage structures and modification of blast design to meet blast limits at these sites where required.

8 References

Australian and New Zealand Environment Council (ANZEC) (1990), *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration.*

Australian Standard AS 2187:2006, *Explosives – Storage and Use – Part 2: Use of Explosives.*

Australian Standard, 1997, *AS1055.1 Acoustics – Description environmental noise – Part 3: Acquisition of data pertinent to land use.*

Australian Standard AS 1055:1997, *Acoustics – Description and measurement of environmental noise.*

British Standard, 1993, *BS 7385-2 Evaluation and measurement for vibration in buildings. Guide to damage levels from groundborne vibration.*

British Standard 5228 *Code of practice for noise and vibration control on construction and open sites.*

CONCAWE Report No. 4/81, Manning C.J., 1981, *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities.*

German Standard DIN 4150-3(1999), *Structural Vibration – Part 3 Effects of vibration on structures.*

International Standards Organisation (1996), ISO 9613-2:1996, *Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation.*

NSW Department of Environment Climate Change (2009), *Interim Construction Noise Guidelines* (ICNG).

Roads and Maritime Services (2016) *Construction Noise and Vibration Guideline*

SMEC (2018) *Warragamba Dam Raising Transport and Traffic*

Transport for New South Wales (2017) *Construction Noise Strategy*

Appendix A Project Figures

Figure A-1: Existing dam and features

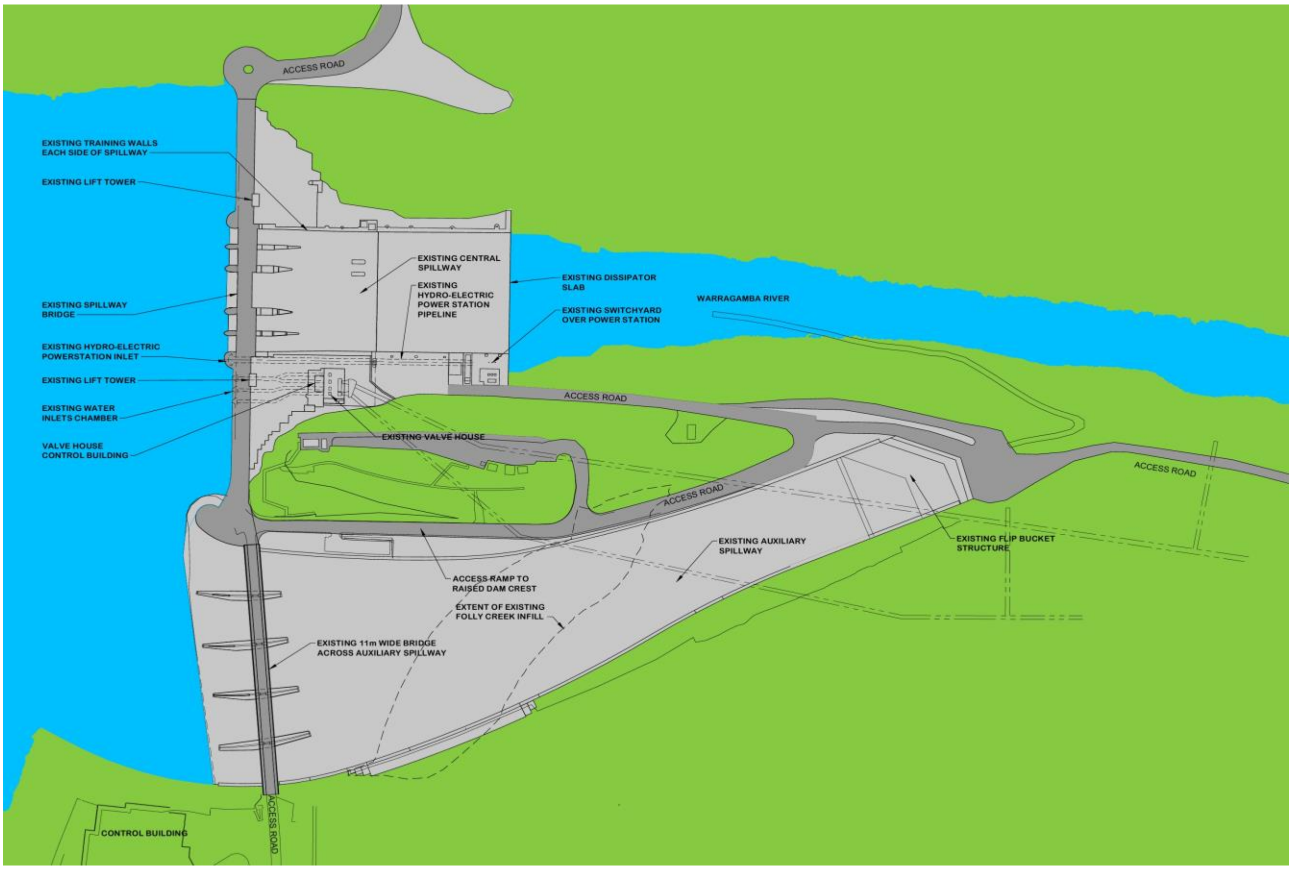


Figure A-2: Modified dam from the Project works

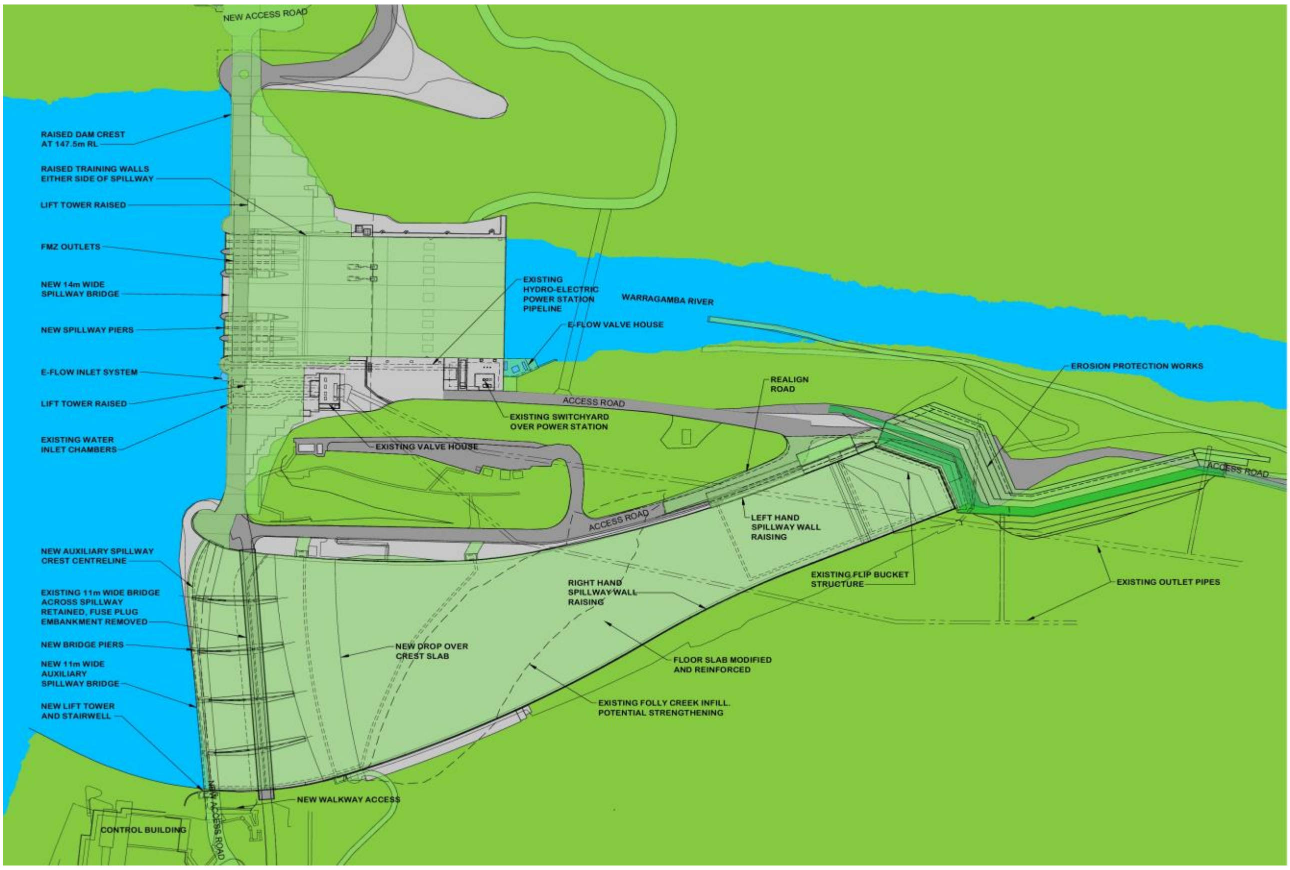


Figure A-3: Abutment works

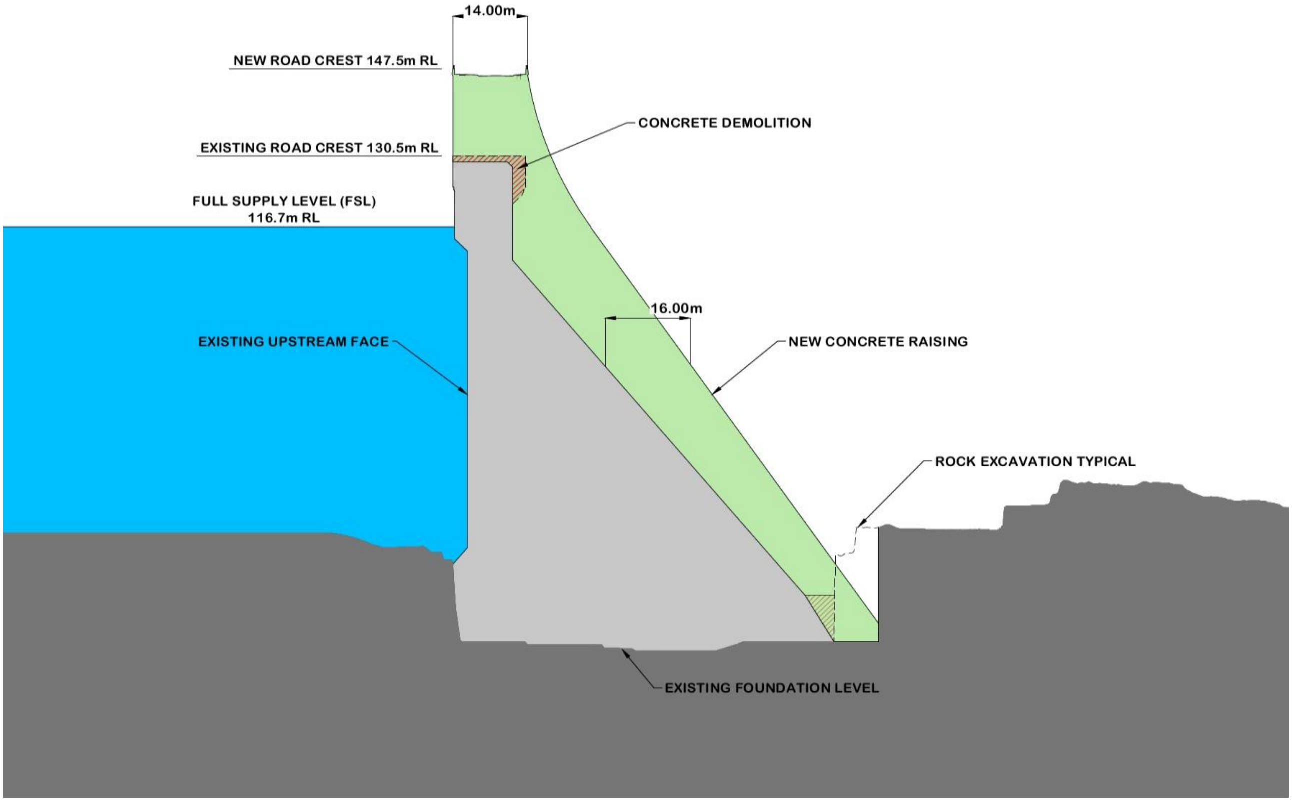


Figure A-4: Cross section of central spillway works.

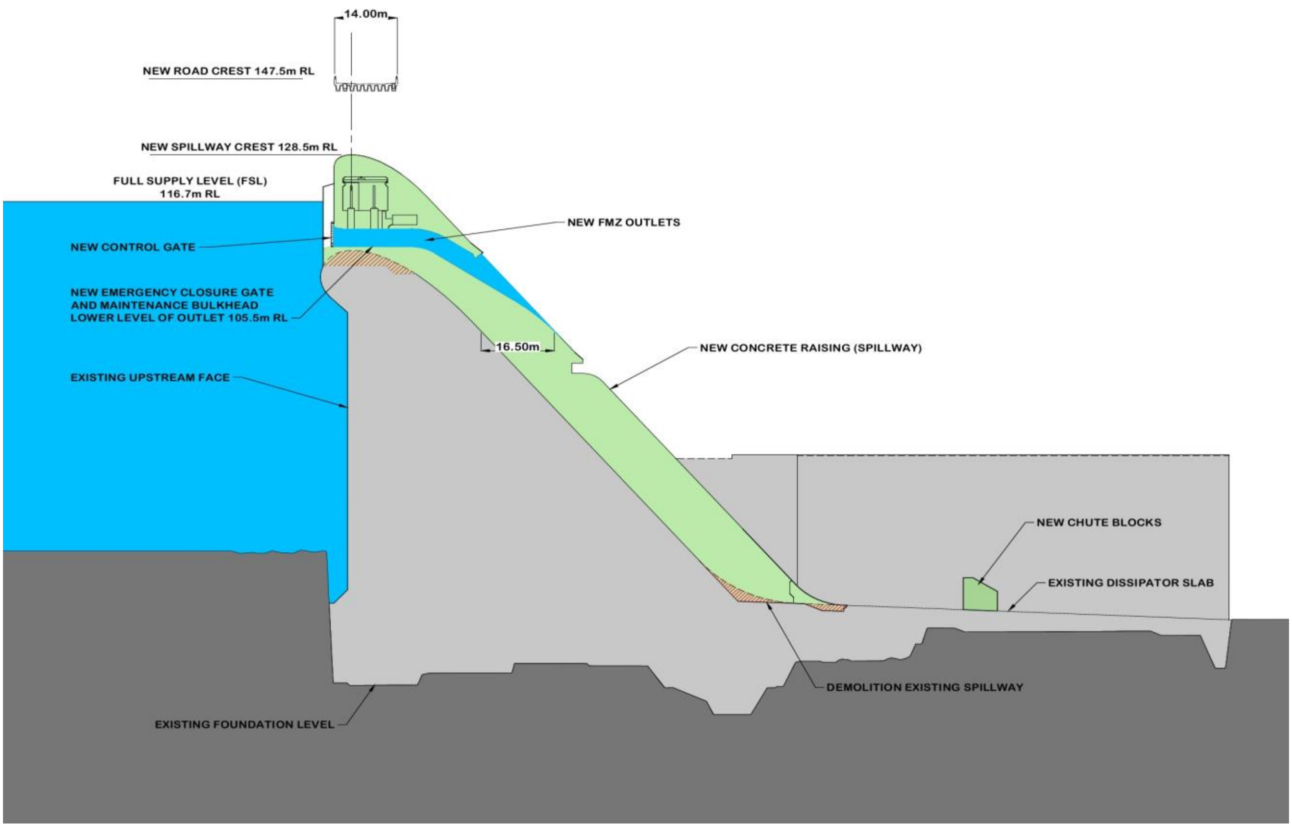


Figure A-5: Modified auxiliary spillway crest

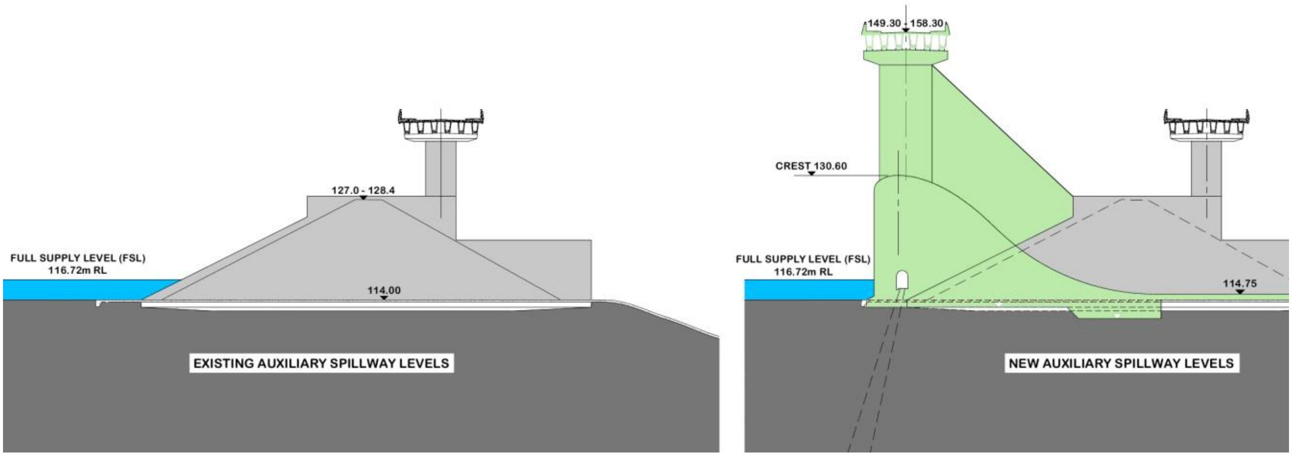


Figure A-6: Southern access route to site

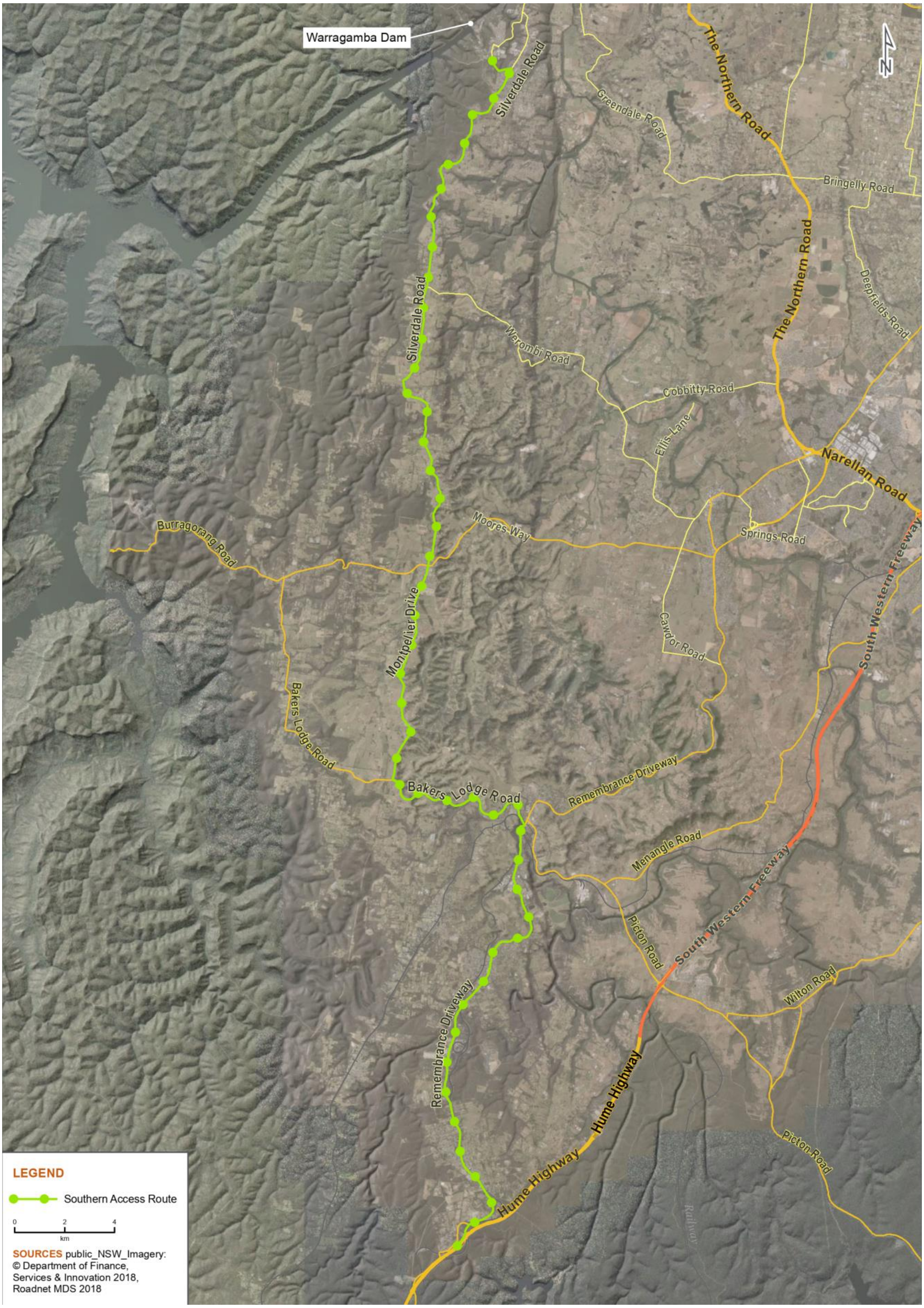
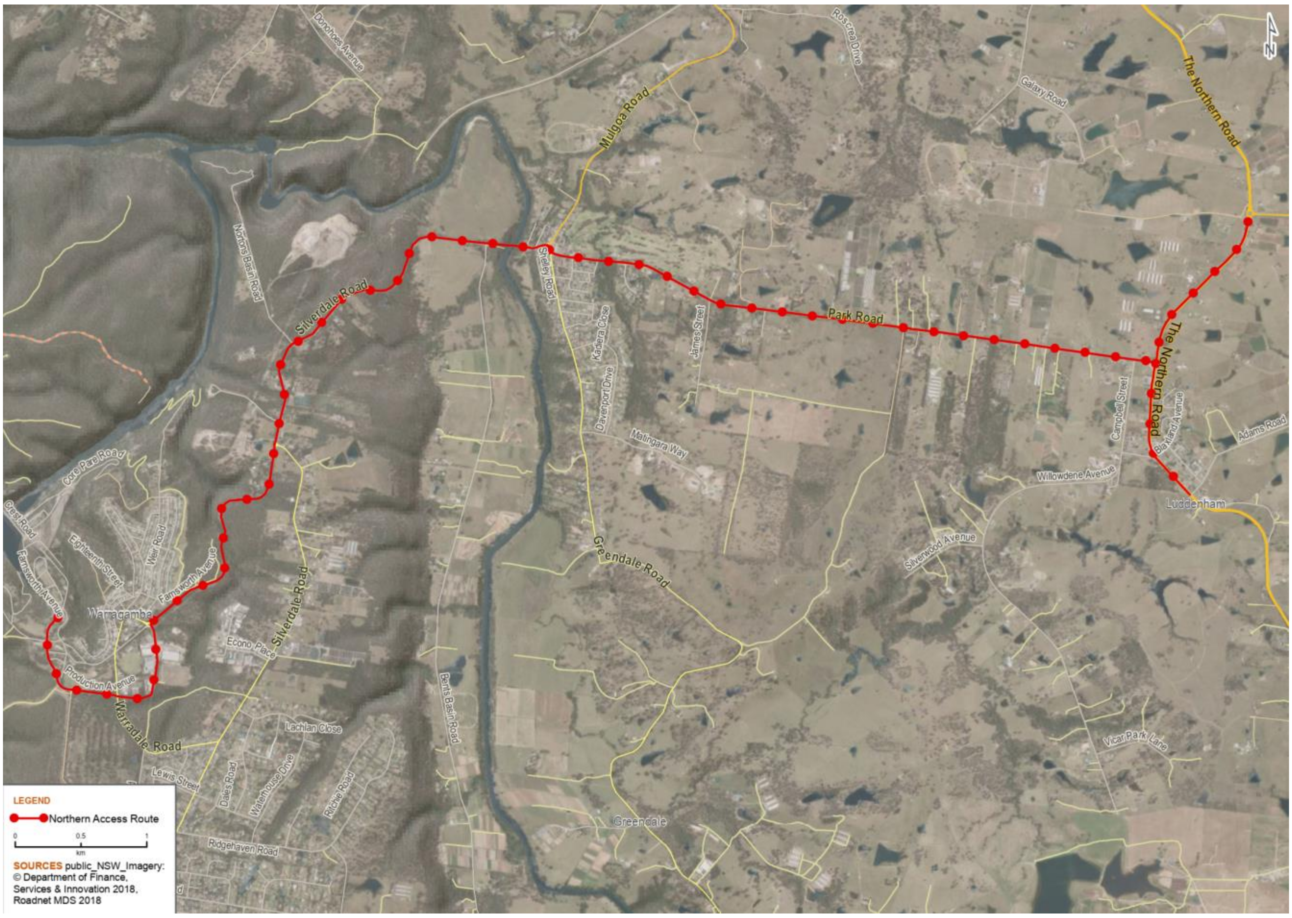
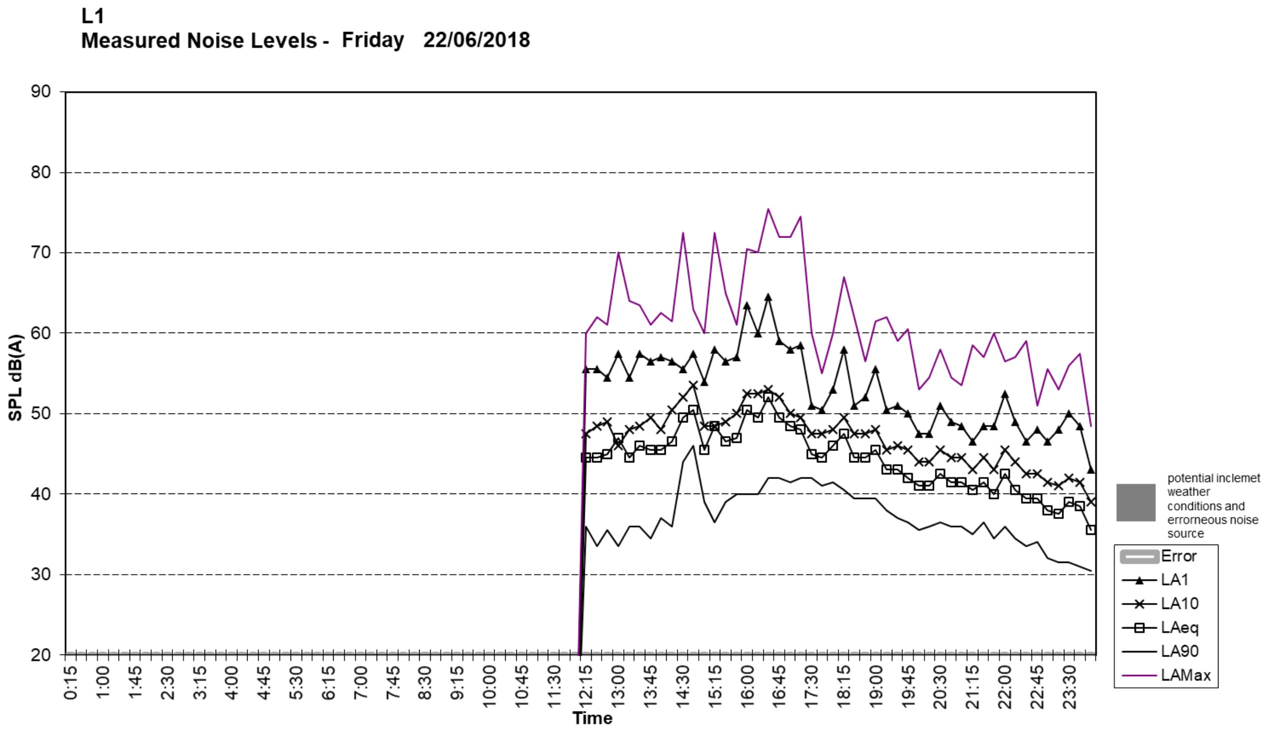


Figure A-7: Northern access route to site

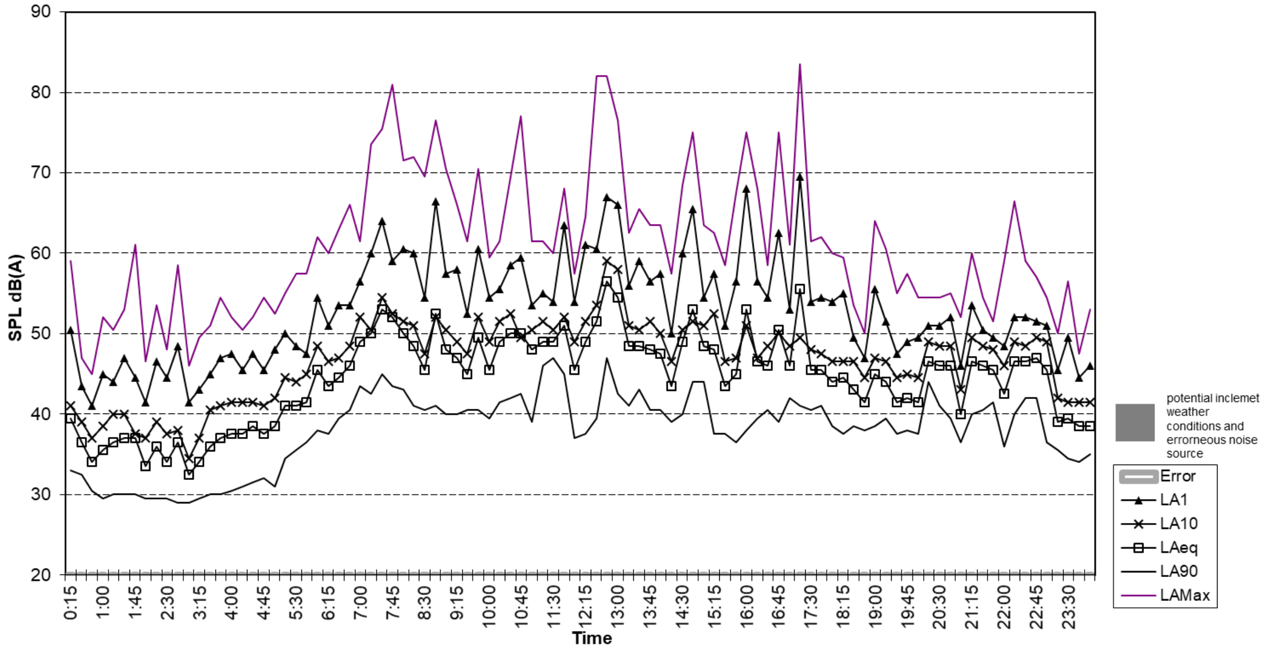


Appendix B Noise Monitoring Results

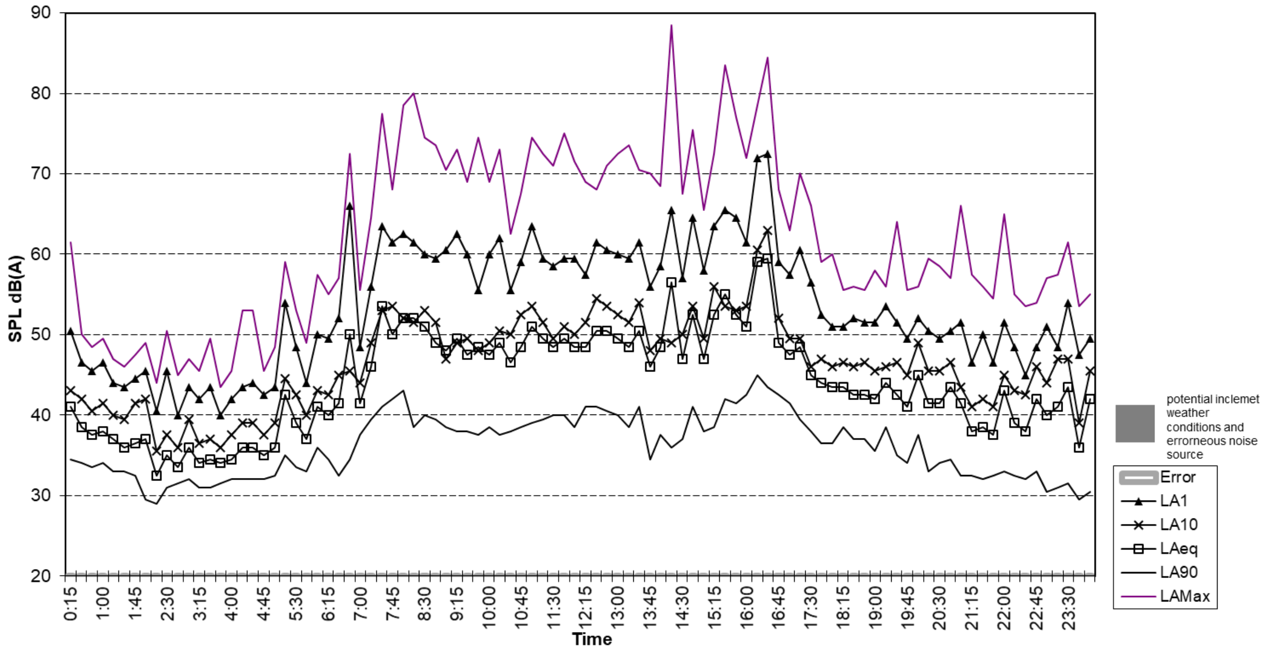
L1 – 11 Green Street

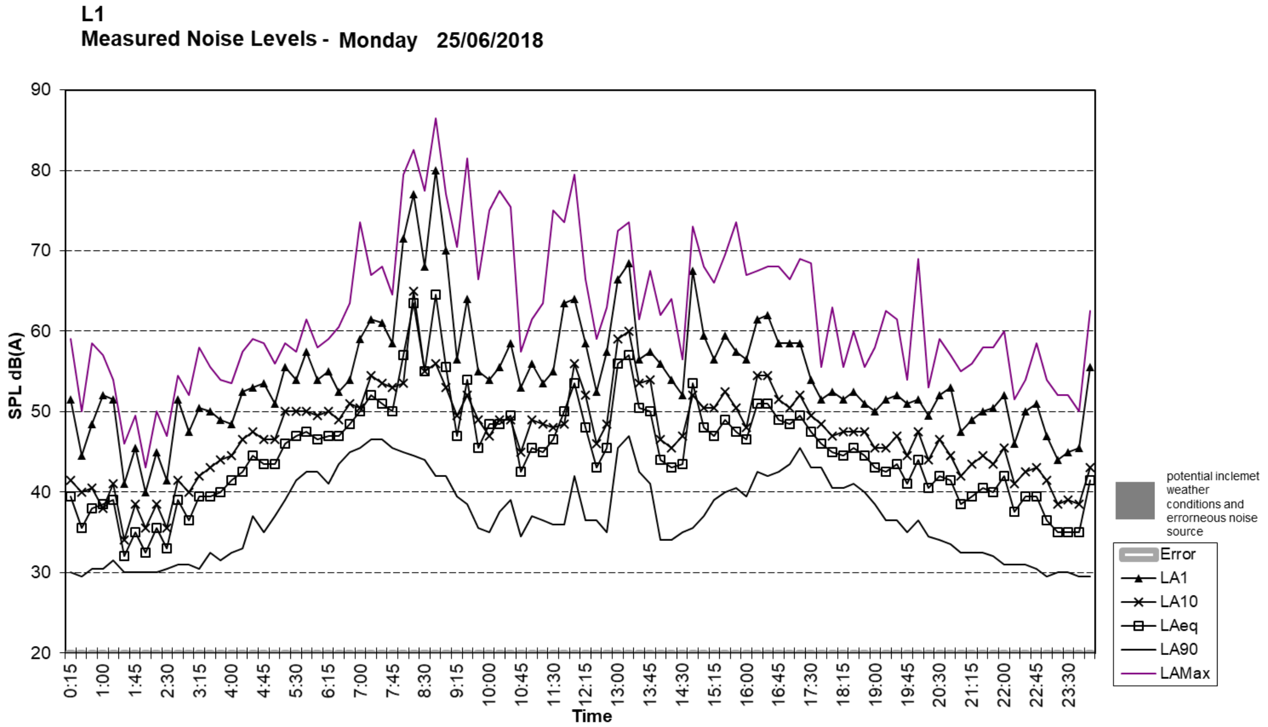


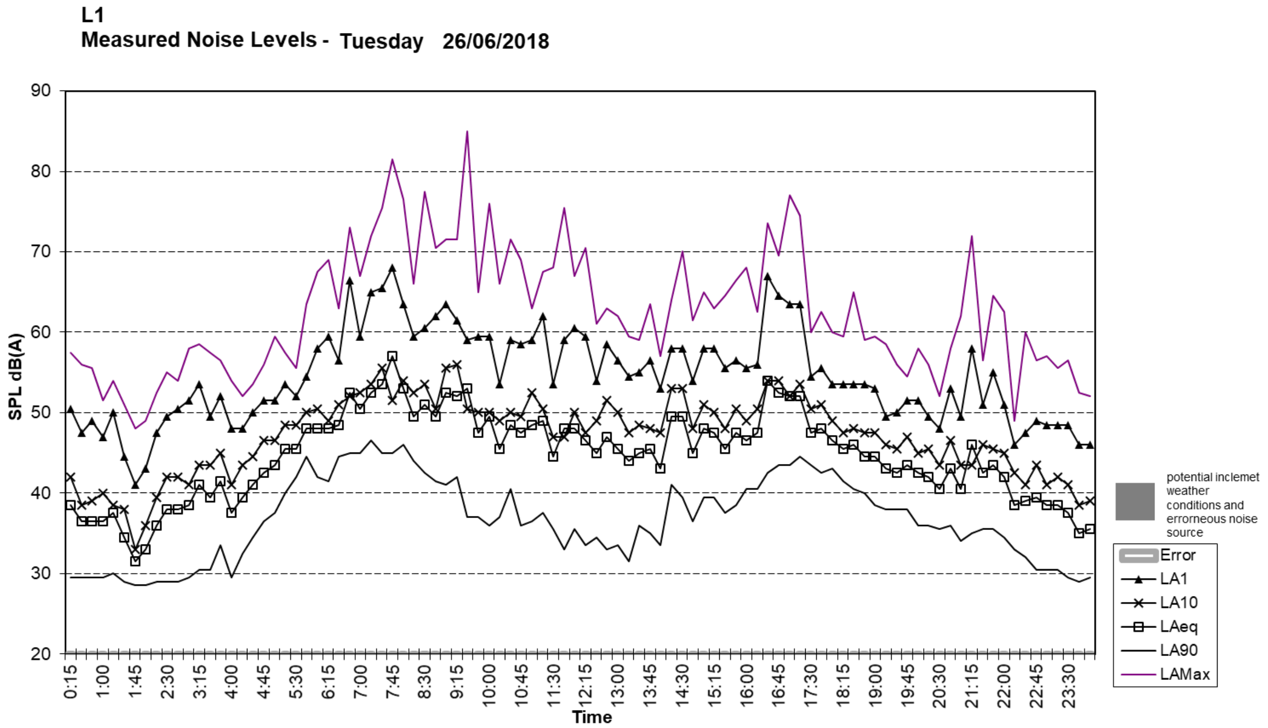
L1
Measured Noise Levels - Saturday 23/06/2018



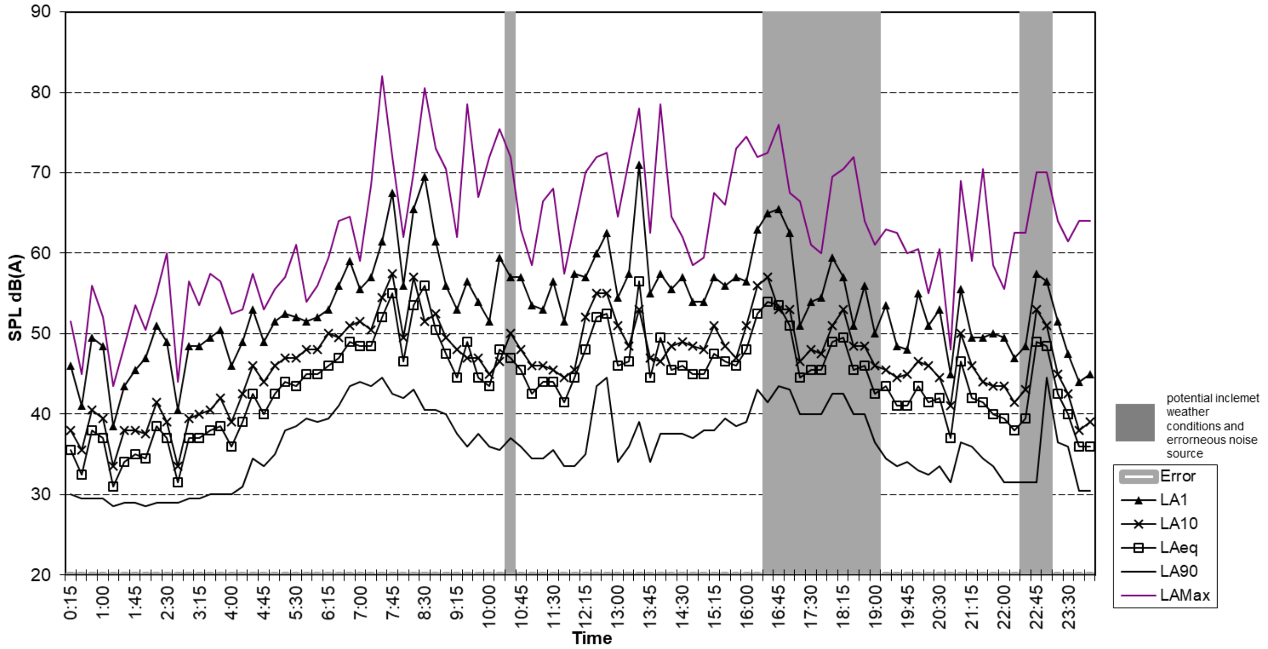
L1
Measured Noise Levels - Sunday 24/06/2018



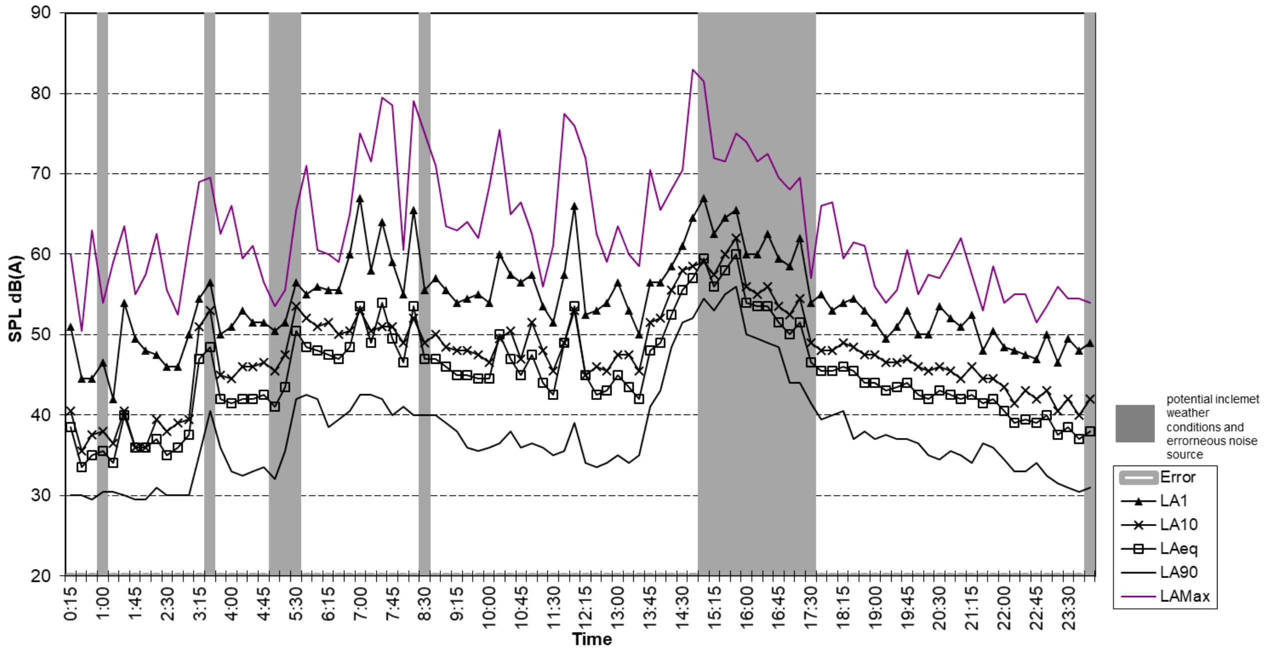

L1
Measured Noise Levels - Monday 25/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

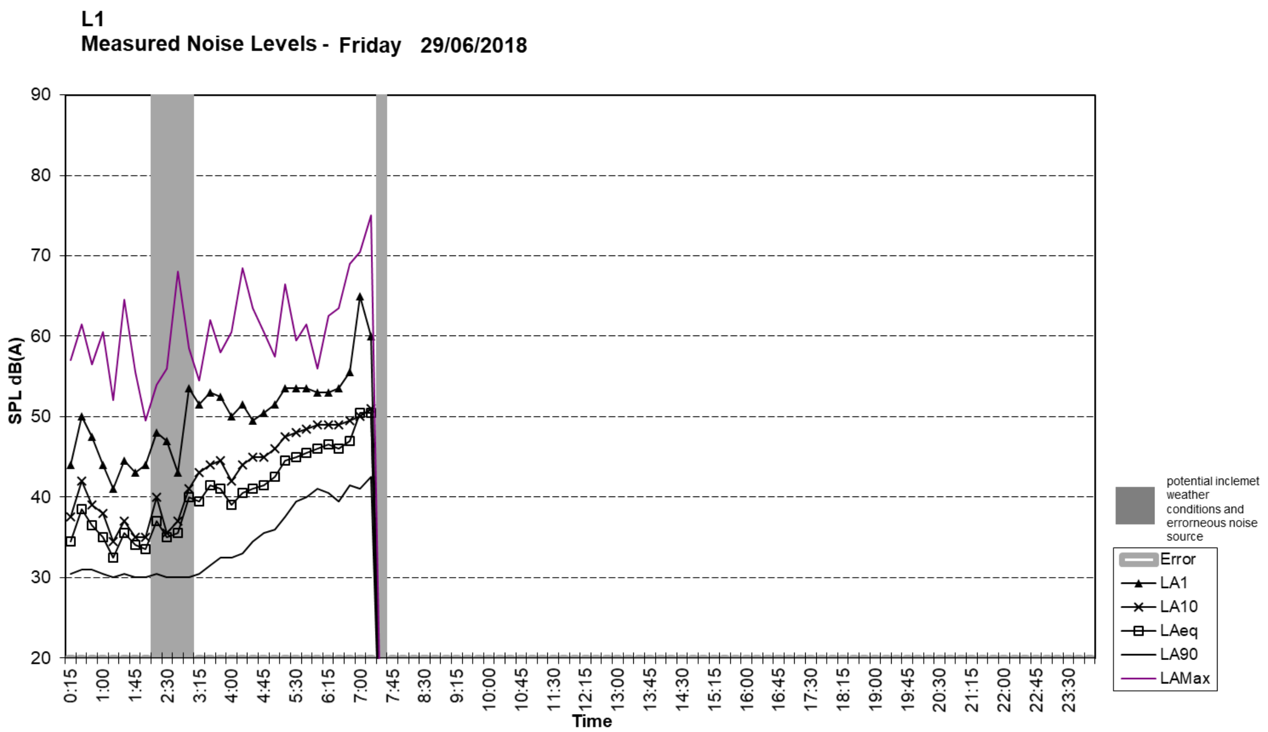

L1
Measured Noise Levels - Tuesday 26/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

L1
Measured Noise Levels - Wednesday 27/06/2018

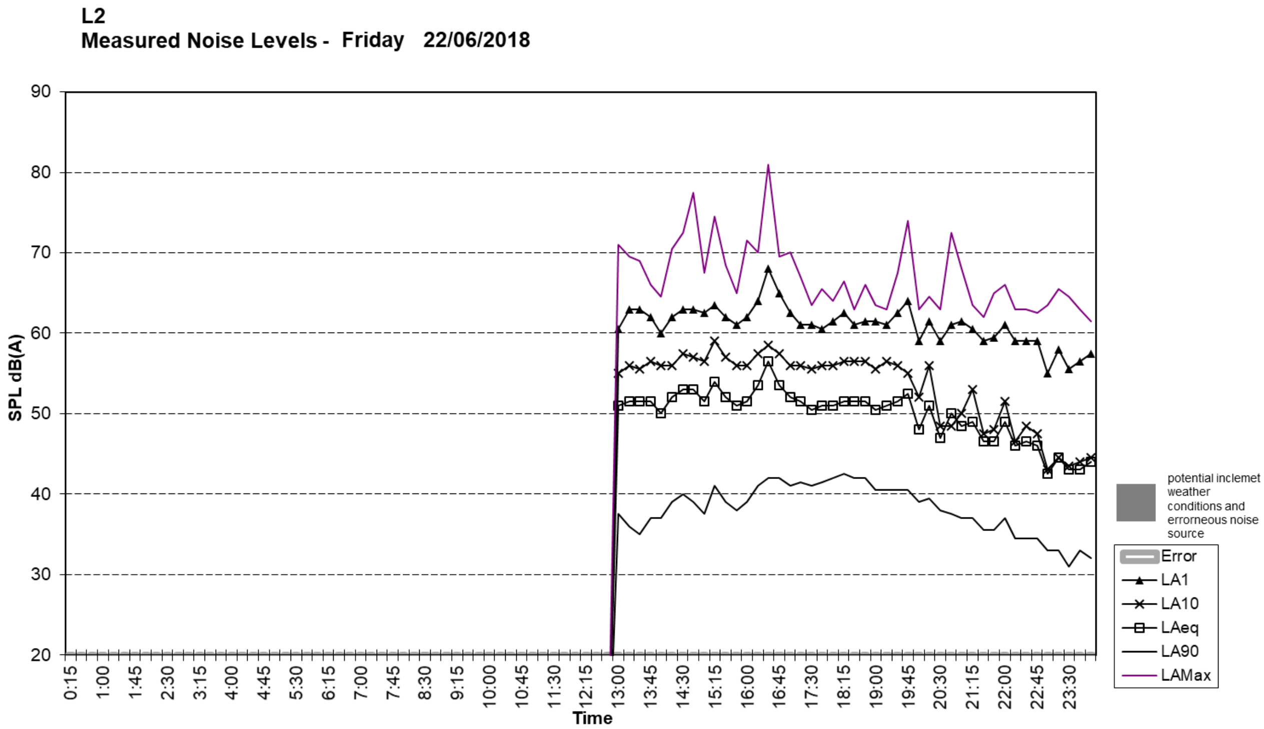


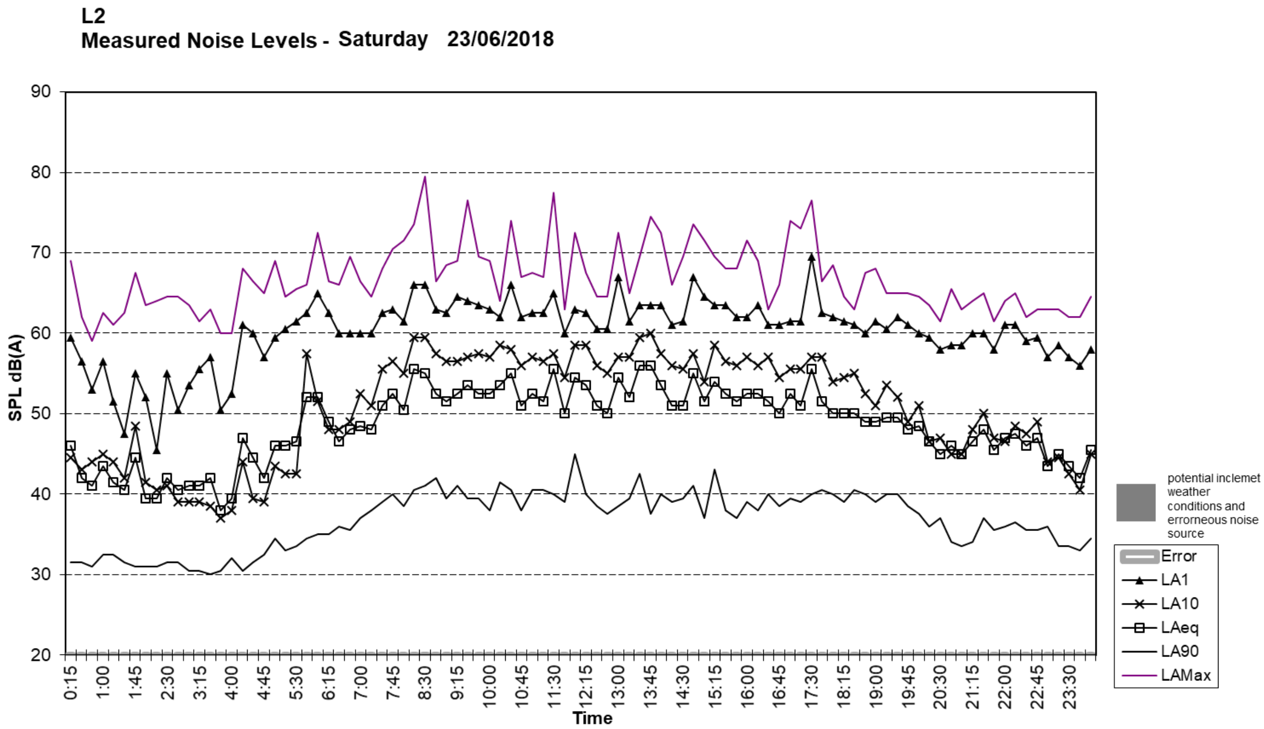
L1
Measured Noise Levels - Thursday 28/06/2018



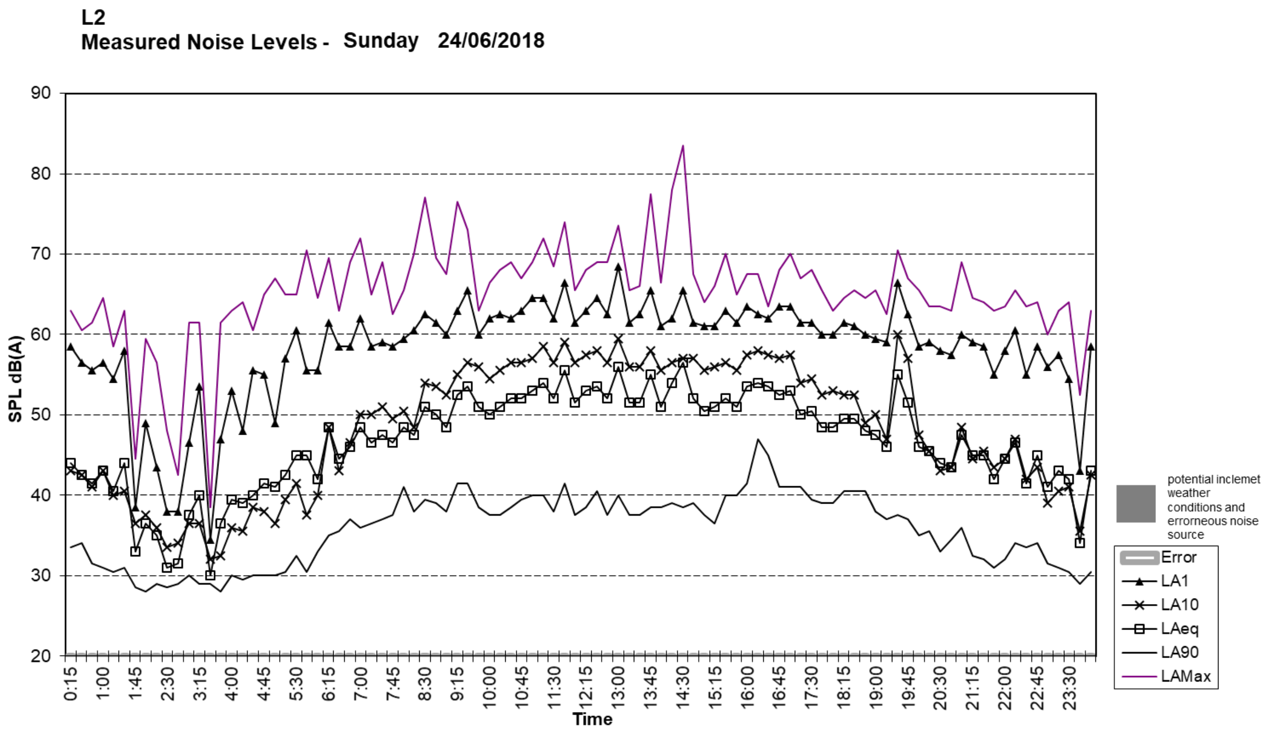

L1
Measured Noise Levels - Friday 29/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax


L2


L2
Measured Noise Levels - Friday 22/06/2018
SPL dB(A)
90
80
70
60
50
40
30
20
0:15
1:00
1:45
2:30
3:15
4:00
4:45
5:30
6:15
7:00
7:45
8:30
9:15
10:00
10:45
11:30
12:15
13:00
13:45
14:30
15:15
16:00
16:45
17:30
18:15
19:00
19:45
20:30
21:15
22:00
22:45
23:30
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

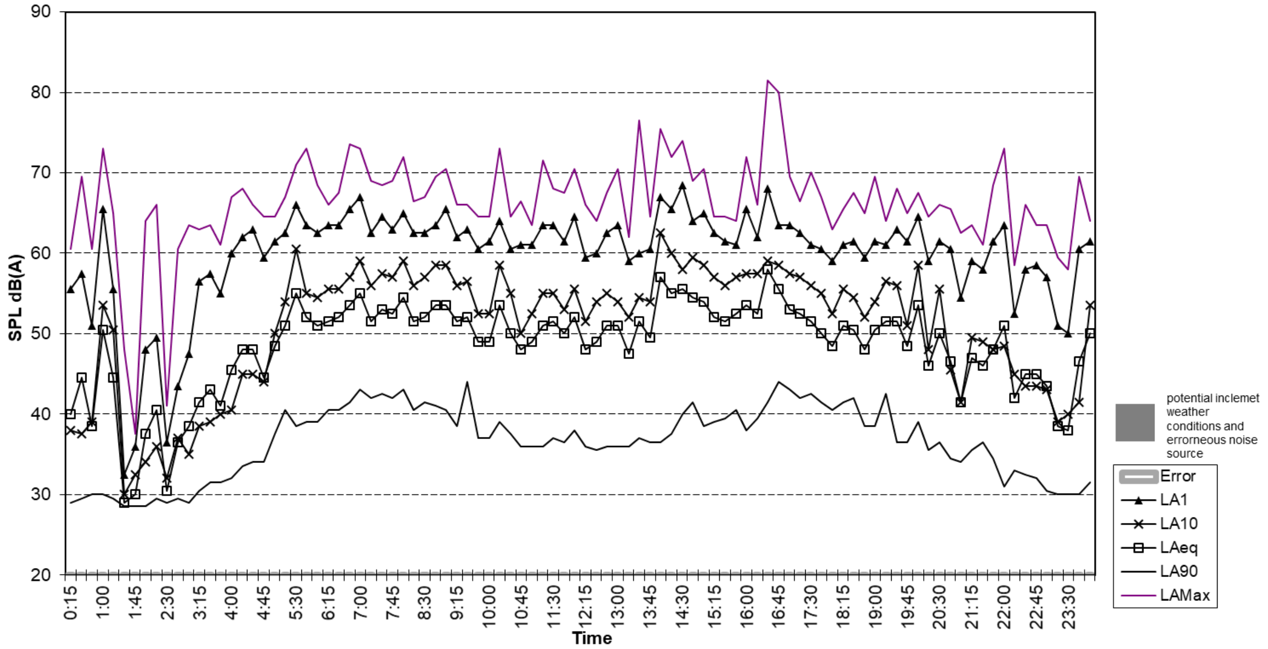


L2
Measured Noise Levels - Saturday 23/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

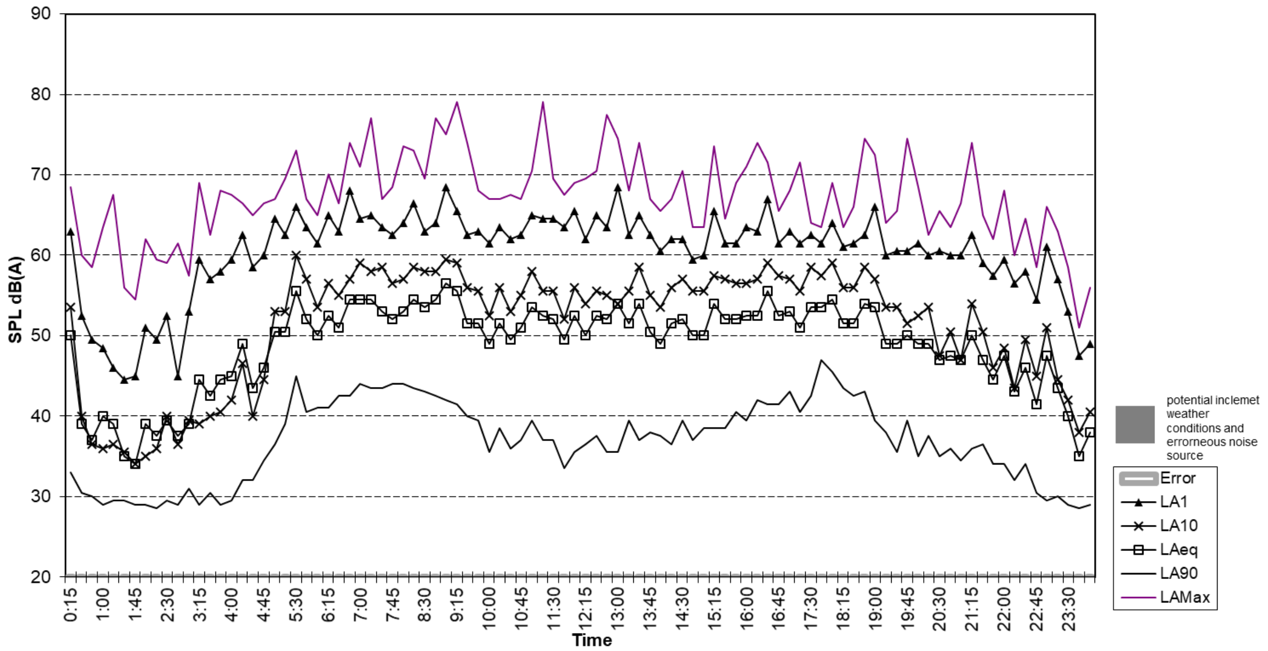


L2
Measured Noise Levels - Sunday 24/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

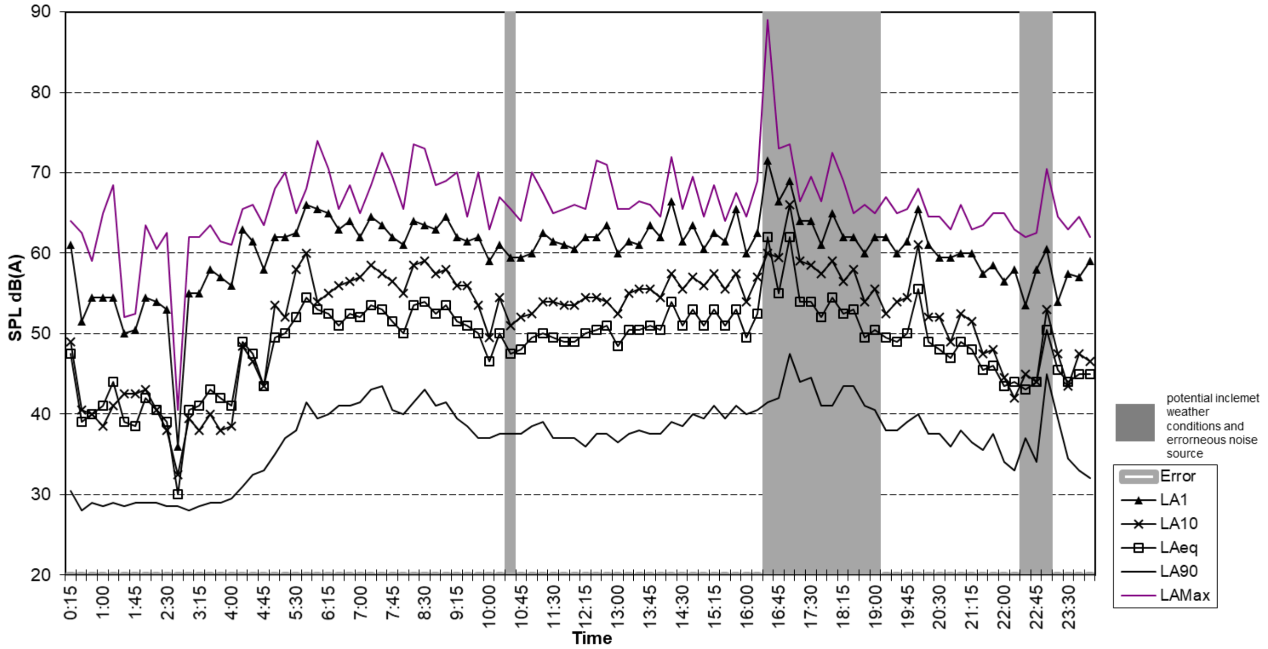
L2
Measured Noise Levels - Monday 25/06/2018



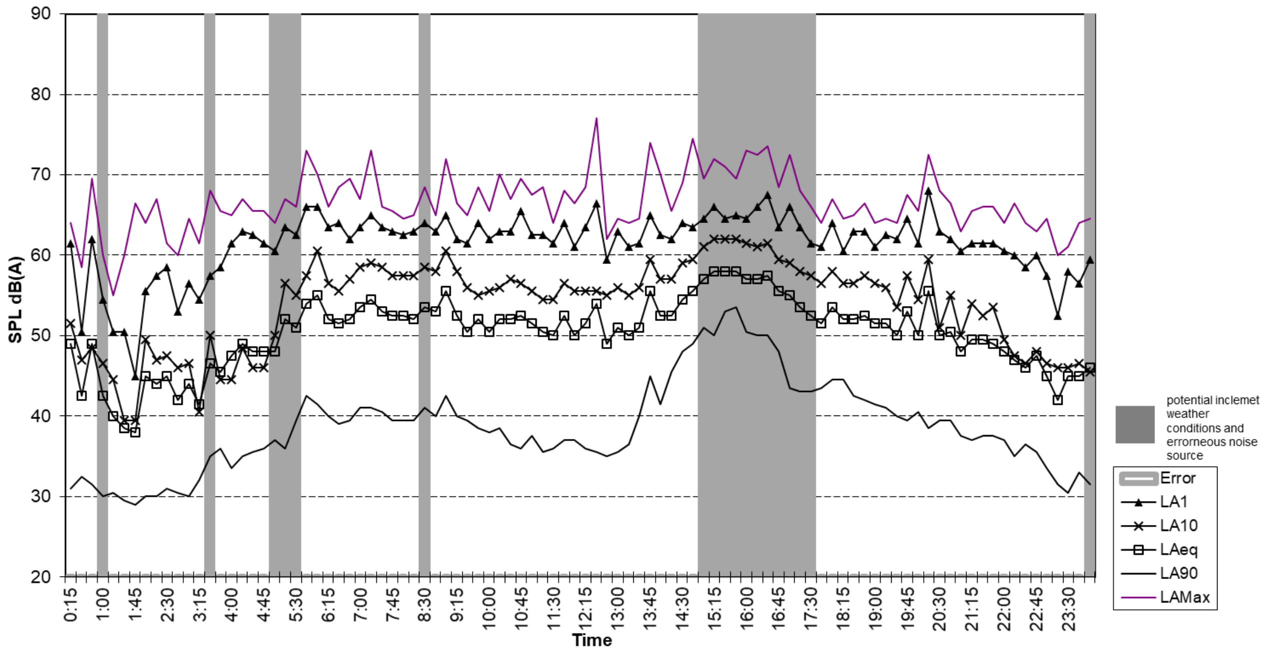
L2
Measured Noise Levels - Tuesday 26/06/2018

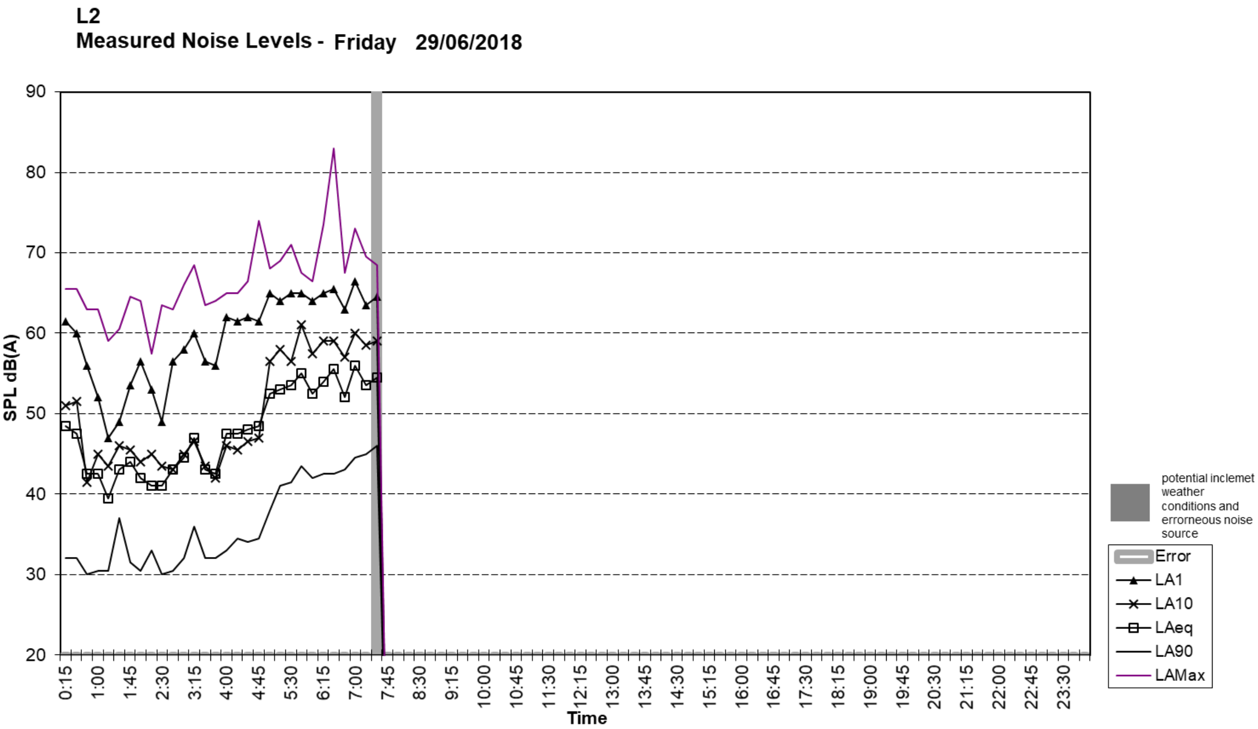


L2
Measured Noise Levels - Wednesday 27/06/2018



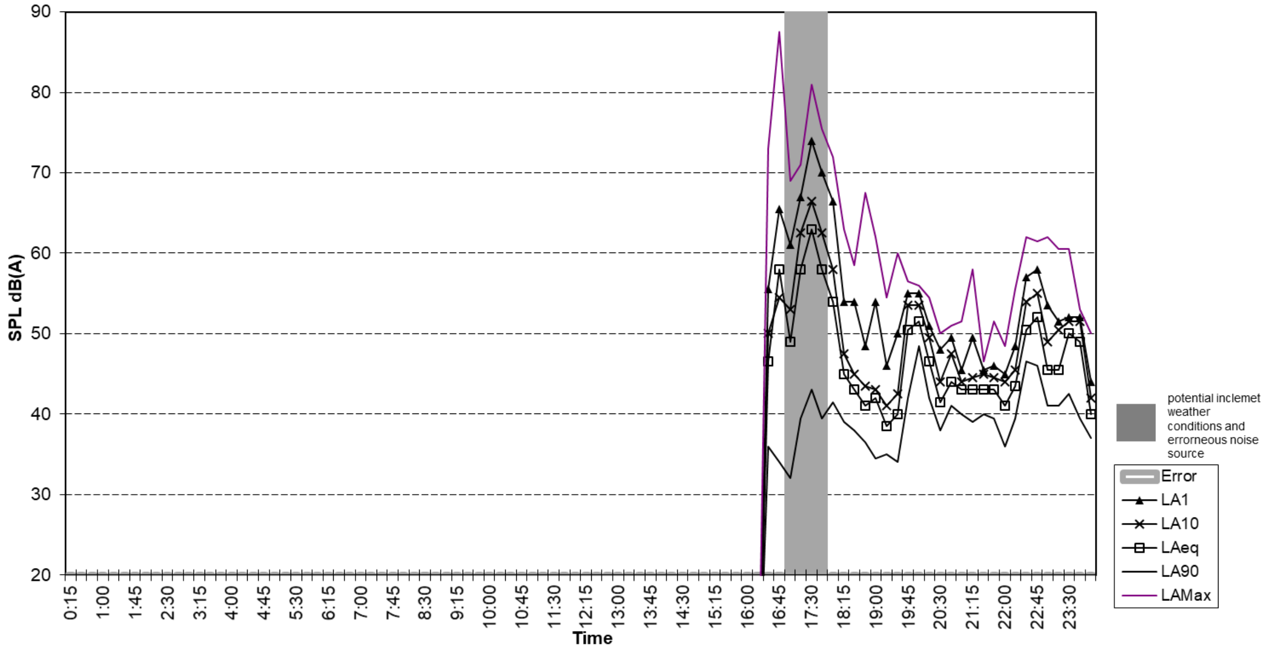
L2
Measured Noise Levels - Thursday 28/06/2018



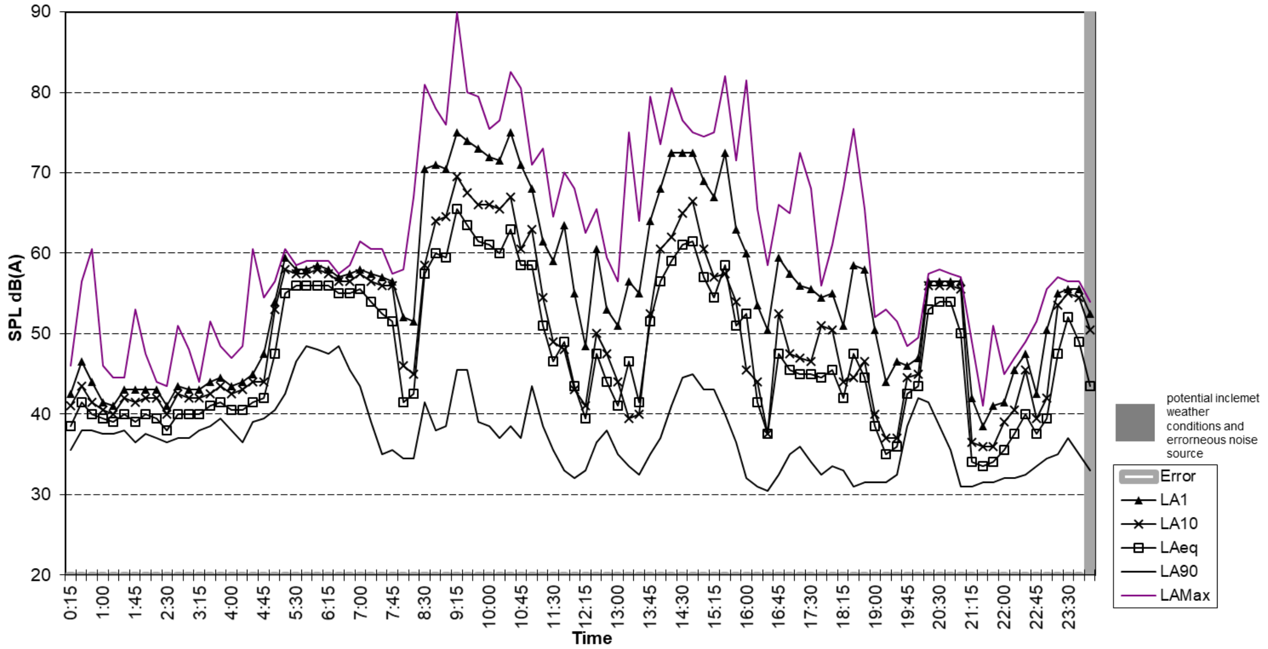

L2
Measured Noise Levels - Friday 29/06/2018
90
80
70
60
50
40
30
20
SPL dB(A)
0:15
1:00
1:45
2:30
3:15
4:00
4:45
5:30
6:15
7:00
7:45
8:30
9:15
10:00
10:45
11:30
12:15
13:00
13:45
14:30
15:15
16:00
16:45
17:30
18:15
19:00
19:45
20:30
21:15
22:00
22:45
23:30
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

L3 – 37 Thirteenth Street

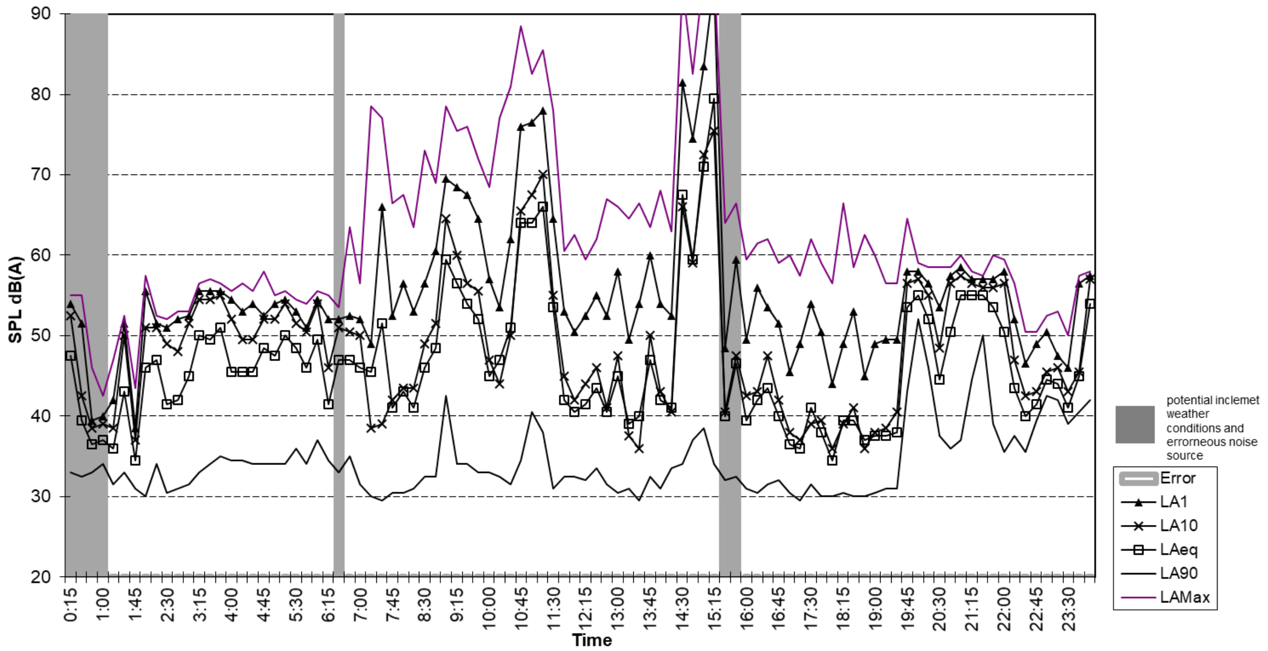
L3
Measured Noise Levels - Monday 12/03/2018



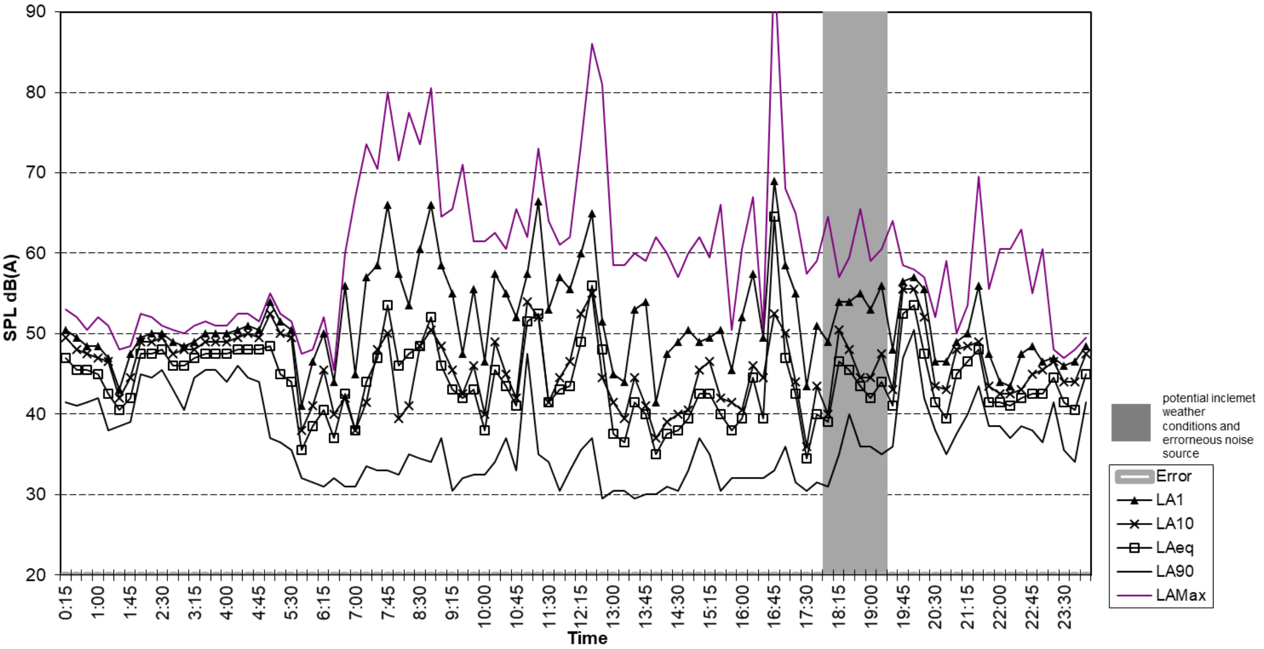
L3
Measured Noise Levels - Tuesday 13/03/2018



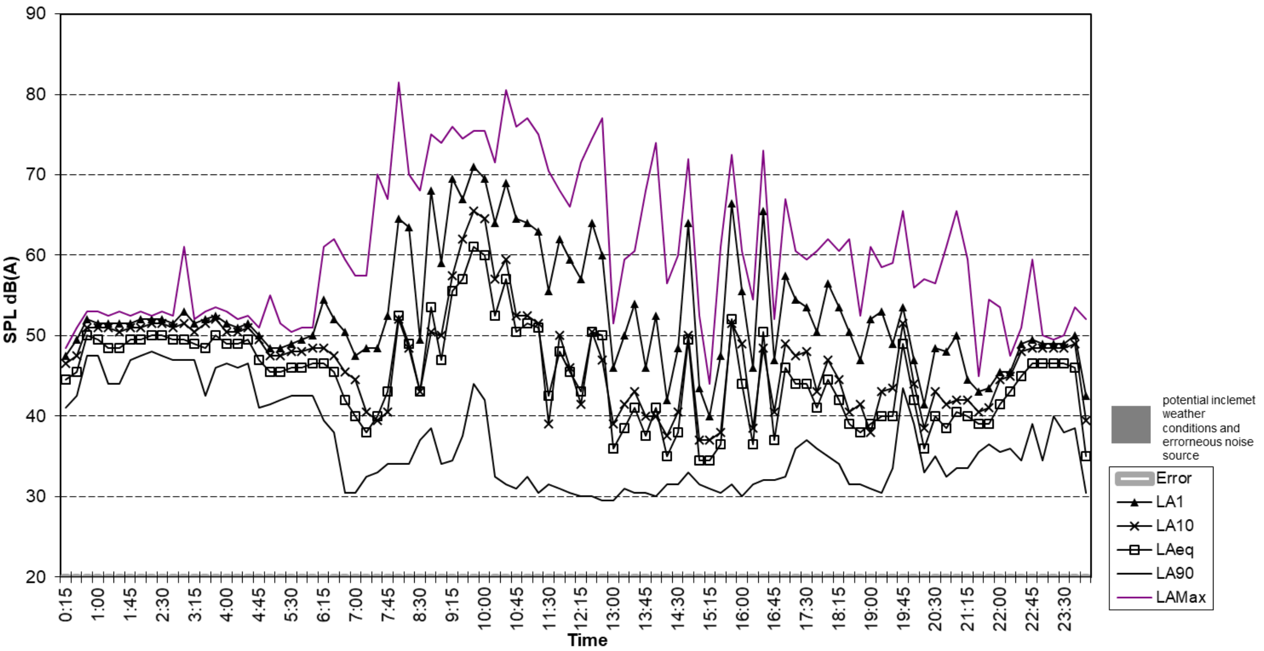
L3
Measured Noise Levels - Wednesday 14/03/2018



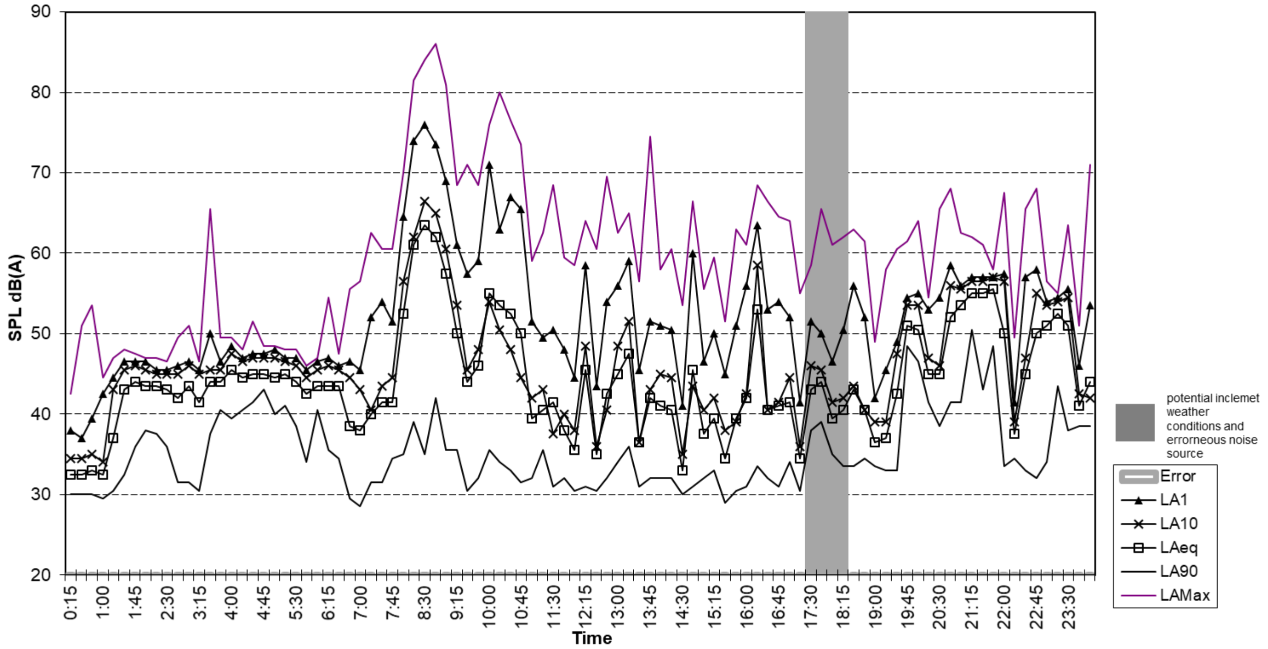
L3
Measured Noise Levels - Thursday 15/03/2018



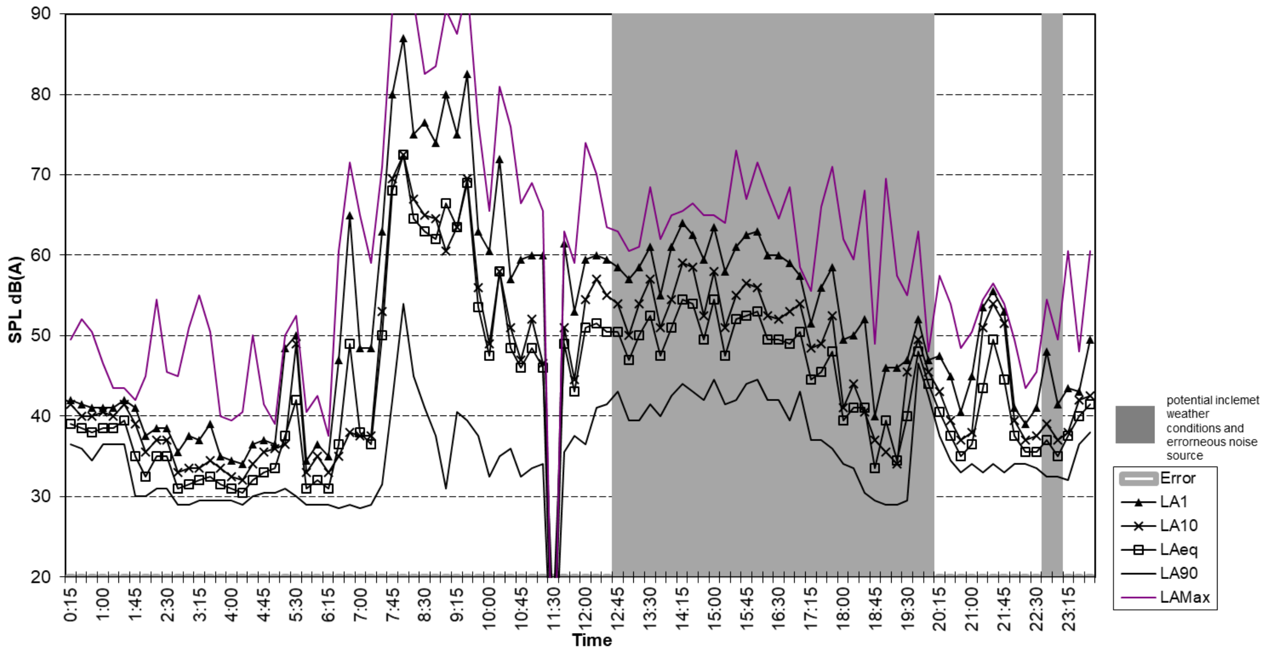
L3
Measured Noise Levels - Friday 16/03/2018

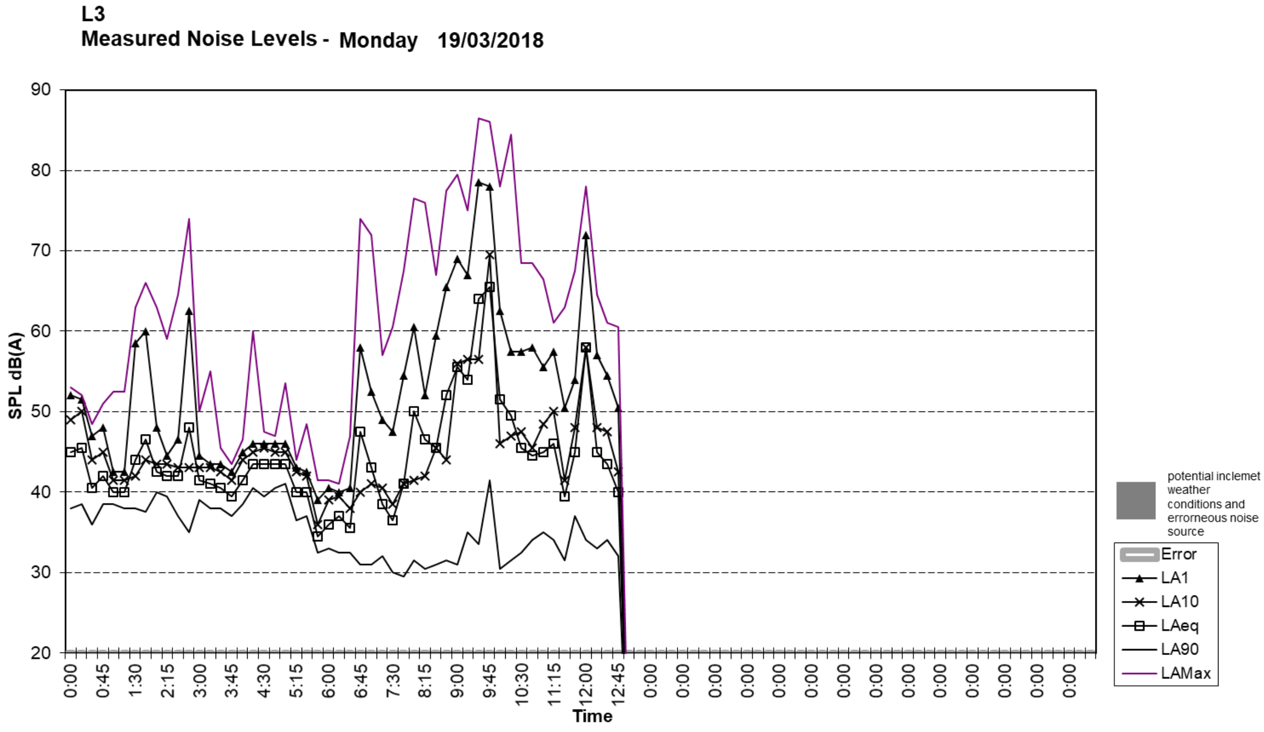


L3
Measured Noise Levels - Saturday 17/03/2018

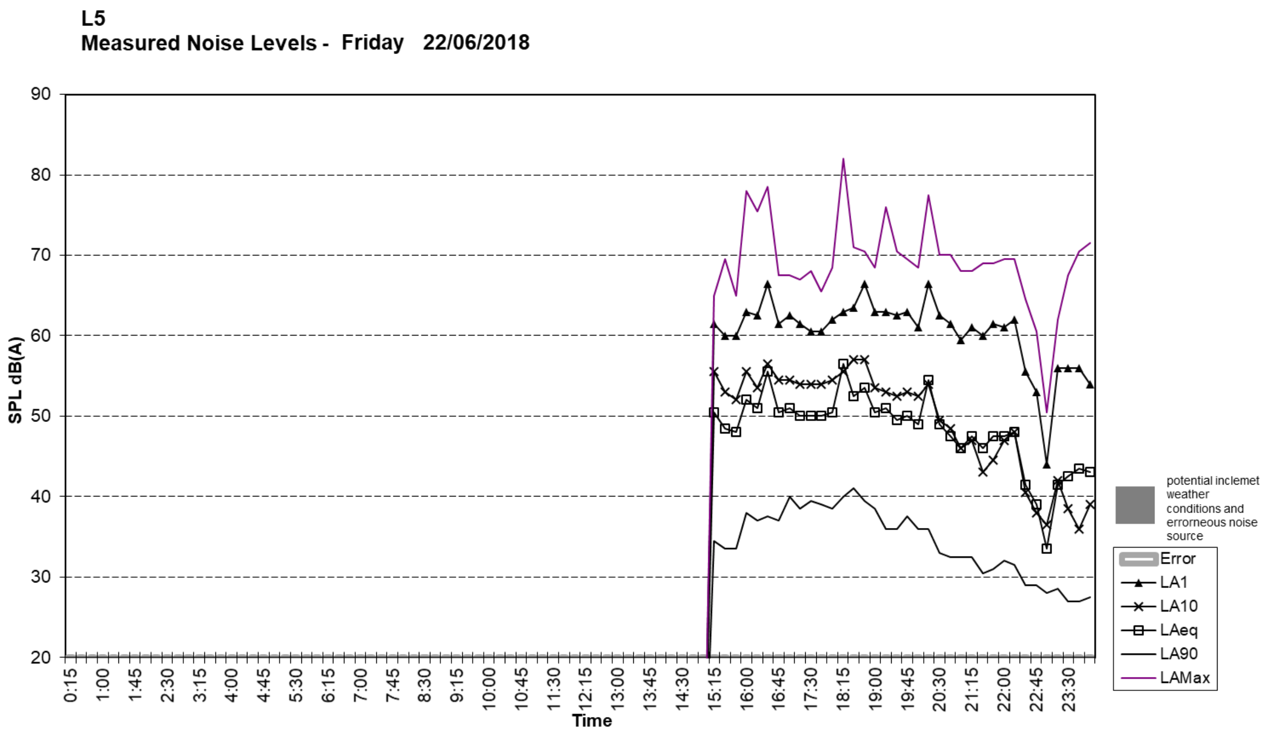


L3
Measured Noise Levels - Sunday 18/03/2018

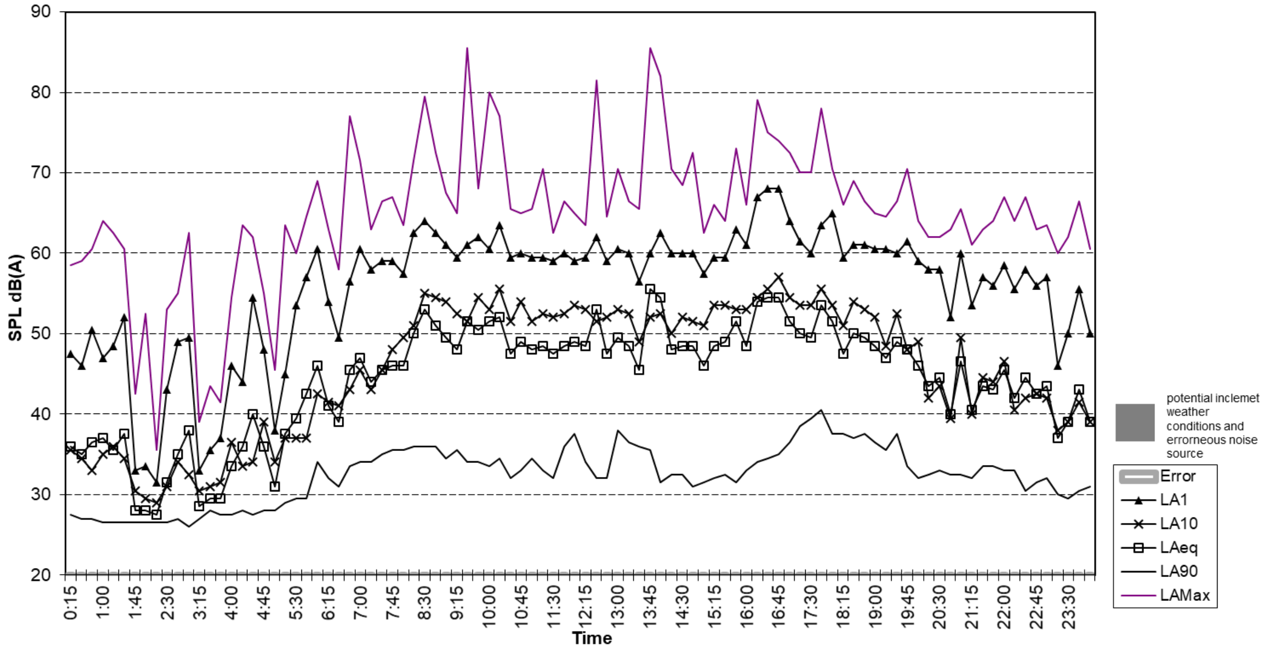



L3
Measured Noise Levels - Monday 19/03/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

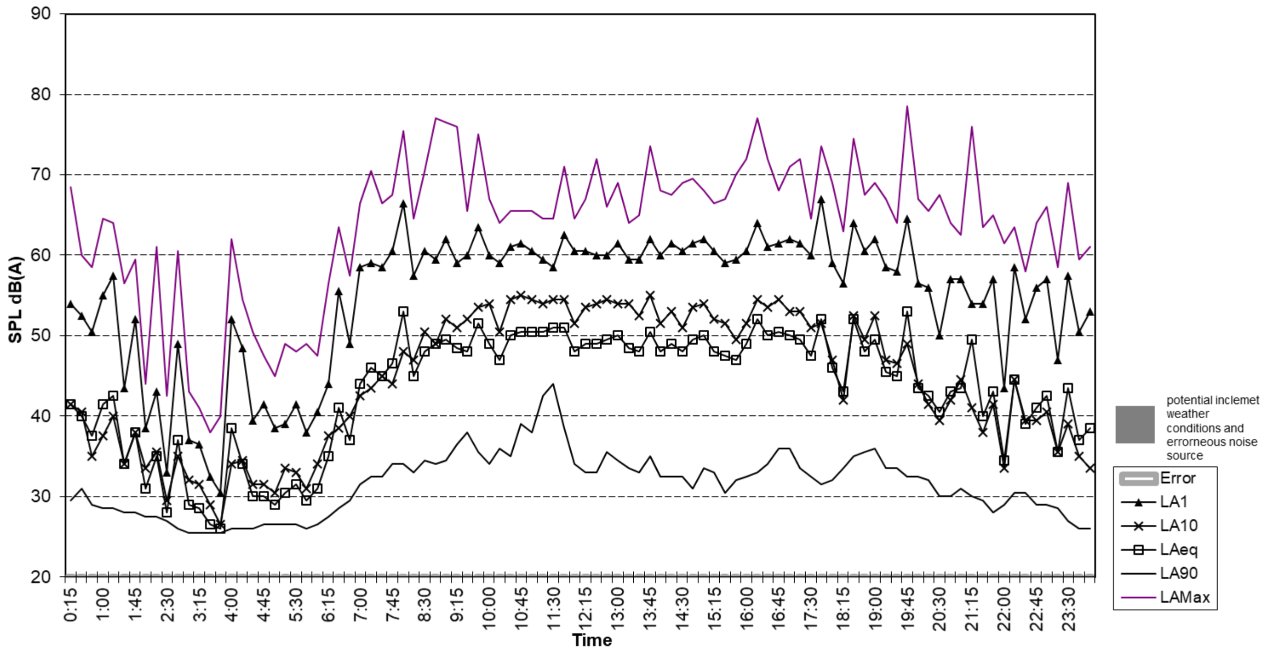
L5 – 15 Warradale Road

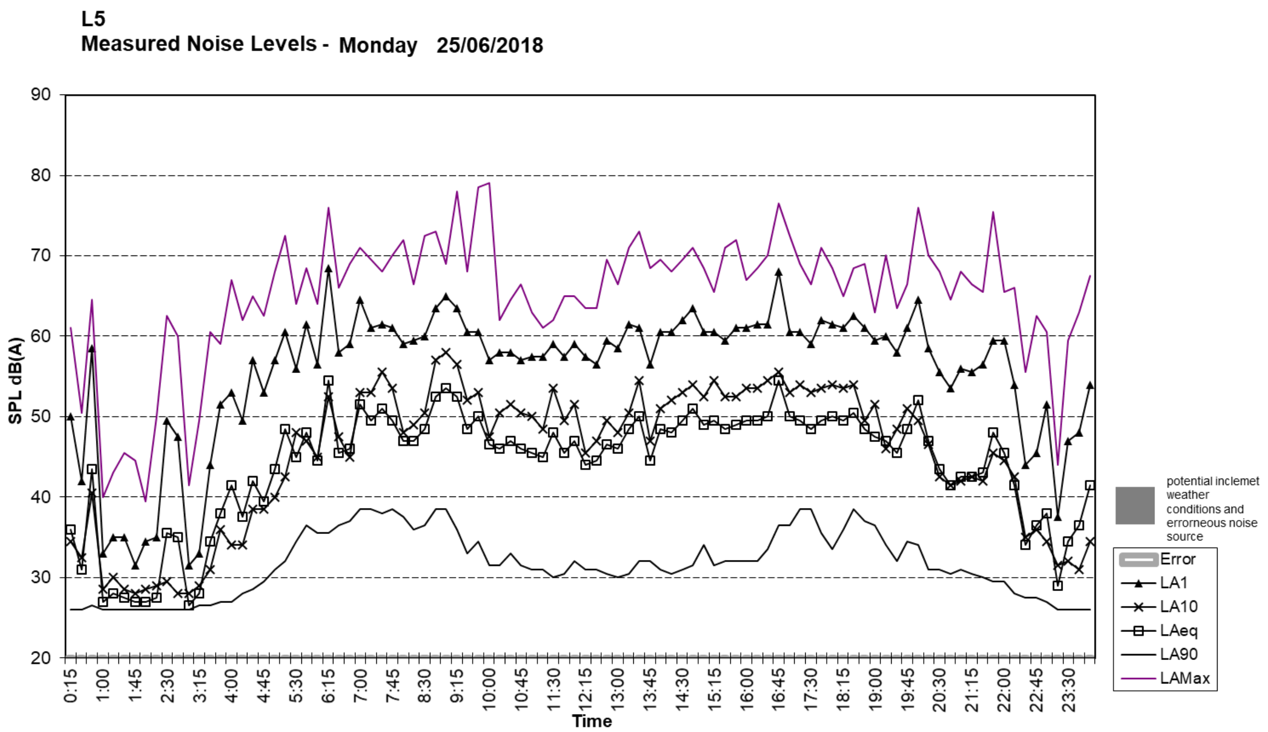


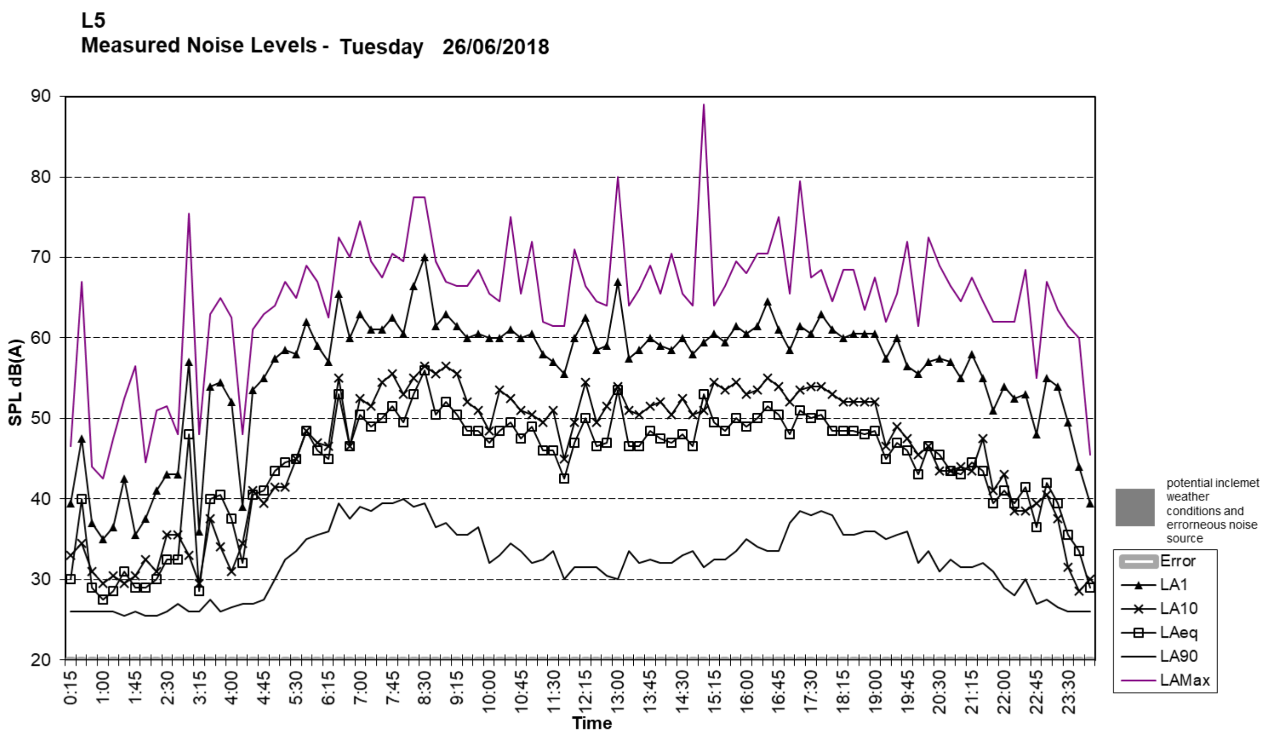
L5
Measured Noise Levels - Saturday 23/06/2018



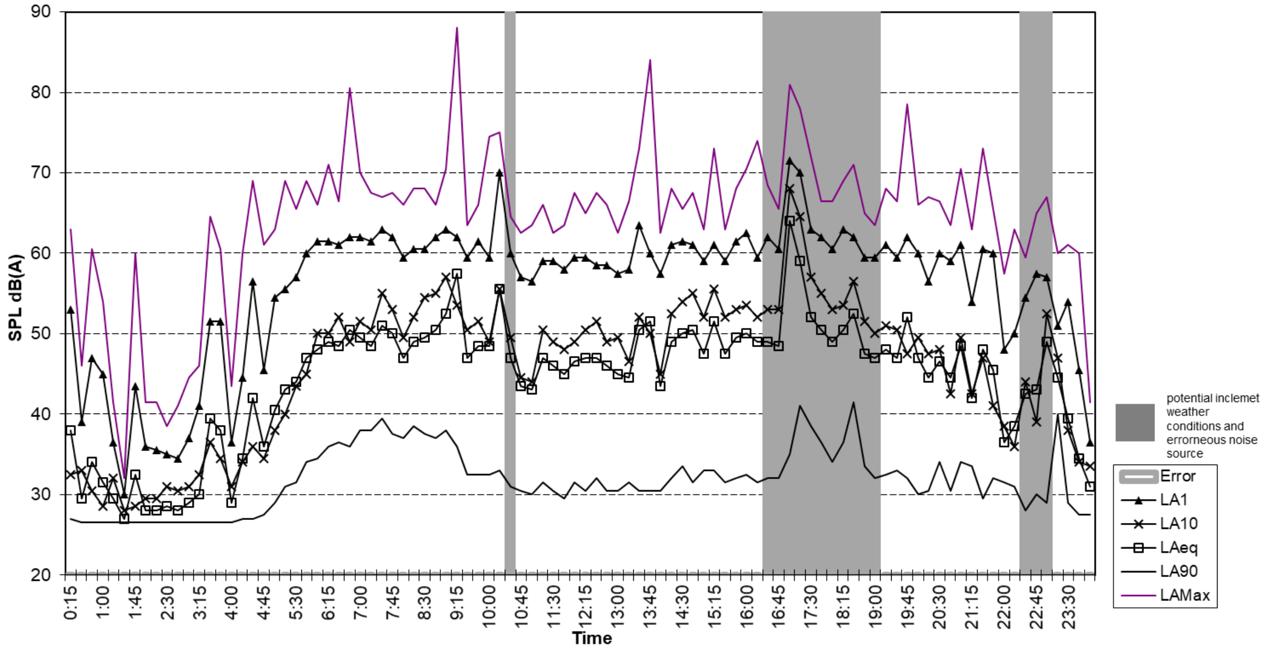
L5
Measured Noise Levels - Sunday 24/06/2018



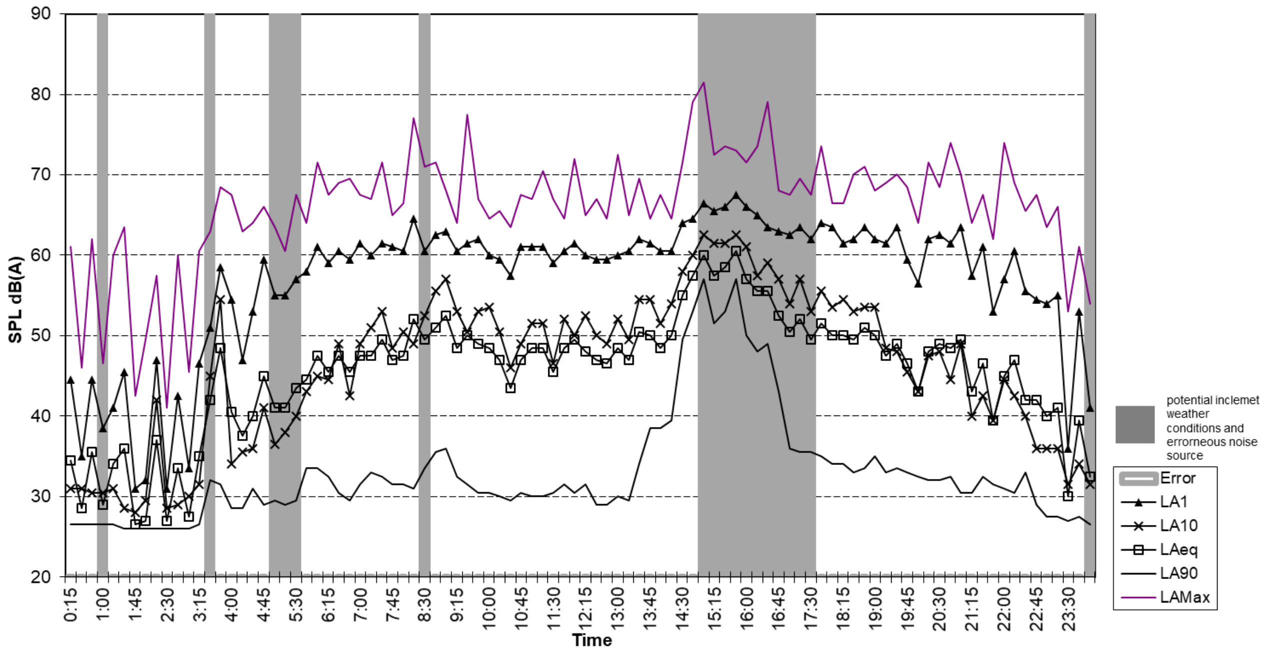

L5
Measured Noise Levels - Monday 25/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax


L5
Measured Noise Levels - Tuesday 26/06/2018
SPL dB(A)
Time
potential inclemet weather conditions and erroneous noise source
Error
LA1
LA10
LAeq
LA90
LAMax

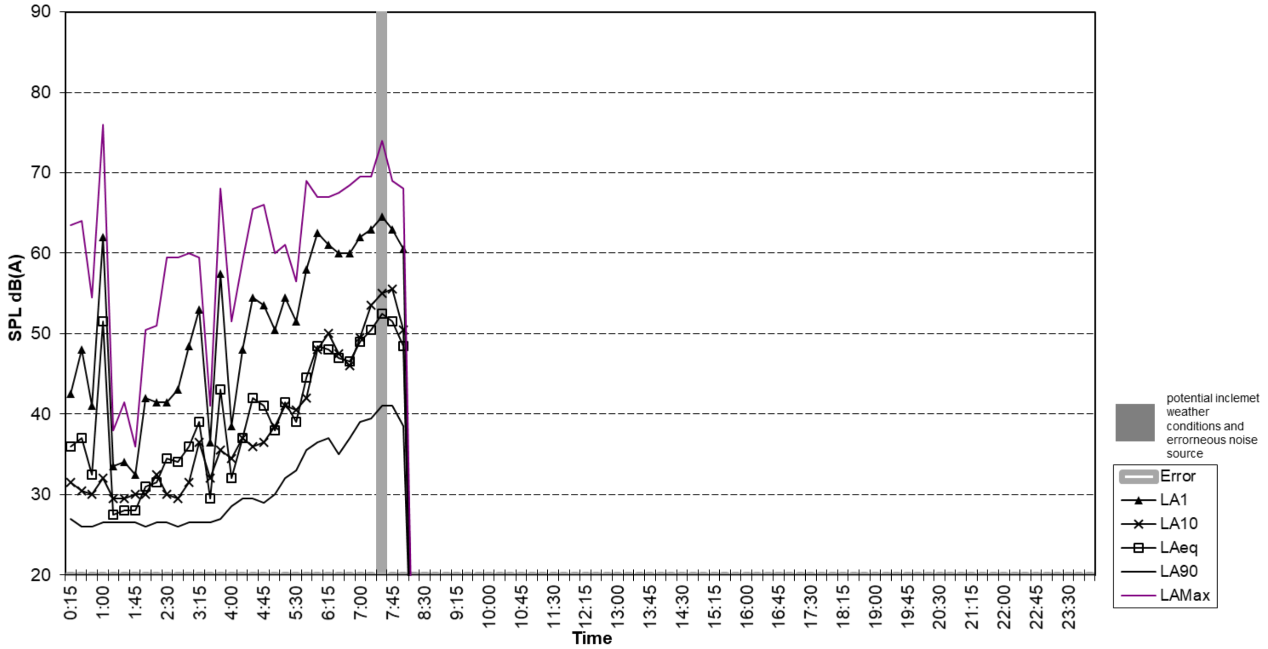
L5
Measured Noise Levels - Wednesday 27/06/2018



L5
Measured Noise Levels - Thursday 28/06/2018



L5
Measured Noise Levels - Friday 29/06/2018



Appendix C Noise Modelling Inputs and Results

Model Scenario Inputs Per scenario/site Location

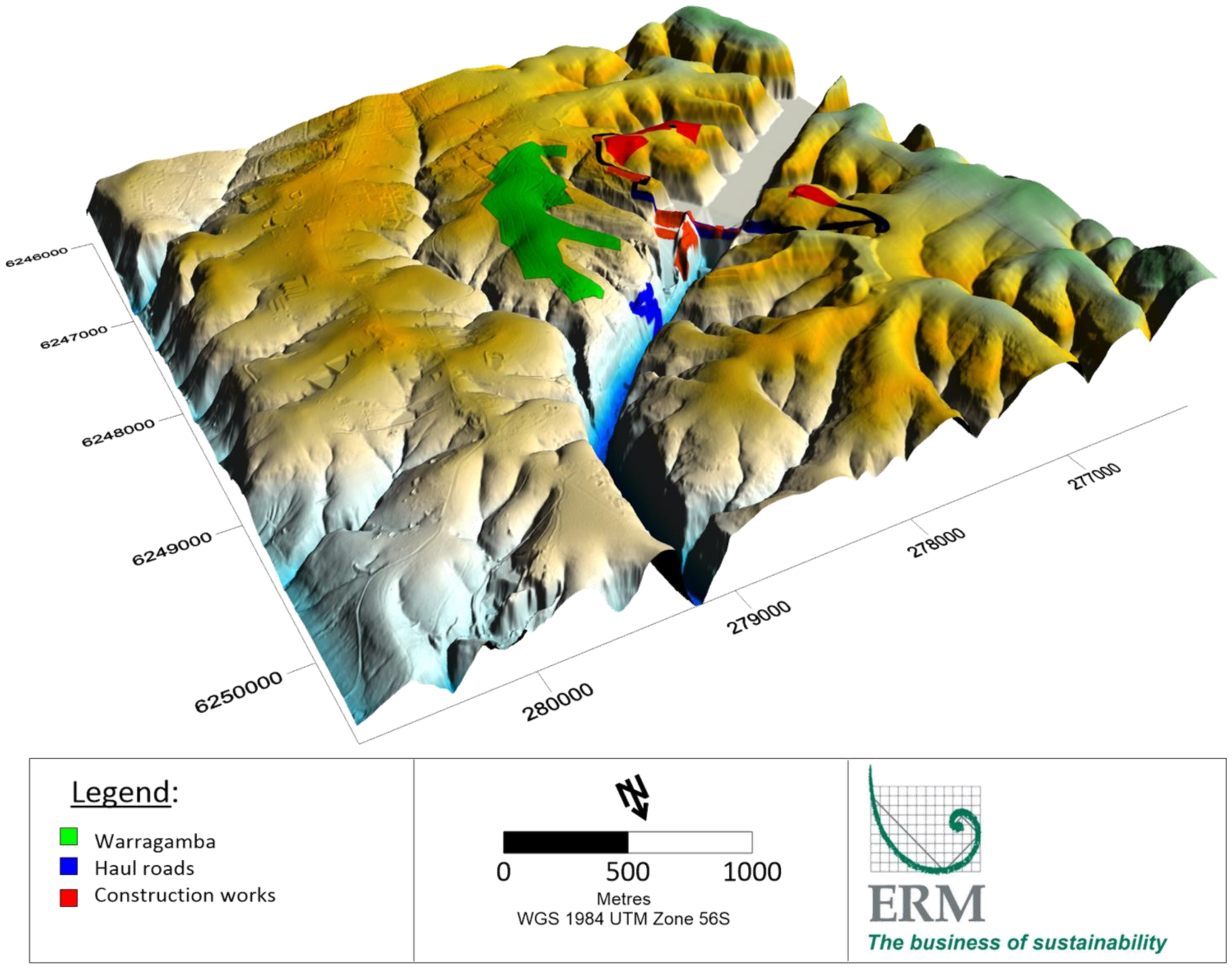
EQUIPMENT	QUANTITY	BASE LW VALUE
Batch plants/early works		
50T Crane	1	113
Franna Crane	2	98
15t Excavator	1	106
12t Truck	2	108
Grader	1	115
Vibrating Roller	1	109
15kl Water Cart	1	109
Bobcat	1	102
Hydraulic Hammer	1	122
D6 Dozer	1	105
Generator	1	103
Compressor	1	109
Auxiliary spillway works/upstream coffer dam		
40t Excavator	2	114
Spoil Trucks	8	107
Articulated Dump Trucks (40t Moxy)	3	110
Longreach Excavator	1	105
D6 Dozer	1	103
10t Vibratory Roller	1	110
15kl Water Cart	1	109
Borrow pit		
Dozer	1	105
Front End Loader	1	114
Dam foundation works		
Compressors	2	109
Pneumatic Drill	1	119
40t Excavator w/ Rock Hammer	2	122
Spoil Trucks	4	107
Air Compressors	2	109
5t Excavator	2	95
4" Dewatering Pumps	2	106
Dam preparation works		
High Pressure Hoses	1	119
Spoil Truck	1	107
Excavator - Rock Hammer	1	122
Misc. Plant (site establishment – mainly clearing)		
30t Excavator	1	110
Spoil Trucks	2	107
12t Trucks	3	108
D7 Dozer	1	109
Chainsaws	4	114
Grader	1	115
Tub Grinder	2	116
20t Excavator with Grabs	2	108
15kl Watercart	2	109

EQUIPMENT	QUANTITY	BASE LW VALUE
D10 Dozer	2	121
Roadworks (during site establishment and main works)		
Grader	1	114
Roller	1	110
Bobcat	1	102
Pavement crew (minor – during site establishment main works)		
Paver	1	105
Roller	2	110
Profiler	1	117
Various Tools (Breakers, Road saw etc)	1	114
Franna Crane	1	98
Drainage crew (minor – during site establishment main works)		
28t Excavator	1	110
Hand Compaction Gear (upright rammers, vibration plate)	1	114
Flatbed Truck	1	107
Utilities location crew		
Vacuum Truck	1	109
Generator	2	103
Lighting Plant	1	100
Grout Mixer/Agitator	1	90
Grouting Pump	1	105
Main construction works		
Batch Plant #1 (Adjacent to Dam Wall)		
Front End Loader	1	114
Cement Truck	1	109
Tower Crane	2	113
Mixing Unit/Agitator	1	107
Cooling plant	1	102
Generator	1	103
Conveyers	1	84
Elevated Conveyers	1	84
Conveyer Drive	1	97
Compressor	1	109
Concrete Line Pump	1	109
Concrete Boom Pump	1	109
Batch Plant #2 (Havilland Park/Security Gate)		
Cooling Plant	1	102
Mixing Unit/Agitator	1	107
Front End Loader	1	114
Cement Truck	2	109
Generator	1	103
Conveyers	1	84
Elevated Conveyers	1	84
Conveyer Drive	1	97
Compressor	1	109
Concrete Line Pump	1	109
Concrete Boom Pump	1	109

EQUIPMENT	QUANTITY	BASE LW VALUE
Large laydown area		
Franna Crane	1	98
Tele handler	1	99
Loader With Folks (Integrated tool Carrier)	1	108
12t Trucks	2	108
Elevated Working Platform	1	95
Laydown areas		
Franna Crane	1	98
Tele handler	1	99
12t Truck	1	108
Elevated Working Platform	1	95
Main dam wall works		
100t Mobile Crane	2	110
Powered Hand Tools	8	114
Service Truck 12t	8	108
Conveyor	1	84
Elevated Conveyers	1	84
Conveyer Drives	1	97
Compressor	4	109
Dewatering Pump	1	106
Water Cart	1	109
Auxiliary spillway works		
50t Mobile Crane	4	110
Powered Hand Tools	4	114
Service Truck 12t	4	108
Concrete Pump	4	109
Agitator	4	107
Compressor	1	109
Excavator - Rock Hammer	1	122
Miscellaneous plant		
30t Excavator	1	110
Spoil Trucks	2	107
Cooling plant	4	102
Generators	4	103
Backhoe Loader	2	111
Demobilisation Plant		
Batch Plant sites as per early works	(refer above)	(refer above)
Road and pavement crew a	(refer above)	(refer above)
Articulated Dump truck	1	110

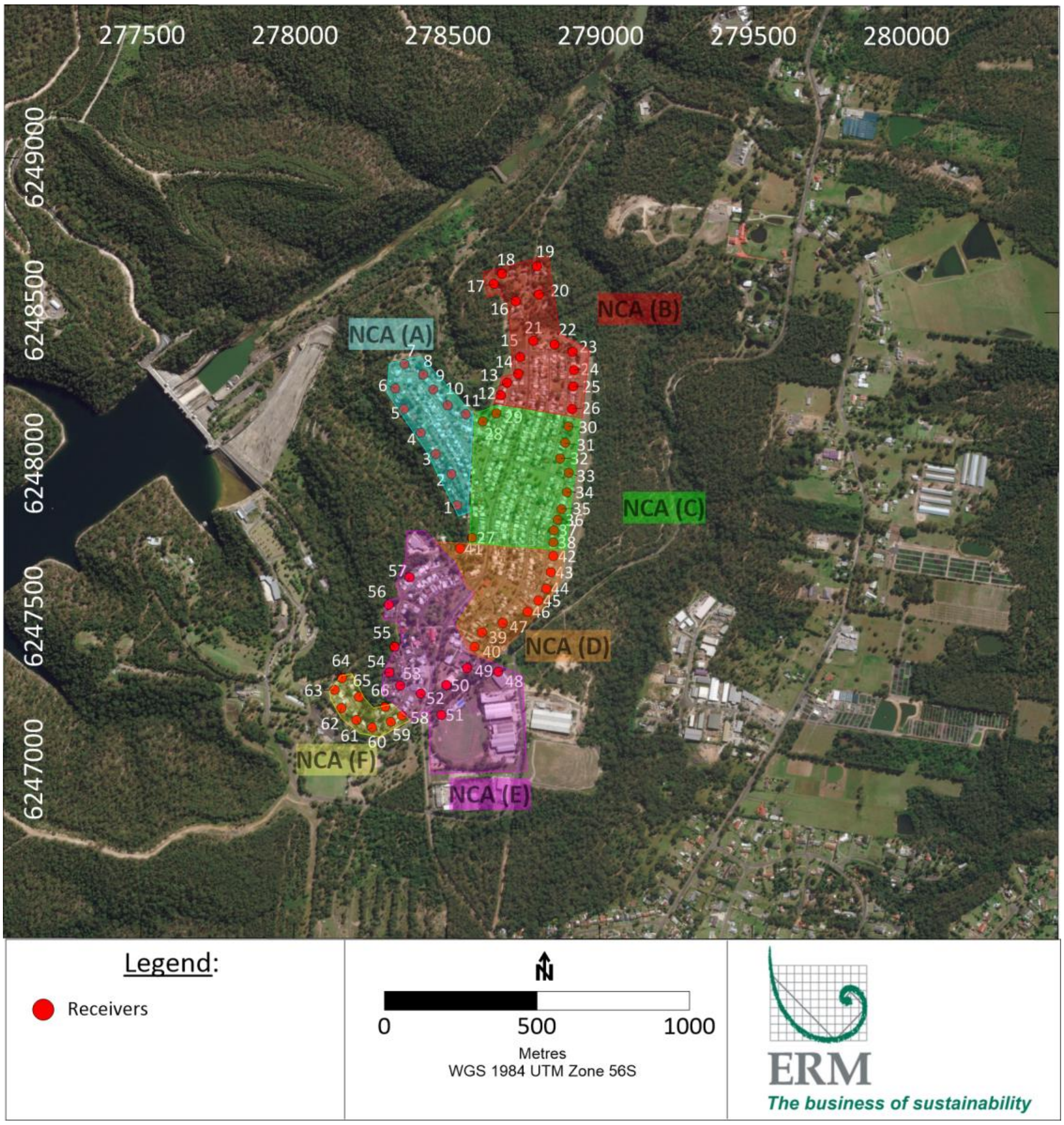
Project 3D layout

Figure C-1: 3D site layout



Modelled Receiver Points

Figure C-2: Existing dam and location of receivers



Model results – daytime works

RECEIVER	CRITERIA	NOISE LEVEL (DECIBELS A WEIGHTED)			
	LAeq,15min dB(A)	Early Works	Establishing Works and Demolition	Main works	Demobilisation and Site Restoration
NCA (A)					
1	41	46	50	49	49
2	41	47	51	51	50
3	41	46	52	50	51
4	41	48	53	52	52
5	41	47	53	53	52
6	41	47	53	54	52
7	41	47	51	52	50
8	41	45	48	47	47
9	41	46	50	50	50
10	41	46	50	49	50
11	41	44	49	48	48
NCA (B)					
12	41	43	47	47	46
13	41	44	47	48	47
14	41	45	48	48	47
15	41	43	46	47	46
16	41	44	46	46	44
17	41	48	47	47	45
18	41	48	46	47	44
19	41	41	43	42	42
20	41	40	43	42	42
21	41	41	45	46	44
22	41	40	43	42	42
23	41	39	42	41	42
24	41	40	43	42	42
25	41	40	43	42	42
26	41	40	43	42	42
NCA (C)					
27	41	46	49	49	49
28	41	44	47	47	47
29	41	44	48	47	47
30	41	40	43	42	43
31	41	41	43	42	43
32	41	40	43	42	43
33	41	40	43	42	43
34	41	41	43	42	43
35	41	42	44	43	43
36	41	42	44	43	44
37	41	42	45	44	44
38	41	43	44	43	44
NCA (D)					
39	41	49	47	48	48

RECEIVER	CRITERIA	NOISE LEVEL (DECIBELS A WEIGHTED)			
	LAeq,15min dB(A)	Early Works	Establishing Works and Demolition	Main works	Demobilisation and Site Restoration
40	41	49	48	49	48
41	41	46	49	48	49
42	41	43	44	44	44
43	41	43	44	44	44
44	41	45	45	45	45
45	41	46	45	46	45
46	41	46	46	46	46
47	41	47	47	47	47
NCA (E)					
48	41	45	45	45	45
49	41	49	47	49	48
50	41	50	48	50	48
51	41	50	47	50	47
52	41	51	49	51	49
53	41	53	52	53	52
54	41	53	52	54	52
55	41	53	54	54	54
56	41	53	57	56	57
57	41	52	56	55	56
NCA (F)					
58	41	52	49	52	49
59	41	53	49	52	49
60	41	52	49	51	49
61	41	53	50	51	50
62	41	56	51	55	51
63	41	58	52	57	53
64	41	57	52	56	53
65	41	52	50	52	51
66	41	53	50	53	50

Model Results

RECEIVER GROUP	OOH CRITERIA LAEQ, 15MIN (DBA)			NOISE LEVEL (DECIBELS A WEIGHTED LEQ)					LMAX
	Day/ Evening	Night	Sleep Disturbance	Batch Plant 1	Batch Plant 2	Dam Wall Construction	Cooling Plant 24hr operation	Sum	
NCA (A)									
1	36	35	40 (52 LMax)	41	45	41	28	47	49
2	36	35	40 (52 LMax)	44	47	42	31	49	51
3	36	35	40 (52 LMax)	44	46	43	30	49	51
4	36	35	40 (52 LMax)	45	47	43	31	50	52
5	36	35	40 (52 LMax)	46	47	43	33	50	52
6	36	35	40 (52 LMax)	47	46	43	33	50	52
7	36	35	40 (52 LMax)	45	44	41	31	48	51
8	36	35	40 (52 LMax)	41	43	38	26	46	48
9	36	35	40 (52 LMax)	44	45	40	29	48	49
10	36	35	40 (52 LMax)	43	45	40	29	48	50
11	36	35	40 (52 LMax)	42	43	39	26	46	47
NCA (B)									
12	36	35	40 (52 LMax)	40	41	38	26	45	47
13	36	35	40 (52 LMax)	41	43	39	28	46	48
14	36	35	40 (52 LMax)	41	42	39	27	46	47
15	36	35	40 (52 LMax)	40	40	38	26	44	46
16	36	35	40 (52 LMax)	39	38	35	25	43	45
17	36	35	40 (52 LMax)	41	39	37	26	44	46
18	36	35	40 (52 LMax)	40	39	37	25	43	46
19	36	35	40 (52 LMax)	37	37	33	22	41	42
20	36	35	40 (52 LMax)	36	37	34	22	41	42
21	36	35	40 (52 LMax)	39	39	37	25	43	44

RECEIVER GROUP	OOH CRITERIA LAEQ, 15MIN (DBA)			NOISE LEVEL (DECIBELS A WEIGHTED LEQ)					LMAX
	Day/ Evening	Night	Sleep Disturbance	Batch Plant 1	Batch Plant 2	Dam Wall Construction	Cooling Plant 24hr operation	Sum	
22	36	35	40 (52 LMax)	35	38	33	20	40	42
23	36	35	40 (52 LMax)	35	37	33	20	40	42
24	36	35	40 (52 LMax)	35	37	33	20	40	42
25	36	35	40 (52 LMax)	35	38	33	20	41	42
26	36	35	40 (52 LMax)	35	38	34	20	41	42
NCA (C)									
27	36	35	40 (52 LMax)	42	46	42	28	49	49
28	36	35	40 (52 LMax)	40	42	38	25	45	46
29	36	35	40 (52 LMax)	41	41	39	26	45	47
30	36	35	40 (52 LMax)	35	38	34	20	41	42
31	36	35	40 (52 LMax)	34	39	34	20	41	42
32	36	35	40 (52 LMax)	34	39	34	20	41	42
33	36	35	40 (52 LMax)	34	39	34	20	41	43
34	36	35	40 (52 LMax)	34	39	34	20	41	43
35	36	35	40 (52 LMax)	34	40	34	20	42	43
36	36	35	40 (52 LMax)	34	40	34	21	42	43
37	36	35	40 (52 LMax)	36	40	35	21	43	44
38	36	35	40 (52 LMax)	35	40	35	22	42	43
NCA (D)									
39	36	35	40 (52 LMax)	41	44	40	25	47	47
40	36	35	40 (52 LMax)	41	45	40	24	47	48
41	36	35	40 (52 LMax)	40	45	39	26	47	48
42	36	35	40 (52 LMax)	35	40	35	22	42	43
43	36	35	40 (52 LMax)	36	41	35	23	43	44

RECEIVER GROUP	OOH CRITERIA LAEQ, 15MIN (DBA)			NOISE LEVEL (DECIBELS A WEIGHTED LEQ)					LMAX
	Day/ Evening	Night	Sleep Disturbance	Batch Plant 1	Batch Plant 2	Dam Wall Construction	Cooling Plant 24hr operation	Sum	
44	36	35	40 (52 LMax)	37	41	36	23	43	44
45	36	35	40 (52 LMax)	39	42	38	23	45	45
46	36	35	40 (52 LMax)	39	42	38	23	45	46
47	36	35	40 (52 LMax)	40	44	39	24	46	47
48	36	35	40 (52 LMax)	41	44	40	25	47	47
NCA (E)									
49	36	35	40 (52 LMax)	36	42	36	21	44	44
50	36	35	40 (52 LMax)	41	45	40	23	47	48
51	36	35	40 (52 LMax)	41	45	41	23	48	48
52	36	35	40 (52 LMax)	41	44	40	22	47	47
53	36	35	40 (52 LMax)	42	46	41	24	48	49
54	36	35	40 (52 LMax)	44	48	42	29	50	51
55	36	35	40 (52 LMax)	45	49	43	26	51	52
56	36	35	40 (52 LMax)	46	51	45	31	53	53
57	36	35	40 (52 LMax)	47	53	47	33	55	55
NCA (F)									
58	36	35	40 (52 LMax)	42	47	41	24	49	49
59	36	35	40 (52 LMax)	42	46	41	24	49	49
60	36	35	40 (52 LMax)	42	46	42	24	49	49
61	36	35	40 (52 LMax)	43	47	42	25	49	50
62	36	35	40 (52 LMax)	44	48	43	26	51	51
63	36	35	40 (52 LMax)	46	50	45	27	52	52
64	36	35	40 (52 LMax)	46	50	45	27	53	53
65	36	35	40 (52 LMax)	43	48	42	26	50	50

RECEIVER GROUP	OOH CRITERIA LAEQ, 15MIN (DBA)			NOISE LEVEL (DECIBELS A WEIGHTED LEQ)					LMAX
	Day/ Evening	Night	Sleep Disturbance	Batch Plant 1	Batch Plant 2	Dam Wall Construction	Cooling Plant 24hr operation	Sum	
66	36	35	40 (52 LMax)	43	47	42	25	49	50

Noise Contours

Figure C-3: Early Works

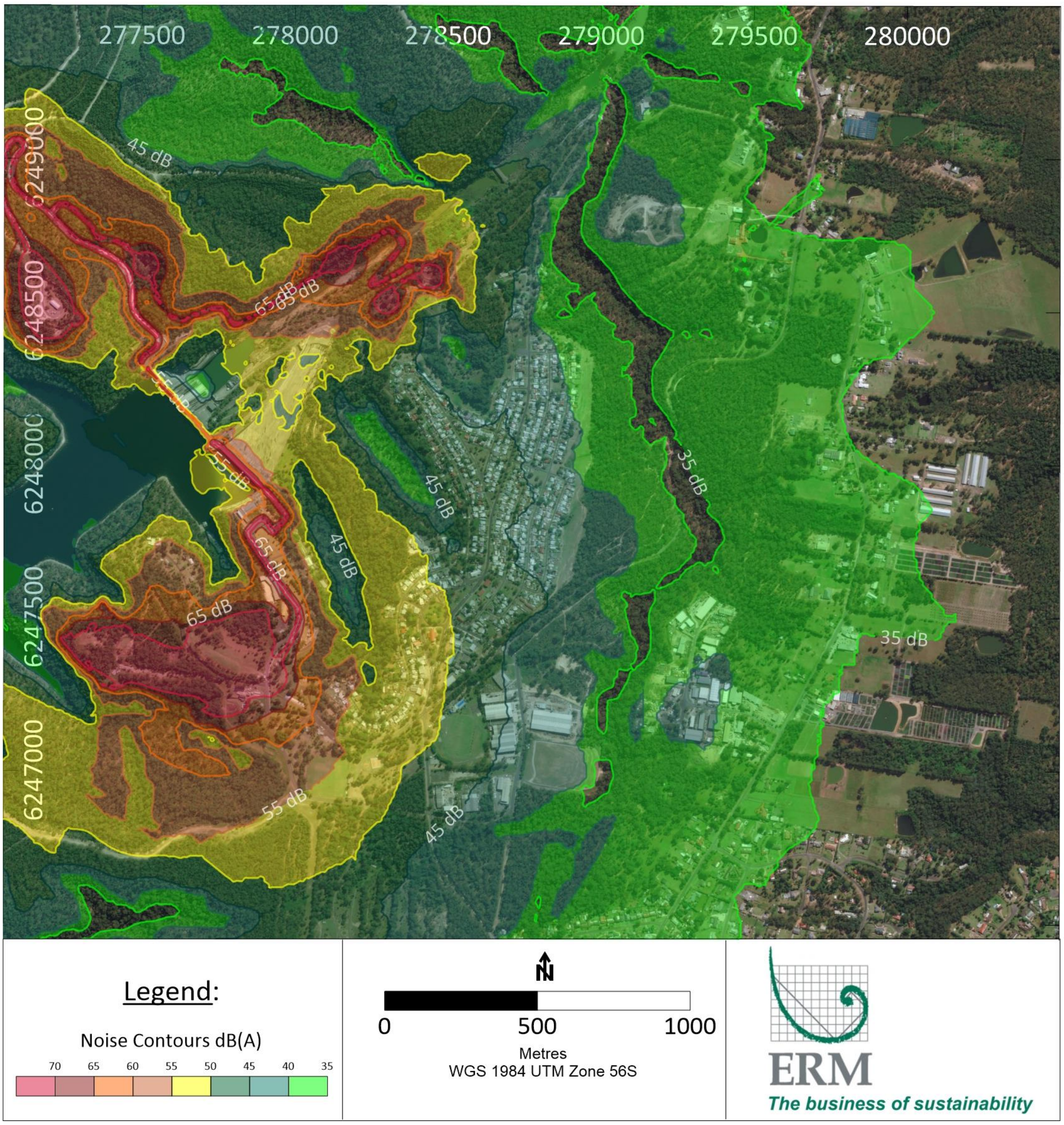


Figure C-4: Enabling Works and Demolition

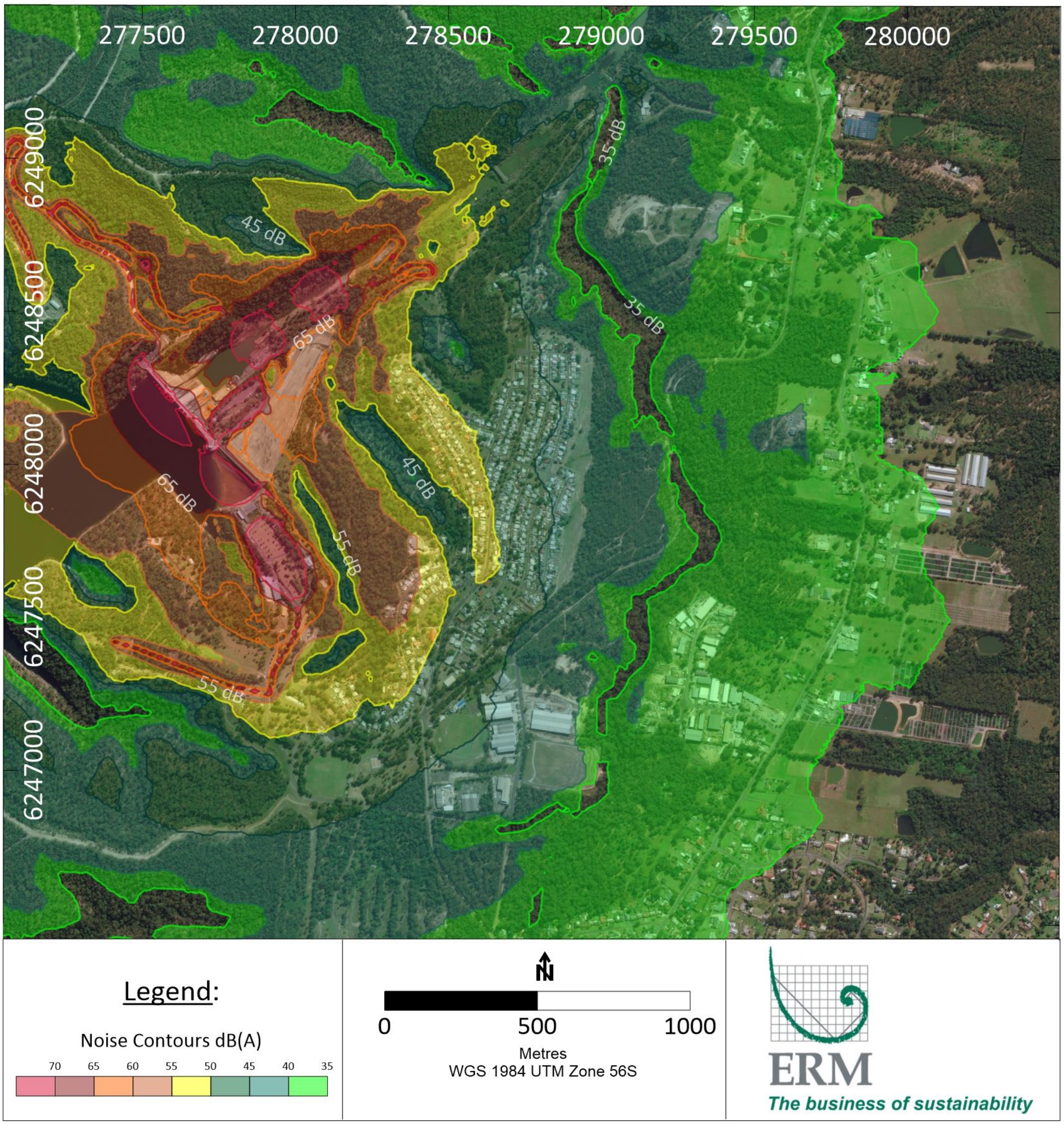


Figure C-5: Main Works

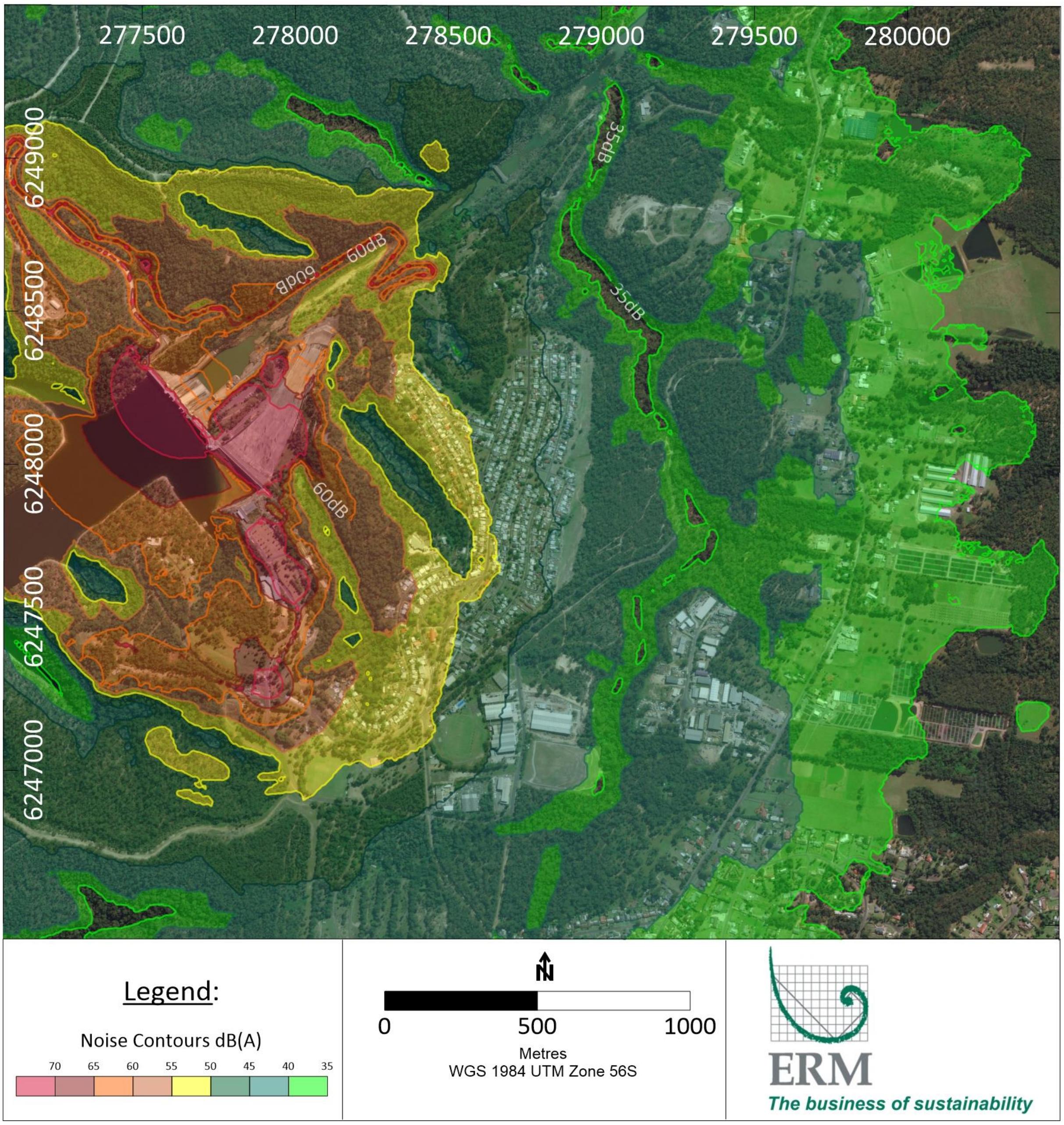


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Figure C-6: Night Works

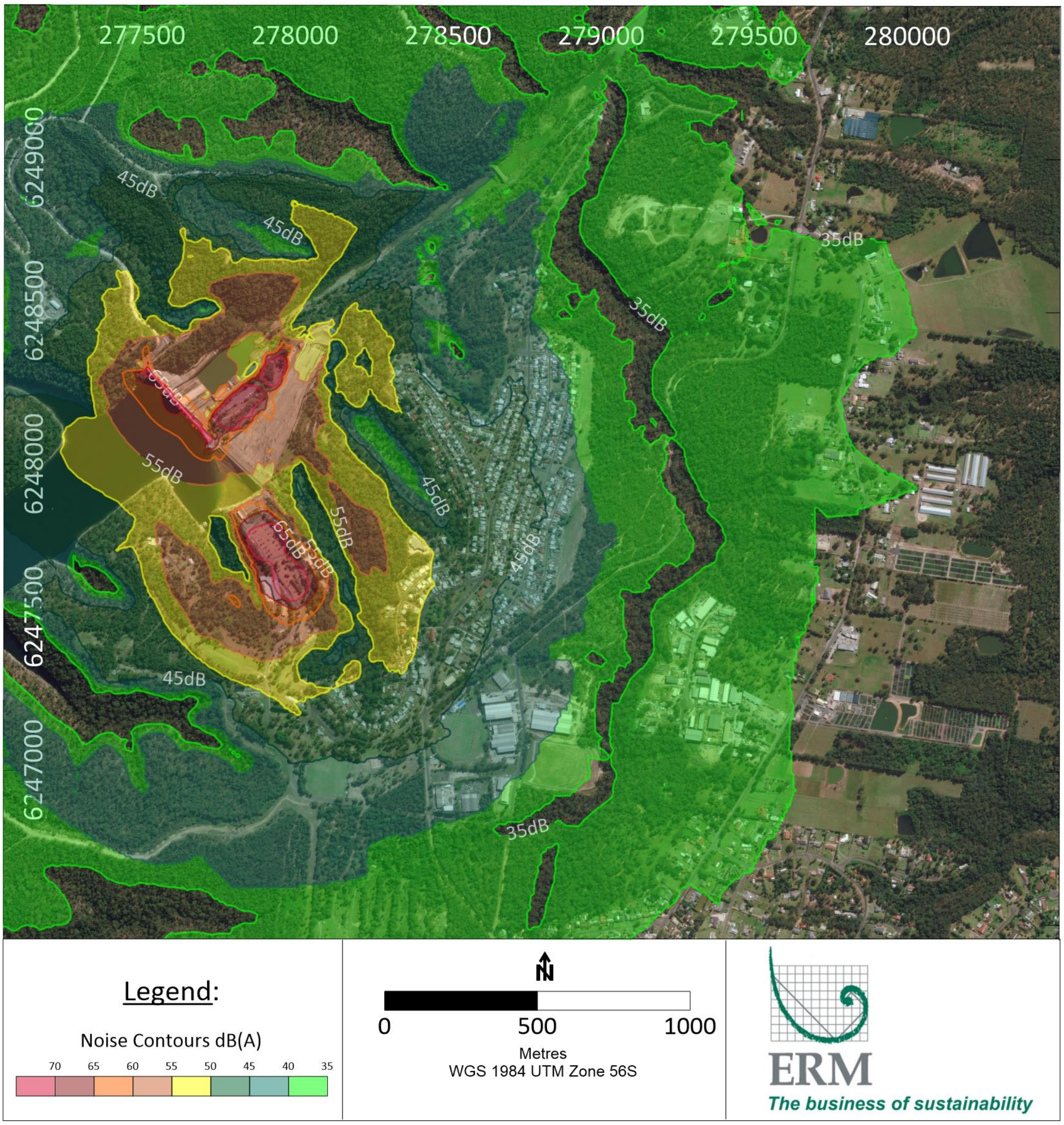


Figure C-7: Cooling Plant

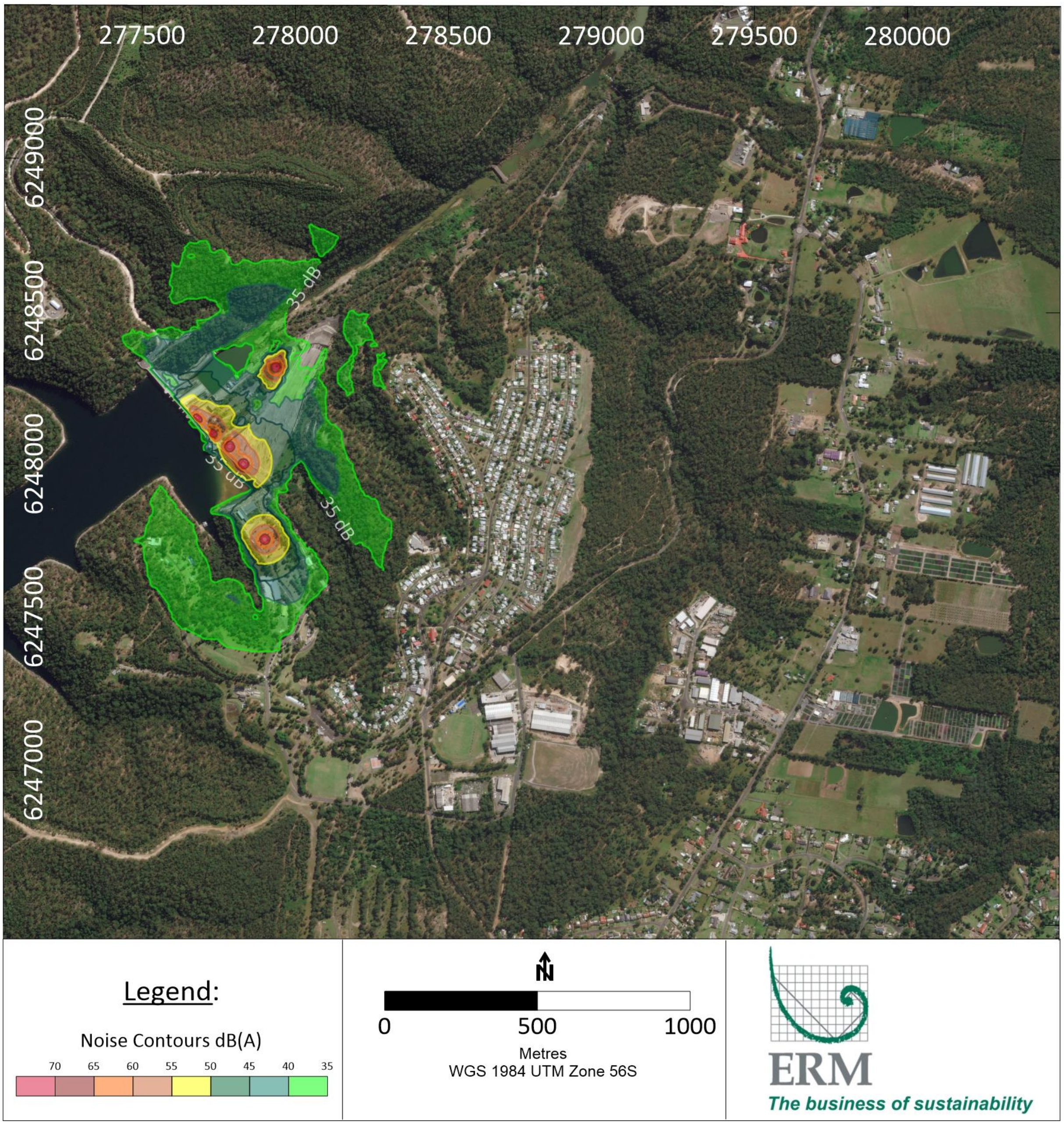
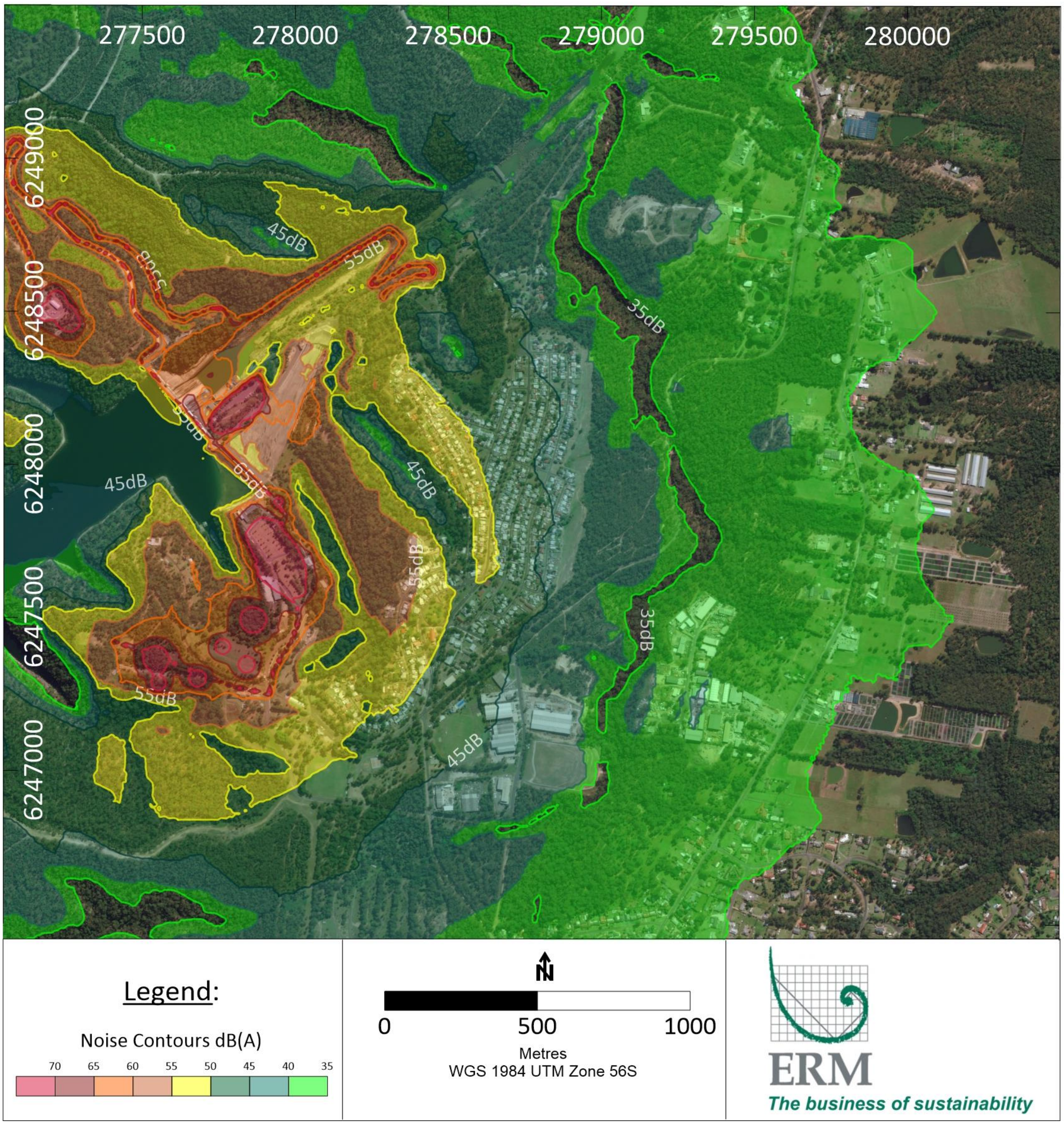


Figure C-8: Demobilisation



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ERM's Sydney Office
Level 15
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Sydney NSW 2000

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