WestConnex

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M4 East

Environmental Impact Statement

Appendices J-L



Volume 2D

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Volume 2D

Appendices

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WestConnex

Appendix J

Human health risk assessment

WestConnex

WestConnex Delivery Authority

WestConnex M4 East

Human Health Risk Assessment

September 2015

Prepared for

WestConnex Delivery Authority

Prepared by

Jackie Wright

Environmental Risk Sciences Pty Ltd (enRiskS)

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Prepared by:	Jackie Wright (Environmental Risk Sciences Pty Ltd)
Authorised by AECOM Australia Pty Ltd:	Jay Stricker Industry Director – Transport
Signed:	
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Glossary of terms and abbreviations

Term	Meaning
Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days).
Absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems.
AAQ	Ambient air quality
ANZECC	Australia and New Zealand Environment and Conservation Council
AQAR	Air Quality Assessment Report (Pacific Environment 2015)
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).
Body burden	The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.
BTX	Benzene, toluene and total xylenes
Carcinogen	A substance that causes cancer.
Chronic exposure	Contact with a substance that occurs over a long time (more than 1 year) [compare with *acute exposure* and *intermediate duration exposure*].
CO	Carbon monoxide
COPD	Chronic Obstructive Pulmonary Disease
DECCW	Department of Environment, Climate Change and Water
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An 'exposure dose' is how much of a substance is encountered in the environment. An 'absorbed dose' is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
EC	European Commission
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	Environment Protection Authority
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [*acute exposure*], of intermediate duration, or long-term [*chronic exposure*].
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.
Exposure pathway	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed) to it. An exposure pathway has five parts: a source of contamination (such as chemical leakage into the subsurface); an *environmental media and transport mechanism* (such as movement through groundwater); a *point of exposure* (such as a private well); a *route of exposure* (eating, drinking, breathing, or touching), and a *receiver population* (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Guideline value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organisation (WHO)), that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines will have different names, such as investigation level, trigger value, ambient guideline etc.
HIA	Health Impact Assessment
HHRA	Human Health Risk Assessment
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see *route of exposure*].
Intermediate exposure Duration	Contact with a substance that occurs for more than 14 days and less than a year [compare with *acute exposure* and *chronic exposure*].
LGA	Local Government Area
LOAEL	Lowest-observed-adverse-effect-level - The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
LOR	Limit of Reporting
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NO_2	Nitrogen dioxide
NOAEL	No-observed-adverse-effect-level - The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
NSW	New South Wales
OEH	Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA)
PAH	Polycyclic aromatic hydrocarbon
PM	Particulate matter
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 µm and less
PM_{10}	Particulate matter of aerodynamic diameter 10 µm and less
Point of exposure	The place where someone can come into contact with a substance present in the environment [see *exposure pathway*].
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).
Receiver population	People who could come into contact with hazardous substances [see *exposure pathway*].
Risk	The probability that something will cause injury or harm.
Roads and Maritime	NSW Roads and Maritime Services
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [*inhalation*], eating or drinking [*ingestion*], or contact with the skin [*dermal contact*]
Toxicity	The degree of danger posed by a substance to human, animal or plant life.

Toxicity data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical for relevant exposure pathway (inhalation, oral or dermal), with special emphasis on dose-response characteristics. The data are based on based on available toxicity studies relevant to humans and/or animals and relevant safety factors.
Toxicological profile	An assessment that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.
Toxicology	The study of the harmful effects of substances on humans or animals.
TSP	Total suspended particulate
Uncertainty factor	Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the *lowest-observed-adverse-effect-level (LOAEL)* or the *no-observed-adverse-effect-level (NOAEL)* to derive a *minimal risk level (MRL)*. Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WDA	WestConnex Delivery Authority
WHO	World Health Organisation

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Executive summary

The WestConnex Delivery Authority (WDA), on behalf of the NSW Roads and Maritime Services (Roads and Maritime), is seeking approval to upgrade and extend the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield. This includes twin 5.5 kilometre long tunnels and associated surface works. These proposed works are described as the M4 East project (the project).

The project is a component of WestConnex, which is a proposal to provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. This technical report was prepared to assess potential risks to human health associated with key aspects of the project, namely local air quality impacts, noise and vibration and social impacts.

A human health risk assessment is a way of deciding now, what the consequences (to health) of some future action (such as this project) may be. We try to learn from previous experience about impacts from road tunnels and their potential effects on people who live or work around them. We then use this information to predict the impacts of the project on community health.

In this case, this report includes a detailed review of what impacts may occur, who may be exposed to these impacts and whether there is potential for these impacts to result in adverse health effects within the local community. It is conducted in accordance with national guidance available from enHealth (enHealth 2001, 2012a) and it has involved the following:

- Review of predicted impacts to air quality, noise and vibration during construction and operation of the project. In some cases the issues identified (such as those during construction) are short-term and can be mitigated/managed through the implementation of specific management measures. For other impacts (such as those from operations) the impacts may occur over a longer period of time and require a more detailed assessment of how these impacts affect health
- Identification and characterisation of the community (including the presence of sensitive receivers such as childcare centres, aged care centres, schools and hospitals) who may be affected by these impacts
- Assessment of air quality impacts on health including:
  - Reviewing the key air pollutants (associated with vehicle emissions) that are predicted from the operation of the project (within the tunnel and outside of the tunnel)
  - Identifying guidelines that are based on protection of the health of all members of the population for exposure to these pollutants all day, every day
  - Comparing the predicted impacts with the health based guidelines
  - Undertaking a more detailed assessment of potential risks of changes in nitrogen dioxide and particulates (such as particulate matter (PM)2.5 (Particulate matter of aerodynamic diameter 2.5 microns (µm) and less) or PM10 (particulate matter of aerodynamic diameter 10 µm and less) associated with specific health effects (or health endpoints). The assessment conducted has evaluated the impact of the project on these health endpoints within the local community
- Assessment of noise and vibration impacts on health including:
  - Reviewing the impacts that are predicted from the construction and operation of the project
  - Identifying guidelines that are based on the protection of the health and wellbeing (including sleep disturbance) during all phases of the project (construction to operation)
  - Comparing predicted impacts with the health based guidelines. Where the health based guidelines cannot be met, consideration of the implementation of mitigation/management measures and whether these can be effectively implemented to ensure the identified impacts meet the health based guidelines

- Assessment of social changes associated with the project on health:
  - This has involved a qualitative assessment. Aspects of the project that have the potential to result in impacts or changes in the community (including traffic, pedestrian and cycle access, property acquisitions and access, visual changes and community access/cohesion) have been evaluated with respect to potential effects on health and wellbeing. In addition the equity of changes associated with the project has also been evaluated.

Based on the assessment undertaken and presented in this report the following has been concluded:

- In relation to air quality:
  - Impacts in the community outside the tunnel: the project is expected to result in a decrease in total pollutant levels in the community. The project is expected to result in a redistribution of impacts associated with vehicle emissions. For much of the community this will result in an improvement (ie decreased concentrations and health impacts), however for a number of areas a small increase in pollutant concentration may occur. Potential health impacts associated with changes in air quality (specifically nitrogen dioxide and particulates) within the local community have been assessed and are considered to be low and essentially negligible
  - Impacts within the tunnel: while concentrations of pollutants from vehicle emissions are higher within the tunnel (compared with outside the tunnel) the time spent exposed to these pollutants is very short (minutes). Where health based guidelines are available, exposures within the tunnel are expected to be below these guidelines. However for nitrogen dioxide and particulates there are no health based guidelines and exposure to pollutants derived from congested traffic (including within tunnels) may increase the risk of adverse health effects. Drivers who regularly use tunnels or drive in congested traffic in Sydney can minimise exposure to vehicle emissions by keeping windows up and air conditioning on recirculation when in tunnels or heavy traffic conditions. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent
- In relation to noise and vibration, potential impacts during construction and operation have been considered:
  - Construction: without implementation of mitigation measures there is the potential for noise and vibration impacts associated with a range of construction activities to result in adverse health effects in the community. Hence it is important that management and/or mitigation measures are implemented throughout the construction period to minimise the potential for adverse health effects. These management and mitigation measures (including the requirement for noise monitoring) are to be outlined in detail within the Construction Noise and Vibration Management Plan
  - Operation: during the operational phase of the project a number of properties have been identified where road noise has the potential to be elevated and adversely affect health. For these properties mitigation measures are required to protect the health of occupants. These mitigation measures may include low noise pavement, noise barriers and/or noise treatments on individual properties. The recommended mitigation measures would ensure that the levels of road traffic noise experienced by residents would be reduced as low as feasible and reasonable

1 Introduction

1.1 Overview of the project

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to upgrade and extend the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield. This includes twin tunnels about 5.5 kilometres long and associated surface works to connect to the existing road network. These proposed works are described as the M4 East project (the project). The location of the project is shown in **Figure 1.1**.

Approval is being sought under Part 5.1 of the Environmental Planning and Assessment Act 1979 (NSW) (EP&A Act). The project was declared by the Minister for Planning to be State significant infrastructure and critical State significant infrastructure and an environmental impact statement (EIS) is therefore required.

The project is a component of WestConnex, which is a proposal to provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. The location of WestConnex is shown in **Figure 1.2**. The individual components of WestConnex are:

- M4 Widening – Pitt Street at Parramatta to Homebush Bay Drive at Homebush (planning approval granted and under construction)
- M4 East (the subject of this report)
- New M5 – King Georges Road at Beverly Hills to St Peters (planning application lodged and subject to planning approval)
- King Georges Road Interchange Upgrade (planning approval granted and work has commenced)
- M4–M5 Link – Haberfield to St Peters, including the Southern Gateway and Southern Extension (undergoing concept development and subject to planning approval).

Separate planning applications will be lodged for each individual component project. Each project will be assessed separately, but the impacts of each project will also be considered in the context of the wider WestConnex.

The NSW Government has established the WestConnex Delivery Authority (WDA) to deliver WestConnex. WDA has been established as an independent public subsidiary corporation of Roads and Maritime. Its role and functions are set out in Part 4A of the Transport Administration (General) Regulation 2013 (NSW). WDA is project managing the planning approval process for the project on behalf of Roads and Maritime. However, for the purpose of the planning application for the project, Roads and Maritime is the proponent.

1.2 Project location

The project is generally located in the inner west region of Sydney within the Auburn, Strathfield, Canada Bay, Burwood and Ashfield local government areas (LGAs). The project travels through 10 suburbs: Sydney Olympic Park, Homebush West, Homebush, North Strathfield, Strathfield, Concord, Burwood, Croydon, Ashfield and Haberfield.

The project is generally located within the M4 and Parramatta Road corridor, which links Broadway at the southern end of the Sydney central business district (CBD) and Parramatta in Sydney's west, about 20 kilometres to the west of the Sydney CBD. This corridor also provides the key link between the Sydney CBD and areas further west of Parramatta (such as Penrith and western NSW).

The western end of the project is located at the interchange between Homebush Bay Drive and the M4, about 13 kilometres west of the Sydney CBD. The project at this location would tie in with the M4 Widening project in the vicinity of Homebush Bay Drive.

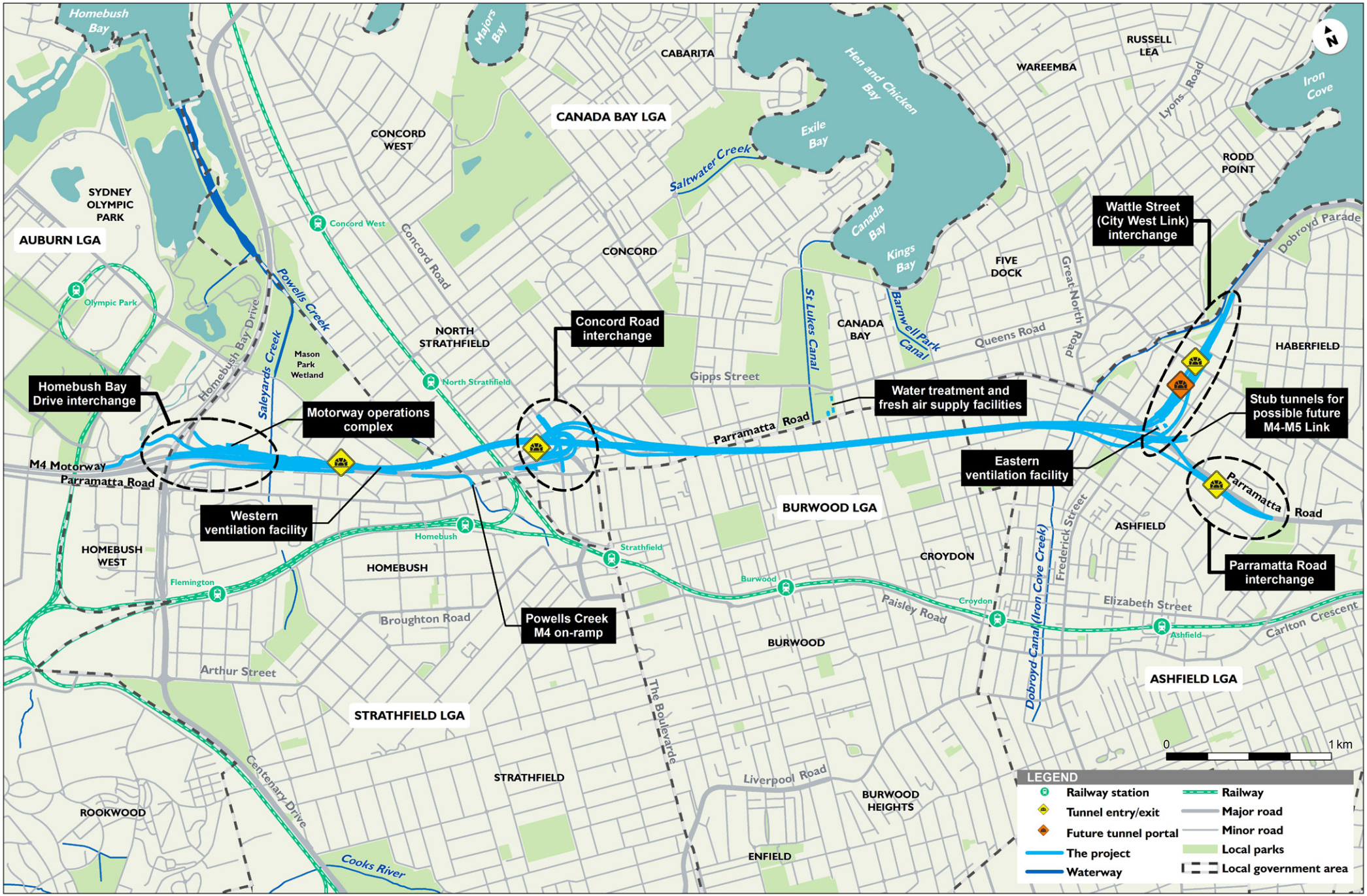


Figure 1.1 Local context of the project

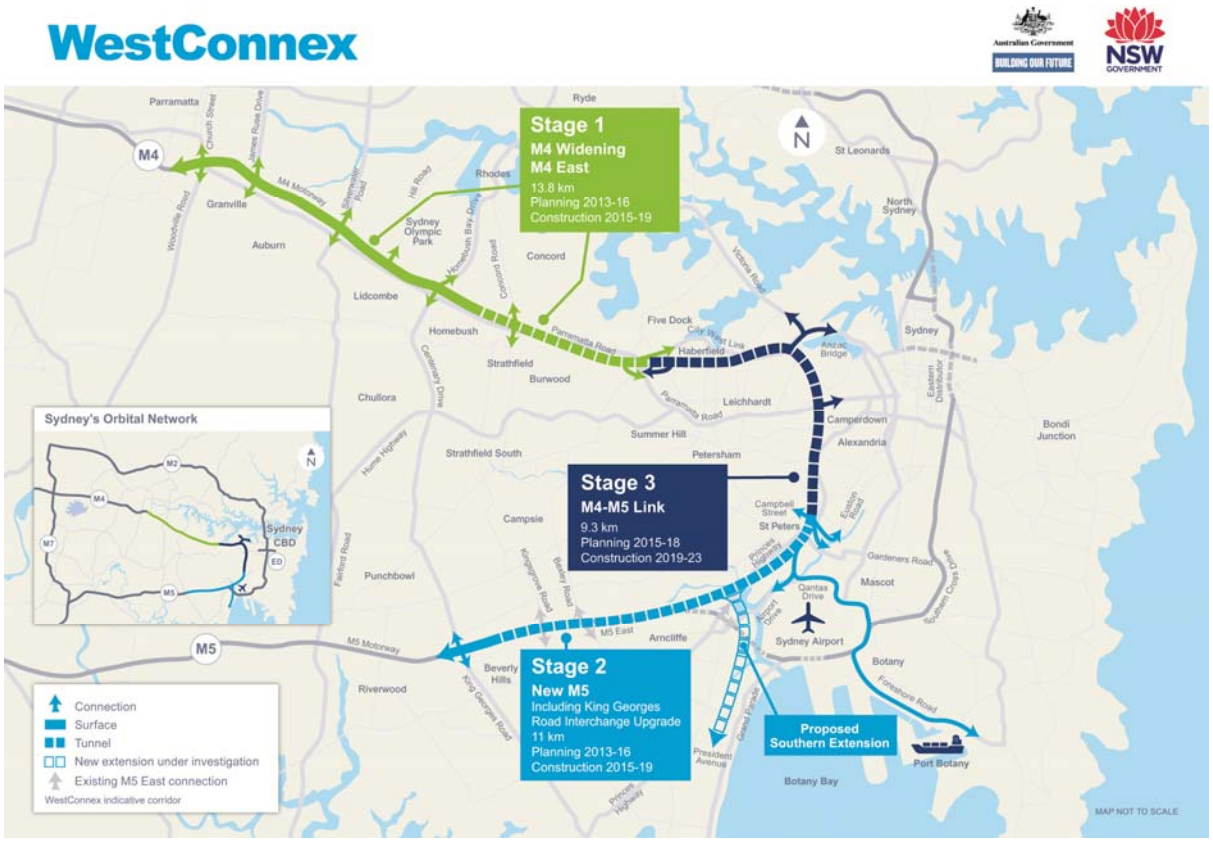


Figure 1.2 WestConnex

The tunnel dive structures would start at the centre of the M4, west of the existing pedestrian footbridge over the M4 at Pomeroy Street, and would continue underground to the north of the existing M4 and Parramatta Road, before crossing beneath Parramatta Road at Broughton Street at Burwood. The tunnels would continue underground to the south of Parramatta Road until the intersection of Parramatta Road and Wattle Street at Haberfield. Ramps would connect the tunnels to Parramatta Road and Wattle Street (City West Link) at the eastern end of the project. The tunnels would end in a stub connection to the possible future M4–M5 Link (M4–M5 Link), near Alt Street at Haberfield.

The project would include interchanges between the tunnels and the above ground road network, along with other surface road works, at the following locations:

- M4 and Homebush Bay Drive interchange at Sydney Olympic Park and Homebush (Homebush Bay Drive interchange)
- Powells Creek, near George Street at North Strathfield (Powells Creek M4 on-ramp)
- Queen Street, near Parramatta Road at North Strathfield (Queen Street cycleway westbound on-ramp)
- M4 and Sydney Street, Concord Road and Parramatta Road interchange at North Strathfield (Concord Road interchange)
- Wattle Street (City West Link), between Parramatta Road and Waratah Street at Haberfield (Wattle Street (City West Link) interchange)
- Parramatta Road, between Bland Street and Orpington Street at Ashfield and Haberfield (Parramatta Road interchange).

1.3 Secretary's Environmental Assessment Requirements

The NSW Department of Planning and Environment has issued a list of Secretary's Environmental Assessment Requirements (SEARs) that inform the environmental impact assessment. **Table 1.1** displays the SEARS that are specific to the assessment of human health impacts; and also provides a cross reference to the relevant section(s) of this report which address these requirements.

In addition, agency letters, which accompany the SEARs and are applicable to the assessment of human health, were issued by NSW Health and Ashfield Council.

Table 1.2 Error! Reference source not found. provides details of the human health requirements outlined in the agency letters and a cross reference to the relevant section(s) of this report which address these conditions.

Table 1.1 How SEARs have been addressed in this report

SEARs	
Human health requirements	
Requirement	**Section addressed**
• how the design of the proposal minimises adverse health impacts	• **Section 2** (also refer to main EIS)
• human health impacts from the operation of the tunnel under a range of conditions, including worst case operating condition	• **Sections 6** and **7**
• human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal	• **Sections 6**, **8** and **9**
• the Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth, 2012) and Air Quality in and Around Traffic Tunnels (NHMRC, 2008)	• **Section 3** (and whole document)

Table 1.2 How agency comments have been addressed in this report

Agency letters	
NSW Health	
Requirement	**Section where addressed in EIS**
• Impacts to air during construction and operation, including impacts to the surrounding community (addressing the most affected receivers and other sensitive receivers such as childcare centres, schools, hospitals and aged care facilities) and in-tunnel exposures for vehicle occupants and motorcyclists. The assessment should include consideration of all reasonable and feasible mitigation measures.	• **Sections 6** and **7**
• Impacts associated with noise and vibration during construction and operation.	• **Section 8**
• Opportunities to integrate cycleway and pedestrian elements to promote physical activity	• **Section 9**

Agency letters	
Ashfield Council	
Requirement	**Section where addressed in EIS**
• Air pollution - significant impacts on physical health (respiratory and cardiovascular health)	• **Sections 6** and **7**
• Additional traffic noise - implications for mental health due to stress and loss of sleep	• **Section 8**
• Increased danger from traffic - implications for the community's health (especially vulnerable groups)	• **Section 9**
• Loss of open space - green space is crucial to human health; loss of parkland will mean that there is less space for both passive and active recreation	• **Section 9**
• Community severance and dislocation - this has implications for all community members, but particularly vulnerable groups (children, the aged and those with disabilities)	• **Section 9**
• Reduced neighbourhood amenity - mental and health implications	• **Section 9**
• Assessment of cumulative impacts.	• **Sections 6**, **7** and **8**

1.4 Purpose of this report

This technical working paper presents a Human Health Risk Assessment (HHRA) associated with impacts identified in relation to air quality, noise and vibration and social aspects.

Other aspects of the SEARs relating to air quality, noise and vibration and social have been addressed in the relevant technical papers, as follows:

- *Air Quality Assessment Report* (AQRA) prepared by Pacific Environment (2015), presented in Appendices H and I of the EIS
- *Noise and Vibration Impact Assessment* (NVIA) prepared by SLR (2015), presented in Appendix K of the EIS
- *Social Impact Assessment* (SIA) prepared by AECOM and GHD (2015), presented in Appendix M of the EIS.

2 Proposed project

2.1 Project features

The project would comprise the construction and operation of the following key features:

- Widening, realignment and resurfacing of the M4 between Homebush Bay Drive and Underwood Road at Homebush
- Upgrade of the existing Homebush Bay Drive interchange to connect the western end of the new tunnels to the existing M4 and Homebush Bay Drive, while maintaining all current surface connections
- Two new three-lane tunnels (the mainline tunnels), one eastbound and one westbound, extending from west of Pomeroy Street at Homebush to near Alt Street at Haberfield, where they would terminate until the completion of the M4–M5 Link. Each tunnel would be about 5.5 kilometres long and would have a minimum internal clearance (height) to in-tunnel services of 5.3 metres
- A new westbound on-ramp from Parramatta Road to the M4 at Powells Creek, west of George Street at North Strathfield
- An interchange at Concord Road, North Strathfield/Concord with on-ramps to the eastbound tunnel and off-ramps from the westbound tunnel. Access from the existing M4 to Concord Road would be maintained via Sydney Street. A new on-ramp would be provided from Concord Road southbound to the existing M4 westbound, and the existing on-ramp from Concord Road northbound to the existing M4 westbound would be removed
- Modification of the intersection of the existing M4 and Parramatta Road, to remove the left turn movement from Parramatta Road eastbound to the existing M4 westbound
- An interchange at Wattle Street (City West Link) at Haberfield with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. The project also includes on- and off-ramps at this interchange that would provide access to the M4–M5 Link. In addition, the westbound lanes of Wattle Street would be realigned
- An interchange at Parramatta Road at Ashfield/Haberfield, with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. In addition, the westbound lanes of Parramatta Road would be realigned
- Installation of tunnel ventilation systems, including ventilation facilities within the existing M4 road reserve near Underwood Road at Homebush (western ventilation facility) and at the corner of Parramatta Road and Wattle Street at Haberfield (eastern ventilation facility). The eastern ventilation facility would serve both the project and the M4–M5 Link project. Provision has also been made for a fresh air supply facility at Cintra Park at Concord
- Associated surface road work on the arterial and local road network, including reconfiguration of lanes, changes to traffic signalling and phasing, and permanent road closures at a small number of local roads
- Pedestrian and cycle facilities, including permanently re-routing a portion of the existing eastbound cycleway on the northern side of the M4 from west of Homebush Bay Drive to near Pomeroy Street, and a new westbound cycleway on-ramp connection from Queen Street at North Strathfield to the existing M4
- Tunnel support systems and services such as electricity substations, fire pump rooms and tanks, water treatment facilities, and fire and life safety systems including emergency evacuation infrastructure
- Motorway operations complex on the northern side of the existing M4, east of the Homebush Bay Drive interchange
- Provision of road infrastructure and services to support the future implementation of smart motorway operations (subject to separate planning approval)

- Installation of tolling gantries and traffic control systems along the length of the project
- Provision of new and modified noise walls
- Provision of low noise pavement for new and modified sections of the existing M4
- Temporary construction ancillary facilities and temporary works to facilitate the construction of the project.

An overview of the project at completion is shown in .

The project does not include work required for reconfiguring Parramatta Road as part of the urban transformation program. The project does not include ongoing motorway maintenance activities during operation. These would be subject to separate assessment and approval as appropriate.

2.2 Construction activities

2.2.1 Overview

Construction activities associated with the project would generally include:

- Enabling and temporary works, including construction power, water supply, ancillary site establishment, demolition works, property adjustments and public transport modifications (if required)
- Construction of the road tunnels, interchanges, intersections and roadside infrastructure
- Haulage of spoil generated during tunnelling and excavation activities
- Fitout of the road tunnels and support infrastructure, including ventilation and emergency response systems
- Construction and fitout of the motorway operations complex and other ancillary operations buildings
- Realignment, modification or replacement of surface roads, bridges and underpasses
- Implementation of environmental management and pollution control facilities for the project.

The project assessed in this report does not include surveys, sampling or investigation to inform the design or assessment, such as test drilling, test excavations, geotechnical investigations, or other tests. It also does not include adjustments to, or relocation of, existing utilities infrastructure undertaken prior to commencement of construction. These would be subject to separate assessment and approval as appropriate.

2.2.2 Construction footprint

The total area required for construction of the project, including construction ancillary facilities, is referred to as the ‘construction footprint’. The construction footprint would be about 65 hectares in total, comprising about 48 hectares at the surface and about 17 hectares below ground.

In addition to below ground works, surface works would be required to support tunnelling activities and to construct surface infrastructure such as interchanges, tunnel portals, ventilation facilities, ancillary operations buildings and facilities, and new cycleway facilities near the Homebush Bay Drive interchange and Queen Street at North Strathfield.

The overall surface construction footprint generally aligns with the operational footprint, with the locations of future operational ancillary facilities being used to support construction work. Some additional areas adjacent to the operational footprint (around the portals and on- and off-ramps, and also at the tunnel mid-point) would also be required during the construction stage only to facilitate construction.

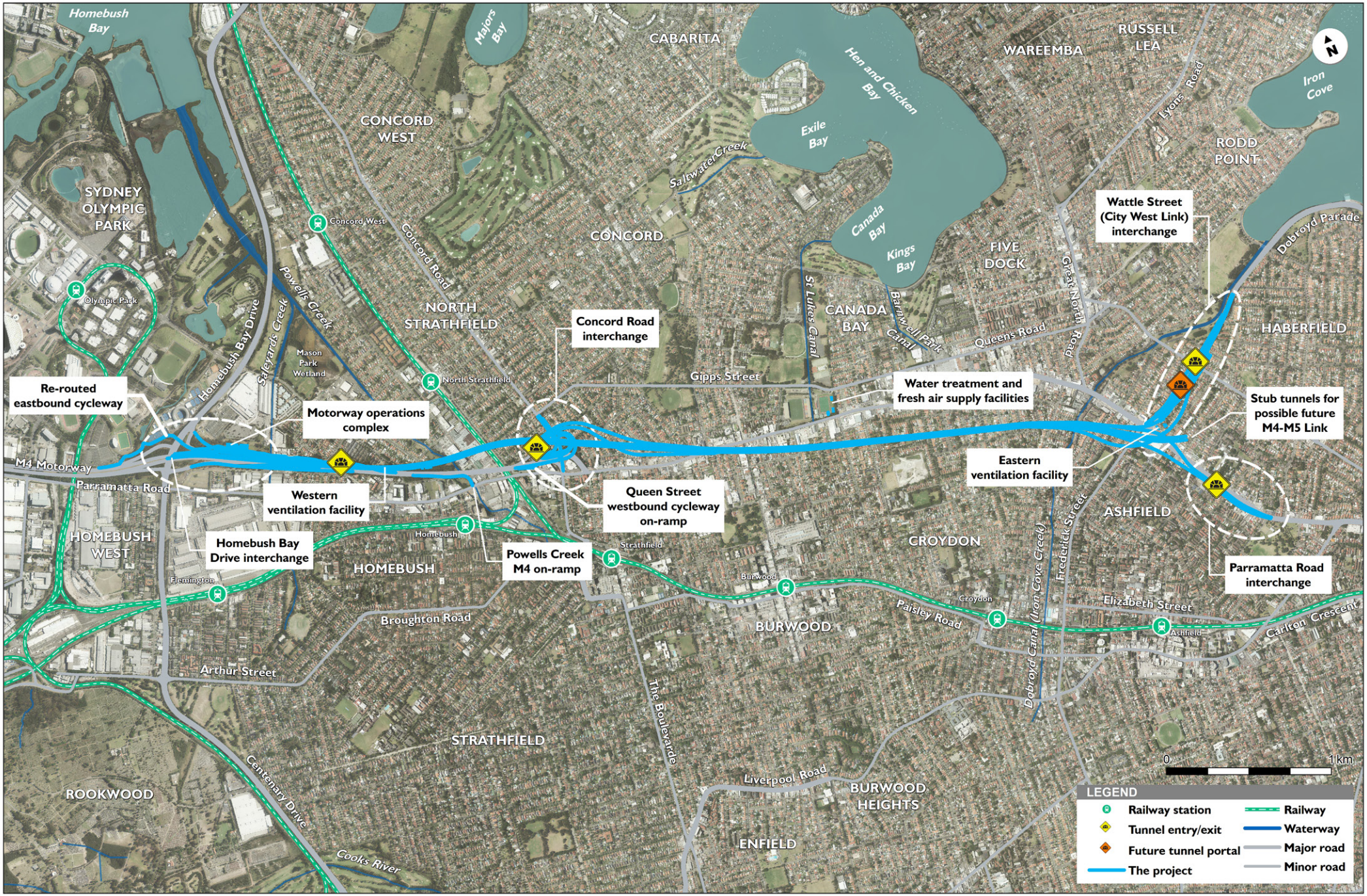


Figure 2.1 Overview of the proejct

Construction ancillary facilities currently proposed would be required at the following 10 locations:

- Homebush Bay Drive civil site (C1)
- Pomeroy Street civil site (C2)
- Underwood Road civil and tunnel site (C3)
- Powells Creek civil site (C4)
- Concord Road civil and tunnel site (C5)
- Cintra Park tunnel site (C6)
- Northcote Street tunnel site (C7)
- Eastern ventilation facility site (C8)
- Wattle Street and Walker Avenue civil site (C9)
- Parramatta Road civil site (C10).

An overview of the construction footprint is shown in .

The final size and configuration of construction ancillary facilities would be further developed during detailed design.

2.2.3 Construction program

Subject to planning approval, construction of the project is planned to start in the second quarter of 2016, with completion planned for the first quarter of 2019. The total period of construction works is expected to be around three years, including nine months of commissioning occurring concurrently with the final stages of construction. The indicative construction program is shown in .

Table 2.1 Indicative construction program overview

Construction activity	Indicative construction timeframe															
	2016				2017				2018				2019			
Construction access excavation (all sites)																
Tunnelling (excavation)																
Tunnel drainage and pavement works																
Tunnel mechanical and electrical fitout works																
Tunnel completion works																
Homebush Bay Drive interchange																
M4 surface works																
Western ventilation facility																
Powells Creek on-ramp																
Concord Road interchange																
Wattle Street interchange																
Parramatta Road interchange																
Eastern ventilation facility																
Cintra Park fresh air supply facility																
Cintra Park water treatment facility																

Construction activity	Indicative construction timeframe															
Motorway operations complex																
Mechanical and electrical fitout works																
Site rehabilitation and landscaping																

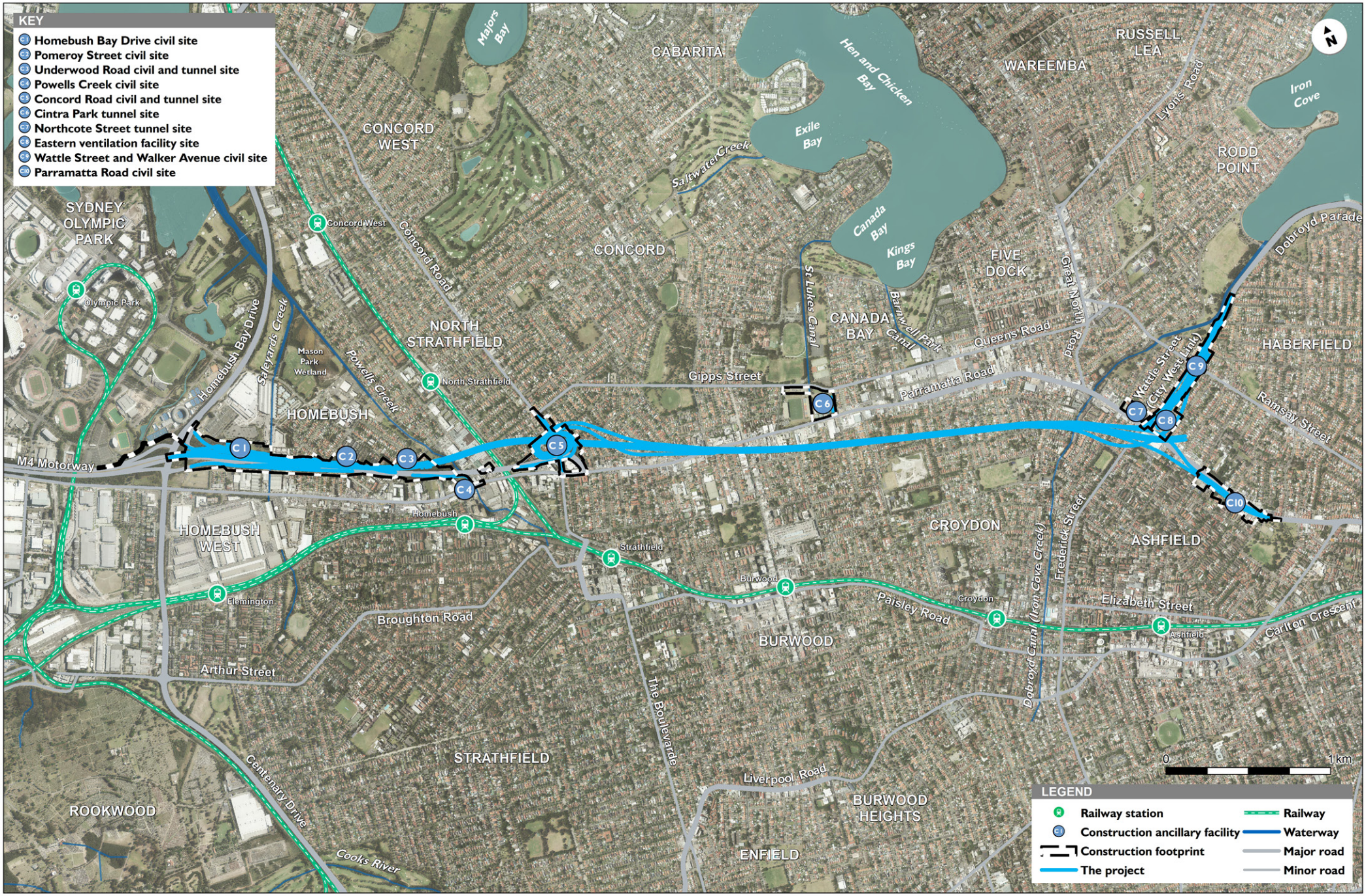


Figure 2.2 Overview of construction footprint and construction ancillary facilities

3 Assessment methodology

3.1 What is a risk assessment?

3.1.1 Risk

Risk assessment is used extensively in Australia and overseas to assist in decision making on the acceptability of the risks associated with the presence of contaminants in the environment and evaluation of projects with potential risks to the public. Risk is commonly defined as the chance of injury, damage, or loss. Therefore, to put oneself or the environment 'at risk' means to participate, either voluntarily or involuntarily, in an activity or activities that could lead to injury, damage, or loss.

Voluntary risks are those associated with activities that we decide to undertake such as driving a vehicle, riding a motorcycle and smoking cigarettes. Involuntary risks are those associated with activities that may happen to us without our prior consent or forewarning. Acts of nature such as being struck by lightning, fires, floods, tornados, and exposures to environmental contaminants are examples of involuntary risks.

3.1.2 Defining risk

Risks to the public and the environment are determined by direct observation or by applying mathematical models and a series of assumptions to infer risk. No matter how risks are defined or quantified, they are usually expressed as a probability of adverse effects associated with a particular activity. Risk is typically expressed as a likelihood of occurrence and/or consequence (such as negligible, low or significant) or quantified as a fraction of, or relative to, an acceptable risk number.

Risks from a range of facilities (eg industrial or infrastructure) are usually assessed through qualitative and/or quantitative risk assessment techniques. In general, risk assessments seek to identify all relevant hazards; assess or quantify their likelihood of occurrence and the consequences associated with these events occurring; and provision of an estimate of the risk levels for people who could be exposed, including those beyond the perimeter boundary of a facility.

3.2 Overall approach

The methodology adopted for the conduct of the HHRA is in accordance with national and international guidance that is endorsed/accepted by Australian health and environmental authorities, and includes:

- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards,* 2012 (enHealth 2012a)
- *Health Impact Assessment Guidelines*, (enHealth 2001)
- *Australian Exposure Factor Guide*, EnHealth Council, 2012 (enHealth 2012b)
- *Schedule B8 Guideline on Community Engagement and Risk Communication*, National Environment Protection (Assessment of Site Contamination) Measure, 1999 National Environment Protection Council (NEPC) (NEPC 1999 amended 2013a)
- *National Environmental Protection (Air Toxics) Measure*, Impact Statement for the National Environment Protection (Air Toxics) Measure, 2003 (NEPC 2003)
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment), EPA-540-R-070-002, January 2009 (United States Environment Protection Agency (USEPA)(USEPA 2009b).

More specifically, in relation to the assessment of health impacts associated with exposure to particulates, guidelines available from the NEPC ((Burgers & Walsh 2002; NEPC 1998, 2002, 2003, 2009, 2010), World Health Organisation (WHO) (Ostro 2004; WHO 2003, 2006b; 2006a, {Ostro, 2004 #861; 2013a) and the USEPA (USEPA 2005a, 2009a) have been used as required.

These guidance have been used to evaluate health impacts associated with the project that relate to:

- Changes in air quality in the tunnel (as presented in Section 7)

- Changes in air quality arount the tunnel (within the community) (as presented in Section 6)
- Changes in the noise environment during construction and operation (as presented in Section 8)
- Changes in the social environment (as presented in Section 9).

In following this guidance, the following tasks have been completed and are presented in this technical working paper.

3.2.1 Data evaluation and issue identification

This task involves a review of all available information that relates to the proposed design and outcomes from relevant specialist studies undertaken in relation to air quality within the tunnel itself, air quality around the tunnel (within the surrounding community), noise and vibration. Specifically the assessment has considered existing conditions (in relation to air quality and noise) and estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project.

This aspect of the assessment also considers the available guidelines for air quality and noise, whether these guidelines are based on the protection of community health, and if a more detailed evaluation of specific impacts is required. The HHRA has considered a more detailed evaluation of exposures to nitrogen dioxide and particulate emissions within the surrounding community from the operation of the project. In addition a review of health risk impacts associated with air quality within the tunnel itself has been included.

3.2.2 Exposure assessment

This involves the identification of populations located in the project study area who may be exposed to impacts from the project, in particular, the populations in areas adjacent to the Homebush Bay Drive, Concord Road, Wattle Street and Parramatta Road interchanges. The existing air and noise environments as well as the health of the existing population has been considered in relation to the key health endpoints, relevant to the assessment of exposures to particulate matter, that require further detailed consideration in this assessment. The assessment of potential nitrogen dioxide and particulate matter exposure has considered both acute and chronic inhalation exposures relevant to the project.

3.2.3 Toxicity assessment

The objective of the toxicity assessment is to identify the adverse health effects and quantitative toxicity values or exposure-response relationships that are associated with the key pollutants that have been identified and evaluated as part of this assessment. This has been applied to the assessment of exposures to particulate matter where the following has been undertaken:

- Identify the adverse health effects associated with exposure to particulate matter. Based on the available information, the most robust health end-points (effects or outcomes) for the assessment of inhalation exposure to particulate matter (assessed over different size fractions) have been identified. The most robust health end-points are where a relationship has been established between exposure to particulate matter and a specific health end-point (effect/outcome)
- Identify the most relevant and robust exposure-response relationship for the quantitative assessment of exposure to particulate matter. The exposure-response relationships are derived from published peer reviewed sources and relate to the identified health end-points (effects/outcomes)
- The health-endpoints and associated exposure-response relationships adopted for the assessment of particulate matter, particularly derived from combustion sources (such as petrol and diesel vehicles) have been agreed with NSW Health prior to the completion of this assessment.

For other air pollutants national guidelines based on the protection of health have been adopted.

3.2.4 Risk characterisation

Risks have been characterised using quantitative and qualitative assessment methods. For the assessment of particulates, the quantitative assessment has involved identification of an exposure concentration that relates to the project (ie the change in particulate concentration associated with the project) and use with relevant exposure-response relationships (for the health-endpoints/effects assessed). This enables an assessment of an increased annual risk and an increased incidence of the effect occurring within the population of concern.

In some cases a qualitative assessment has been undertaken. A qualitative assessment does not specifically require the quantification of risk or exposure. Rather, the assessment provides a relative or comparative evaluation of whether the exposure or impact considered is either acceptable or unacceptable in the local population.

The assessment presented has also considered the level of uncertainty associated with all aspects of the technical studies relied on for the conduct of the HHRA and within the HHRA. The final determination of risks to human health will be based on the quantification of risks as well as consideration of these uncertainties.

3.2.5 Features of the risk assessment

The HHRA has been carried out in accordance with international best practice and general principles and methodology accepted in Australia by groups such as National Health and Medical Research Committee (NHMRC), NEPC and enHealth. There are certain features of risk assessment methodology that are fundamental to the assessment of the outputs and to drawing conclusions on the significance of the results. These are summarised below:

- A risk assessment is a tool (that is systematic) that addresses potential exposure pathways based on an understanding of the nature and extent of the impact assessed and the uses of the local area by the general public. The risk assessment is based on an estimation of maximum, or worst-case, ground level concentrations modelled in the local community and hence is expected to overestimate the actual risks
- Conclusions can only be drawn with respect to emissions to air derived from the project as outlined in this technical working paper
- Available statistics in relation to the existing health status of the existing community are presented in the technical working paper; however the HHRA does not provide an evaluation of the overall health status of the community or any individuals. Rather, it is a logical process of calculating and comparing potential exposure concentrations (acute and chronic) in surrounding areas (associated with the project) with regulatory and published acceptable air concentrations that any person may be exposed to over a lifetime without unacceptable risk to their health. It can also involve calculating an incremental impact that can be evaluated in terms of an acceptable level of risk
- The risk assessment reflects the current state of knowledge regarding the potential health effects of chemicals identified and evaluated in this assessment. This knowledge base may change as more insight into biological processes is gained, further studies are undertaken and more detailed and critical review of information is conducted.

This assessment has focused on key impacts to air quality, noise and vibration and social changes. These are the aspects that were identified in the SEARs as requiring detailed consideration within the EIS.

4 Community profile

4.1 General

This section provides an overview of the community potentially impacted by the project. The key focus of the assessment presented is the local community evaluated in relation to the project, referred to as the study area. The study area comprises an area that is approximately eight by six kilometres in size, with the proposed project tunnel alignment located in the centre. The study area is generally illustrated in **Figure 4.1**.

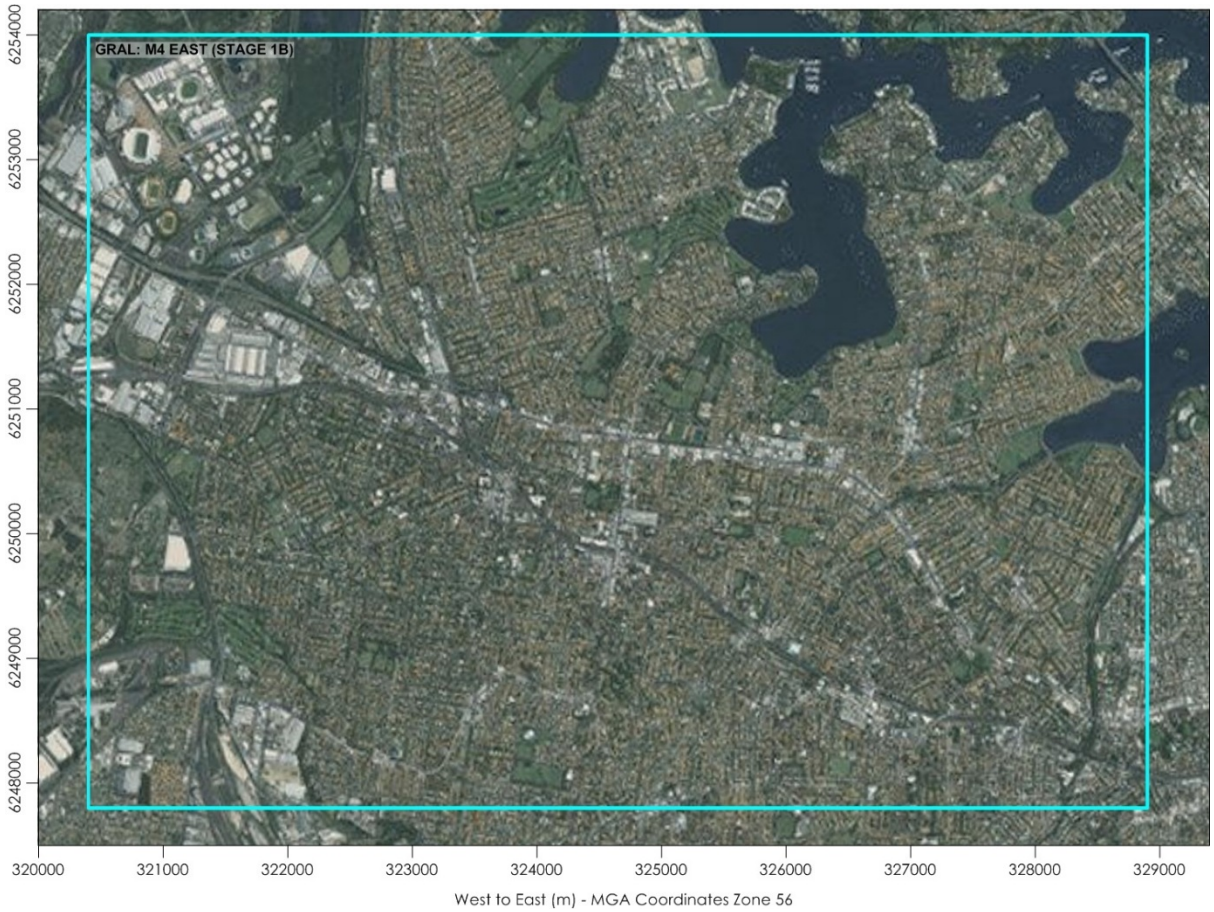


Figure 4.1 Project study area

In reviewing key aspects of the local community that are relevant to the conduct of the HHRA, information has been obtained from the Australian Bureau of Statistics (ABS) Census 2011, information relevant to LGAs and health districts (in particular the Sydney Area Health Service). In some cases (where local data is lacking) information has been obtained (or compared with) data from larger population areas of Sydney and/or NSW.

4.2 Surrounding area and population

The mainline tunnels cover a distance of around 5.5 kilometres from Homebush in the west to Haberfield and Ashfield in the east. The population considered in this assessment includes those who live or work within the vicinity of the western and eastern interchanges (ie where the tunnel interfaces with the surface road network) and the local road network.

The suburbs (or part suburbs) considered are:

- Lidcombe
- Sydney Olympic Park
- Rookwood
- Homebush
- Concord West
- North Strathfield
- Strathfield
- Concord
- Burwood
- Canada Bay
- Croydon
- Five Dock
- Wareemba
- Ashfield
- Russell Lea
- Rodd Point
- Haberfield
- Summer Hill
- Leichardt.

4.3 Sensitive receivers

The assessment of potential impacts on the surrounding community, particularly in relation to air quality, has considered the location where maximum impacts from the project may occur. In addition, impacts in the wider community have also been considered. Within the wider community, a number of additional locations, referred to as community receivers, have been identified in the suburbs close to the project. Community receivers are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations comprise hospitals, child care facilities, schools and aged care homes/facilities.

Table 4.1 presents a list of the community receivers included in this assessment. It is noted that this is representative only and is not intended to comprise an exhaustive list of community receivers in the study area.

Table 4.1 Community receivers included in health risk assessment

Community Receptors	Type of Receptor	Suburb
Peek-A-Boo Early Learning Centre	Childcare	Haberfield
Aiya Medical Centre	Medical	Homebush
St John of God Burwood Hospital	Medical	Burwood
MLC School Sydney	School	Burwood

Community Receptors	Type of Receptor	Suburb
Southern Cross Catholic Vocational College	School	Burwood
Burwood ENT Surgery	Medical	Burwood
Burwood Chest Clinic	Medical	Burwood
Homebush Boys High School	School	Strathfield
Homebush Public School	School	Strathfield
Homebush Medical Centre	Medical	Strathfield
Pre-Uni New College	School	Strathfield
McDonald College	School	North Strathfield
Light House Child Care	Childcare	North Strathfield
MLC School Sydney	School	Burwood
Strathfield Private Hospital	Medical	Strathfield
St Mary's Catholic Primary School	School	Concord
Rosebank College	School	Five Dock
Little VIPs	Childcare	Haberfield
Ella Community Child Care Centre	Childcare	Haberfield
Ramsay Street Medical Centre	Medical	Haberfield
St. John of Arc Catholic Primary School	School	Haberfield
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	Haberfield
Dobroyd Point Public School	School	Haberfield
Domremy College	School	Five Dock
The Infants Home	Childcare	Ashfield
Lucas Gardens School	School	Canada Bay
Educare Playschool	Childcare	Croydon
Goodstart Early Learning	Childcare	Haberfield
Haberfield Public School	School	Haberfield
Happy Little Campers	Childcare	Five Dock
Burwood Girls High School	School	Burwood
St Mary's Nursing Home	Aged care	Concord
Linburn Nursing Home	Aged care	Burwood
Redleaf Manor Aged Care	Aged care	Concord
BUPA Aged Care	Aged care	Ashfield
Presbyterian Aged Care Haberfield	Aged care	Haberfield
Wyoming Aged Care	Aged care	Summer Hill
Woodfield Aged Care	Aged care	Haberfield

In addition to these community receivers, approximately 10,000 individual receivers have been modelled in the streets/suburbs located in the study area. These individual receivers represent residential dwellings, workplaces or recreational areas in the surrounding community. These receptors are referred to as residential, workplace and recreational (RWR) receivers. The RWR will include other community receivers located in the study area, not included in **Table 4.1**. The maximum impacts from all of the RWR receivers have also been evaluated in this assessment.

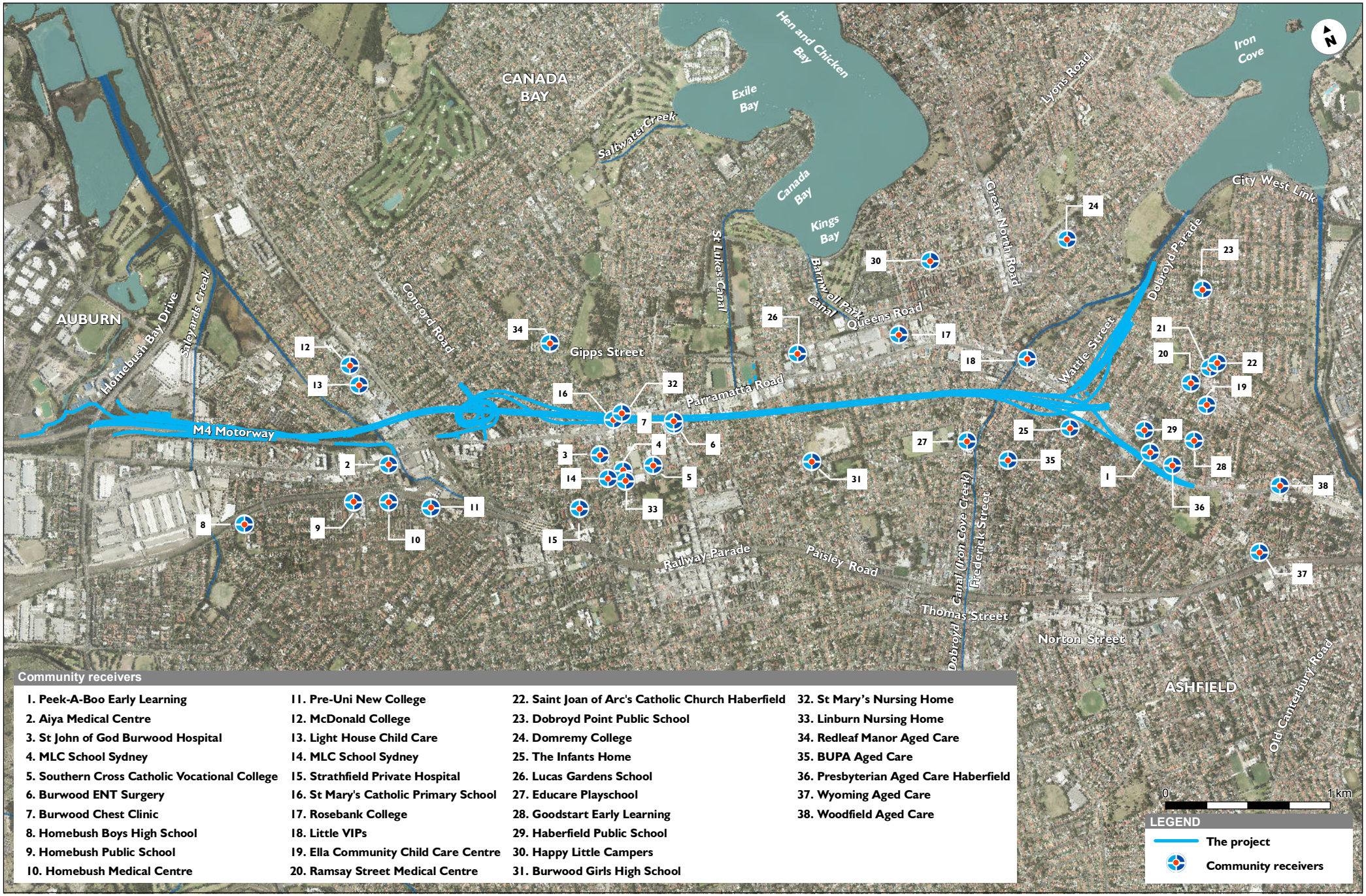


Figure 4.2 Community receivers evaluated in human health risk assessment

4.4 Population profile

The population within the study area comprise residents and workers as well as those attending schools, day-care, hospitals and recreational areas. The composition of the populations located within the study area is expected to be generally consistent with population statistics for the larger individual suburbs that are wholly or partially included in the study area. Population statistics for the suburbs considered in this assessment (based on state suburb areas) are available from the Australian Bureau of Statistics (ABS) for the Census year 2011 and are summarised in **Table 4.2**. For the purpose of comparison, the population statistics presented also include the statistics for the larger statistical areas of Greater Sydney and the rest of the NSW (excluding Greater Sydney) (as defined by the ABS).

Table 4.3 presents a summary of a selected range of demographic measures relevant to the population of interest with comparison to statistical local area of Greater Sydney and the rest of the NSW (excluding Greater Sydney).

Table 4.2 Summary of population statistics

Location	Total population		% Population by key age groups					
	Male	Female	0–4	5–19	20–64	65+*	1–14*	30+*
State suburbs (SA2)								
North Strathfield	2246	2195	7.6	15.3	68.9	8.2	15.5	53.5
Homebush	6497	6022	6.4	15.9	71.1	6.9	14.4	51.7
Concord West	2849	3001	6.4	19.4	59.9	14.3	17.9	62.5
Sydney Olympic Park	44	21	9.2	26.6	67.7	0.0	26.6	53.1
Concord	6892	7258	6.4	19.1	58.5	16.0	18.2	63.0
Strathfield	11,864	11,775	4.2	16.3	65.4	14.1	13.0	55.7
Lidcombe	8473	8197	6.4	16.7	67.1	9.8	15.4	56.7
Rookwood	3	5	0.0	0.0	100.0	0.0	0.0	33.3
Haberfield	3234	3416	5.4	18.8	54.9	20.9	17.5	66.9
Ashfield	10,845	11,344	5.6	12.5	68	10.6	12.5	60.7
Five Dock	4186	4561	7.4	14.8	62.2	15.7	16.2	66.6
Rodd Point	605	690	8.0	18.2	57.5	16.4	18.8	65.8
Russell Lea	2292	2488	7.1	16.3	60.0	16.6	16.7	65.4
Wareemba	696	778	7.5	15.1	59.1	18.3	16.4	68.7
Canada Bay	640	656	7.6	16.9	60.1	15.3	17.7	64.9
Leichhardt	6335	7185	8.9	10.7	69.6	10.8	14.5	65.4
Summer Hill	3167	3420	6.6	11.6	72.0	9.8	13.0	63.5
Burwood	6070	6396	4.3	13.5	69.2	13.0	11.1	55.1
Croydon	4991	5390	6.2	17.0	61.3	15.5	16.1	62.4
Larger local statistical areas (SA3)								
Strathfield – Burwood – Ashfield	67,285	69,922	5.7	15.3	65.9	13.1	14.3	59.8%
Canada Bay	35,938	38,218	6.9	14.9	64.2	14.0	15.5	63.4
Leichhardt	24,726	27,471	8.2	11.7	69.9	10.2	14.9	67.2
Auburn	38,568	35,853	7.6	18.3	65.5	8.6	18.0	53.6
Bankstown	78,234	80,838	7.7	21	57.5	13.8	20.3	57.7
Statistical areas of Sydney and NSW								
Greater Sydney	2,162,221	2,229,453	6.8	18.7	61.7	12.9	17.9	60
Rest of NSW (excluding Greater Sydney)	1,239,007	1,273,942	6.3	19.7	55.9	18	18.2	63

Ref: Australian Bureau of Statistics, Census Data 2011

SA2 are statistical areas based on state suburbs

SA3 are larger statistical areas that are aggregates of SA2 areas with populations between 30,000 and 130,000

* Age groups specifically relevant to the characterisation of risk (as presented in **section 6**)

Based on this general population data, the suburbs surrounding the proposed interchanges are generally similar to Greater Sydney with the exception of the following:

- Homebush, Summer Hill and Leichardt has a greater proportion of adults aged 20–64 years, and a lower proportion of adults aged over 65 years
- Sydney Olympic Park has a higher proportion of children with none of the population aged 65 years and older
- Burwood, Ashfield, Strathfield and Lidcombe have a lower proportion of children and higher proportion of adults aged 20–64 years
- Haberfield has a higher proportion of the population ages 64 years and older
- Rookwood comprises only eight residents, all aged 20–64 years.

The suburbs of interest in the project study area are located in five different LGAs: Bankstown City Council, Strathfield Council, City of Canada Bay Council, Burwood Council and Ashfield City Council. In addition a small number of residents (63 residents) located in the study area reside in the Auburn City Council LGA.

The estimated population growth from 2011 to 2031 for these areas are (NSW Planning & Infrastructure 2013):

- Strathfield: 52.2 per cent (with 57.6 per cent increase expected for children aged under 15 years and 93.1per cent increase expected in the population aged 65 years and older)
- Canada Bay: 35.3 per cent (with 52.3 per cent increase expected for children aged under 15 years and 56.9 per cent increase expected in the population aged 65 years and older)
- Burwood: 48.2 per cent (with 54 per cent increase expected for children aged under 15 years and 89.9 per cent increase expected in the population aged 65 years and older)
- Ashfield: 23.5 per cent (with 34.4 per cent increase expected for children aged under 15 years and 46.7 per cent increase expected in the population aged 65 years and older)
- Bankstown: 16.5 per cent (with 52.7 per cent increase expected in the population aged 65 years and older)
- Auburn: 55.4 per cent (with 154.4 per cent increase expected in the population aged 65 years and older)

Table 4.3 Selected demographics of population of interest

Location	Median age	Median household income ($/week)	Median mortgage repayment ($/month)	Median rent ($/week)	Average household size	Unemployment rate (%)
State suburbs (SA2)						
North Strathfield	31	1590	2400	440	2.6	5.7
Homebush	30	1390	2000	390	2.7	7.4
Concord West	39	1750	2383	390	2.9	3.9
Sydney Olympic Park	31	0	0	0	0.0	0.0
Concord	39	1734	2500	426	2.9	4.2
Strathfield	33	1470	2500	420	2.9	6.1
Lidcombe	33	1230	2000	370	3.1	7.6
Rookwood	51	2833	0	330	3.5	0.0
Haberfield	44	1730	2600	390	2.8	4.1
Ashfield	35	1314	2100	365	2.4	7.1
Five Dock	39	1706	2800	440	2.5	3.7
Rod Point	41	1900	2500	620	2.7	3.8
Russell Lea	39	1829	3000	430	2.6	3.2
Wareemba	41	1634	2903	480	2.5	4.5
Canada Bay	39	1738	3200	420	2.6	3.9
Leichardt	36	1924	2817	460	2.3	4.0
Summer Hill	35	1570	2100	360	2.2	5.1
Burwood	32	1185	2167	421	2.7	8.6
Croydon	38	1509	2400	390	2.8	5.6
Larger local statistical areas (SA3)						
Strathfield - Burwood - Ashfield	35	1418	2167	380	2.6	6.2
Canada Bay	37	1832	2600	480	2.5	4.2
Leichhardt	37	2234	3000	480	2.3	4.0
Auburn	31	1158	2000	350	3.1	8.6
Bankstown	35	1104	2058	315	3	7.4
Statistical areas of Sydney and NSW						
Greater Sydney	36	1447	2167	351	2.7	5.7
Rest of NSW (excluding Greater Sydney)	41	961	1560	220	2.4	6.1

Source: Australian Bureau of Statistics, Census Data 2011

SA2 are statistical areas based on state suburbs

SA3 are larger statistical areas that are aggregates of SA2 areas with populations between 30,000 and 130,000

The social demographics of an area have some influence on the health of the existing population. As shown in

Table 4.3, the population located in the study area generally has lower unemployment (with the exception of Homebush, Strathfield, Lidcombe, Ashfield and Burwood) with a higher income and also higher mortgage repayments and rental costs compared with Greater Sydney and the rest of NSW.

4.5 Existing health of population

4.5.1 General

The assessment presented in this report has focused on key pollutants that are associated with construction and combustion sources (from vehicles), including nitrogen dioxide and particulate matter (namely $PM_{2.5}$ and PM_{10}). For these pollutants there are a large number of sources in the study area including other combustion sources (other than from the project), other local construction/earthworks, personal exposures (such as smoking) and risk taking behaviours that have the potential to affect the health of any population.

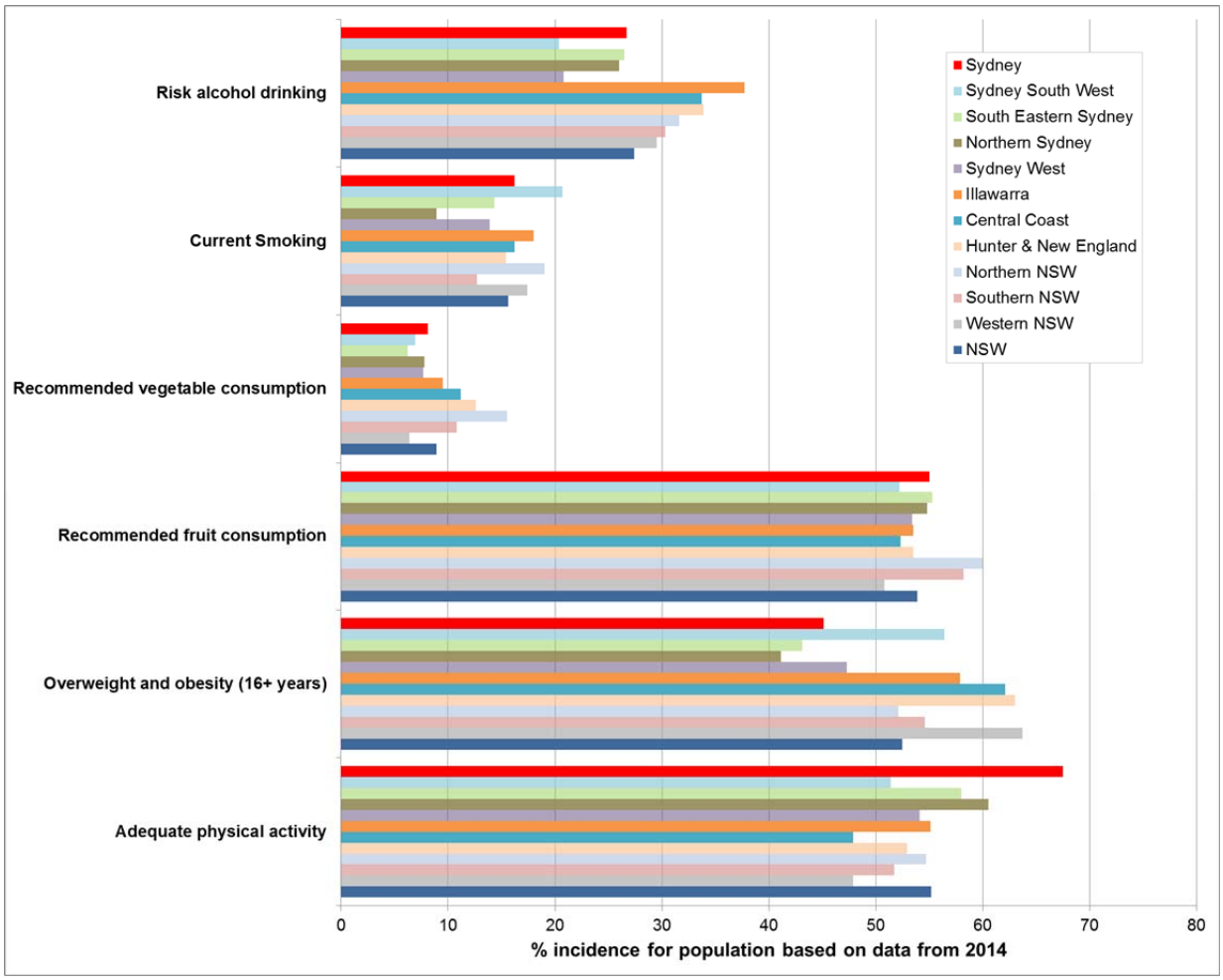
When considering the health of a local community there are a large number of factors to consider. The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care. Hence, while it is possible to review existing health statistics for the local areas surrounding the project, and compare them to the Greater Sydney area and NSW, it is not possible or appropriate to be able to identify a causal source, particularly individual or localised sources.

Information relevant to the health of populations in NSW is available from NSW Health for populations grouped by local area health service (where most of the project area is located in the Sydney Area Health Service) or LGA. Not all of the health data is available for all of these areas.

Most of the health indicators presented in this report are not available for each of the smaller suburbs/statistical areas surrounding the site, as outlined in **section 0**. Health indicators are only available from a mix of larger areas (that incorporate the study area), namely the Sydney Area Health Service. There are few health statistics that are reported for the smaller local government areas relevant to this project. The health statistics for these larger areas (and in some cases data for the Greater Sydney area) are assumed to be representative of the smaller population located in the vicinity of the western and eastern interchanges given the similar demographics of these populations to Greater Sydney.

4.5.2 Health-related behaviours

Information in relation to health-related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) is available for the larger populations within the local area health services in Sydney and NSW. This includes risky alcohol drinking, smoking, consumption of fruit and vegetables, being overweight or obese, and adequate physical activity. The study population is largely located within the Sydney Area Health Service. The incidence of these health-related behaviours in this area, compared with other health areas in NSW, and the state of NSW (based on data from 2014) is illustrated in **Figure 4.3**.



Note: these health-related behaviours include those where the behaviour/factor may adversely affect health (eg alcohol drinking, smoking, being overweight/obese) and others where the behaviour/factor may positively affect (enhance) health (eg adequate fruit and vegetable consumption and adequate physical activity)

Project area is located in the Sydney Area Health Service (Sydney in the graph) with the far western portion located in Sydney West Area Health Service (Sydney West in the graph).

Figure 4.3 Summary of incidence of health-related behaviours 2009 (source: NSW Health 2015)

Review of this data generally indicates the population in the Sydney Area Health Service area (that include the project area):

- Have similar rates of risky alcohol drinking and smoking and similar intakes of recommended consumption of fruit and vegetables compared with NSW
- Have higher rates of adequate physical activity and lower rates of being overweight and obese compared with NSW.

In addition, it is noted that the LGAs of Ashfield, Burwood and Strathfield have similar rates for psychological distress compared with NSW. The Canada Bay LGA has slightly lower rates for psychological distress compared with NSW.

4.5.3 Health indicators

Figure 4.4 presents a comparison of the rates of the key mortality indicators based on data from 2011 for all causes, potentially avoidable, cardiovascular disease, lung cancer and chronic obstructive pulmonary disease (COPD), reported in the larger Sydney Area Health Service, with comparison to other NSW area health services (in urban and regional areas) as well as NSW as a whole.

Figure 4.5 present a comparison of the rates of the hospitalisations for key health effects based on data from 2013–14 for diabetes, cardiovascular disease, asthma (5–34 years) and COPD (65+ years) reported in the larger Sydney Area Health Service, with comparison to other NSW area health services (in urban and regional areas) as well as NSW as a whole.

It is noted that the data reported in these figures is based on statistics that are publically available from NSW Health. Hence some of the statistics for mortality and hospitalisations relate to slightly different health endpoints and/or different age groups. The statistics are included for general comparison and discussion. Actual health statistics considered in the characterisation of risk are presented in **Table 4.4**.

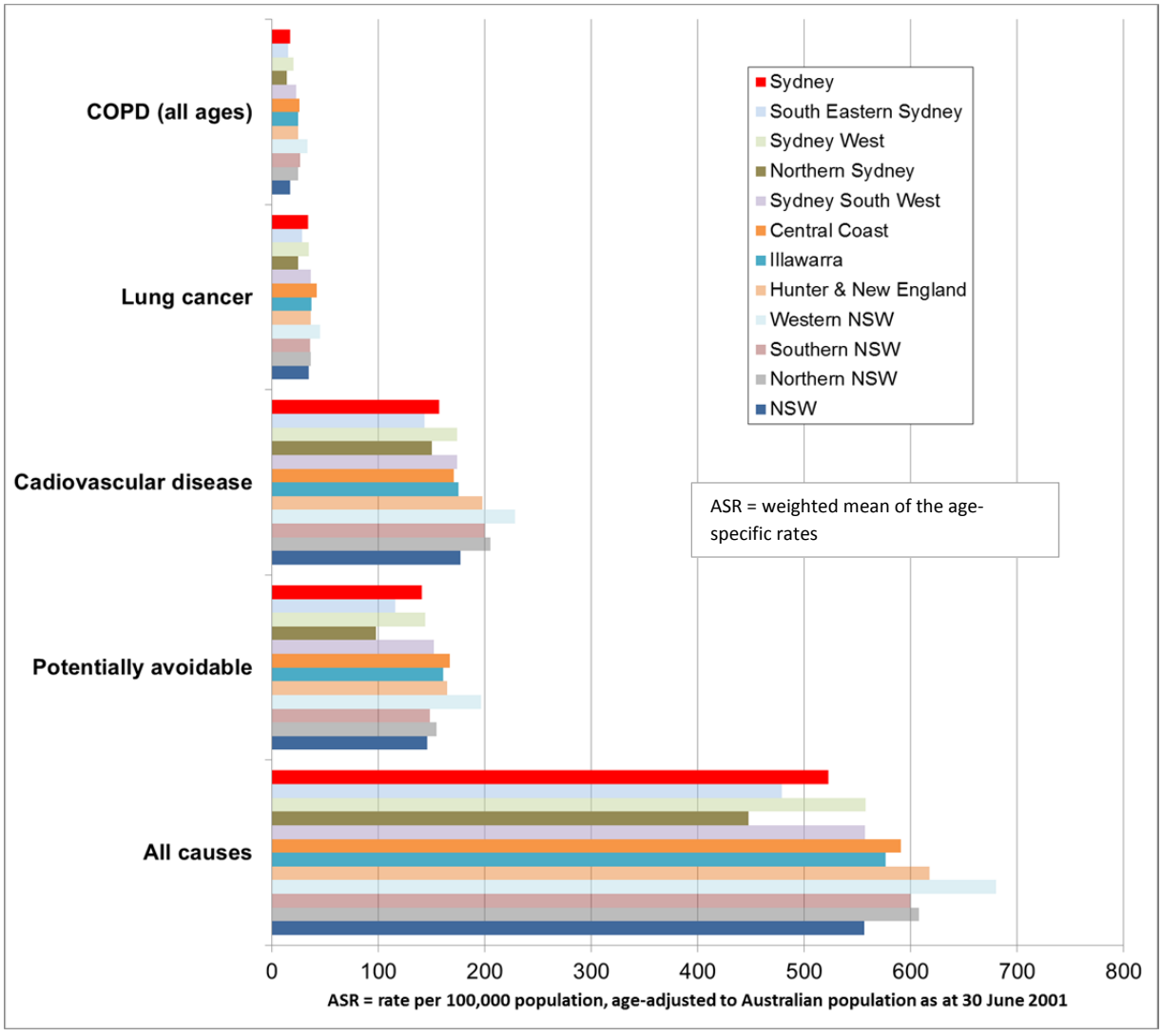


Figure 4.4 Summary of mortality data 2011. (Source: NSW Health 2015)

Review of the figures presented above indicate that the rate of mortality for the indicators presented in the Sydney Area Health Service is slightly lower than but similar to that reported for NSW.

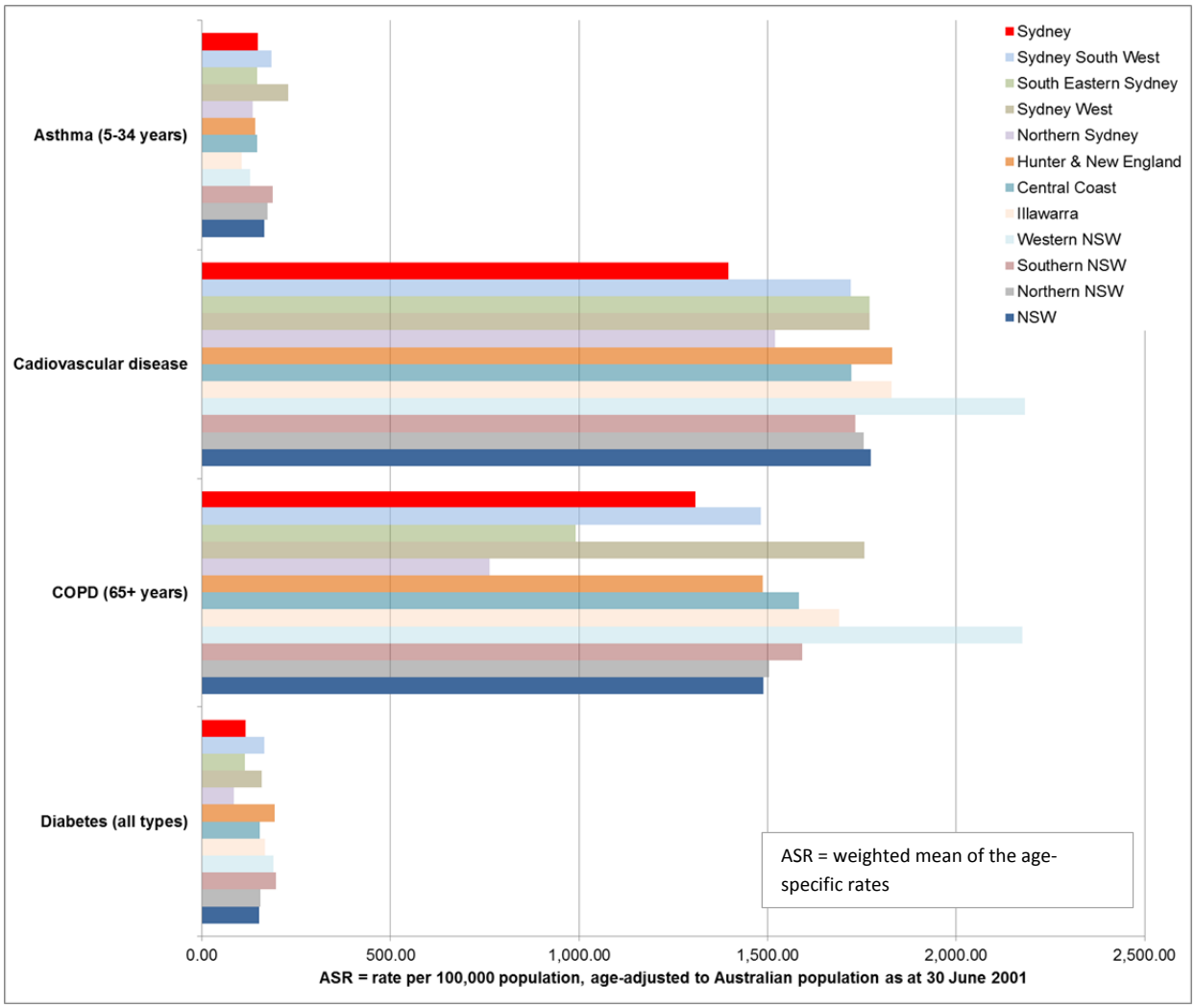


Figure 4.5 Summary of hospitalisation data 2013–14. (Source: NSW Health 2015)

Review of the figures presented above indicate that the rate of hospitalisations for the indicators presented in the Sydney Area Health Service is slightly lower than but similar to that reported for NSW.

In relation to some more specific health indicators **Table 4.4** presents the available data for the slightly smaller population areas in the LGAs of Ashfield, Burwood, Canada Bay and Strathfield. These have been compared with available data for the Sydney Area Health District, Sydney and NSW. It is noted that health statistics are not available for the LGAs for all the health endpoints considered in this assessment. Where available, they have been presented for the purpose of comparison with statistics from Sydney and NSW.

The health indicators presented in the table include those that are specifically relevant to the quantification of exposure to nitrogen dioxide and particulate matter presented in **Section 6**.

Table 4.4 Summary of key health indicators

Health indicator	Data available for population of (rate per 100,000 population)						
	Ashfield	Burwood	Canada Bay	Strathfield	Sydney area Health	Sydney (wider metro area)	NSW
Mortality							
All causes – all ages	994.4 (6)	931.7 (6)	580.0 (6)	1232.4 (6)	**522.3 (6)**	--	556.6 (6)
All causes (non-trauma) ≥30 years	--	--	--	--	--	**56.9***	--
All causes ≥30 years	--	--	--	--	--	**976.6***	--
Cardiopulmonary ≥30 years	--	--	--	--	--	**392.4***	
Cardiovascular – all ages	261.8 (4)	176.5 (4)	150.4 (4)	160.0 (4)	**152.4 (4)**	191.8*	160.4 (4)
Respiratory – all ages	--	--	--	--	**51.5 (4)**	51.5*	49.4 (4)
Hospital admissions							
Coronary heart disease	309.2 (5)	375.8 (5)	381.5 (5)	448.9 (5)	361.3 (5)	--	567.1 (5)
COPD >65 years	1109.7 (5)	1141.0 (5)	1029.8 (5)	911.2 (5)	1308.8 (5)	--	1489.1 (5)
Cardiovascular disease							
All ages	1499.1 (5)	1518.5 (5)	1575.5 (5)	1551.9 (5)	1394.5 (5)	2001.1*	1773.0 (5)
>65 years	--	--	--	--	--	**9064.6***	
Respiratory disease							
All ages	--	--	--	--	1520.1 (5)	**2028.5***	1770.2 (5)
>65 years	--	--	--	--	--	**3905.1***	
Asthma							
Asthma hospitalisations (ages 5–34 years)	--	--	--	--	149.0 (5)	--	165.8 (5)
Asthma hospitalisations (1–14 years)	--	--	--	--	--	**1220.7***	--
Asthma prevalence (current) for children aged 2–15 years	--	--	--	--	6.9% (6)	--	--
Current asthma for ages 16 and over	--	--	--		7.7% (5)	--	--

* Data for Sydney Metropolitan area for 2010 based on hospital statistics and population data (both for 2010) used in review of exposure and risks to inform recommendations for updating the National Environment Protection Measure (NEPM) Ambient Air Quality (AAQ) (Golder 2013)

All other data has been obtained from Health Statistics New South Wales, where

4: Data for 2010–11 5: Data for 2013–14 or 2014 only 6: Data for 2011–12 or 2012 only

-- No data available

Bold: Data used in the characterisation of risk (refer to section 6)

In addition the following is noted from the LGA Health Profiles for the council areas:

- Ashfield: this LGA has the highest number of General Practitioners (GPs) per-capita than any LGA in the Sydney area. Ashfield LGA is serviced by Royal Prince Alfred (RPA) and the Repatriation General Hospital in Concord as well as Canterbury Hospital. The availability of aged care facilities is the highest in the Sydney area
- Burwood: residents present to emergency departments at a significantly greater rate than most other LGAs in the Sydney area, potentially reflecting a gap in availability of primary care
- Canada Bay and Strathfield: the number of GPs per capita is one of the lowest in the Sydney area.

Review of the data presented in **Table 4.4** generally indicates that for the population in the LGAs that include the project area and the Sydney Area Health Service, the health statistics (including mortality rates and hospitalisation rates for most of these categories) are generally lower than compared with a number of other health areas and the whole of NSW.

For the assessment of potential health impacts from the project, where specific health statistics for the smaller populations within the project area is not available (and not reliable due to the small size of the population), adopting health statistics from the whole of NSW is considered to provide a representative, if not cautious (eg over estimating existing health issues), summary of the existing health of the population of interest.

4.6 Uncertainties

There are limitations in the use of this data for the quantification of impact and risk. This data is derived from statistics recorded by hospitals and doctors, reported by postcode of residence, and are dependent on the correct categorisation of health problems upon presentation at the hospital. There may be some individuals who may not seek medical assistance particularly with less serious conditions and hence there is expected to be some level of under-reporting of effects commonly considered in relation to morbidity. Quantitatively, the baseline data considered in this assessment is only a general indicator (not a precise measure) of the incidence of these health endpoints.

5 Community concerns

A number of community consultation activities associated with the project have been undertaken as part of the EIS process.

Feedback was received from the community on the project's preliminary concept design, which was announced in November 2013 and displayed until February 2014. Community members provided comments through a range of mechanisms, including information sessions, emails, an online forum, stakeholder meetings, letters, phone calls and other discussions. Consultation with five local councils (Ashfield, Burwood, Canada Bay, Strathfield and Auburn) was undertaken between May and July 2015. In addition these councils provided submissions to the then NSW Department of Planning and Infrastructure on the preliminary concept design. Social infrastructure providers (including those directly affected by property acquisition) were also consulted between June and July 2015.

A range of concerns were raised that related to changes associated with the project that may affect health and wellbeing. These issues are summarised below:

Property impacts

Concern that the property acquisition process may lead to the severance of communities with the following potential impacts identified:

- Residents who are required to relocate and can no longer remain in the local area due to lack of available properties and escalating housing prices
- Division of neighbourhoods due to new road infrastructure, loss of public open space and housing
- Families who are required to relocate may be required to remove their children from local schools, resulting in a loss of social connections
- Property acquisition reducing the number of residents on some streets leading to a loss of friendship, community and quality of life, as well as increased concerns about safety
- New road and tunnel infrastructure surrounding some residential properties may sever local road links to local community facilities and the rest of the community
- Loss of connectivity between some areas.

Traffic and transport

- Safety of residents relating to changed traffic conditions, increases in traffic around tunnel entry and exit points, and construction traffic
- Impacts on Parramatta Road including:
  - Decreased traffic leading to improved safety, increased efficiency, reduced congestion and increased capacity for additional public transport services. Improved urban design and access of the area
  - Reduction in amount of parking along Parramatta Road
- Disruption for motorists and bus passengers during construction
- Increased traffic on local roads during construction, or during operation due to motorists trying to avoid tolls
- Increased travel times
- Opportunities for improved pedestrian and bicycle connections, and concerns about pedestrian and cyclist safety and accessibility (including for the elderly)
- Changed traffic conditions, access to and parking at local destinations, schools, community facilities and other roads.

Air quality, ventilation and health

- The potential impacts on current and future air quality resulting from the project, including the impact on local residential areas, community facilities (eg aged care, schools, childcare)

- The location, design, number and visual impact of the tunnel ventilation components (eg ventilation stacks)
- Adverse health impacts resulting from construction (eg noise, dust, vibration and impacts on health)
- Stress for property owners resulting from uncertainty of property acquisition process, and potential resulting need to relocate.

Concept design

- Issues were raised about whether the financial cost and the local community impacts of the project could be justified, funding approach, location of toll collection points and tolling system, whether there were better alternative transport solutions and whether the concept design could be improved.

Open space, recreational and community facilities

- Use and treatment of residual/remaining land and the need to ensure it is maintained to reduce potential for vandalism and anti-social behaviour, as well as opportunities to use this land as public open space or community use to provide a benefit to the local community
- Impacts on local community facilities during and after construction, including noise, vibration and dust, and changed access
- Loss of access to those community facilities that may be used as construction ancillary facilities sites (eg Concord Oval) or are adjacent to these sites
- Loss of access to those community facilities that may be acquired and the impact of this on the community.

Heritage and environment

- Impact on heritage areas and sites, particularly the Yasmar training facility, Ashfield Park, the Bunyas, and overall heritage of Haberfield
- Concerns about loss of trees and impacts on the Powell's Creek catchment during construction.

Noise and vibration

- Increased noise and vibration resulting from construction and operation of the project, and the impacts of this on residents.

Amenity

- Issues were raised about the visual impact of infrastructure on ground level, the loss of amenity on residential streets (eg visual, noise, character) or improved amenity due to decreased traffic noise and improved public transport
- Impacts and opportunities related to the urban revitalisation of Parramatta Road
- Loss of green space.

Construction

- Issues were raised related to the staging of construction, and potential loss of access to community facilities, particularly those that may be used for construction ancillary facilities sites.

Further community consultation is proposed as outlined in the Community Involvement Plan (WestConnex 2015).

6 Assessment of air quality impacts on local community

6.1 General

The characterisation of changes in air quality as a result of the project is complex. Full details of the assessment undertaken are presented in the Air Quality Assessment Report (AQAR) conducted by Pacific Environment (2015, as presented in Appendices H and I of the EIS). This section presents an overview of the key aspects of the assessment undertaken and an assessment of potential health impacts associated with the predicted changes in air quality in the local community.

6.2 Existing air quality

When predicting the impact of any new or modified source of air pollution, it is necessary to take into account the way in which the emissions from the source will interact with existing pollutant levels. Defining these existing levels and the interactions can be challenging, especially in a large urban area such as Sydney where there is a complex mix of sources. It is important to consider both the temporal and spatial variation in pollutant concentrations; these fluctuate a great deal on short time scales, but also show cyclical variations. Moreover, in large urban areas there is usually a complex mix of pollution sources, and substantial concentration gradients. Short-term meteorological conditions and local topography are also important.

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives to reduce emissions from industry, motor vehicles, businesses and residences.

Historically, elevated levels of carbon monoxide (CO) were generally only encountered near busy roads, but concentrations have fallen as a result of improvements in motor vehicle technology. Since the introduction of unleaded petrol and catalytic converters in 1985, peak CO concentrations in central Sydney have plummeted, and the last exceedance of the air quality standard for CO in NSW was recorded in 1998 (NSW DECCW 2010).

While levels of nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and CO continue to be below national standards, levels of ozone and particulate matter (PM) can exceed the standards from time to time.

Ozone and PM levels are affected by:

- The annual variability in the weather
- Natural events such as bushfires and dust storms, as well as hazard-reduction burns
- The location and intensity of local emission sources, such as wood heaters, transport and industry.

The project lies within an urbanised area of Sydney and hence it is important that the background air quality considered is representative of existing conditions in the local area.

Assessment of background air quality, including meteorological data, requires the use of data that has been collected from equipment that complies with Australian Standards (to ensure that data is reliable and comparable).

The NSW Office of Environment and Heritage (OEH) operates a number of monitoring stations in the Sydney area, with the closest stations being located at Chullora, Earlwood and Rozelle (all within three to four kilometres of the project). The OEH sites at Lindfield, Liverpool, Randwick and Prospect were further away (between around 11 and 17 kilometres from the project), but were still considered important in terms of characterising air quality in the Sydney region.

In addition Roads and Maritime has established several long-term monitoring stations in response to community concerns relating to the ventilation outlet of the M5 East tunnel, and to monitor operational compliance of the tunnel with ambient air quality standards. Four of the Roads and Maritime sites (shown on **Figure 6.1** as CBMS, T1, U1, X1) were in the vicinity of the ventilation outlet. Two Roads and Maritime sites (shown on **Figure 6.1** as F1 and M1) were much closer to busy roads near the M5 East tunnel portals. Other Roads and Maritime ambient air modelling locations established as part of the NorthConnex project (five locations, shown on **Figure 6.1** as NC: 01 to 05) and near the intersection of Epping Road and Longueville Road (to assess impacts form the Lane Cove Tunnel) were also considered.

WDA has established five monitoring stations in the project area to gain a greater understanding of local air quality. The monitoring stations were designed to supplement the existing OEH and Roads and Maritime stations, to establish the representativeness of the data from these sites and to provide long-term air quality data in the vicinity of the project. The project's network includes five monitoring stations at the following locations:

- Wattle Street, Haberfield: roadside monitoring location (WDA: 01)
- Edward Street, Concord: near-road monitoring location (WDA M4 East: 02)
- Bill Boyce Reserve, Homebush: near-road monitoring location WDA M4 East: 03)
- Concord Oval, Concord: roadside monitoring location (WDA M4 East: 04)
- St Lukes Park, Concord: urban background location (WDA M4 East: 05).

These monitoring stations are shown on **Figure 6.1**.

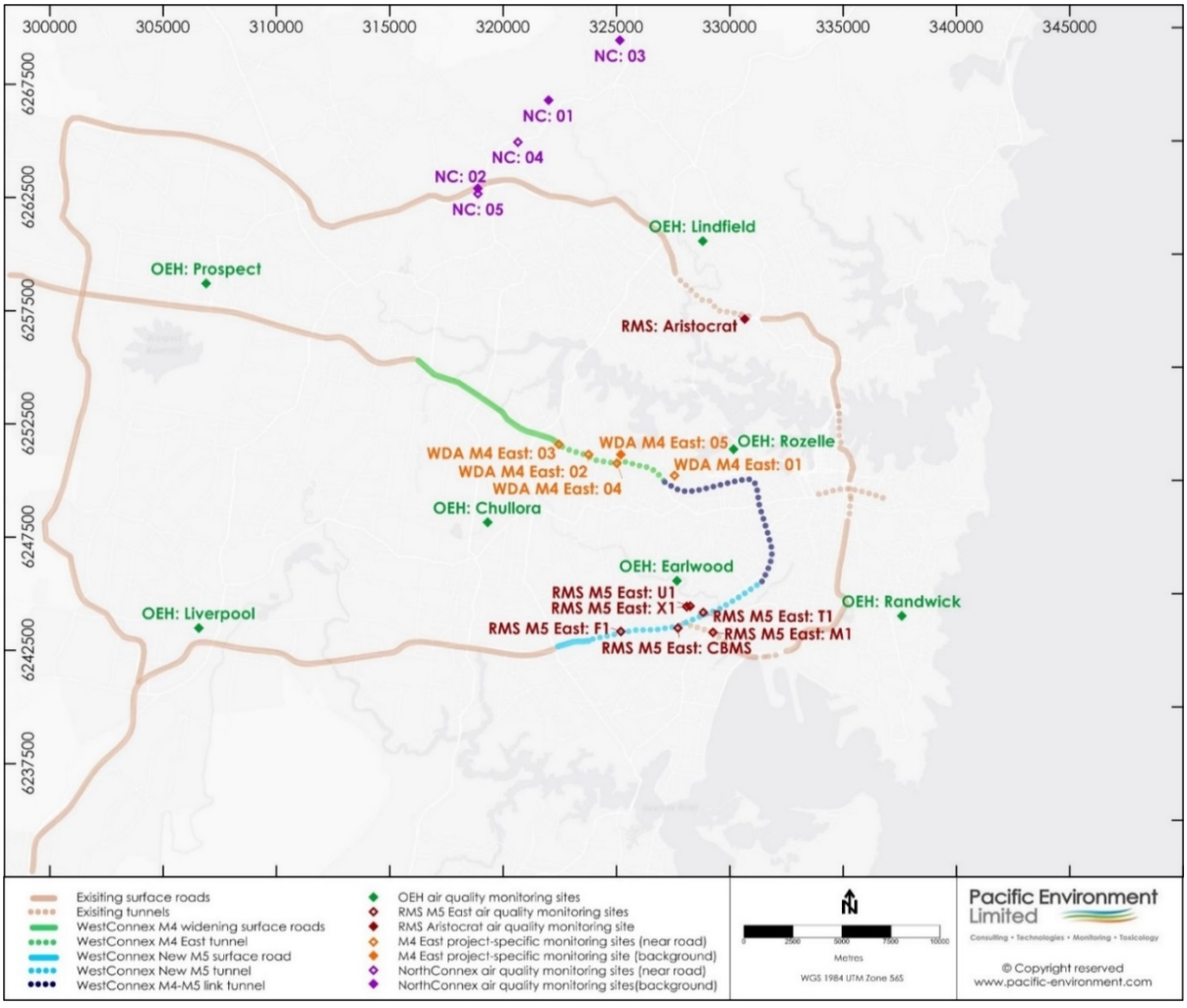


Figure 6.1 Locations of air quality monitoring sites in relation to WestConnex.

Background air quality relevant to the assessment of carbon monoxide, nitrogen dioxide and particulate matter were determined in the AQAR on the basis of data from these monitoring stations. The background air quality considered in the AQAR related to air quality in areas away from major roadways.

In relation to the background air quality considered in the AQAR for the project area, the following is noted:

- **Carbon monoxide**: background air concentrations (as one-hour and eight-hour averages) were below the current air quality guidelines. A general downward trend in background air concentrations was observed, however it was not statistically significant are any monitoring site.
- **Nitrogen dioxide**: background air concentrations (as one-hour and annual averages) were below the current air quality guidelines. The concentration of nitrogen dioxide reported at roadside monitoring stations (not used as background data) were noted to be higher than the background locations.
- **PM_{10}**: background concentrations of PM_{10} (as 24-hour and annual averages) were below the current air quality guidelines. Annual average concentrations of PM_{10} at the OEH sites have shown a downward trend between 2004 and 2014. 24-hour average concentrations of PM_{10} also show a slight downward trend however there is a large amount of variability from year to year.
- **$PM_{2.5}$**: $PM_{2.5}$ is only measured at three OEH sites in the study area. Concentrations at the two OEH sites close to WestConnex – Chullora and Earlwood – showed a broadly similar pattern, with a systematic reduction between 2004 and 2012 being followed by a substantial increase between 2012 and 2014. The main reason for the increase was a change in the measurement method (as the reporting of $PM_{2.5}$ in air varies depending on the type of equipment used). The increases meant that background $PM_{2.5}$ concentrations in the study area during 2014 were already very close to or above the advisory reporting standard in the ambient air quality AAQ NEPM of 8 micrograms per cubic metre. As with the annual mean $PM_{2.5}$ concentration, the maximum 24-hour average concentrations are very close to or above the advisory reporting standard in the PM AAQ NEPM of 25 micrograms per cubic metre.

6.3 Overview of air quality impact assessment

6.3.1 Construction

The AQAR evaluated impacts to air that may occur during construction. The assessment considered impacts that may occur during tunnelling activities and surface works and involved a qualitative assessment approach. The assessment identified the range of activities and equipment proposed to be used during construction, potential emissions from these activities and the location of these activities in relation to sensitive receivers. This approach then allocated a risk associated with the generation of dust and impacts on human health in the adjacent community. For all demolition, earthworks, construction and track-out activities, where no mitigation measures are implemented, the risk of impacts on human health were identified in the AQAR as high. On this basis appropriate mitigation measures are required to minimise impacts on the local community during construction.

For almost all construction activities, the aim should be to prevent significant impacts on receptors through the use of effective mitigation. Experience from similar construction projects shows that this is normally possible. Hence, where mitigation measures are appropriately implemented the AQAR concluded that the residual risk level would normally be ‘not significant’.

However, even with a rigorous Air Quality Management Plan in place, it is not possible to guarantee that the dust mitigation measures will be effective all the time. There is the risk that nearby residences, commercial buildings, hotel, cafés and schools in the immediate vicinity of the construction zone, might experience some occasional dust soiling impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall construction dust is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receptor, at a time when dust is being generated and mitigation measures are not being fully effective.

The likely scale of this would not normally be considered sufficient to change the conclusion that with mitigation the effects will be 'not significant'.

An Air Quality Management Plan will be produced to cover all construction phases of the project. These measures include site management, monitoring, preparing and maintaining the construction sites, maintenance and controls on vehicles and machinery and waste management. Chapter 10 of the AQAR provides additional details on the dust management measures proposed.

6.3.2 Operation

The assessment of changes in air quality associated with the operation of the project has been undertaken on the basis of the tunnel designs specifications and forecasts of tunnel and surface road traffic volumes (and speeds) as outlined in the WestConnex Road Traffic model (WRTM). The project does not include portal emissions (ie emissions from the tunnel entrances and exits), hence emissions associated with the operation of the tunnel relate to the discharge of air from within the tunnel to atmosphere via two ventilation facilities located at the western and eastern ends of the tunnel.

The assessment of potential impacts associated with the project utilised an air dispersion model to predict changes in ambient air quality within the study area (or modelling domain) associated with a range of emissions scenarios. The model used for the assessment was GRAL (Graz Lagrangian Model). This model was selected as it has been shown to provide robust/validated results for assessing air quality in complex urban environments and the model enables simultaneous consideration of all the different types of emission sources in the study area (ie local and regional roads, ventilation outlets and other emissions sources of various types). The model has also been used to evaluate the cumulative air quality impacts associated with all WestConnex projects by considering a larger study area. The following figure (**Figure 6.2**) shows the air modelling domain (study area) considered for the project, as a sub-set of the larger modelling domain considered for all WestConnex projects.

The modelling considered meteorology relevant to the study area, local terrain, and project-specific emission sources. The emission sources relevant to the project addressed in the modelling included the following:

- Emissions from the traffic on the surface road network, including any new roads associated with the project.
- Emissions from the proposed ventilation outlets of the tunnel.
- Emissions from the ventilation outlet of the M5 East tunnel (the only existing tunnel in the GRAL domain). These were defined based on in-stack measurements.

The assessment of cumulative impacts, from the operation of all WestConnex projects, evaluated changes in air quality in the study area from all changes in surface traffic and ventilation outlets associated with all projects in the wider area.

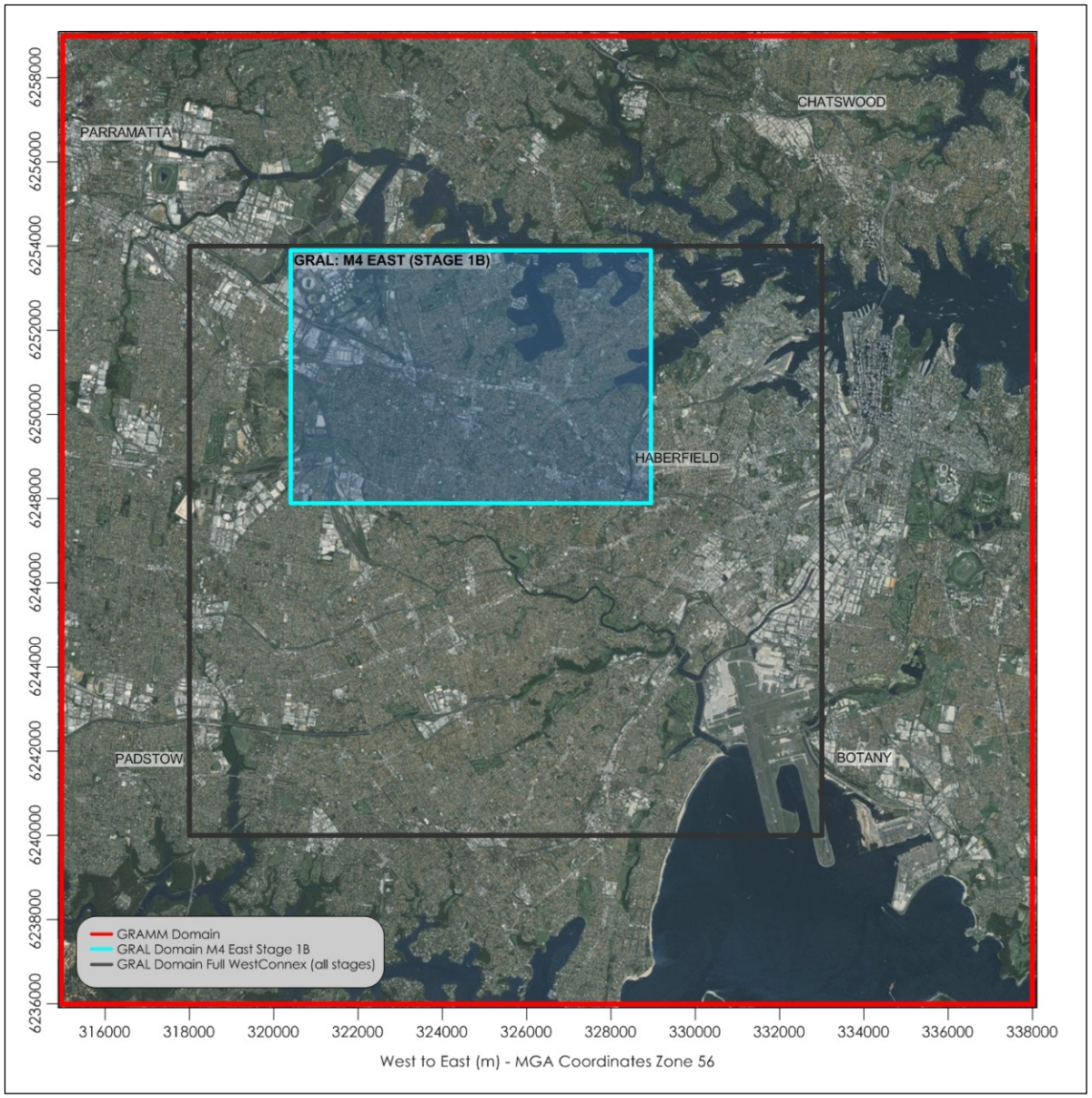


Figure 6.2 **Air quality modelling domains considered for the project and overall WestConnex projects**

When determining the potential emissions to air that may require ventilation from the tunnel the assessment has considered a range of factors associated with the tunnel design, traffic volumes, vehicle mix and age. In addition in-tunnel air quality limits have also been considered (based on the conditions of approval for NorthConnex). These have been taken to be limits/criteria that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters have been designed to ensure the in-tunnel concentration limits are not exceeded.

Table 6.1 In-tunnel average limits along length of tunnel

Pollutant	Concentration limit	Averaging period
Carbon monoxide	87 ppm	Rolling 15-minute average
Carbon monoxide	50 ppm	Rolling 30-minute average
Carbon monoxide	200 ppm	Rolling 3-minute average
Nitrogen dioxide	0.5 ppm	Rolling 15-minute average

Emissions to air from the western and eastern ventilation outlets has involved estimation of emissions from vehicles using the tunnel under expected traffic conditions (ie operating normally with traffic volumes fluctuating over the day with peak and out of peak traffic loads) and regulatory worst-case scenarios (such as may occur during a breakdown).

Additional details on the assessment scenarios and the emission sources considered in the AQAR are summarised in the following sections.

6.4 Assessment scenarios

The assessment of impacts to air quality associated with the project has considered a range of scenarios that include the existing situation, construction works and various future operational scenarios both with and without the project. In addition a cumulative scenario, associated with impacts from all the WestConnex projects was assessed.

In all of the air modelling scenarios considered, the existing M5 East ventilation outlet has been included.

The air modelling scenarios have included the following:

- Existing case (2012): Current road network with no new projects or upgrades
- Construction (2017): Current road network with the inclusion of the completed M4 Widening project. The scenario includes worst-case construction traffic assumed during the spoil removal from the tunnel construction of the project
- ‘Do minimum’ (2021): This assumes traffic levels in 2021 in the study area, where local road upgrades (King Georges Road Interchange Upgrade and the M4 Widening projects) are complete, but other WestConnex projects, including the project are not constructed
- 'Do something' (2021): This assumes the above 'do minimum' scenario for traffic in 2021, however it also assumes the project is complete and open to traffic. No other WestConnex projects are included in this scenario
- ‘Do minimum’ (2031): This assumes traffic levels in 2031 in the study area, where local road upgrades (including the King Georges Road Interchange Upgrade and the M4 Widening projects and some upgrades to the broader transport network over time) to improve capacity and cater for traffic growth, but other WestConnex projects, including the project are not constructed
- 'Do something' (2031): This assumes the above 'do minimum’ scenario for traffic in 2031, however it also assumes the project is complete and open to traffic. No other WestConnex projects are included in this scenario
- Cumulative scenario (2031): This assumes the above 'do minimum' scenario for traffic in 2031 and all WestConnex projects are completed (including the project, New M5 and M4–M5 Link, Sydney Gateway and the Southern Extension.

More specific details associated with each of these scenarios is outlined in the *Traffic and Transport Assessment Report* (included in **Appendix G** of the EIS).

Assessment scenarios evaluated in the health risk assessment

For the assessment of health impacts that may be associated with changes in air quality that are associated with the project have been assessed for the following years:

- Tunnel operation in 2021
- Tunnel operation in 2031
- Cumulative impacts associated with all WestConnex projects in 2031.

The assessment has considered both cumulative impacts (both without and with the project) and changes in air quality associated with the project. The assessment of changes in air quality is based on the predicted air quality impacts for all the local roads plus the project (the 'do something scenario') minus the air quality impacts for all the local roads without the project (the 'do minimum' scenario).

In relation to the operation of the project considered in each of the above scenarios the air quality modelling has been undertaken to consider expected traffic volumes within the tunnel, with traffic moving at 80 kilometres per hour at all times. The number of vehicles moving through the tunnel varies depending on the hour of the day. Air modelling predictions associated with the expected traffic movements through the tunnel have been used for the assessment of long-term/chronic exposures in the local community.

For the assessment of worst-case emissions (as regulatory worst-case) from the project (such as a breakdown in the tunnel) the changes in air quality that may occur during such a situation have the potential to affect short-term exposures and health in the local community.

6.5 Vehicle emissions

Emissions from vehicles using the tunnel have been estimated based on published emission factors relevant to vehicle fleets in the year 2020. These emissions have been assumed to remain the same for assessing impacts in 2021 and 2031. The mix of vehicles considered in the project are summarised in **Table 6.2** based on the average traffic mix travelling at 50 kilometres per hour considered in the AQAR. This mix of vehicles has been assumed to be the same for vehicles within the tunnel and vehicles on surface roads.

Table 6.2 Assumed vehicle mix for project

Vehicle/fuel	Proportion of traffic (%)	
	2021	2031
Petrol vehicles (passenger cars and LDV)	89.3	79.9
Diesel LDV	6.4	16.9
Diesel HGV	4.2	3.1

6.6 Assessment of volatile organic compounds and polycyclic aromatic hydrocarbons

6.6.1 General

The AQAR has considered emissions of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) to air from the project. Both VOCs and PAHs refer to a group of compounds with a mix of different proportions and toxicities. It is the individual compounds within the group that are of importance for evaluating adverse health effects. The composition of individual compounds in the VOCs and PAHs evaluated will vary depending on the source of the emissions. Hence it is important that the key individual compounds present in emissions considered for this project are speciated (ie identified and quantified as a percentage of the total VOCs or total PAHs) to ensure that potential impacts associated with exposure to these compounds can be adequately assessed.

VOCs in air in Sydney (OEH 2012) are primarily derived from domestic/commercial sources (54 per cent) with on-road vehicles contributing around 24 per cent, industrial emissions eight per cent with the remainder from off-road mobile sources and other commercial sources.

VOCs and PAHs from the project are associated with emissions from vehicles assumed to be using the tunnel (and approaches) and surface roads. The makeup of the VOCs and PAHs emissions would depend on the mix of vehicles considered as these pollutants will be emitted in different proportions from petrol and diesel powered vehicles. In addition the age and the fuel used by the vehicle fleet would affect these emissions. The vehicle fleet mix considered in this project is summarised in **Table 6.2**.

6.6.2 Volatile organic compounds

VOCs have been modelled in the AQAR based on emissions from all vehicles considered. The proportion of each of the individual VOCs that may be present in the air is then estimated based on the assumed composition of the vehicle fleet and the type of fuel used.

Most of the VOC emissions comprise a range of hydrocarbons that are of low toxicity (such as methane, ethylene, ethane, butenes, butanes, pentenes, pentanes, heptanes etc) (EPA 2012). From a toxicity perspective the key VOCs that have been considered for the vehicle emissions are BTX, 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (DEH 2003; EPA 2012).

The proportion of each of the key VOCs considered are derived from the 2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW (EPA 2012), for the vehicle fleet assessed in the AQAR (as summarised above). In relation to passenger vehicles it has been assumed that 60 per cent[1] of fuel used is E10. It is conservatively assumed that the composition of VOCs in vehicle emissions remains the same over time, and does not improve with enhanced vehicle emissions technology.

Table 6.3 presents a summary of VOCs speciation profile considered for the different vehicle types considered in the project as well as the weighted mass fraction for these VOCs considered for the project in 2021 and 2031.

Table 6.3 Volatile organic compounds speciation profile for vehicle emissions

VOC	Mass fraction (%VOC)					Mass Fraction for Vehicle Fleet in Project (%VOC)	
	Passenger Vehicles		Light duty vehicles		Heavy goods vehicles	2021	2031
	No ethanol	E10	Petrol	Diesel*	Diesel		
1,3-butadiene	1.27	1.2	1.27	0.4	0.4	1.1	1.1
acetaldehyde	0.46	1.3	0.46	3.81	3.81	1.3	1.5
benzene	4.96	4.54	4.96	1.07	1.07	4.3	4.0
formaldehyde	1.46	1.82	1.46	9.86	9.86	2.5	3.3
xylenes	7.6	7.22	7.6	0.38	0.38	6.6	6.0
toluene	9.18	8.79	9.18	0.47	0.47	8.0	7.2

Volatile organic compounds speciation from EPA (2012)

* speciation for diesel emissions also adopted for diesel passenger vehicles

1 The value of 60 per cent of ethanol in total fuel volume sales was adopted as the target for petrol sold in NSW as outlined in the *Biofuels Act 2007*.

6.6.3 Polycyclic aromatic hydrocarbons

PAHs have been considered in the AQAR as key pollutants that may be derived from diesel powered heavy goods vehicles. The presence of PAHs in diesel exhaust has been found to be more a function of the PAH content of the fuel than of engine technology. For a given refinery and crude oil, diesel fuel PAH levels correlate with total aromatic content and T90 (distillation temperature where 90 per cent of the fuel is evaporated). Representative data on aromatic content for diesel fuels in Australia is limited, however emissions tests have been conducted on a range of light and heavy vehicles under different traffic congestion conditions (DEH 2003). The data presented from these emissions tests is assumed to include fuels commonly used in Australia and are considered to provide an indication of the likely proportions of individual PAHs in diesel exhaust.

The PAHs reported in diesel exhaust by the Australian Department of Environment and Heritage (DEH 2003) comprise the 16 most commonly reported (and highest proportion) PAHs present in exhaust. The data available from this study is dated (from vehicles manufactured from 1990 to 1996) and use of this data is likely to provide an overestimation of PAH emissions from current (and future) diesel vehicles. The evaluation of potential health impacts associated with exposure to PAHs from the project requires consideration of the 16 individual PAHs, present at the highest levels in exhaust and which have the most information on chronic health effects.

The toxicity of individual PAHs varies significantly, with some considered to be carcinogenic while others are not carcinogenic. For the carcinogenic PAHs, these are commonly assessed as a group with the total carcinogenic PAH concentration calculated using weighting factors that relate the toxicity of individual carcinogenic PAHs to the most well studied PAH, benzo(a)pyrene. For the carcinogenic PAHs the weighting factors presented by the Canadian Council of Ministers of the Environment (CCME 2010) have been adopted. Other PAHs that are not carcinogenic have been considered separately.

On the basis of this approach the speciation of individual PAHs (as per cent of total polycyclic aromatic hydrocarbons) has been calculated based on the data from DEH (2003). The data presented relates to emissions that occur during two traffic scenarios (termed segments):

- Segment 1 – congested urban traffic which comprises stop/start traffic flow. This data has been used to be representative of the worst-case situation of heavy congested traffic in the project area and has been used for the assessment of the worst-case scenario
- Segment 4 – highway or freeway traffic which comprises moving traffic. This data is considered more representative of the continuous flow traffic expected in the project area and has been used for the assessment of expected traffic conditions in 2021 and 2031.

Table 6.4 presents a summary of the polycyclic aromatic hydrocarbon speciation profile considered in this assessment for the above traffic conditions.

Table 6.4 Polycyclic aromatic hydrocarbon speciation profile for diesel vehicle emissions

Individual PAH	**Fraction of total PAH emissions (% PAHs)** Highway/freeway (steady traffic flow) – Used to evaluate emissions for expected conditions in 2021 and 2031
Non-carcinogenic PAHs:	
Naphthalene	65.7
Acenaphthalene	5.4
Acenaphthene	1.4
Fluorene	6.9
Phenanthrene	13.7
Anthracene	1.1
Fluoranthene	0.8
Pyrene	1.4
Carcinogenic PAHs:	
Benzo(a)pyrene TEQ	0.9

6.6.4 Assessment of health impacts

The maximum increase in total VOCs and PAHs in the community is lower where the project is operating compared with the situation of no project (ie the project results in a lower total impact of VOCs and PAHs in the community). The change in VOC and PAH concentrations associated with the project is a decrease for most receptors, however in some areas there is a small increase in concentrations associated with the redistribution of emissions from vehicles (primarily associated with surface roads). The following evaluation has been undertaken to assess the potential health impacts associated with the maximum increases predicted.

The assessment of potential health impacts associated with exposure to changes in VOCs and PAHs concentrations (calculated for individual VOCs and PAHs based on the speciation outlined above) in air within the community has been assessed on the basis of the following:

- For VOCs and PAHs that are considered to be genotoxic carcinogens (consistent with guidance provided by enHealth (enHealth 2012a) an incremental lifetime carcinogenic risk has been calculated. For the VOCs and PAHs evaluated in this assessment a carcinogenic risk calculation has been adopted for the assessment of maximum potential (incremental) increase in benzene and carcinogenic PAHs (as a benzo(a)pyrene toxicity equivalent or TEQ). The assessment undertaken has adopted the calculation methodology outlined in **Appendix B**, adopting the inhalation unit risk values presented in
- **Table** 6.6**.**
- For other VOCs and PAHs, where the health effects are associated with a threshold (ie a level below which there are no effects), the maximum predicted (incremental) increase in concentration of individual VOCs and PAHs associated with the project have been compared against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures that may occur to all members of the general public (including sensitive individuals) with no adverse health effects. The guidelines available relate to the duration of exposure and the nature of the health effects considered where:
- Acute guidelines are based on exposures that may occur for a short period of time (typically between an hour or up to 14 days). These guidelines are available to assess peak exposures (based on the modelled one-hour maximum concentration) that may be associated with volatile organic compounds in the air, and are presented in **Table 6.5**.
- Chronic guidelines are based on exposures that may occur all day, every day for a lifetime. These guidelines are available to assess long-term exposures (based on the modelled annual average concentration) that may be associated with volatile organic compounds and polycyclic aromatic hydrocarbons in the air, and are presented in
- **Table** 6.6.

Table 6.5 Adopted acute inhalation guidelines based on protection of public health

Compound assessed	Acute health based guideline ($\mu g/m^3$)	Basis
Volatile organic compounds		
Toluene	4500	Acute 1 hour health based guideline, based on eye and nose irritation, increased occurrence of headache and intoxication in human male volunteers from TCEQ evaluation (TCEQ 2013d). The TCEQ value includes additional 3.3 fold safety factor.
Xylenes	2200	Acute 1 hour health based guideline, based on mild respiratory effects and subjective symptoms of neurotoxicity in human volunteers from TCEQ evaluation (TCEQ 2013c). The TCEQ value includes additional 3.3 fold safety factor.

Compound assessed	Acute health based guideline (µg/m^3)	Basis
1,3-Butadiene	660	Acute 1 hour health based guideline, based on developmental effects derived by the California Office of Environmental Health Hazard Assessment (OEHHA 2013). The guideline developed is lower than developed by TCEQ (TCEQ 2007) based on the same critical study.
Formaldehyde	15	Acute 1 hour health based guideline, based on eye and nose irritation in human volunteers from TCEQ evaluation (TCEQ 2013b). The TCEQ value includes additional 3.3 fold safety factor. This guideline is noted to be lower than the acute guideline available from the WHO (WHO 2000a, 2010) of 100 µg/m^3 for formaldehyde.
Acetaldehyde	470	Acute 1 hour health based guideline, based on effects on sensory irritation, bronchoconstriction, eye redness and swelling derived by the California OEHHA (OEHHA 2013).

Table 6.6 Adopted chronic guidelines and carcinogenic unit risk values based on protection of public health

Compound assessed	Chronic health based guideline (µg/m^3)	Basis
Threshold guidelines for volatile organic compounds		
Toluene	5000	Chronic guideline derived by the USEPA (USEPA 2005b) based on neurological effects in an occupational study (converted to public health value using safety factors). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NECM (NEPC 1999 amended 2013b) health based guidelines.
Xylenes	220	Chronic guideline derived by ATSDR (ATSDR 2007) based on mild subjective respiratory and neurological symptoms in an occupational study (converted to public health value using safety factors).
1,3-Butadiene	0.3	1,3-Butadiene is classified by IARC as a probable human carcinogen. Chronic air guideline derived by the USEPA (USEPA) based on an excess risk of leukaemia (lower of the guideline derived for protecting threshold and non-threshold carcinogenic effects). The value is more conservative than more recent review (TCEQ 2013a).
Formaldehyde	3.3	Formaldehyde is classified by IARC as carcinogenic to humans. The guideline developed by TCEQ (TCEQ 2013b) is derived on the basis of irritation of the eyes and airway discomfort in humans, with review of carcinogenic and other non-carcinogenic effects found to be adequately protected by this guideline. The guideline is more conservative than derived by the WHO (WHO 2010).
Acetaldehyde	4.5	Chronic guideline derived by the USEPA (USEPA) based on nasal effects (in a rat study) (converted to a public health value using safety factors). Value is more conservative that more recent evaluations from WHO and Californian OEHHA.

Compound assessed	Chronic health based guideline ($\mu g/m^3$)	Basis
Threshold guidelines for polycyclic aromatic hydrocarbons		
Naphthalene	3	Chronic guideline from USEPA (USEPA 1998) based on nasal effects (in a mouse study) (converted to a public health value using safety factors) and is consistent with the value used to derive the NEPC (NEPC 1999 amended 2013b) health based guidelines.
Acenaphthylene	200#	These are the non-carcinogenic PAHs. Guideline available from the USEPA (USEPA). Chronic guidelines are based on criteria derived from oral studies (for critical effects on the liver, kidney and haematology) which are then converted to an inhalation value (relevant for the protection of public health, including the use of safety factors) for use in this assessment. The value presented in the above table has been converted from an acceptable dose in mg/kg/day to an acceptable air concentration assuming a body weight of 70 kg and inhalation of 20 m^3/day (as per (USEPA 2009b)). # No guideline available for individual polycyclic aromatic hydrocarbon, hence a surrogate compound has been used for the purpose of assessment. The surrogate compound is a polycyclic aromatic hydrocarbon of similar structure and toxicity. In relation to the surrogates adopted in this evaluation, acenaphthene has been adopted as a surrogate for acenaphthylene, fluoranthene has been adopted as a surrogate for phenanthrene.
Acenaphthene	200	
Fluorene	140	
Phenanthrene	140#	
Anthracene	100	
Fluoranthene	140	
Pyrene	100	
Carcinogenic inhalation unit risk values adopted for carcinogenic risk calculation		
Benzene	$6x10^{-6}$ $(\mu g/m^3)^{-1}$	Benzene is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC). Inhalation unit risk value is from the WHO (WHO 2000a, 2010) and is based on excess risk of leukaemia from epidemiological studies.
Benzo(a)pyrene TEQ	0.087 $(\mu g/m^3)^{-1}$	BaP is classified by IARC as a known human carcinogen, which relates to BaP as well as all the other carcinogenic PAHs assessed as a BaP toxicity equivalent (TEQ) value. Inhalation unit risk value is from the WHO (WHO 2010) and is based on protection from lung cancer for an occupational study associated with coke oven emissions. It is noted that carcinogenic risks associated with lung cancer from diesel particulate matter (which is dominated by the presence of carcinogenic PAHs) is also assessed as outlined in **Section 6.9.5** and **Appendix B**).

Table 6.7 and **Table 6.8** present a summary of the maximum predicted one-hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all the threshold VOCs and PAHs considered. The total HI is a sum of the potential hazards associated with all the threshold VOCs and PAHs together assuming the health effects are additive, and is evaluated as follows (enHealth 2012a):

- A total HI less than or equal to one means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern

- A total HI greater than one means that the predicted concentrations (for at least one individual compound) are above the health based guidelines, or that there are at least a few individual VOCs or PAHs where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

Table 6.9 presents a summary of the calculated incremental lifetime carcinogenic risk associated with exposure to the maximum predicted concentrations of benzene and carcinogenic PAHs (as benzo(a)pyrene TEQ). The calculated carcinogenic risk for these compounds has been summed, in accordance with enHealth guidance where the following has been considered (enHealth 2012a). The calculated risks are considered in conjunction with what are considered negligible, tolerable/acceptable and unacceptable risks as outlined in **Appendix C**.

The values presented in the tables have been rounded to two significant figures for individual calculations and one significant figure for the total HI and total carcinogenic risk, reflecting the level of uncertainty in the calculations presented.

The following evaluation is based on the maximum predicted change (incremental) concentration in air for 2021, 2031 and the cumulative scenario as modelled in the AQAR. Concentrations in all other areas of the surrounding community are lower than evaluated in this assessment. In most locations the change due to the project is a lowering of VOC and PAH concentrations in air (ie a benefit).

Table 6.7 Assessment of acute exposures to VOCs – maximum impacts in community associated with project

Key VOC	Maximum predicted 1-hour average concentration associated with project and calculated HI					
	2021 Maximum concentration ($\mu g/m^3$)	HI	2031 Maximum concentration ($\mu g/m^3$)	HI	Cumulative - 2031 Maximum concentration ($\mu g/m^3$)	HI
Total VOCs	**172**		**109**		**113**	
Toluene	14	0.0031	7.9	0.0017	9.0	0.0020
Xylenes	11	0.0052	6.6	0.0030	7.5	0.0034
1,3-Butadiene	1.9	0.0029	1.2	0.0018	1.2	0.0019
Formaldehyde	4.3	0.29	3.6	0.24	2.8	0.19
Acetaldehyde	2.2	0.0048	1.6	0.0035	1.5	0.0031
	Total HI	**0.3**		**0.2**		**0.2**

Table 6.8 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project and calculated HI					
	2021		2031		Cumulative - 2031	
	Max concentration ($\mu g/m^3$)	HI	Max concentration ($\mu g/m^3$)	HI	Max concentration ($\mu g/m^3$)	HI
Total VOCs	**2.8**		**1.6**		**1.2**	
Toluene	0.17	0.000035	0.095	0.000019	0.075	0.000015
Xylenes	0.14	0.00065	0.079	0.00036	0.062	0.00028
1,3-Butadiene	0.027	0.090	0.015	0.050	0.012	0.039
Formaldehyde	0.12	0.036	0.073	0.022	0.052	0.016
Acetaldehyde	0.051	0.011	0.030	0.0067	0.022	0.0049
Total PAHs	**0.00084**		**0.00050**		**0.00038**	
Naphthalene	0.00055	2×10^{-4}	0.00033	1×10^{-4}	0.00025	8×10^{-5}
Acenaphthylene	0.000045	2×10^{-7}	0.000027	1×10^{-7}	0.000020	1×10^{-7}
Acenaphthene	0.000012	6×10^{-8}	0.0000069	3×10^{-8}	0.0000053	3×10^{-8}
Fluorene	0.000058	4×10^{-7}	0.000034	2×10^{-7}	0.000026	2×10^{-7}
Phenanthrene	0.000012	8×10^{-7}	0.000068	5×10^{-7}	0.000052	4×10^{-7}
Anthracene	0.0000093	9×10^{-8}	0.0000055	5×10^{-8}	0.0000041	4×10^{-8}
Fluoranthene	0.0000067	4×10^{-8}	0.0000040	3×10^{-8}	0.0000030	2×10^{-8}
Pyrene	0.000012	1×10^{-7}	0.0000069	7×10^{-8}	0.0000053	5×10^{-8}
Total HI		**1**		**1**		**0.9**

Table 6.9 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project

Key VOC	Maximum predicted 1-hour average concentration associated with project and calculated HI					
	2021		2031		Cumulative - 2031	
	Maximum concentration ($\mu g/m^3$)	ILCR	Maximum concentration ($\mu g/m^3$)	ILCR	Maximum concentration ($\mu g/m^3$)	ILCR
Benzene	0.10	3×10^{-7}	0.055	2×10^{-7}	0.043	1×10^{-7}
Benzo(a)pyrene TEQ	0.0000076	3×10^{-7}	0.0000045	2×10^{-7}	0.0000034	2×10^{-7}
Total carcinogenic risk		**6×10^{-7}**		**4×10^{-7}**		**3×10^{-7}**

ILCR = incremental lifetime carcinogenic risk (refer to **Appendix B** for calculation methodology and **Table 6.6** for inhalation unit risk values)

For the assessment of acute exposures to VOCs (**Table 6.7**), the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2021, 2031 and the cumulative scenario. On this basis there are no acute risk issues in the local community associated with the project.

For the assessment of chronic exposures to VOCs and PAHs (**Table 6.8**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for 2021, 2031 and the cumulative scenario. For the assessment of lifetime cancer risks associated with the maximum change in benzene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are all below $1x10^{-6}$ and are considered to be negligible. On this basis there are no chronic risk issues in the local community associated with the project. It is noted that the calculations undertaken for PAHs is based on a conservative estimate of the fraction of emissions from vehicles that comprises PAHs (as a percentage of total VOCs). The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented are considered to be a conservative upper limit estimate.

6.7 Assessment of carbon monoxide

Motor vehicles are the dominant source of carbon monoxide in air (DECCW 2009). Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to carbon monoxide and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease; and some birth outcomes (such as low birth weights) have been identified (NEPC 2010).

Guidelines are available in Australia from NEPC (NEPC 2003) and NSW EPA that are based on the protection of adverse health effects associated with carbon monoxide. Review of these guidelines by NEPC (2010) identified additional supporting studies[2] for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2011[3], specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

The NEPC ambient air quality guideline for the assessment of exposures to carbon monoxide has considered lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL) associated with a range of health effects in healthy adults, people with ischemic heart disease and foetal effects. In relation to these data, a guideline level of carbon monoxide of nine parts per million (ppm) by volume (or 10 milligrams per cubic metre or 10,000 micrograms per cubic metre) over an eight-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population. An additional 1.5 fold uncertainty factor to protect more susceptible groups in the population was included. On this basis the NEPC (and the EPA) guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The NSW EPA have also established a guideline for 15-minute average (100 milligrams per cubic metre) and one-hour average (30 milligrams per cubic metre) concentrations of carbon monoxide in ambient air. These guidelines are based on criteria established by the WHO (WHO 2000b) using the same data used by the NEPC to establish the guideline (above) with extrapolation to different periods of exposure on the basis of known physiological variables that affect carbon monoxide uptake.

2 Many of the more current studies are epidemiology studies that relate to a mix of urban air pollutants (including particulate matter) where it is more complex to determine the effects that can be attributed to carbon monoxide exposure only.

3 Most recent review of the Primary National Ambient Air Quality Standards for Carbon Monoxide published by the USEPA in the Federal Register Volume 76, No. 169, 2011, available from: http://www.gpo.gov/fdsys/pkg/FR-2011-08-31/html/2011-21359.htm

Table 6.10 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of carbon monoxide for the assessment years 2021 and 2031 both without and with the project.

Table 6.10 Review of potential acute and chronic health impacts – carbon monoxide (CO)

Scenario	Maximum 1-hour average concentration of CO (mg/m^3)		Maximum 8-hour average concentration of CO (mg/m^3)	
	Without project	With project	Without project	With project
2021				
Maximum	8.5	7.9	5.8	5.4
2031				
Maximum	7.0	6.2	4.8	4.3
Cumulative				
Maximum	--	5.9	--	4.3
Relevant health based guideline	30		10	

All the concentrations of carbon monoxide presented in the above table are below the relevant health based guidelines. On the basis of the assessment undertaken there are no adverse health effects expected in relation to exposures (acute and chronic) to carbon monoxide in the local area surrounding the project.

It is noted that the maximum concentrations of carbon monoxide in the local community are lower for the situation where the project is operating. This indicates that the operation of the project provides some benefit (ie an improvement) in lowering the concentrations of carbon monoxide in the local community.

6.8 Assessment of nitrogen dioxide

6.8.1 Approach

Nitrogen oxides (NOx) refer to a collection of highly reactive gases containing nitrogen and oxygen, most of which are colourless and odourless. Nitrogen oxide gases form when fuel is burnt. Motor vehicles, along with industrial, commercial and residential (eg gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In Sydney, the OEH (2012) estimated that on-road vehicles account for about 62 per cent of emissions of nitrogen oxides, industrial facilities account for 12 per cent, other mobile sources account for about 22 per cent, with the remainder from domestic/commercial sources.

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen that may be of concern (WHO 2000c). Nitrogen dioxide is a colourless and tasteless gas with a sharp odour. Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013b). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide (Morgan, Broom & Jalaludin 2013; NEPC 2010). The health effects associated with exposure to nitrogen dioxide depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC (NEPC 2003) which indicate acceptable concentrations of nitrogen dioxide. These guidelines are based on protection from adverse health effects following both short-term (acute) and longer-term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly. Recently these guidelines have been reviewed by NEPC (Golder 2013; NEPC 2010, 2014). The review identified additional supporting studies for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The reviews undertaken to date have not recommended any change to the existing health-based guidelines.

When reviewing the available literature on the health effects associated with exposure to nitrogen dioxide it is important to consider the following:

- Whether the evidence suggests that associations between exposure to nitrogen dioxide concentrations and effects on health are causal. The most current review undertaken by the USEPA (USEPA 2015) specifically evaluated evidence of causation. The review identified that a causal relationship existed for respiratory effects (for short-term exposure with long-term exposures also likely to be causal). All other associations related to exposure to nitrogen dioxide (specifically cardiovascular effects, mortality and cancer) were considered to be suggestive
- Whether the reported associations are distinct from, and additional to, those reported and assessed for exposure to particulate matter. Co-exposures to nitrogen dioxide and particulate matter complicates review and assessment of many of the epidemiology studies as both these air pollutants occur together in urban areas. There is sufficient evidence (epidemiological and mechanistic) to suggest that some of the health effect associations identified relate to exposure to nitrogen dioxide after adjustment/correction for co-exposures with particulate matter (COMEAP 2015)
- Whether the assessment of potential health effects associated with exposure to different levels of nitrogen dioxide can be undertaken on the basis of existing guidelines, or whether specific risk calculations are required to be undertaken. The current guidelines in Australia for the assessment of nitrogen dioxide in air relate to cumulative (total) exposures, and adopt criteria that are considered to be protective of short and long term exposures. Hence, it is relevant that these guidelines be considered in this assessment
- In addition, it is noted that in areas of high traffic congestion (as is the case with the project area evaluated in this assessment) background levels of nitrogen dioxide may already be elevated such that use of the existing guideline is limited for the purpose of assessing health impacts from a particular project or activity. For these situations it is relevant to also evaluate the impact on community health of the change in nitrogen dioxide concentration in the local community using appropriate risk calculations. For the conduct of risk assessments in relation to exposure to nitrogen dioxide, the WHO (WHO 2013b) identified that the strongest evidence of health effects related to respiratory hospitalisations and to a lesser extent mortality (associated with short-term exposures) and recommend that these health endpoints should be considered in any core assessment of health impacts associated with exposure.

On the basis of the above, potential health effects associated with exposure to nitrogen dioxide will be undertaken for this project using both comparison with guidelines (assessing cumulative exposures) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

6.8.2 Assessment of cumulative exposures

Assessment of acute exposures

The NEPC ambient air quality guideline for the assessment of acute (short-term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) 1-hour average concentration in air. The guideline of 246 micrograms per cubic metre (or 120 parts per billion by volume) is based on a LOAEL of 409–613 micrograms per cubic metre derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma. An uncertainty factor of two to protect susceptible people (i.e. asthmatic children) was applied to the LOAEL (NEPC 1998). On this basis the NEPC (and Environment

Protection Authority) acute guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 6.11 presents a summary of the maximum predicted cumulative one-hour average concentration of nitrogen dioxide the modelled scenarios.

Table 6.11 Review of potential acute health impacts – nitrogen dioxide (NO_2)

Location and scenario	Maximum 1-hour average concentration of NO_2 without the project ($\mu g/m^3$)	Maximum 1-hour average concentration of NO_2 with the project ($\mu g/m^3$)
2021		
Maximum residential	375	307
Maximum commercial	360	286
2031		
Maximum residential	286	243
Maximum commercial	359	238
Cumulative - 2031		
Maximum residential	--	249
Maximum commercial	--	277
Acute health based guideline	**246**	**246**

The maximum cumulative concentrations of nitrogen dioxide presented in the above table are above the acute NEPC guideline of 246 micrograms per cubic metre, principally due to the contribution of nitrogen dioxide from the surface roads that are predicted to exceed the short-term criteria without the construction of the project. The maximum cumulative concentrations of nitrogen dioxide are lower with operation of the project, which indicates that the project provides some benefit (ie an improvement) in lowering concentrations of nitrogen dioxide within the local community (compared with the situation where the project was not constructed).

To further address potential risks to human health that may be associated with localised changes in short-term exposures to nitrogen dioxide that relate to the project, incremental risk calculations have been undertaken and are presented in **section 6.6.3**.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long-term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) annual average concentration in air. The guideline of 62 micrograms per cubic metre (or 30 ppbv) is based on a LOAEL of the order of 40–80 parts per billion by volume (around 75–150 micrograms per cubic metre) during early and middle childhood years which can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school. An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20-40 parts per billion by volume (38–75 micrograms per cubic metre) (NEPC 1998). On this basis the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 6.12 presents a summary of the maximum predicted cumulative annual average concentration of nitrogen dioxide for the modelled scenarios.

Table 6.12 Review of potential chronic health impacts – Nitrogen dioxide (NO_2)

Location and scenario	Maximum annual average concentration of NO_2 ($\mu g/m^3$)	
	Without the project	With the project
2021		
Maximum residential	37.6	34.4
Maximum commercial	38.5	32.6
2031		
Maximum residential	30.6	31.0

Location and scenario	Maximum annual average concentration of NO_2 (µg/m^3)	
Maximum commercial	31.0	30.1
Cumulative – 2031		
Maximum residential	--	31.6
Maximum commercial	--	31.3
Chronic health based guideline	**62**	

All the concentrations of nitrogen dioxide presented in the above table are below the chronic NEPC guideline of 62 micrograms per cubic metre. Hence there are no adverse health effects expected in relation to chronic exposures to nitrogen dioxide in the local area surrounding the project.

It is noted that the maximum concentrations of nitrogen dioxide are lower or equivalent in the local community for the situation where the project (and all of the WestConnex projects) is operating. This indicates that that the operation of the project provides some benefit (ie an improvement) in lowering the concentrations of nitrogen dioxide in the local community.

6.8.3 Assessment of incremental exposures

The evidence base supports quantification of effects of short-term exposure, using the averaging time as in the relevant studies. The strongest evidence is for respiratory effects, in particular exacerbation of asthma, with some support also for all-cause mortality. These health endpoints have been evaluated in relation to changes in nitrogen dioxide concentrations in air associated with the project within the local community in 2021 and 2031.

Table 6.13 presents a summary of the health endpoints considered in this assessment, the β coefficient relevant to the calculation of a relative risk (refer to **Appendix A** for details on the calculation of a β coefficient from published studies). The coefficients adopted for the assessment of impacts on mortality and asthma emergency department admissions are derived from the detailed assessment undertaken for the current review of health impacts of air pollution undertaken by NEPC (Golder 2013) and are considered to be robust.

Table 6.13 Adopted exposure-responses relationships for assessment of changes in nitrogen dioxide concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (as %) for 1 µg/m^3 increase in NO_2	Reference
Mortality, all causes (non-trauma)	Short-term	30+	0.00188 (0.19%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Mortality, respiratory	Short-term	All ages*	0.00426 (0.43%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Asthma emergency department admissions	Short-term	1–14 years	0.00115 (0.11%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Golder 2013; Jalaludin et al. 2008)

* Relationships established for all ages, including young children and the elderly

Table 6.14 presents the change in individual risk associated with changes in nitrogen dioxide at the maximum impacted receptor (regardless of the land use), the maximum impacts residential and workplace receptors in the surrounding community, as well as the community receptors, for the operational years 2021 and 2031, including the cumulative scenario (refer to **Appendix A** for methodology for the calculation of individual risks). The maximum impacted receptor has been included and evaluated for potential exposures by residents to address any future changes in land use that may occur during redevelopment. These calculations reflect the maximum population risk in the community from changes in nitrogen dioxide concentrations associated with the project. Risks for all other receptors (including other sensitive receivers) will be lower than the maximums presented.

All risks are presented to one significant figure, reflecting the level of uncertainty associated with the calculations presented.

Figure 6.3 presents a summary of the calculated change in individual risk associated with changes in nitrogen dioxide concentrations at each community receptor location evaluated.

Appendix C presents a discussion on levels of the levels of risk that are considered to be negligible, tolerable/acceptable and unacceptable. A summary of these risk levels are included in the table.

Calculations relevant to the characterisation of risks associated with changes in nitrogen dioxide concentrations in the community are presented in **Appendix D**.

It is noted that while the maximum concentrations of nitrogen dioxide are lower in the local community with the operation of the project, the concentrations ate individual receptors vary. While the concentrations at most receptors decrease with the operation of the project, there are some receptors where there is an increase, associated with the redistribution of emissions from vehicles using surface roads.

Table 6.14 Maximum calculated risks associated with short-term exposure to changes in nitrogen dioxide concentrations with operation of the project

Scenario and Receptor	Maximum change in individual risk from short-term exposure to nitrogen dioxide for the following health endpoints		
	Mortality: All causes (ages 30+)	Mortality: Respiratory (all ages)	Asthma ED Admissions (1–14 years)
2021			
Maximum	2×10^{-6}	4×10^{-6}	3×10^{-5}
Maximum residential	2×10^{-6}	4×10^{-6}	2×10^{-5}
Maximum workplace	2×10^{-6}	4×10^{-6}	2×10^{-5}
Childcare centres	-4×10^{-7}	-8×10^{-7}	-5×10^{-6}
Hospitals	-7×10^{-7}	-1×10^{-6}	-9×10^{-6}
Schools	3×10^{-7}	7×10^{-7}	4×10^{-6}
Aged care	4×10^{-7}	9×10^{-7}	6×10^{-6}
2031			
Maximum	2×10^{-6}	4×10^{-6}	2×10^{-5}
Maximum residential	2×10^{-6}	4×10^{-6}	2×10^{-5}
Maximum workplace	$2x\ 10^{-6}$	4×10^{-6}	2×10^{-5}
Childcare centres	-2×10^{-7}	-5×10^{-7}	-3×10^{-6}
Hospitals	-6×10^{-7}	-1×10^{-6}	-7×10^{-6}
Schools	5×10^{-7}	1×10^{-6}	7×10^{-6}
Aged care	4×10^{-7}	8×10^{-7}	5×10^{-6}
Cumulative - 2031			
Maximum	3×10^{-6}	7×10^{-6}	4×10^{-5}
Maximum residential	3×10^{-6}	7×10^{-6}	4×10^{-5}
Maximum workplace	2×10^{-6}	4×10^{-6}	2×10^{-5}
Childcare centres	-5×10^{-7}	-1×10^{-6}	-6×10^{-6}
Hospitals	-9×10^{-7}	-2×10^{-6}	-1×10^{-5}
Schools	3×10^{-7}	6×10^{-7}	4×10^{-6}

Scenario and Receptor	Maximum change in individual risk from short-term exposure to nitrogen dioxide for the following health endpoints		
Aged care	-3×10^{-8}	-5×10^{-8}	-3×10^{-7}
Negligible risks	$< 1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$> 1 \times 10^{-4}$		

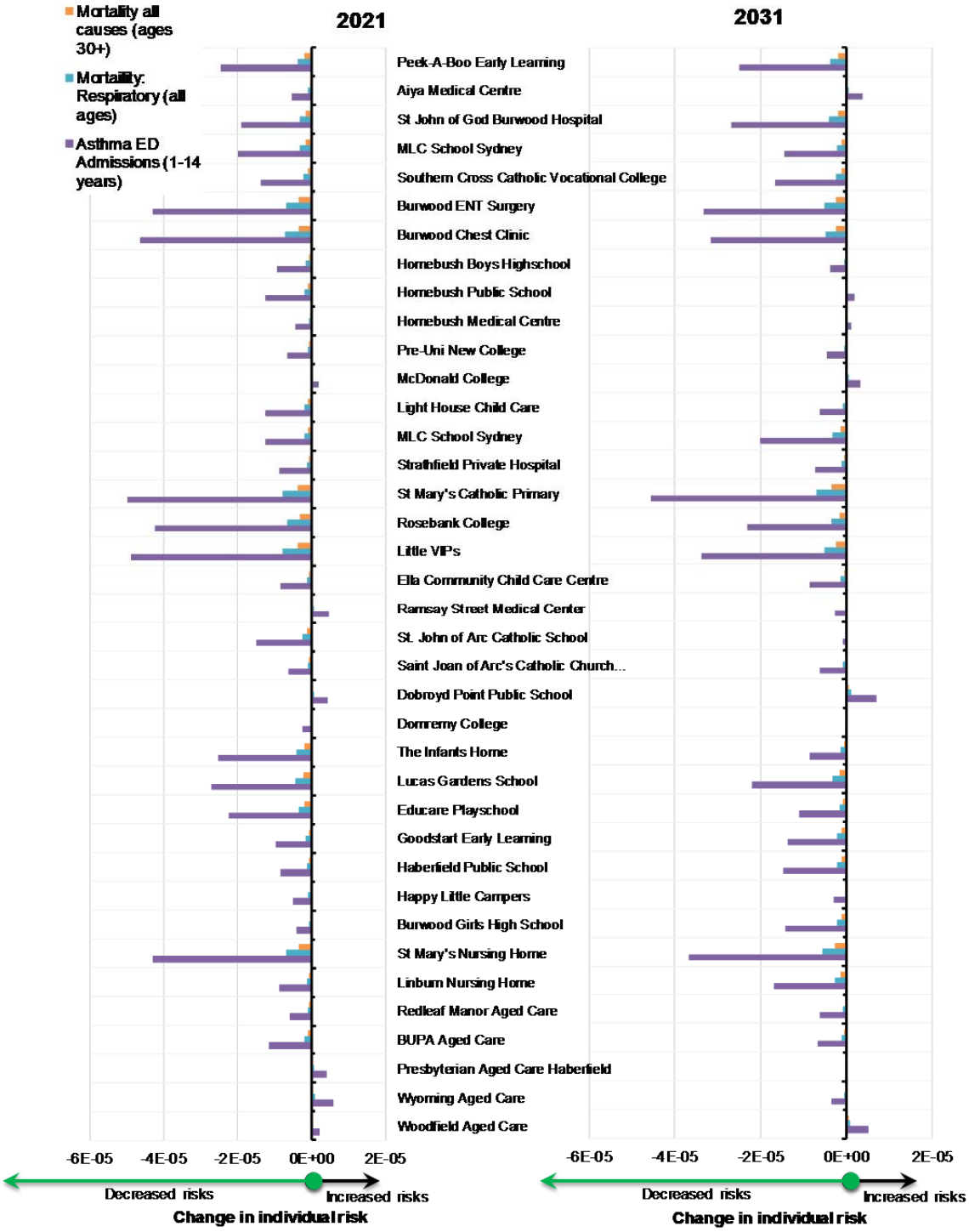


Figure 6.3 **Change in calculated risk for key health end-points associated with changes in nitrogen dioxide concentrations at community receptors (2021 and 2031).**

For this project, all maximum impacted locations lie in the range $2x10^{-6}$ to $3x10^{-5}$ and are considered to be tolerable/acceptable. Risks at all community receptors vary from $-5x10^{-5}$ to 7×10^{-6} with the majority of the calculated risks for community receptors calculated to be negative, indicating that the project is expected to result in a lower level of risk at these locations. Where an increase in risk was calculated at the community receptors, they are all considered to be tolerable/acceptable.

These conclusions remain unchanged where risks associated with cumulative impacts from the operation of all WestConnex projects are considered.

6.9 Assessment of particulate matter

6.9.1 Particle size

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location (and source). Unlike many other pollutants, particulates comprise a broad class of diverse materials and substances, with varying morphological, chemical, physical and thermodynamic properties, with sizes that vary from less than 0.005 microns to greater than 100 microns. Particulates can be derived from natural sources such as crustal dust (soil), pollen and moulds, and other sources that include combustion and industrial processes. Secondary particulate matter is formed via atmospheric reactions of primary gaseous emissions. The gases that are the most significant contributors to secondary particulates include nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust, combustion sources, agricultural, industrial and biogenic emissions).

Numerous epidemiological studies[4] have reported significant positive associations between particulate air pollution and adverse health outcomes, in particular mortality as well as a range of adverse cardiovascular and respiratory effects.

The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter. The common measures of particulate matter that are considered in the assessment of air quality and health risks are:

- Total suspended particulates (TSP): This refers to all particulates with an equivalent aerodynamic particle[5] size below 50 microns in diameter[6]. It is a fairly gross indicator of the presence of dust with a wide range of sizes. Larger particles (termed 'inspirable', comprise particles around 10 microns and larger) are more of a nuisance as they will deposit out of the air (measured as deposited dust) close to the source and, if inhaled, are mostly trapped in the upper respiratory system[7] and do not reach the lungs. Finer particles (smaller than 10 microns, termed 'respirable') tend to be transported further from the source and are of more concern with respect to human health as these particles can penetrate into the lungs (see following point). Hence not all of the dust characterised as total suspended particulates is relevant for the assessment of health impacts, and total suspended particulates as a measure of impact, has not been further evaluated in this assessment. The assessment has only focused on particulates of a size where significant associations have been identified between exposure and adverse health effects.
- PM_{10} (particulate matter below 10 microns in diameter), $PM_{2.5}$ (particulate matter below 2.5 microns in diameter) and PM1 (particulate matter below one micron in diameter, often termed very fine particles) and ultrafines (particulate matter below 0.1 microns in diameter): These particles are small and have the potential to penetrate beyond the body's natural clearance mechanisms of cilia and mucous in the nose and upper respiratory system, with smaller particles

4 Epidemiology is the study of diseases in populations. Epidemiological evidence can only show that this risk factor is associated (correlated) with a higher incidence of disease in the population exposed to that risk factor. The higher the correlation the more certain the association. Causation (i.e. that a specific risk factor actually causes a disease) cannot be proven with only epidemiological studies. For causation to be determined a range of other studies need to be considered in conjunction with the epidemiology studies.

5 The term equivalent aerodynamic particle is used to reference the particle to a particle of spherical shape and particle of density one gram per cubic metre.

6 The size, diameter, of dust particles is measured in micrometers (microns).

7 The upper respiratory tract comprises the mouth, nose, throat and trachea. Larger particles are mostly trapped by the cilia and mucosa and swept to the back of the throat and swallowed.

able to further penetrate into the lower respiratory tract[8] and lungs. Once in the lungs adverse health effects may result (OEHHA 2002).

Evaluation of size alone as a single factor in determining the potential for particulate toxicity is difficult since the potential health effects are not independent of chemical composition. There are certain particulate size fractions that tend to contain certain chemical components, such as metals in fine particulates (less than $PM_{2.5}$) and crustal materials (like soil) in the coarse mode (PM_{10} or larger). In addition, different sources of particulates have the potential to result in the presence of other pollutants in addition to particulate matter. For example combustion sources, prevalent in urban areas, result in the emission of particulate matter (more dominated by $PM_{2.5}$) as well as gaseous pollutants (such as nitrogen dioxide and carbon monoxide). This results in what is referred to as co-exposure, and is an issue that has to be accounted for when evaluating studies that come from studying health effects in large populations exposed to pollution from many sources (as is the case in urban air).

Where co-exposure is accounted for the available science supports that exposure to fine particulate matter (less than 2.5 microns, $PM_{2.5}$) is associated (and shown to be causal in some cases) with health impacts in the community (USEPA 2012). A more limited body of evidence suggests an association between exposure to larger particles, PM_{10} and adverse health effects (USEPA 2009a; WHO 2003).

It is noted that when assessing potential health impacts associated with changes in particulate matter concentrations the studies relied upon for establishing associations (between changes in concentrations in air and health effects) are large epidemiological studies. These studies relate changes in health indicators with changes in measured concentrations of particulate matter. As a result the particle size fractions addressed in these studies relate to the fractions measured in the urban air environment studies. In relation to measuring particulate matter in urban air, the following should be noted:

- The measurement of particulate matter in urban air most commonly reports PM_{10}. This is the concentration of particulate matter that less than or equal to 10 microns in diameter (and includes the smaller fractions of $PM_{2.5}$ and very fine particles). The measurement techniques for PM_{10} are well established and provide stable, robust, verifiable data that is considered to be consistently reported across all countries. This means this data on PM_{10} collected in different parts of a city, in different parts of a country and by different countries can be compared against each other. This is the key reason why many of the epidemiological studies have looked at associations between PM_{10} and various health effects
- The measurement of $PM_{2.5}$ is becoming more common in urban environments. This is the concentration of particulate matter that less than or equal to 2.5 microns in diameter (and includes the smaller fractions of very fine particles and ultrafines). The measurement techniques used for $PM_{2.5}$ are less well established resulting in data that varies depending on the type of equipment used and how it is set-up and maintained. Due to either a lack of monitoring data or the inconsistency of monitoring data some epidemiology studies have assessed associations between $PM_{2.5}$ and health effects by using PM_{10} data and assuming that a certain percentage of PM_{10} comprises $PM_{2.5}$. Some studies have directly used measurements of $PM_{2.5}$ in urban air. Even where these measurement issues are considered, the studies still clearly show strong relationships between changes in $PM_{2.5}$ concentrations and health effects
- The measurement of ultrafine particles is difficult (using equipment that is less robust/stable and provides variable data) and has not been undertaken in most urban air environments. As a result there are no robust epidemiological studies that relate changes in ultrafine particle levels and health effects that can be used in a risk assessment. There is sufficient data available to confirm that motor vehicles are a key source of ultrafine particles. Available studies in animals and humans have identified a range of adverse health effects associated with exposure to ultrafine

8 The lower respiratory tract comprises the smaller bronchioles and alveoli, the area of the lungs where gaseous exchange takes place. The alveoli have a very large surface area and absorption of gases occurs rapidly with subsequent transport to the blood and the rest of the body. Small particles can reach these areas, be dissolved by fluids and absorbed.

particulates, however the studies do not show that short-term exposure to ultrafine particulates have effects that are significantly different from those associated with exposure to $PM_{2.5}$ (HEI 2013).

When assessing health impacts from fine particulates, the robust associations of effects (that are based on large epidemiology studies primarily from the US and Europe) have been determined on the basis of $PM_{2.5}$, as $PM_{2.5}$ is what is commonly measured in urban air. No robust associations (that can be used in a quantitative assessment) are available for PM_1 and the current science is inconclusive in relation to ultrafine particulates. The associations developed for $PM_{2.5}$ would include a significant contribution from PM_1 (as $PM_{2.5}$ comprises a significant proportion of PM_1) and hence health effects observed for PM1 would be captured in the studies that have been conducted on the basis of $PM_{2.5}$. It is important that the quantitative evaluation of potential health impacts adopts robust health effects associations and utilises particulate matter measures that are collected in the urban air environment. Hence the further assessment of exposure to fine particulate matter has focused on particulates reported/evaluated as $PM_{2.5}$.

6.9.2 Health effects

Adverse health effects associated with exposure to particulate matter have been well studied and reviewed by Australian and International agencies. Most of the studies and reviews have focused on population-based epidemiological studies in large urban areas in North America, Europe and Australia, where there have been clear associations determined between health effects and exposure to $PM_{2.5}$ and to a lesser extent, PM_{10}. These studies are complemented by findings from other key investigations conducted in relation to the characteristics of inhaled particles; deposition and clearance of particles in the respiratory tract; animal and cellular toxicity studies; and studies on inhalation toxicity by human volunteers (NEPC 2010).

Particulate matter has been linked to adverse health effects after both short-term exposure (days to weeks) and long-term exposure (months to years). The health effects associated with exposure to particulate matter vary widely (with the respiratory and cardiovascular systems most affected) and include mortality and morbidity effects.

In relation to mortality, for short-term exposures in a population this relates to the increase in the number of deaths due to existing (underlying) respiratory or cardiovascular disease; for long-term exposures in a population this relates to mortality rates over a lifetime, where long-term exposure is considered to accelerate the progression of disease or even initiate disease.

In relation to morbidity effects, this refers to a wide range of health indicators used to define illness that have been associated with (or caused by) exposure to particulate matter. In relation to exposure to particulate matter, effects are primarily related to the respiratory and cardiovascular system and include (Morawska, Moore & Ristovski 2004; USEPA 2009a):

- Aggravation of existing respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits)
- Changes in cardiovascular risk factors such as blood pressure
- Changes in lung function and increased respiratory symptoms (including asthma)
- Changes to lung tissues and structure
- Altered respiratory defence mechanisms.

These effects are commonly used as measures of population exposure to particulate matter in community epidemiological studies (from which most of the available data in relation to health effects is derived), and are more often grouped (through the use of hospital codes) into the general categories of cardiovascular morbidity/effects and respiratory morbidity/effects. The available studies provide evidence for increased susceptibility for various populations, particularly older populations, children and those with underlying health conditions (USEPA 2009a).

There is consensus in the available studies and detailed reviews that exposure to fine particulates, $PM_{2.5}$, is associated with (and causal to) cardiovascular and respiratory effects and mortality (all causes) (USEPA 2012). Similar relationships have also been determined for PM_{10}, however, the supporting studies do not show relationships as clear as shown with $PM_{2.5}$ (USEPA 2012).

There are a number of other studies that have been undertaken where other health effects have been evaluated. These studies are suggestive (but do not show effects as clearly as the effects noted above) of an association between exposure to $PM_{2.5}$ and reproductive and developmental effects as well as cancer, mutagenicity and genotoxicity (USEPA 2012). IARC (2013) has classified particulate matter as carcinogenic to humans based on data relevant to lung cancer.

Other studies have been reviewed to determine relationships/associations between particulate matter exposure (either PM_{10} or $PM_{2.5}$) and a wide range of other health effects and health measures including mortality (for different age groups), chronic bronchitis, medication use by adults and children with asthma, respiratory symptoms (including cough), restricted work days, work days lost, school absence and restricted activity days (Anderson et al. 2004; EC 2011; Ostro 2004; WHO 2006a). While these relationships/associations have been identified the exposure-response relationships established are not as strong as those discussed above. Also the available baseline data does not include information for many of these health effects which means it is not possible to undertake a quantitative assessment.

6.9.3 Approach to the assessment of particulate exposures

In relation to the assessment of exposures to particulate matter there is sufficient evidence to demonstrate that there is an association between exposure to $PM_{2.5}$ (and to a lesser extent PM_{10}) and effects on health that are causal. In addition the effects related to exposures to $PM_{2.5}$ (or PM_{10}) alone (ie without co-exposures).

The available evidence does not suggest that there is a threshold below which health effects do not occur. Hence there are likely to be health effects associated with background levels of $PM_{2.5}$ and PM_{10}, even where the concentrations are below the current guidelines. Guidelines are currently available for the assessment of $PM_{2.5}$ and PM_{10} in New South Wales (DEC 2005) and Australia (NEPC 2002, 2003). These guidelines are not based on any acceptable level of risk, rather they are based on levels that are desirable in the community to balance background/urban sources with lowering impacts on health and cost savings in the health system.

The air quality goals relate to average or regional exposures by populations from all sources, not to localised 'hot-spot' areas such as locations near industry, busy roads or mining. They are intended to be compared against ambient air monitoring data collected from appropriately sited regional monitoring stations. In some cases there may be local sources (including busy roadways and industry) to result in background levels of PM_{10} and $PM_{2.5}$ that are close to, equal to, or in exceedance of, the air quality goals. Where impacts are being evaluated from a local source it is important to not only consider cumulative impacts associated with the project (undertaken using the current air quality goals) but also evaluate the impact of changes in air quality within the local community.

This assessment has therefore been undertaken to consider both cumulative exposure impacts (refer to **section 6.9.4**) and incremental exposure impacts associated with changes in $PM_{2.5}$ and PM_{10} concentrations that are associated with the project (refer to **section 6.9.5**).

6.9.4 Assessment of cumulative exposures

The assessment of cumulative exposures to $PM_{2.5}$ and PM_{10} is based on a comparison of the cumulative concentrations predicted in 2021 (both without and with the project) and 2031 (without the project, with the project and with all the WestConnex projects) with the relevant air quality guidelines available from the NEPC and NSW EPA. The current NEPC and EPA air quality goals and guidelines for particulate matter are presented in **Table 6.15**. These guidelines are for cumulative impacts and should also be considered in conjunction with incremental impact calculations presented in **section 6.9.5**.

Table 6.15 Air quality goals for particulates

Pollutant	Averaging period	Criteria (µg/m^3)	Reference
PM_{10}	24-hour	50 Maximum of 5 days exceedance per year	(DEC 2005; NEPC 2003)
	Annual	30	(DEC 2005)
$PM_{2.5}$	24-hour	25	Advisory goal [9] (NEPC 2003)
	Annual	8	

In relation to the current NEPC PM_{10} guideline, the following is noted (NEPC 1998, 2010, 2014):

- The guideline was derived through a review of appropriate health studies by a technical review panel of the NEPC where short-term exposure-response relationships for PM_{10} and mortality and morbidity health endpoints were considered
- Mortality health impacts were identified as the most significant and were the primary basis for the development of the guideline
- On the basis of the available data for key air sheds in Australia, the imposition of a criterion of 50 micrograms per cubic metre was based on analysis of the number of premature deaths that would be avoided and associated cost savings to the health system (using data from the US). The development of the goal is not based on any acceptable level of risk
- The acceptable number of exceedances per year is not based on an assessment of health, rather it is based on review of existing air quality in urban areas and identifying a number of exceedances that are consistent with these existing areas
- The assessment undertaken considered exposures and issues relevant to urban air environments that are expected to also be managed through the PM_{10} guideline. These issues included emissions from vehicles and wood heaters
- Review of the air goals in 2010 did not identify that there was a need to revise the PM_{10} guideline. However the review undertaken in 2014/2015 recommended a lowering of the PM_{10} guideline (as an annual average to 20 micrograms per cubic metre; and 24-hour average to 40–50 micrograms per cubic metre) based on a current review of health benefits and implementation of cost-effective abatement policies. These recommendations have not yet been incorporated by the NEPC.

A similar approach has been adopted by NEPC (Burgers & Walsh 2002; NEPC 2002, 2014) in relation to the derivation of the $PM_{2.5}$ air quality goals, with specific studies related to $PM_{2.5}$ and mortality and morbidity indicators considered. The 2014 review recommended that the advisory goals for $PM_{2.5}$ be formally adopted by the NEPC.

Table 6.16 presents a comparison of the NEPC guidelines with those established (following more recent reviews) by the WHO (WHO 2005), the EU and the USEPA (2012). The goals established by the NEPC for $PM_{2.5}$ (and adopted in this assessment) are similar to but slightly more conservative (health protective) than those provided by the WHO, EU and the USEPA. The NEPC and NSW OEH PM_{10} guidelines are also similar to those established by the WHO and EU, however the guidelines are significantly lower than the 24-hour average guideline available from the USEPA.

9 The $PM_{2.5}$ criteria established by the National Environment Protection Council are advisory goals. The goals have been derived on the basis of available health based information that relates exposure to $PM_{2.5}$ to adverse health effects. However, as $PM_{2.5}$ had not been routinely monitored in the community at the time when the criteria were being considered, existing urban (and regional) levels were not known, and the ability to meet the advisory goals could not be determined in individual states. Hence these criteria were not established as standards as defined in the *National Environment Protection Council Act 1994*. The relevance of any exceedance of these goals will be fully assessed once a sufficient database of monitoring data is available. They are, however, goals that are based on the protection of population health.

Table 6.16 Comparison of particulate matter air quality goals

Pollutant	Averaging period	Criteria/guidelines/goals			
		NEPC and NSW OEH	WHO (2005)	EU #	USEPA (2012)
PM_{10}	24-hour	50 µg/m^3 Maximum of 5 days exceedance per year	50 µg/m^3	50 µg/m^3 as limit value with 35 exceedances permitted each year	150 µg/m^3 (not to be exceeded more than once per year on average over 3 years)
	Annual	30 µg/m^3	20* µg/m^3	40 µg/m^3 as limit value	NA
$PM_{2.5}$	24-hour	25 µg/m^3 (goal)	25 µg/m^3	NA	35 µg/m^3 (98th percentile, averaged over 3 years)
	Annual	8 µg/m^3 (goal)	10* µg/m^3	25 µg/m^3 as target value from 2010 and limit value from 2015. 20 µg/m^3 as a 3 year average (average exposure indicator) from 2015 with requirements for ongoing percentage reduction and target of 18 µg/m^3 as 3 year average by 2020	12 µg/m^3 (annual mean averaged over 3 years)

Current EU Air Quality Standards available from http://ec.europa.eu/environment/air/quality/standards.htm

* The WHO Air Quality guidelines are based on the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ in the ACS study (Pope et al. 2002). The use of a $PM_{2.5}$ guideline is preferred by the WHO (WHO 2005).

The air quality guidelines for $PM_{2.5}$ and PM_{10} relate to total concentrations in the air (from all sources including the project). The background air quality data that has been used in the AQAR for this project is summarised in **section 6.2** and generally relates to urban air quality in areas located away from major roadways. The background data includes a contribution of PM that is derived from vehicles that utilise the existing road network (but not representative of locations adjacent to main roadways). Hence use of this background data will result in some double counting of the contribution of vehicle emissions to air quality in the local area, as the project has then modelled emissions from surface roads and added these to the background.

Table 6.17 and **Table 6.18** present a summary of the maximum 24-hour average and annual average concentrations of $PM_{2.5}$ and PM_{10} relevant to the assessment of emissions in 2021 and 2031.

Table 6.17 Review of cumulative PM concentrations – 24-hour average

Location and scenario	Maximum 24-hour average $PM_{2.5}$ concentration (µg/m^3)		Maximum 24-hour average PM_{10} concentration (µg/m^3)	
	without project	with project	without project	with project
2021				
Maximum residential	29.3	28.2	54.0	52.0
Maximum commercial	30.5	26.6	55.4	50.0
2031				
Maximum residential	28.7	28.2	53.8	53.4
Maximum commercial	29.5	26.1	55.2	51.0

Location and scenario	Maximum 24-hour average $PM_{2.5}$ concentration ($\mu g/m^3$)		Maximum 24-hour average PM_{10} concentration ($\mu g/m^3$)	
Cumulative – 2031				
Maximum residential	28.7	26.5	53.8	51.1
Maximum commercial	29.5	27.8	55.2	51.3
Guideline	**25**	**25**	**50**	**50**

Table 6.18 Review of cumulative PM concentrations – annual average

Location and scenario	Maximum annual average $PM_{2.5}$ concentration ($\mu g/m^3$) without project	with project	Maximum annual average PM_{10} concentration ($\mu g/m^3$) without project	with project
2021				
Maximum residential	11.0	10.8	22.1	22.3
Maximum commercial	11.5	10.1	22.7	21.3
2031				
Maximum residential	10.9	10.9	22.1	22.4
Maximum commercial	11.1	10.1	22.8	21.5
Cumulative - 2031				
Maximum residential	10.9	10.2	22.1	21.3
Maximum commercial	11.1	10.4	22.8	21.1
Guideline	**8**	**8**	**30**	**30**

The maximum total/cumulative concentrations of $PM_{2.5}$ presented in the above tables are above the guidelines for both a 24-hour average and an annual average. This is due to the existing levels of $PM_{2.5}$ in air within the existing urban environment. These elevated background levels will be present in the community regardless of the construction and operation of the project. Concentrations of total $PM_{2.5}$, however, are essentially unchanged or lower within the local community with the operation of the project, as well as the construction and operation of WestConnex.

The maximum cumulative concentrations of PM_{10} presented in the above tables are above the 24-hour average guideline, but below the annual average guideline. The elevated levels of total PM_{10} is due to the existing levels of PM_{10} in air within the existing urban environment. These elevated background levels will be present in the community regardless of the construction and operation of the project. Concentrations of total PM_{10}, however, are essentially unchanged or lower within the local community with the construction and operation of the project, as well as the construction and operation of WestConnex.

Based on the above the project provides some benefit (ie an improvement) in generally lowering concentrations of $PM_{2.5}$ and PM_{10} within the local community (compared with the situation where the project was not constructed).

To further address potential risks to human health that may be associated with localised changes (or redistribution) in exposures to $PM_{2.5}$ and PM_{10} that relate to the project, an assessment of incremental impacts have been undertaken and are presented in **section 6.9.5**.

6.9.5 Changes in air quality associated with project

Methodology for assessment of $PM_{2.5}$ and PM_{10}

A detailed assessment of potential health effects associated with exposure to changes in air quality as a result of the project has been undertaken. As no threshold has been determined for exposure to $PM_{2.5}$ or PM_{10} the assessment of impacts on health has utilised robust, published, quantitative relationships (exposure-response relationships) that relate a change in $PM_{2.5}$ or PM_{10} concentration with a change in a health indicator. **Appendix A** presents an overview of the methodology adopted for using exposure-response relationships for the assessment of health impacts in a community.

This report has presented an assessment of changes in individual risk associated the predicted changes in air quality, as well as a change in population health impacts (as would be measured by changes in mortality statistics or hospital admissions) related to changes in exposures to particulates in the surrounding community.

For the assessment of changes in particulate matter exposures in the community the assessment has focused on health effects and exposure-response relationships that are robust and relate to $PM_{2.5}$, being the more important particulate fraction size relevant for emissions from combustion sources. Assessment of PM_{10} has also been included.

The specific health effects (or endpoints) evaluated in this assessment have been identified and include the following:

Primary health endpoints:

- Long-term exposure to $PM_{2.5}$ and changes in all-cause mortality (equal or greater than 30 years of age)
- Short-term exposure and changes to the rate of hospitalisations with cardiovascular and respiratory disease (equal or greater than 65 years of age).

Secondary health endpoints (to supplement the primary assessment):

- Short-term exposure to PM_{10} and changes in all-cause mortality (all ages)
- Long-term exposure to $PM_{2.5}$ and changes in cardiopulmonary mortality (equal or greater than 30 years of age)
- Short-term exposure to $PM_{2.5}$ and changes in cardiovascular and respiratory mortality (all ages)
- Short-term exposure to $PM_{2.5}$ and changes in emergency department admissions for asthma in children aged 1–14 years.

Table 6.19 presents a summary of the health endpoints considered in this assessment, the relevant health impact functions (from the referenced published studies) and the associated β coefficient relevant to the calculation of a relative risk (refer to **Appendix A** for details on the calculation of a β coefficient from published studies).

The health impact functions presented in this table are considered to be the most current and robust values, and are appropriate for the quantification of potential health effects for the health endpoints considered in this assessment.

Table 6.19 Adopted health impact functions and exposure-responses relationships

Health endpoint	Exposure period	Age group	Published relative risk [95% confidence interval] per 10 µg/m^3	Adopted β coefficient (as %) for 1 µg/m^3 increase in PM	Reference
Primary assessment health endpoints					
$PM_{2.5}$: Mortality, all causes	Long-term	≥30yrs	1.06 [1.04-1.08]	0.0058 (0.58%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500,000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009). This study is an extension (additional follow-up and exposure data) of the work undertaken by Pope (2002), is consistent with the findings from California (1999-2002) (Ostro et al. 2006) and is more conservative than the relationships identified in a more recent Australian and New Zealand study (EPHC 2010).
$PM_{2.5}$: Cardiovascular hospital admissions	Short-term	≥65yrs	1.008 [1.0059-1.011]	0.0008 (0.08%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 0 (exposure on same-day)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
$PM_{2.5}$: Respiratory hospital admissions	Short-term	≥65yrs	1.0041 [1.0009-1.0074]	0.00041 (0.041%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 2 (exposure 2 days previous)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
Secondary assessment health endpoints					
PM_{10}: Mortality, all causes	Short-term	All ages*	1.006 [1.004-1.008]	0.0006 (0.06%)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
$PM_{2.5}$: Mortality, all causes	Short-term	All ages*	1.0094 [1.0065-1.0122]	0.00094 (0.094%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

Health endpoint	Exposure period	Age group	Published relative risk [95% confidence interval] per 10 µg/m^3	Adopted β coefficient (as %) for 1 µg/m^3 increase in PM	Reference
$PM_{2.5}$: Cardio-pulmonary mortality	Long-term	≥30yrs	1.14 [1.11-1.17]	0.013 (1.3%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500,000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009).
$PM_{2.5}$: Cardiovascular mortality	Short-term	All ages*	1.0097 [1.0051-1.0143]	0.00097 (0.097%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
$PM_{2.5}$: Asthma (emergency department admissions)	Short-term	1-14 years	--	0.00148 (0.148%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Jalaludin et al. 2008)
$PM_{2.5}$: Respiratory mortality (including lung cancer)	Short-term	All ages*	1.0192 [1.0108-1.0278]	0.0019 (0.19%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

* Relationships established for all ages, including young children and the elderly

The assessment of health impacts for a population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004) (also outlined in **Appendix A**) where the exposure-response relationships (presented in **Table 6.19**) have been directly considered.

A change in relative risk has then been calculated on the basis of the following:

- Estimates of the changes in $PM_{2.5}$ and PM_{10} exposure levels due to the project in 2021 and 2031 (as provided by the AQAR) at each of the community receptors (refer to
- **Table** 4.1) as well as the maximum off-site residential and workplace receptors
- Baseline incidence of the key health endpoints that are relevant to the population exposed (refer to **Table 4.4**)
- Exposure-response relationships expressed as a percentage change in health endpoint per micrograms per cubic metre change in particulate matter exposure (refer to **Table 6.19**).

The change in incidence of each health indicator relevant to changes in $PM_{2.5}$ exposures in the local community (for the population exposed) has been calculated on the basis of the following:

- The relative risk has been calculated for a population weighted annual average incremental increase in $PM_{2.5}$ concentrations (using the approach outlined above). The population weighted average change in concentration has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics within a suburb (ie mesh blocks – which are small blocks that cover an area of approximately 30 urban residences). For each mesh block in a suburb the average change in $PM_{2.5}$ concentration has been calculated and multiplied by the population living in the mesh block (data available from the ABS for the 2011 census year). The

weighted average has been calculated by summing these calculations for each mesh block in a suburb and dividing by the total population in the suburb (i.e. in all the mesh block)

- A change in the number of cases associated with the change in $PM_{2.5}$ impact evaluated in the population within the study area has been calculated (refer to **Appendix A** for details on the methodology). The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered (refer to **Table 4.4**) and the population (for the relevant age groups) present in the suburb (refer to **Table 4.2**).

Methodology for assessing exposure to diesel particulate matter

In addition to the above exposure-response relationships, potential exposure to diesel particulate matter (DPM) derived from the project has been evaluated.

Diesel exhaust (DE) is emitted from 'on-road' diesel engines (vehicle engines) and can be formed from the gaseous compounds emitted by diesel engines (secondary particulate matter). After emission from the exhaust pipe, diesel exhaust undergoes dilution and chemical and physical transformations in the atmosphere, as well as dispersion and transport in the atmosphere. The atmospheric lifetime for some compounds present in diesel exhaust ranges from hours to days.

Available evidence indicates that there are human health hazards associated with exposure to diesel particulate matter. The hazards include acute exposure-related symptoms, chronic exposure related non-cancer respiratory effects, and lung cancer. The non-cancer health effects associated with exposure to DPM are adequately addressed on the basis of the current $PM_{2.5}$ and PM_{10} guidelines. However the potential for exposure to DPM to result in an increased risk of lung cancer in the community requires further consideration. **Appendix B** presents the methodology adopted for the assessment of lung cancer risks associated with exposure to DPM. In summary, the following has been assumed/undertaken:

- It has been conservatively assumed that 100 per cent of $PM_{2.5}$ predicted in the local community is derived from diesel vehicles and comprises DPM
- An incremental lifetime risk of lung cancer has been calculated (refer to **Appendix B** for methodology) on the basis of the inhalation toxicity value available from the World Health Organisation (WHO 1996).

Acceptability of health impacts

Based on the methodology outlined above, potential health impacts associated with the project have been assessed on the basis of two calculations:

- Calculation of an annual risk for each health endpoint. This is a change in risk that differs from the baseline risk (or incidence) of the effect occurring for any member of the population, where exposed to the change in particulate matter concentration estimated
- Calculation of a change in incidence of the health effect occurring within the population exposed. This calculates the change in the number of cases (mortality or hospitalisations) that may occur for the population assumed to be exposed to the changes in particulate matter concentration estimated.

To determine if the calculated annual risk or change in incidence within a population associated with particulate matter impacts from the project may be considered to be acceptable a number of factors need to be considered. These are discussed further in **Appendix C**.

It is noted that the change in risk and health incidence calculated in this assessment includes negative values (where there is a lower risk and incidence of health effects in the community with the operation of the project) and positive values (where there is an increase in risk and health incidence in the community with the operation of the project).

Any negative values are related to improved health impacts in the community and are considered acceptable. The following discussion relates to the evaluation of positive values.

Risk:

While it is not possible to provide a rigid definition of acceptable risk due to the complex and context-driven nature of the challenge, it is possible to propose some general guidelines as to what might be an acceptable risk for specific development projects.

If a level of less than 10^{-6} (one chance in a million) were retained as a level of increased risk that would be considered as a negligible risk in the community, then the level of risk that could be considered to be tolerable would lie between this level and an upper level that is considered to be unacceptable.

While there is no guidance available on what level of risk is considered to be unacceptable in the community, a level in excess of 10^{-4} for increased risk (one chance in 10,000) has been generally adopted by health authorities as a point where risk is considered to be unacceptable. This level has been adopted in the development of drinking water guidelines (that impact on whole populations) (for exposure to carcinogens as well as for annual risks of disease (Fewtrell & Bartram 2001)) and in the evaluation of exposures from pollutants in air (NSW DEC 2005).

Between an increased risk level considered negligible (less than 10^{-6}) and unacceptable (greater than 10^{-4}) lie risks that may be considered to be tolerable or even acceptable. Tolerable risks are those that can be tolerated (and where the best available, and most appropriate, technology has been implemented to minimise exposure) in order to realise some benefit.

In a societal context, risks are inevitable and any new development will be accompanied by risks which are not amenable or economically feasible to reduce below a certain level. It is not good policy to impose an arbitrary risk level to such developments without consideration of the many factors that should be considered to determine what is 'tolerable' or 'acceptable'.

Hence for this project the calculated risks have been considered to be tolerable when in the range of greater than or equal to 10^{-6} and less than or equal to 10^{-4} of increased risk and where the increased incidence of the health impacts are considered to be insignificant.

Population incidence:

The assessment of changes in incidence of particular health indicators in the community results in the calculation of a change in the number of cases (of mortality, hospital or emergency department admissions) within the population evaluated.

As discussed in **Appendix C**, where changes in air quality associated with this project are well below 10 cases per year they are considered to be within the normal variability of health statistics, and these changes would not be measurable in any health statistics for the area. For evaluating impacts from this project a more conservative tenfold margin of safety has been included to determine what changes in incidence may be considered negligible within the study population.

This means that changes in the population incidence of any health effect evaluated that is less than one case per year are considered negligible.

Calculated risks and population incidence for operation of the project

Review of the changes in particulate matter concentrations predicted in 2021 and 2031 indicates that for the majority of receptors in the local community the project results in a decrease in the concentration of $PM_{2.5}$ and PM_{10}. For a small number of receptors there is an increase in the concentration of $PM_{2.5}$ and PM_{10}, which relates to the redistribution of emissions from surface roads in the study area, not from emissions from the ventilation facilities (as discussed in the AQAR). This is illustrated in **Figure 6.4** that presents a contour plot of the change in annual average PM2.5 concentrations associated with the project in the assessment year 2021. For most of the project area the change is negative (ie a decrease in PM2.5 concentrations due to the project) however for some areas adjacent to some roadways the change is positive (ie an increase in PM2.5 concentrations due to the project).

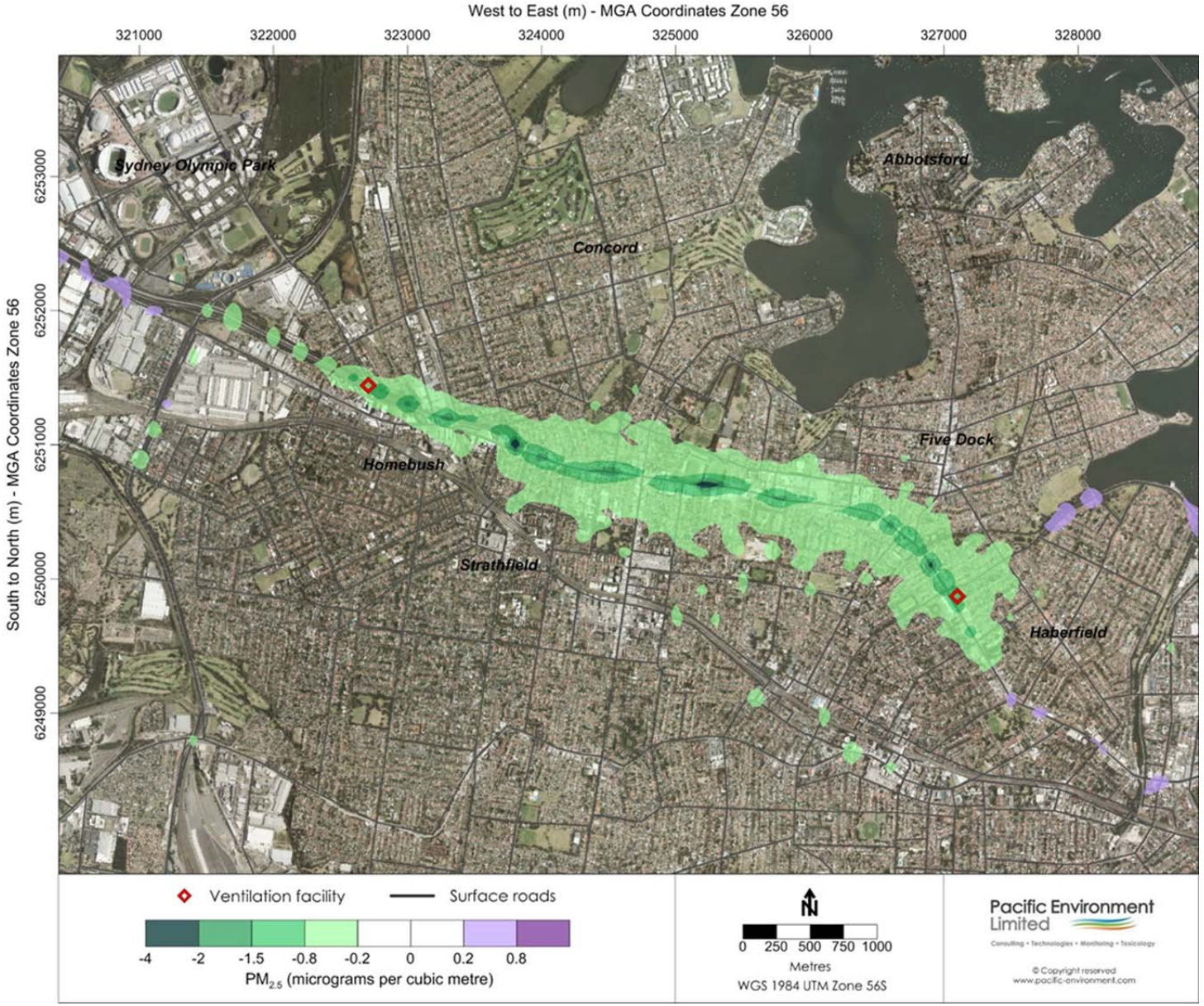


Figure 6.4 Contour plot showing change in annual average PM2.5 concentrations associated with the project in 2021

Based on the methodology outlined above, **Table 6.20** and **Table 6.21** present the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted receptor (regardless of land use), the maximum impacted residential and workplace receptors, as well as the individual community receptors, for the operational years 2021 and 2031. The maximum impacted receptor has been included and calculated assuming exposures by residents to address potential changes in land use that may occur during future redevelopment. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included in the tables.

The calculated change in risk at the maximum receptors represents the worst-case impact associated with the project. Risks for all other receptors (regardless of land use) will be lower than calculated for the maximum receptors.

Figure 6.5 shows the calculated risks for each of the community receptors, associated with the primary health endpoints evaluated in this assessment for the project's operations in 2021 and 2031.

All calculated individual risks are presented in **Appendix E**.

Table 6.22 and **Table 6.23** and **Figure 6.6** present a summary of the calculated change in incidence of the relevant health effects for the population living in the suburbs within the study area, associated with changes in $PM_{2.5}$ concentrations for the expected use of the project in 2021 and 2031. All calculations, including the calculated weighted population risk for each suburb evaluated, are presented in **Appendix F**.

Table 6.20 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2021

Health Endpoint	Maximum calculated change in individual risk for key locations in community						
	Maximum	Maximum residential	Maximum workplace	Childcare centres	Hospitals	Schools	Aged Care
Change in annual average concentration							
$PM_{2.5}$ (µg/m^3)	0.46	0.43	0.25	0.026	-0.033	0.14	-0.00009
PM_{10} (µg/m^3)	0.65	0.65	0.50	0.086	-0.20	0.11	0.073
Primary health indicators: $PM_{2.5}$							
Mortality all causes (long-term effects, ages 30+)	3×10^{-5}	2×10^{-5}	1×10^{-5}	1×10^{-6}	-2×10^{-6}	8×10^{-6}	-5×10^{-9}
Cardiovascular hospitalisations (short-term effects, ages 65+)	3×10^{-5}	3×10^{-5}	2×10^{-5}	2×10^{-6}	-2×10^{-6}	1×10^{-5}	-7×10^{-9}
Respiratory hospitalisations (short-term effects, ages 65+)	7×10^{-6}	7×10^{-6}	4×10^{-6}	4×10^{-6}	-5×10^{-7}	2×10^{-6}	-1×10^{-9}
Secondary health indicators: $PM_{2.5}$							
Mortality all causes (short-term effects, all ages)	2×10^{-6}	2×10^{-6}	1×10^{-6}	1×10^{-7}	-2×10^{-7}	7×10^{-7}	-4×10^{-10}
Mortality, cardiopulmonary (long-term effects, ages 30+)	2×10^{-5}	2×10^{-5}	1×10^{-5}	1×10^{-6}	-2×10^{-6}	7×10^{-6}	-5×10^{-9}
Mortality, cardiovascular (short-term effects, all ages)	7×10^{-7}	6×10^{-7}	4×10^{-7}	4×10^{-8}	-5×10^{-8}	2×10^{-7}	-1×10^{-10}
Mortality, respiratory (short-term effects, all ages)	5×10^{-7}	4×10^{-7}	2×10^{-7}	3×10^{-8}	-3×10^{-8}	1×10^{-7}	-9×10^{-11}
Asthma emergency department hospitalisations (1-14 years)	8×10^{-6}	8×10^{-6}	5×10^{-6}	5×10^{-7}	-6×10^{-7}	2×10^{-6}	-2×10^{-9}

Health Endpoint	Maximum calculated change in individual risk for key locations in community						
Secondary health indicators: PM_{10}							
Mortality all causes (short-term effects, all ages)	2×10^{-6}	2×10^{-6}	8×10^{-7}	3×10^{-7}	-6×10^{-7}	4×10^{-7}	2×10^{-7}
Diesel particulate matter							
Lung cancer	8×10^{-6}	7×10^{-6}	4×10^{-6}	4×10^{-7}	-6×10^{-7}	2×10^{-6}	-2×10^{-9}
Negligible risks	$< 1 \times 10^{-6}$						
Tolerable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$						
Unacceptable risks	$> 1 \times 10^{-4}$						

Negative value indicates that risks have decreased with operation of the project

Table 6.21 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2031

Health Endpoint	Maximum calculated change in individual risk for key locations in community						
	Maximum	Maximum residential	Maximum workplace	Childcare centres	Hospitals	Schools	Aged Care
Change in annual average concentration							
$PM_{2.5}$ ($\mu g/m^3$)	0.41	0.33	0.26	0.15	-0.12	0.086	0.083
PM_{10} ($\mu g/m^3$)	0.61	0.61	0.46	0.15	-0.35	0.021	0.042
Primary health indicators: $PM_{2.5}$							
Mortality all causes (long-term effects, ages 30+)	3×10^{-5}	3×10^{-5}	2×10^{-5}	8×10^{-6}	-7×10^{-6}	5×10^{-6}	5×10^{-6}
Cardiovascular hospitalisations (short-term effects, ages 65+)	4×10^{-5}	4×10^{-5}	2×10^{-5}	1×10^{-5}	-8×10^{-6}	6×10^{-6}	6×10^{-6}
Respiratory hospitalisations (short-term effects, ages 65+)	8×10^{-6}	8×10^{-6}	5×10^{-6}	2×10^{-6}	-2×10^{-6}	1×10^{-6}	1×10^{-6}
Secondary health indicators: $PM_{2.5}$							
Mortality all causes (short-term effects, all ages)	3×10^{-6}	3×10^{-6}	2×10^{-6}	7×10^{-7}	-6×10^{-7}	4×10^{-7}	4×10^{-7}
Mortality, cardiopulmonary (long-term effects, ages 30+)	3×10^{-5}	3×10^{-5}	2×10^{-5}	7×10^{-6}	-6×10^{-6}	4×10^{-6}	4×10^{-6}
Mortality, cardiovascular (short-term effects, all ages)	8×10^{-7}	8×10^{-7}	5×10^{-7}	2×10^{-7}	-2×10^{-7}	1×10^{-7}	1×10^{-7}
Mortality, respiratory (short-term effects, all ages)	5×10^{-7}	5×10^{-7}	3×10^{-7}	1×10^{-7}	-1×10^{-7}	8×10^{-8}	8×10^{-8}
Asthma emergency department hospitalisations (1–14 years)	9×10^{-6}	7×10^{-6}	6×10^{-6}	3×10^{-6}	-2×10^{-6}	2×10^{-6}	1×10^{-6}
Secondary health indicators: PM_{10}							
Mortality all causes (short-term effects, all ages)	2×10^{-6}	2×10^{-6}	1×10^{-6}	5×10^{-7}	-1×10^{-6}	7×10^{-8}	1×10^{-7}
Diesel particulate matter							
Lung cancer	9×10^{-6}	9×10^{-6}	5×10^{-6}	2×10^{-6}	-2×10^{-6}	1×10^{-6}	1×10^{-6}
Negligible risks	$< 1 \times 10^{-6}$						
Tolerable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$						
Unacceptable risks	$> 1 \times 10^{-4}$						

Negative value indicates that risks have decreased with operation of the project

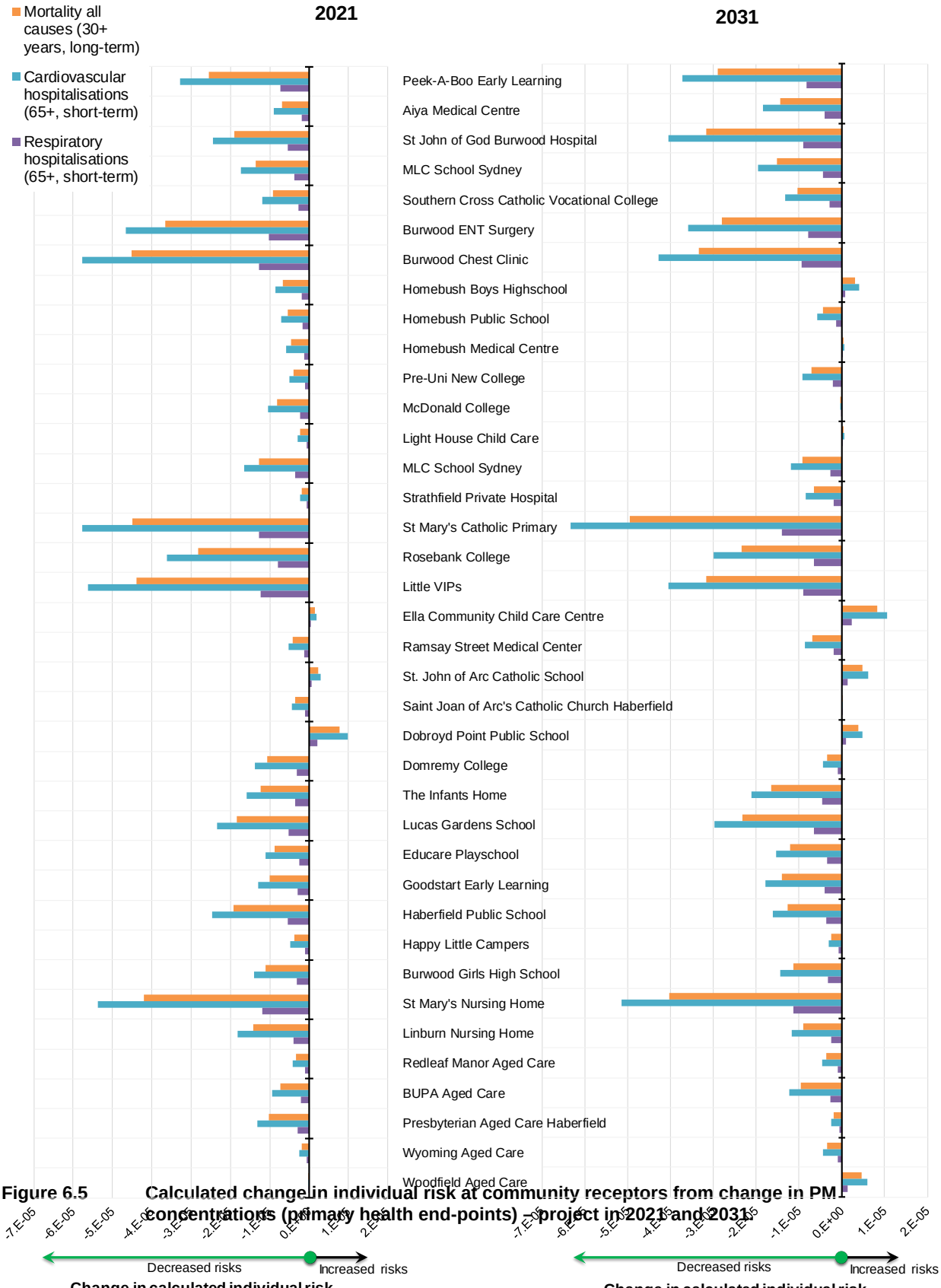


Figure 6.5 **Calculated change in individual risk at community receptors from change in PM concentrations (primary health end-points) – project in 2021 and 2031**

Table 6.22 **Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations – project in 2021**

Health endpoint	Change in incidence of health effects in population assessed (cases per year)				
	Strathfield – Burwood – Ashfield	Canada Bay	Leichhardt	Bankstown*	All suburbs
Primary health indicators: $PM_{2.5}$					
Mortality all causes (long-term effects, ages 30+)	-0.22	-0.084	-0.00052	-0.00075	-0.3
Cardiovascular hospitalisations (short-term effects, ages 65+)	-0.062	-0.024	-0.00010	-0.00023	-0.09
Respiratory hospitalisations (short-term effects, ages 65+)	-0.014	-0.0052	-0.000022	-0.000050	-0.02
Secondary health indicators: $PM_{2.5}$					
Mortality all causes (short-term effects, all ages)	-0.032	-0.011	-0.000067	-0.00011	-0.04
Mortality, cardiopulmonary (long-term effects, ages 30+)	-0.20	-0.075	-0.00047	-0.00067	-0.3
Mortality, cardiovascular (short-term effects, all ages)	-0.0097	-0.0034	-0.000020	-0.000034	-0.01
Mortality, respiratory (short-term effects, all ages)	-0.0064	-0.0023	-0.000013	-0.000022	-0.009
Asthma emergency department hospitalisations (1–14 years)	-0.017	-0.0065	-0.000037	-0.000084	-0.02

* includes small number of people (63) residing in Auburn within the study area

Negative value indicates that there is a decrease in incidence associated with the project

Table 6.23 Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations– project in 2031

Health Endpoint	Change in incidence of health effects in population assessed (cases per year)				
	Strathfield – Burwood – Ashfield	Canada Bay	Leichhardt	Bankstown*	All suburbs
Primary health indicators: $PM_{2.5}$					
Mortality all causes (long-term effects, ages 30+)	-0.22	-0.079	0.00094	-0.00047	-0.3
Cardiovascular hospitalisations (short-term effects, ages 65+)	-0.062	-0.022	0.00018	-0.00014	-0.08
Respiratory hospitalisations (short-term effects, ages 65+)	-0.014	-0.0049	0.000040	-0.000032	-0.02
Secondary health indicators: $PM_{2.5}$					
Mortality all causes (short-term effects, all ages)	-0.032	-0.011	0.00012	-0.000071	-0.04
Mortality, cardiopulmonary (long-term effects, ages 30+)	-0.20	-0.071	0.00084	-0.00043	-0.3
Mortality, cardiovascular (short-term effects, all ages)	-0.0096	-0.0032	0.000036	-0.000021	-0.01
Mortality, respiratory (short-term effects, all ages)	-0.0064	-0.0021	0.000024	-0.000014	-0.009
Asthma emergency department hospitalisations (1–14 years)	-0.017	-0.0061	0.000066	-0.000053	-0.02

* includes small number of people (63) residing in Auburn within the study area

Negative value indicates that there is a decrease in incidence associated with the project

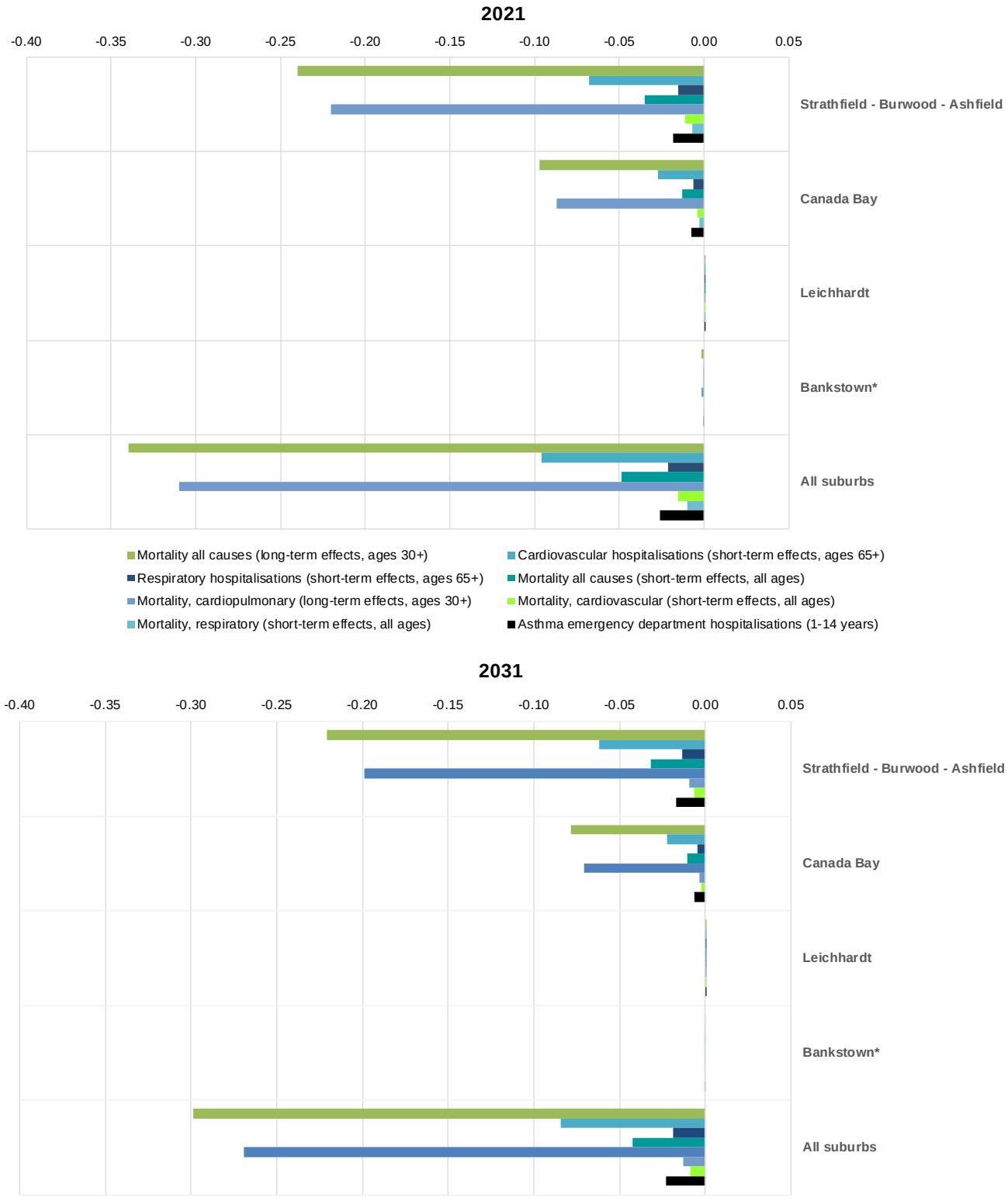


Figure 6.6 **Change in incidence of health endpoints associated with exposure to $PM_{2.5}$ from project (2021 and 2031) (cases per year)**

Review of the calculated changes in risk and incidence indicates the following in relation to impacts associated with the expected operation of the project in 2021 and 2031:

- Most of the calculated individual risks (as shown in **Figure 6.5** for the community receptors) are negative, meaning that the operation of the project will result in lower levels of risk, when compared with the situation where the project is not operating
- There are no calculated individual risks that exceed $1x10^{-4}$ and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated individual risks for the maximum impacted receptor and maximum impacted residential and workplace receptors are in the range $2x10^{-7}$ to $4x10^{-5}$ and are considered to range from negligible to tolerable/acceptable
- In relation to impacts on the health of the population in the local community, the calculated change in incidence of the health indicators evaluated shows that while the calculations suggest that there is likely to be an overall improvement in health within the community, for all the suburbs evaluated in the study area changes calculated are considered negligible.

Calculated risks and population incidence – cumulative scenario

Table 6.24 presents the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted receptor (regardless of land use), maximum impacted residential and workplace receptors, as well as the community receptors, for the cumulative scenario (ie WestConnex) during the year 2031. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included in the table.

All calculations relevant to this scenario are presented in **Appendix G**.

Table 6.24 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – cumulative scenario in 2031

Health Endpoint	Maximum calculated change in individual risk for key locations in community						
	Maximum	**Maximum residential**	**Maximum workplace**	**Childcare centres**	**Hospitals**	**Schools**	**Aged care**
Change in annual average concentration							
$PM_{2.5}$ (µg/m^3)	0.75	0.75	0.70	0.010	-0.22	0.057	0.00008
PM_{10} (µg/m^3)	1.0	1.0	0.90	0.011	-0.43	0.16	0.10
Primary health indicators: $PM_{2.5}$							
Mortality all causes (long-term effects, ages 30+)	4×10^{-5}	4×10^{-5}	4×10^{-5}	6×10^{-7}	-1×10^{-5}	3×10^{-6}	2×10^{-7}
Cardiovascular hospitalisations (short-term effects, ages 65+)	5×10^{-5}	5×10^{-5}	5×10^{-5}	7×10^{-7}	-2×10^{-5}	4×10^{-6}	6×10^{-9}
Respiratory hospitalisations (short-term effects, ages 65+)	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-3×10^{-6}	9×10^{-7}	1×10^{-9}
Secondary health indicators: $PM_{2.5}$							
Mortality all causes (short-term effects, all ages)	4×10^{-6}	4×10^{-6}	3×10^{-6}	5×10^{-8}	-1×10^{-6}	3×10^{-7}	4×10^{-10}
Mortality, cardiopulmonary (long-term effects, ages 30+)	4×10^{-5}	4×10^{-5}	4×10^{-5}	5×10^{-7}	-1×10^{-5}	3×10^{-6}	4×10^{-9}
Mortality, cardiovascular (short-term effects, all ages)	1×10^{-6}	1×10^{-6}	1×10^{-6}	2×10^{-8}	-3×10^{-7}	8×10^{-8}	1×10^{-10}
Mortality, respiratory (short-term effects, all ages)	7×10^{-7}	7×10^{-7}	7×10^{-7}	1×10^{-8}	-2×10^{-7}	6×10^{-8}	8×10^{-11}
Asthma emergency department hospitalisations (1–14 years)	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-4×10^{-6}	1×10^{-6}	1×10^{-9}

Health Endpoint	Maximum calculated change in individual risk for key locations in community						
	Maximum	Maximum residential	Maximum workplace	Childcare centres	Hospitals	Schools	Aged care
Secondary health indicators: PM_{10}							
Mortality all causes (short-term effects, all ages)	3×10^{-6}	3×10^{-6}	2×10^{-6}	3×10^{-8}	-1×10^{-6}	5×10^{-7}	3×10^{-7}
Diesel particulate matter							
Lung cancer	1×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-7}	-4×10^{-6}	1×10^{-6}	1×10^{-9}
Negligible risks	$< 1 \times 10^{-6}$						
Tolerable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$						
Unacceptable risks	$> 1 \times 10^{-4}$						

Negative value indicates that risks have decreased with operation of the project

Review of the calculated changes in risk indicates the following in relation to impacts associated with the operation of WestConnex in 2031:

- Most of the calculated individual risks are negative, meaning that the operation of WestConnex will result in lower levels of risk in the community.
- There are no calculated individual risks that exceed $1x10^{-4}$ and hence there are no unacceptable risks identified in the community surrounding the project.
- The calculated individual risks for the maximum impacted receptor and maximum impacted residential and workplace receptors are in the range $7x10^{-7}$ to $5x10^{-5}$ and are considered to range from negligible to tolerable/acceptable.

6.10 Assessment of regulatory worst-case scenarios

Regulatory worst-case scenarios have been evaluated in the AQAR. These scenarios are based on the situation where emissions to air from the tunnel ventilation outlets occur at the maximum discharge limits. This may occur in the event of a breakdown or accident and may result in a short period of time where emissions from the tunnel ventilation facility are higher than during normal operations. Such situations are not planned and where they occur the duration of the event is not expected to last for longer than a few hours to less than a day. The scenarios considered in the AQAR assume that such an event may last for a 24-hour period.

The assumptions underpinning the all regulatory worst-case scenarios were very conservative, and resulted in contributions from project ventilation outlets that were much higher than those that could ever occur under any operational conditions in the tunnel.

In relation to impacts on health a worst-case situation results in short-term changes in air quality. Hence health effects identified and evaluated in this assessment that relate to changes in short-term concentrations of nitrogen dioxide and $PM_{2.5}$ require further assessment. The assessment of short-term health impacts has utilised the methodology outlined in **Appendix A** with the parameters selected to be relevant to a one-hour or 24-hour exposure period (as relevant to each pollutant). The assessment has considered the following scenarios:

- Short-term change in air concentrations associated with maximum emissions from the ventilation outlets from the project tunnel
- Short-term changes in air concentrations associated with maximum emissions form the ventilation outlets for the project tunnel and the M4–M5 link

Risk calculations can be undertaken for the short-term change in air quality associated with each of these scenarios. How often these event occur during any one year may result in some contribution to the total annual individual risk calculated for the expected operation of the project. The frequency of a worst-case traffic scenario occurring is not known, hence for the purpose of this assessment some conservative assumptions have been adopted.

Table 6.25 presents the calculated change in individual risk associated with exposure to worst-case emissions of nitrogen dioxide. The table includes the assumptions adopted for the assessment.

Table 6.26 presents the calculated change in individual risk associated with exposure to worst-case emissions of $PM_{2.5}$. The table includes the assumptions adopted for the assessment.

Appendix H presents the calculations undertaken to evaluate the above scenarios.

Table 6.25 Maximum calculated risks associated with short-term exposure changes in nitrogen dioxide concentrations: regulatory worst case

Scenario	Maximum change in individual risk for the following health endpoints		
	Mortality: All causes (ages 30+)	Mortality: Respiratory (all ages)	Asthma ED admissions (1-14 years)
The project			
Maximum annual risk – expected operations	$2x10^{-6}$	$4x10^{-6}$	$3x10^{-5}$
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 8 hours)*	$9x10^{-9}$	$2x10^{-8}$	$1x10^{-7}$
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	$5x10^{-7}$	$1x10^{-6}$	$6x10^{-6}$
Maximum annual risk – expected conditions plus worst-case event**	$2x10^{-6}$	$5x10^{-6}$	$4x10^{-5}$
The project and M4–M5 (cumulative)			
Maximum annual risk – expected operations	$2x10^{-6}$	$4x10^{-6}$	$3x10^{-5}$
Increase in risk for 1 day of worst-case emissions (assuming event lasts for 8 hours)*	$2x10^{-8}$	$4x10^{-8}$	$2x10^{-7}$
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	$9x10^{-7}$	$2x10^{-6}$	$1x10^{-5}$
Maximum annual risk – expected conditions plus worst-case event**	$3x10^{-6}$	$6x10^{-6}$	$4x10^{-5}$
Negligible risks	$< 1x10^{-6}$		
Tolerable/acceptable risks	$\geq 1x10^{-6}$ and $\leq 1x10^{-4}$		
Unacceptable risks	$> 1x10^{-4}$		

* Assumes that the maximum predicted impact occurs at the same location for eight hours, and occurs at the same location (receptor) every day the worst-case event occurs. With changes in meteorology in the local area the one-hour maximum concentration is expected to change in concentration and location throughout any one day and over different days. Hence this assumption is conservative.

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor).

Table 6.26 Maximum calculated risks associated with short-term exposure changes in $PM_{2.5}$ concentrations: regulatory worst case

Scenario	Maximum change in individual risk for the following short-term health endpoints					
	Cardiovascular hospitalisations (65 years+)	Respiratory hospitalisations (65 years +)	Mortality all causes (all ages)	Mortality cardiovascular (all ages)	Mortality respiratory (all ages)	Asthma ED admissions (1–14 years)
The project						
Maximum annual risk – expected operations	4×10^{-5}	8×10^{-6}	3×10^{-6}	8×10^{-7}	5×10^{-7}	9×10^{-6}
Increase in risk for 1 day of worst-case emissions	3×10^{-7}	6×10^{-8}	2×10^{-8}	6×10^{-9}	4×10^{-9}	7×10^{-8}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	1×10^{-5}	3×10^{-6}	1×10^{-6}	3×10^{-7}	2×10^{-7}	4×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	5×10^{-5}	1×10^{-5}	4×10^{-6}	1×10^{-6}	7×10^{-7}	1×10^{-5}
The project and M4–M5 (cumulative)						
Maximum annual risk – expected operations	5×10^{-5}	1×10^{-5}	4×10^{-6}	1×10^{-6}	7×10^{-7}	1×10^{-5}
Increase in risk for 1 day of worst-case emissions	6×10^{-7}	1×10^{-7}	4×10^{-8}	1×10^{-8}	8×10^{-9}	1×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	3×10^{-5}	7×10^{-6}	2×10^{-6}	6×10^{-7}	4×10^{-7}	7×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	8×10^{-5}	2×10^{-5}	6×10^{-6}	2×10^{-6}	1×10^{-6}	2×10^{-5}
Negligible risks	$< 1 \times 10^{-6}$					
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$					
Unacceptable risks	$> 1 \times 10^{-4}$					

* Assumes that the maximum predicted impact occurs at the same location (receptor) every day the worst-case event occurs. With changes in meteorology in the local area the 24-hour maximum concentration is expected to change in concentration and location over different days. Hence this assumption is conservative.

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor).

Review of the maximum calculated changes in risk associated with short-term changes in nitrogen dioxide (**Table 6.25**) and $PM_{2.5}$ (**Table 6.26**) concentration under the worst-case scenarios evaluated indicates the following:

- The maximum change in short-term risk associated with worst-case scenarios occurring on any one day is negligible
- Where it is conservatively assumed that the worst-case scenario occurs one day each week (and the maximum changes impact the same receptor location every time), the maximum individual risk increases

- The total maximum individual risk does not exceed $1x10^{-4}$ and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range $7x10^{-7}$ to $8x10^{-5}$ and are considered to range from negligible to tolerable/acceptable.

On the basis of the above, emissions from the ventilation outlets during a worst-case scenario (such as a breakdown or accident) has the potential to increase individual risks, however the maximum individual risks (even where conservative assumptions are adopted) remain in the range of negligible to tolerable/acceptable.

6.11 Uncertainties

6.11.1 Exposure concentrations

An assessment on the scale of the project is a complex, multi-step process which involves various different assumptions, inputs, models, and post-processing procedures. There is an inherent uncertainty in each of the methods used to estimate emissions and concentrations, and there are clearly limits to how accurately any impacts in future years can be predicted. Conservatism is built into predictions to ensure that a margin of safety is applied (ie to minimise the risk that any potential impacts are underestimated).

The operational air quality assessment for the project has been conducted, as far as possible, with the intention of providing 'accurate' or 'realistic' estimates of pollutant emissions and concentrations. The general approach has been to use inputs, models and procedures that are as accurate as possible, except where the context dictates that a degree of conservatism is sensible. An example of this is the estimation of the maximum one-hour NO_2 concentration during a given year. Any method which provides a 'typical' or 'average' one-hour NO_2 concentration will tend to result in an underestimate of the likely maximum concentration, and therefore a more conservative approach is required. However, the scale of the conservatism can often be quite difficult to define, and this can sometimes result in some assumptions being overly conservative. Skill and experience is required to estimate impacts that err on the side of caution but are not unreasonably exaggerated or otherwise skewed. By demonstrating that a deliberate overestimate of impacts is acceptable, it can be confidently predicted that the actual impacts that are likely to be experienced in reality would also lie within acceptable limits.

6.11.2 Approach to the assessment of risk for particulates

The available scientific information provides a sufficient basis for determining that exposure to particulate matter (particularly $PM_{2.5}$ and smaller) is associated with adverse health effects in a population. The data is insufficient to provide a thorough understanding of all of the potential toxic properties of particulates to which humans may be exposed. Over time it is expected that many of the current uncertainties will be refined with the collection of additional data, however some uncertainty will be inherent in any estimate. The influence of the uncertainties may be either positive or negative.

Overall, however, the epidemiological and toxicological data on which the assessment presented in this technical working paper are based on current and robust information for the assessment of risks to human health associated with the potential exposure to particulate matter from combustion sources.

6.11.3 Exposure-response functions

The choice of exposure-response functions for the quantification of potential health impacts is important. For mortality health endpoints, many of the exposure-mortality functions have been replicated throughout the world. While many of these have shown consistent outcomes, the calculated relative risk estimates for these studies do vary. This is illustrated by **Figure 6.7**, **Figure 6.8** and **Figure 6.9** that show the variability in the relative risk estimates calculated in published studies for the US (and Canadian) population that are relevant to the primary health endpoints considered in this assessment (USEPA 2012). A similar variability is observed where additional studies from Europe, Asia and Australia/New Zealand are considered.

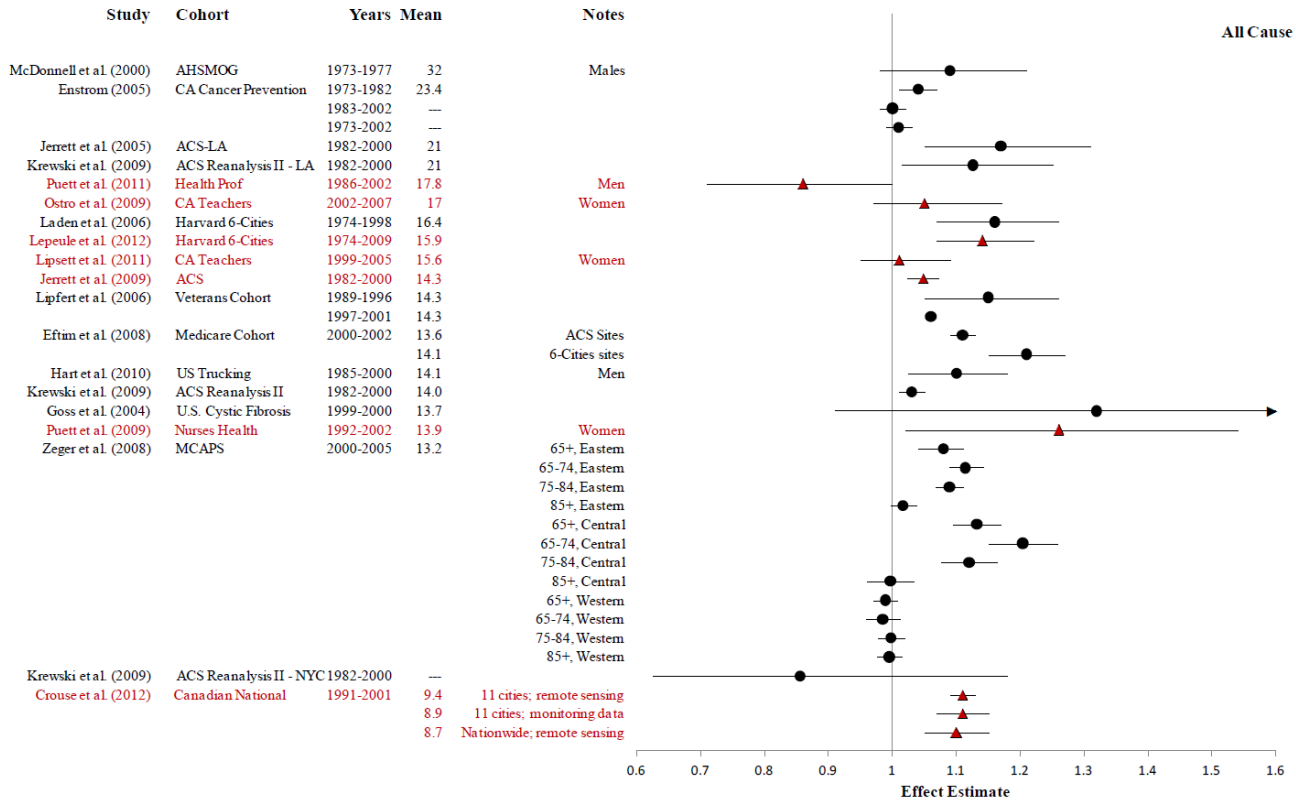


Figure 6.7 **All-cause mortality relative risk estimates for long-term exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)**

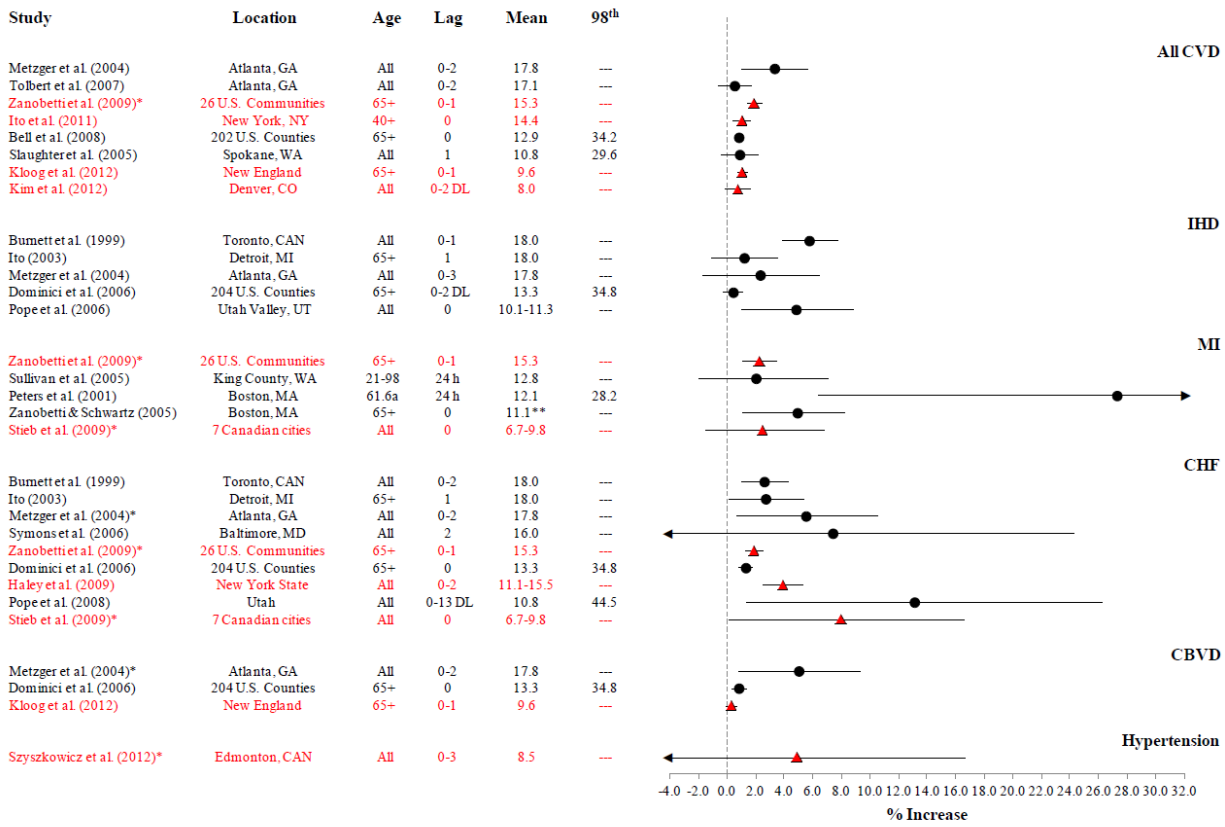


Figure 6.8 **Per cent increase in cardiovascular-related hospital admissions for a 10 microgram per cubic metre increase in short-term (24-hour average) exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)**

(note: CVD = cardiovascular disease; IHD = ischemic heart disease ; MI = myocardial infarction; CHF = congestive heart failure; CBVD = cerebrovascular disease)

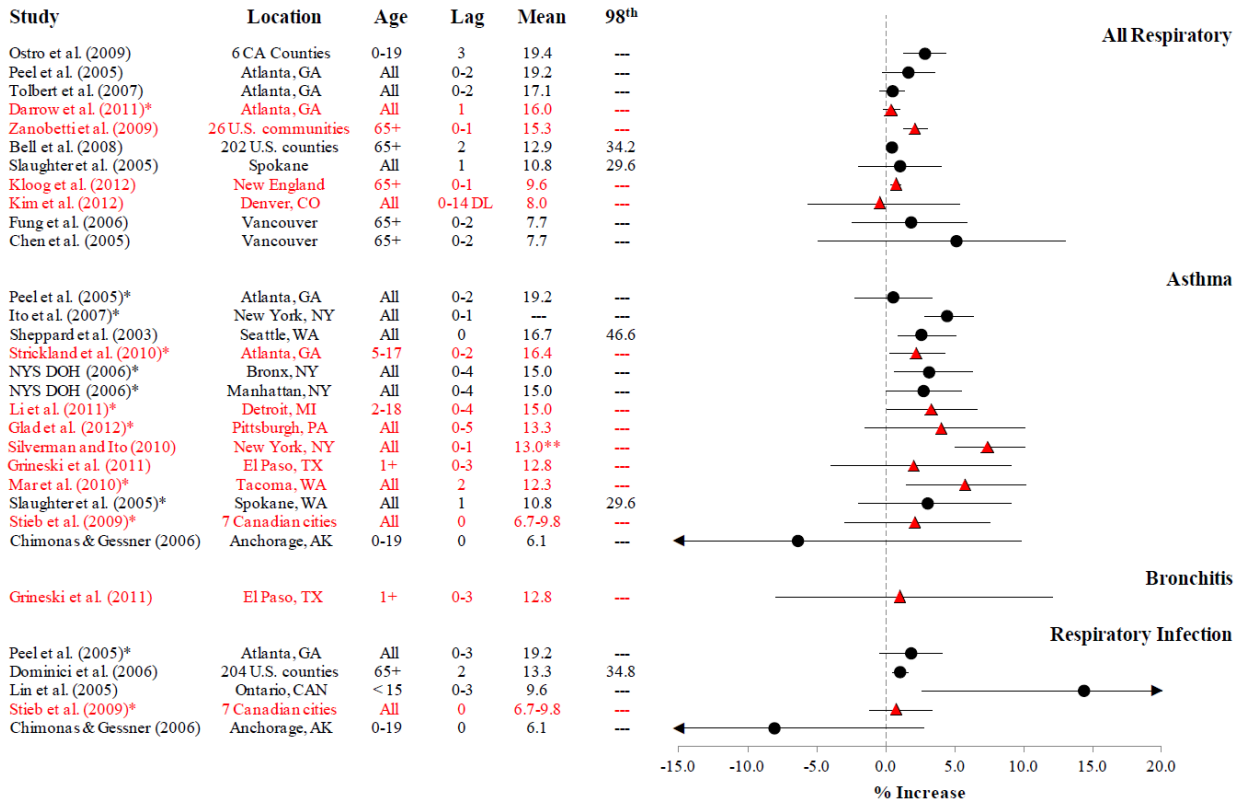


Figure 6.9 **Per cent increase in respiratory-related hospital admissions for a 10 micrograms per cubic metre increase in short-term (24-hour average) exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)**

These figures illustrate the variability inherent in the studies used to estimate exposure-response functions. The variability is expected to reflect the local and regional variability in the characteristics of particulate matter to which the population is exposed.

Based on the available data, and the detailed reviews undertaken by organisations such as the USEPA (USEPA 2010, 2012) and WHO (WHO 2003, 2006b, 2006a) and discussions with NSW Health, the adopted exposure-response estimates are considered to be current, robust and relevant to the characterisation of impacts from $PM_{2.5}$.

6.11.4 Shape of exposure-response function

The shape of the exposure-response function and whether there is a threshold for some of the effects endpoints remains an uncertainty. Reviews of the currently available data (that includes studies that show effects at low concentrations) have not shown evidence of a threshold. However, as these conclusions are based on epidemiological studies, discerning the characteristics of the particulates responsible for these effects and the observed shape of the dose-response relationship is complex. For example, it is not possible to determine if the observed no threshold response is relevant to exposure to particulates from all sources, or whether it relates to particulates from combustion sources only.

Most studies have demonstrated that there is a linear relationship between relative risk and ambient concentration however for long-term exposure-related mortality a log-linear relationship is more plausible and should be considered where there is the potential for exposure to very high concentrations of pollution. In this assessment the impact considered is a localised impact with low level incremental increases in concentration. At low levels the assumption of a linear relationship is considered appropriate.

6.11.5 Co-pollutants

It is likely that some of the health effects observed relate to both particulate matter and other related/correlated pollutants. Many of the pollutants evaluated come from a common source (eg fuel combustion) hence the use of only particulate matter as an index for the mix of pollutants is reasonable but conservative. This is particularly the case where there are multiple sources, or the scenario being evaluated is not from a source type that is likely to have dominated the studies underlying the relative risk values used in the risk assessment.

6.11.6 Selected health outcomes

The assessment of risk has utilised exposure-response functions and relative risk values that relate to the more significant health endpoints where the most significant and robust positive associations have been identified. The approach does not include all possible subsets of effects that have been considered in various published studies. However, the assessment undertaken has considered the health endpoints/outcomes that incorporate many of the subsets, and has utilised the most current and robust relationships.

6.11.7 Changing population size and demographics

The assessment presented has utilised information on the size of the population and distribution of the population in relevant ages from the ABS Census data from 2011. As discussed in **Section 4.4** the population in the study area is projected to increase significantly by 2035. In addition many of the LGAs are expecting a significant increase in the proportion of the population aged 65 years and over.

The increase in population size and distribution does not affect the calculation of an individual risk. The key aspect that does affect this calculation is the baseline incidence of the health effects within the population. Based on statistics from NSW Health the baseline incidence of the health effects evaluated in this assessment have been relatively stable or decreasing over time (with improvements in health care). Hence changes in the population over time are not expected to result in any increase in the calculated individual risk.

For the calculation of the change in incidence in the community the size and distribution of the population is important. However as the project is associated with an overall improvement (ie decrease in incidence) in the health endpoints evaluated, and increase in population will not change this outcome.

6.11.8 Application of exposure-response functions to small populations

The exposure-response functions have been developed on the basis of epidemiological studies from large urban populations where associations have been determined between health effects (health endpoints) and changes in ambient (regional) particulate levels. Typically these exposure response functions are applied to large populations for the purpose of establishing/reviewing air guidelines or reviewing potential impacts of regional air quality issues on large populations. When applied to small populations (less than larger urban centres such as the whole of Greater Sydney) the uncertainty increases.

In addition it is noted that the exposure-response functions relate changes in health endpoints with changes in regional air quality measurements. They do not relate to specific local sources (which occur within a regional airshed), or daily variability in exposure that may occur as a result of various different activities that may occur in any one day.

6.11.9 Diesel particulate matter evaluation

The assessment of exposure to diesel particulate matter has assumed that 100 per cent of the $PM_{2.5}$ associated with the project is derived from diesel sources. This is a conservative assumption.

The health hazard conclusions associated with exposure to diesel particulate matter are based on studies that are dominated by exhaust emissions from diesel engines built prior to the mid-1990s. With current engine use including some new and many older engines (engines typically stay in service for a long time), the health hazard conclusions, in general, are likely to be applicable to engines currently in use.

However as new and cleaner diesel engines, together with different diesel fuels, replace a substantial number of existing engines; the general applicability of the health hazard conclusions may require further evaluation. The NEPC (NEPC 2009) has established a program to reduce diesel emissions from the Australian heavy vehicle fleet. This is expected to lower the potential for all diesel emissions over time.

7 Assessment of in-tunnel air quality

7.1 General

In-tunnel air quality has been determined in the *Stage 1 (M4 East) Ventilation Report* (Stacey Agnew 2015). The in-tunnel air quality has been evaluated for the following reasons:

- To design and control ventilation systems. Tunnel builders and operators aim to minimise the significant costs involved in providing active ventilation. As a result, systems are designed, built and operated to provide sufficient ventilation to maintain acceptable air quality in the tunnel, but at reasonable cost (NHMRC 2008)
- To manage in-tunnel exposure to air pollution
- To manage external air pollution.

In-tunnel air quality limits based on the conditions of approval for NorthConnex have been considered in this assessment, as presented in **Table 7.1**. These have been taken to be limits/criteria that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters have been designed to ensure the in-tunnel concentration limits are not exceeded.

Table 7.1 In-tunnel average limits along length of tunnel

Pollutant	Concentration limit	Averaging period
Carbon monoxide	87 ppm	Rolling 15-minute average
Carbon monoxide	50 ppm	Rolling 30-minute average
Carbon monoxide	200 ppm	Rolling 3-minute average
Nitrogen dioxide	0.5 ppm	Rolling 15-minute average

Another important consideration for tunnel ventilation design is visibility. Consideration of visibility criteria in the design of the tunnel ventilation system is required due to the need for visibility levels that exceed the minimum vehicle stopping distance at the design speed. Visibility is reduced by the scattering and absorption of light by PM suspended in the air. The amount of light scattering or absorption is dependent upon the particle composition (dark particles, such as soot, are particularly effective), diameter (particles need to be larger than around 0.4 µm), and density. Particles causing a loss of visibility also have an effect on human health, and so monitoring visibility also provides the potential for an alternative assessment of the air quality and health risk within a tunnel. However, such an assessment is limited by the short duration of exposure in tunnels compared with the longer exposure times (24 hours and one year) for which the health effects of ambient particles have been established. Moreover, there is no safe minimum threshold for particles, and so visibility cannot reliably be used as a criterion for health risk (NHMRC 2008). Hence visibility limits within the tunnel have not been further evaluated.

Concentrations in the tunnel are expected to vary depending on:

- Time of day: Pollutant concentrations within the tunnels have been estimated to vary by a factor of up to nine times (depending on the particular pollutant and location within the main alignment tunnels) from periods of low traffic to peak traffic.
- Location within the main alignment tunnels: Concentrations of pollutants would gradually increase from the tunnel entrance to around the offtake to the ventilation outlets. The average exposure for a motorist would be around half of the maximum concentration within the tunnel.

The assessment of potential exposures that may occur in the tunnel has been undertaken with consideration of these factors. In addition the following has also been considered:

- The time spent within the tunnel would be limited, taking around four minutes to travel the full distance of the tunnel (when travelling at 80 kilometres per hour). During peak times the time of travel may be slightly longer depending on the speed of traffic flow in the tunnel. As the concentrations are not the same in all parts of the tunnel, with concentrations increasing with distance from the start, the amount of time exposed to the maximum concentration would be much lower (around one minute). The average exposure through the whole tunnel would be lower than, approximately half, the maximum (at the end of the tunnel).
- The concentration of pollutants within the vehicle itself, particularly where all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. Where the air conditioning/ventilation in the car is set to recirculation this would limit the contribution of air derived from within the tunnel to the air within the vehicle. Measurements conducted by NSW Health in relation to the M5 East Tunnel (NSW Health 2003) identified that closing car windows and switching the ventilation to recirculation can reduce exposures by approximately 70-75 per cent for carbon monoxide and nitrogen dioxide, 80 per cent for fine particulates and 50 per cent for volatile organic compounds.

The following provides further discussion on the range of concentrations predicted within the tunnel.

7.2 Carbon monoxide

Figure 7.1 presents the maximum one-hour concentration of carbon monoxide predicted in the eastbound and westbound tunnel of the project (M4 East) and the project plus the M4–M5 Link tunnel (to Rozelle).

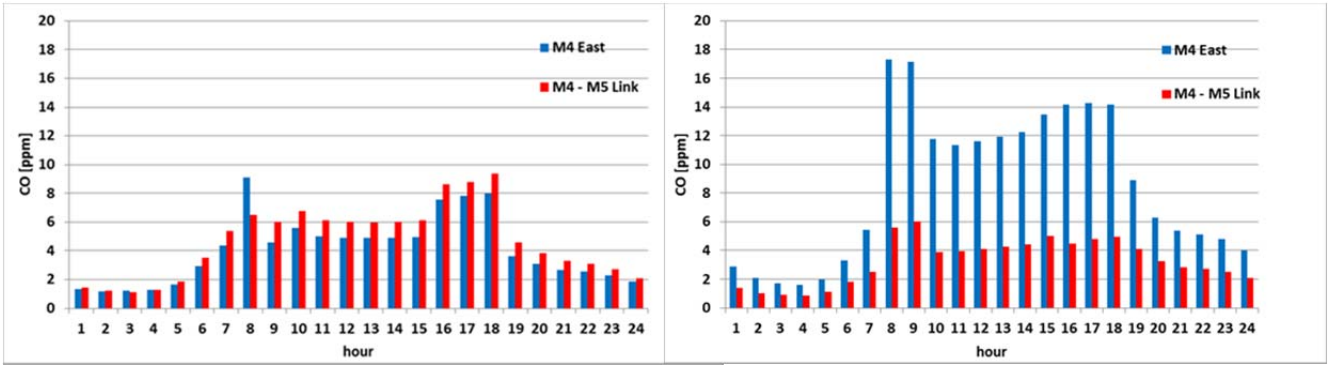


Figure 7.1 Maximum hourly concentration of carbon monoxide in-tunnel (Stacey Agnew 2015)

In relation to the carbon monoxide concentrations predicted within the tunnel, the following is noted:

- The maximum one-hour average concentration of carbon monoxide in the tunnel is predicted to be approximately 9.5 ppm eastbound and 17.5 ppm westbound. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO (WHO 2010) and 34 ppm established by the USEPA (NHMRC 2008). The concentrations are lower than PIARC in-tunnel limits (Longley 2014)
- The NHMRC (2008) has published measured concentrations of carbon monoxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the a range of average concentrations of carbon monoxide have been reported from six to 44 milligrams per cubic metre (NHMRC 2008). The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels.

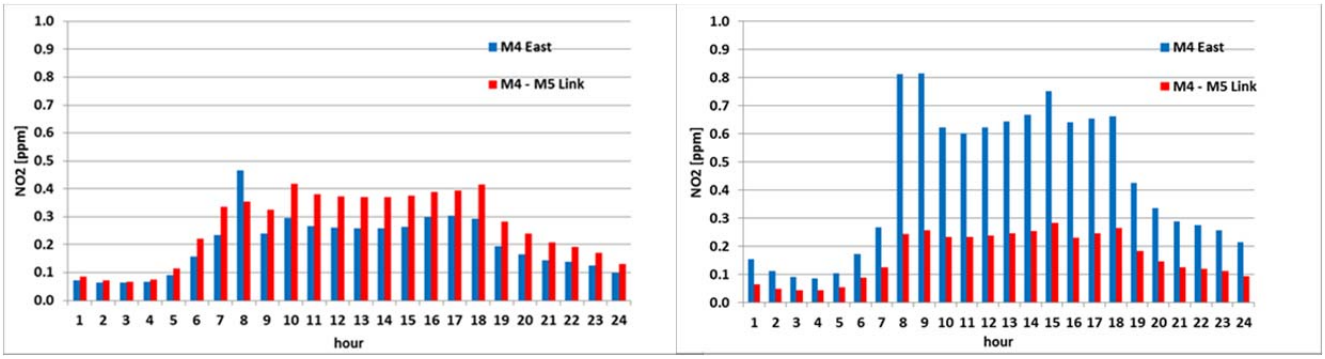
2008). The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels.

- The tunnel is designed to meet in-tunnel limits for carbon monoxide. While actual concentrations in the tunnel are expected to be lower than these limits, where the limits are met the following can be noted:
  - The in-tunnel limit for carbon monoxide of 87 ppm as a 15-minute average is equivalent to the health based guideline of 90 ppm (15-minute average) established by the WHO (WHO 2010)
  - The in-tunnel limit for carbon monoxide of 50 ppm as a 30-minute average is the same as the health based guideline of 50 ppm (30-minute average) established by the WHO (WHO 2000a).

On the basis of the above, where the in-tunnel limits are met there are no health issues of concern related to in-tunnel exposures to carbon monoxide.

7.3 Nitrogen dioxide

Figure 7.2 presents the maximum 1-hour concentration of nitrogen dioxide predicted in the eastbound and westbound tunnel of the project (M4 East) and the project plus the M4–M5 Link tunnel (to Rozelle).



Eastbound **Westbound**

Figure 7.2 Maximum hourly concentration of nitrogen dioxide in-tunnel. (Stacey Agnew 2015)

Figure 7.3 presents further review of the concentration of nitrogen dioxide with distance travelled through the tunnels (the project and M4–M5, ie from M4 portal to Rozelle) at different speeds at maximum traffic flow.

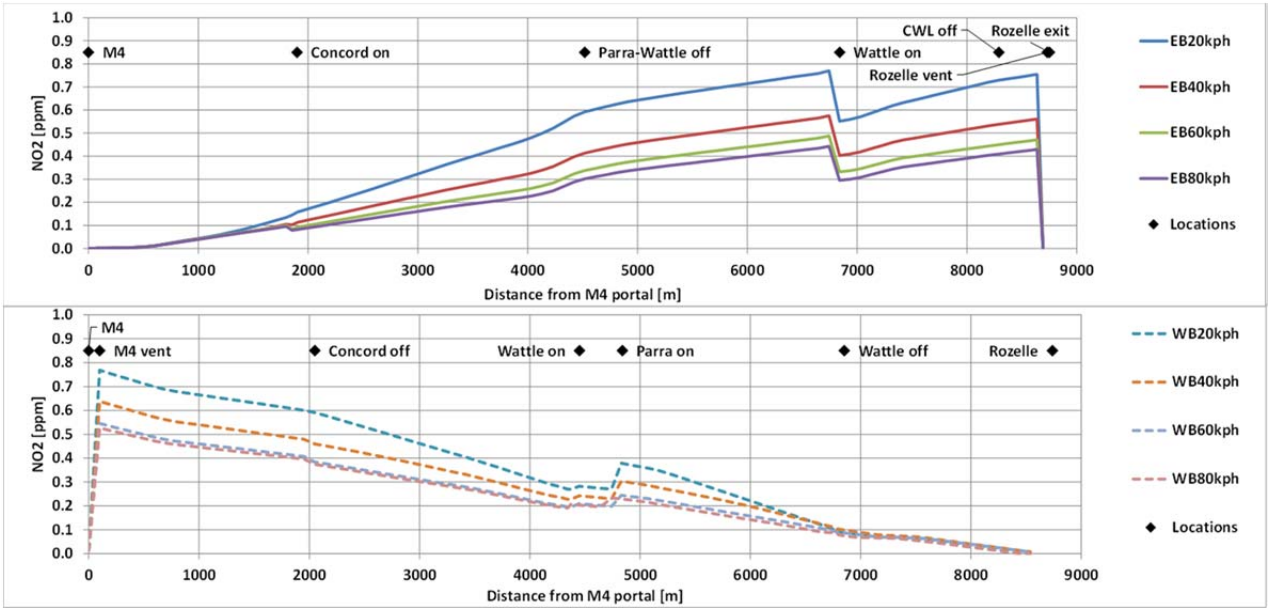


Figure 7.3 Change in concentration of nitrogen dioxide with distance in-tunnel, maximum traffic flow. (Stacey Agnew 2015)

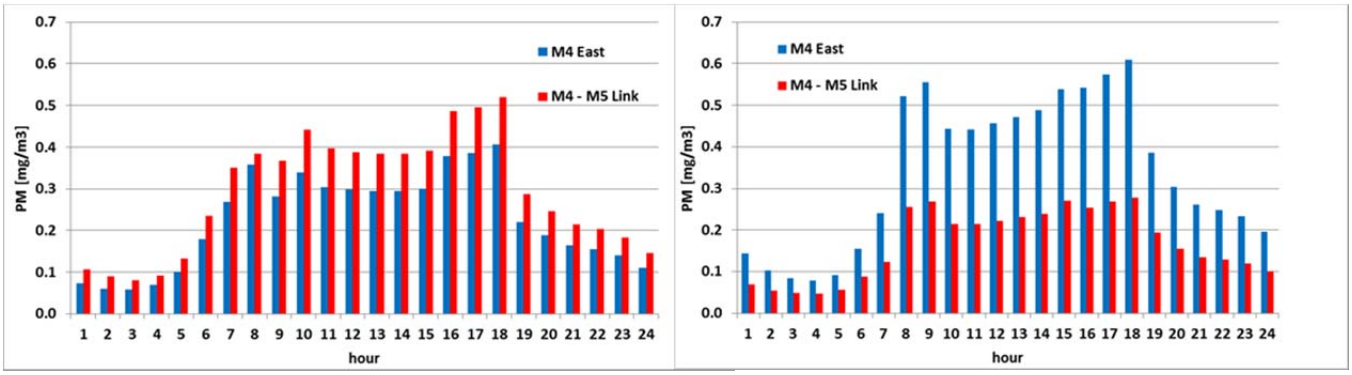
In relation to the nitrogen dioxide concentrations predicted within the tunnel, the following is noted:

- The maximum concentrations in the tunnel vary throughout the day, with the maximum concentration predicted at any time of the day and at the lowest speed less than 0.8ppm. The average concentration in the tunnel is expected to be (at most) approximately 0.4 ppm, less than the in-tunnel limit.
- The maximum in-tunnel concentrations estimated for travelling at 80 kilometres per hour through the tunnel varies from close to zero ppm at the start to approximately 0.45 ppm eastbound and 0.52 ppm westbound. These concentrations are lower than the in-tunnel limit of 0.5 ppm (set as a 15-minute average). Actual exposures will only occur for approximately four minutes at an average concentration of 0.2 to 0.25 ppm (with windows down). Lower concentrations of approximately 0.06 to 0.075 ppm may occur with windows up and ventilation on recirculation
- The NHMRC (2008) has published measured concentrations of nitrogen dioxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the NHMRC (2008) have reported a range of average concentrations of nitrogen dioxide in tunnels that range from 0.05 to 0.3 ppm with levels up to 0.4 ppm reported during peak periods. These levels are based on data with averaging times that vary from 30 seconds during travel through a tunnel, six minute averages, to long term data with (unspecified averaging times). At the downstream end of a tunnel (where exposure is very short, ie minutes) levels up to 0.8 ppm have been reported
- There are very few studies that have evaluated health effects associated with very short duration exposures to nitrogen dioxide. A study conducted in Stockholm (Svartengren et al. 2000) involved exposing 20 adults with mild asthma to air quality inside a car in a tunnel for 30 minutes, where levels of nitrogen dioxide ranged from 0.1 to 0.24 ppm (noting exposure to particulate matter and other pollutants inside the tunnel occurred at the same time). The study showed an increase in bronchial response to allergens several hours after exposure for individuals with allergic asthma. These results are similar to other studies where individuals with mild asthma were exposed to 0.26 ppm nitrogen dioxide for 30 minutes (Barck et al. 2002; Strand et al. 1998), a range of concentrations from zero to 0.53 ppm for 30 minutes (Bylin et al. 1988) or for 15 minutes on one day and then repeated twice in the following day (Barck et al. 2005), followed by an allergen inhalation challenge. None of the available studies have considered individuals with moderate or severe asthma. The data suggest that exposure to elevated concentrations of nitrogen dioxide in a congested tunnel is associated with an increased risk of adverse effects for those with asthma (NHMRC 2008)
- There are no guidelines in Australia for levels of nitrogen dioxide in tunnels. Guidelines for in-tunnel levels of nitrogen dioxide are available from Belgium (0.5 ppm for exposures <20 minutes), France (0.4 ppm for a 15 minute average exposure period), Norway (Norwegian Public Road Admiration (NPRA) guidelines of 0.75 ppm at the tunnel midpoint and 1.5 ppm at the tunnel ends, based on a 15-minute average), Hong Kong (one ppm as a five minute average) and New Zealand (one ppm as a 15 minute average) (Longley 2014). The PIARC has proposed a level of one ppm (as a threshold limit for healthy people). The average expected exposures, including the average during high traffic low speed situations are the same as or lower than the available short term (15 –20 minute average) guidelines.

7.4 Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to PM within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of PM within the tunnel will be higher than ambient air concentrations, and the concentration of PM will increase with increasing distance travelled through the tunnel.

Figure 7.4 presents the maximum one-hour concentration of particulate matter (taken to be PM_{10}) predicted in the eastbound and westbound tunnel of the project (M4 East) and the project plus the M4–M5 Link tunnel (to Rozelle).



Eastbound **Westbound**

Figure 7.4 Maximum hourly concentration of PM in-tunnel. (Stacey Agnew 2015)

In relation to the PM concentrations predicted within the tunnel, the following is noted:

- The in-tunnel concentrations for PM are taken to be PM_{10} concentrations. Concentrations of $PM_{2.5}$ will comprise a significant portion of the PM_{10} concentration
- The maximum concentration of PM_{10} in the tunnel ranges from approximately 0.05 milligrams per cubic metre to 0.6 milligrams per cubic metre. The average concentration in the tunnel may be approximately 0.025 milligrams per cubic metre to 0.3 milligrams per cubic metre. Motorists may be exposed to these levels where widows are open. The average exposure concentration is lower (ranging from 0.0075 to 0.09 milligrams per cubic metre) with windows closed and ventilation on recirculation
- The NHMRC (2008) has published measured concentrations of particulates (as $PM_{2.5}$ and PM_{10}) from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the sampling methodology and averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the range of average concentrations of $PM_{2.5}$ reported typically range from around 0.03 to 0.343 milligrams per cubic metre (AMOG 2012; NHMRC 2008). These levels are based on data with averaging times that vary from one hour averages, peak hour averages, daytime averages to 24-hour averages
- The exposure-response relationships for particulate matter that have been established on the basis of adverse health effects from short-term exposures relate to changes in the health effects associated with variability in 24-hour average concentrations of $PM_{2.5}$ in urban air. They do not relate to much shorter variations in $PM_{2.5}$ exposure that may occur within a 24-hour period, where there may be exposures over a few minutes to higher levels of $PM_{2.5}$. No guidelines are currently available for assessing potential health effects that may occur as a result of exposures to particulates that may occur for minutes (or even an hour)
- Recent review (WHO 2013b) of available studies in relation to short-duration (less than 24-hour) exposures to particulates indicates the following:
  - Epidemiological and clinical studies have demonstrated that sub-daily exposures to elevated levels of particulate matter can lead to adverse physiological changes in the respiratory and cardiovascular system, in particular exacerbation of existing disease. This is generally consistent with the outcome of studies reviewed and considered by the USEPA (USEPA 2009a)

- The studies available do not cover a range of exposure concentrations, nor do they adequately address other variables such as co-pollutants (gases) or repeated short-duration exposures
- The studies have not determined if a one-hour exposure would lead to a different response than a similar dose spread over 24-hours, or if an exposure-response can be determined
- Exposures that occur during the use of various transportation methods (such as in-vehicles) have been found to contribute to and affect 24-hour personal exposures.

The urban epidemiology studies (upon which exposure-response relationships are based and have been used in this assessment) utilise health data for adverse health effects from an urban population, where the urban population will have been exposed to ambient levels of particulate matter (as measured by air monitoring stations) as well as fluctuations that occur throughout the day during various daily activities including in-vehicle exposures (and others such as cooking). These large urban studies have related health effects to regional ambient (urban) air concentrations. They have not measured daily (or longer term) personal exposures to particulate matter, but such fluctuations would occur within the population exposed and would be expected to be accounted for within the health data considered in the epidemiology studies. Specific health effects from the short duration variations in particulate exposures throughout any specific day cannot be determined from these studies. It is therefore important to consider if exposures to $PM_{2.5}$ in the project tunnel would be consistent with other tunnels or in-vehicle exposures (during commuting in an urban environment), where the following can be considered:

- Exposure to particulate matter within vehicles varies with the intensity of the traffic, the age of the vehicle the choice of ventilation used within the vehicle and the type of fuel used (Knibbs, de Dear & Morawska 2010). Levels of $PM_{2.5}$ reported in vehicles in Europe (ETC 2013) vary from 0.022 to 0.085 milligrams per cubic metre for passenger cars and 0.026 to 0.13 milligrams per cubic metre for bus travel
- Levels of $PM_{2.5}$ that have been measured within cars while commuting in Sydney (where tunnel travel was not part of the study) range from 0.009 to 0.045 milligrams per cubic metre(NSW Health 2004)
- Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent (NSW Health 2003). While noting no guidelines are availability for very short duration exposures, this would further reduce exposure to motorists.

7.5 Overall assessment

The duration of exposure to vehicle emissions within the project tunnel is limited (minutes, rather than hours, only) and where guidelines are available for short duration exposures in tunnels, the likely exposure concentrations (representative of the average concentrations from start to end) are generally within or below these guidelines. Short-duration exposure guidelines are not available for nitrogen dioxide or particulate matter (assessed as $PM_{2.5}$). In relation to nitrogen dioxide, the published exposures studies suggest in situations of congested traffic (including delayed traffic in a tunnel) there is an increased risk of adverse health effects amongst individuals with asthma. Particulate matter exposures within the tunnel are estimated to be similar to those expected within other vehicle tunnels and are of limited duration (minutes). Particulate exposures vary throughout a day depending on the activities undertaken. Exposures that may occur within the tunnel are consistent with expected variability of exposure to PM throughout any day where a range of activities are undertaken.

For regular users of tunnels in Sydney, and regular commuters in heavy traffic, repeated short duration exposures to elevated concentrations of pollutants from vehicle emissions would contribute to a higher level of overall (daily) exposure and may be associated with increased risks for asthmatics. Drivers who regularly use tunnels or drive in congested traffic in Sydney can minimise exposure to vehicle emissions by keeping windows up and air conditioning on recirculation when in tunnels or heavy traffic conditions. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent.

8 Assessment of noise and vibration impacts on health

8.1 General

A detailed assessment of noise and vibration impacts associated with the project is presented in the *Noise and Vibration Impact Assessment* (NVIA) report prepared by SLR Consulting (and included in **Appendix K** of the EIS).

The NVIA assessment has been reviewed to determine if the predicted impacts have the potential to affect the health of the surrounding community, and if impacts are predicted, if they can be effectively mitigated.

For the assessment of noise and vibration impacts the project area has been broken into smaller noise catchment areas to allow a more refined picture of the noise levels along the route of the tunnel. The noise catchment areas are outlined in **Table 8.1** and shown in **Figure 8.1** and **Figure 8.2**.

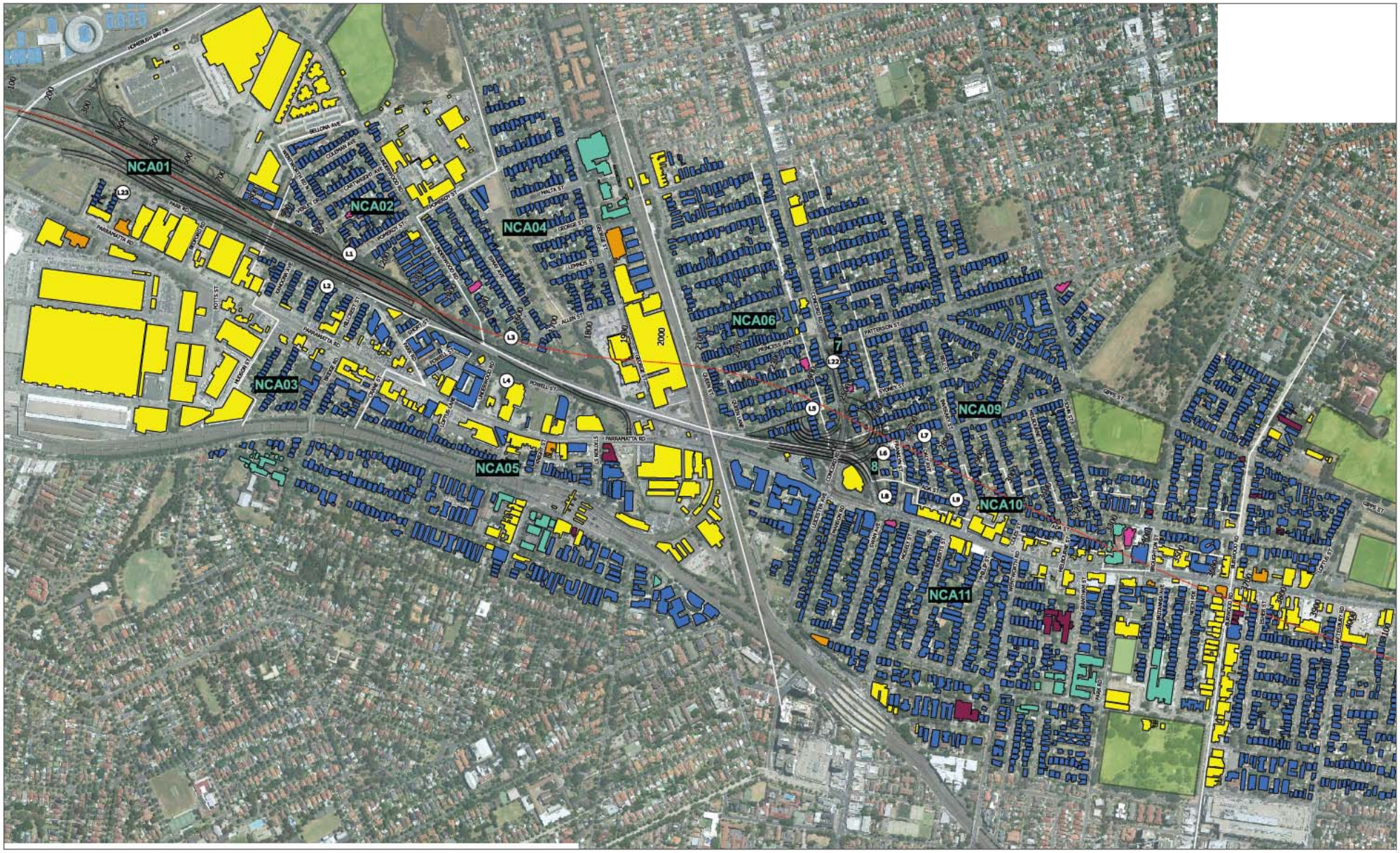
Table 8.1 Noise catchment areas and surrounding land uses (NVIA, SLR 2015)

NCA	Minimum distance (m)[1]	Description
Western works area - Homebush Bay to Concord Rd		
NCA01	17	Western end of the project between Homebush Bay Drive and Wentworth Road. Land use consists of commercial receivers with isolated residential receivers adjoining the M4.
NCA02	10	North of the M4 between Wentworth Road and Underwood Road. Land use comprises largely of residential receivers with isolated commercial receivers.
NCA03	10	South of the M4 between Bedford Road and Park Road at the intersection with Parramatta Road. Land use comprises of a mix of residential and commercial receivers fronting Parramatta Road.
NCA04	7	North of the M4 between Underwood Road and the Northern Line. Land use comprises largely of residential receivers with isolated commercial receivers.
NCA05	15	South of the M4 between Park Road at the intersection with Parramatta Road and the Northern Line. Land use comprises largely of residential and commercial receivers fronting Parramatta Road.
Concord Rd works area		
NCA06	15	North of the M4 between the Northern Line and Concord Lane. Land use is predominantly residential receivers.
NCA07	10	North of the M4 between Concord Lane and Franklyn Street. Land use consists largely of residential receivers with isolated commercial receivers.
NCA08	10	Small cluster of residential receivers fronting the M4 between Ada Street and Alexandra Street.
NCA09	90	Catchment adjoins either side of Gipps Street between Thornleigh Avenue and Burwood Road. Land use comprises of residential receivers and active and passive recreation areas.
NCA10	90	Catchment adjoins either side of Ada Street between Franklyn Street and Burwood Road. Land use comprises of residential receivers, educational facilities and isolated commercial receivers.
NCA11	40	Catchment includes properties that adjoin Parramatta Road and all properties south of Parramatta road between the Northern rail line and Burwood Road. Land use comprises of a mix of residential receivers, special use facilities and commercial receivers fronting Parramatta Road.

NCA	Minimum distance (m)[1]	Description
Central works area – Parramatta Road		
NCA12	n/a[2]	Catchment includes properties either side of Parramatta Road between Burwood Road and Henley Marine Drive. Land use comprises of a mix of residential receivers, special use facilities, active and passive recreation areas and commercial receivers fronting Parramatta Road.
Wattle Street works area		
NCA13	15	South of Parramatta Road between Iron Cove Creek and Bland Street. Land use comprises of a mix of residential receivers, special use facilities, active and passive recreation areas and commercial receivers fronting Parramatta Road.
NCA14	22	North of Parramatta Road between Henley Marine Drive and Walker Avenue. Land use comprises of a mix of residential and commercial receivers fronting Parramatta Road.
NCA15	8	Catchment adjoins either side of Wattle Street between Ash Lane and Ramsey. Land use consists of residential receivers.
NCA16	13	Catchment adjoins Ramsey Street and the western side of Wattle Street and consists of residential receivers and a passive recreational area.
NCA17	12	Catchment adjoins the eastern side of Wattle Street between Martin Street and Motley Avenue and consist of predominantly of residential receivers.
Parramatta Road works area		
NCA18	40	North of Parramatta Road between Walker Avenue and Alt Street. Land use comprises of a mix of residential and commercial receivers fronting Parramatta Road.
NCA19	12	North of Parramatta Road between Bland Street and Chandos Street. Land use comprises of a mix of residential receivers, an education facility and isolated commercial receivers fronting Parramatta Road.
NCA20	10	North of Parramatta Road between Chandos Street and Dalhousie Street. Land use comprises of a mix of residential and isolated commercial receivers fronting Parramatta Road.
NCA21	10	South of Parramatta road between Bland Street and Orpington Street. Land use comprises of a mix of residential and commercial receivers fronting Parramatta Road.

Note 1: Approximate minimum horizontal offset distance from the nearest receiver building facade (receiver of any type) to the centre of the nearest lane of the motorway/access ramps (including future works), in locations where construction works are occurring.

Note 2: Tunnelling works



SLR

2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
www.slrconsulting.com

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Project No.:	610.13569
Date:	18/07/2015
Drawn by:	ALW
Scale:	1:13,000
Sheet Size:	@ A4
Projection:	GDA 1994 MGA Zone 56

N

0 100 200 300 400 m

Design
NCA Boundary
Noise Logging Location

Receiver Building Categories

Residential
Commerical
Other (Educational)
Other (Medical)
Other (Place of Worship)
Other (Remaining)

Outdoor Usage

Outdoor Space (Active)
Outdoor Space (Passive)

Figure 8.1 Location of noise catchment areas, sensitive receivers and background noise monitoring locations: western part (SLR 2015)



SLR
2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
www.slrconsulting.com

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Other (Medical)
Other (Place of Worship)
Other (Remaining)

Outdoor Usage

Outdoor Space (Active)
Outdoor Space (Passive)

Figure 8.2 Location of noise catchment areas, sensitive receivers and background noise monitoring locations: eastern part (SLR 2015)

8.2 Existing noise environment

The existing ambient noise environment is described as variable and is dominated by proximity to major roadways. To undertake the noise assessment required for the project, the existing background noise quality needed to be assessed as the guidelines that relate to noise impacts from a specific project are based on levels allowable above background.

Existing ambient noise was measured during a baseline survey early in 2014 from 23 locations (L1–L23) in the local community (refer to **Figure 8.1** and **Figure 8.2**). Equipment was deployed to 23 locations for a 15 day period in March and April 2014. The rating background level (RBL) has been calculated for use in in the noise assessment. The RBLs calculated relate to specific time periods in the Interim Construction Noise Guideline (ICNG) (NSW DECC 2009) and Road Noise Policy (RNP) (NSW DECCW 2011) guidelines. In addition, attended monitoring was undertaken at a number of locations to supplement this data.

The noise levels at these locations showed a typical diurnal trend with lower noise levels during the night-time than the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

The data is also consistent with observed traffic flows on the adjacent major roads which have a relatively small reduction in traffic volumes during the evening compared to the daytime period, and a more significant reduction in volumes during the night-time.

The measured noise levels were used with consideration of the existing road traffic flows to calibrate the operational noise model and also to establish construction noise management levels (NML) relevant for the project.

8.3 Background noise levels

Noise levels that are measured, or modelled, refer to noise levels over a specified period of time and are presented as LA1, LA10, LA90, LAmax and LAeq levels of the noise environment. The LA1, LA10 and LA90 levels are the levels exceeded for one percent, 10 per cent and 90 per cent of the sample period respectively. The LAmax is indicative of maximum noise levels due to individual noise events. The LA90 is taken as the rating background noise level (RBL). The LAeq is the energy averaged noise level over a defined period.

Background noise levels for construction were established for the day (7am–6pm, varying from 41 to 61 decibels (dB(A)), evening (6–10pm, varying from 43 to 58 dB(A)) and night-time (10pm–7am, varying from 38 to 52 dB(A)) periods as RBL values determined on the basis adopted guidelines.

Background noise levels for operations were established for the day (7am–10pm varying from 55 to 73 dB(A)) as LAeq 15 hour and night-time (10pm–7am varying from 49 to 70 dB(A)) as LAeq 9 hour.

8.4 Noise assessment criteria

8.4.1 General

Noise issues in NSW are managed by the EPA. The EPA has prepared a number of guidance documents with regard to the types of noise that are considered in relation to construction and operation of the project. The *NSW Industrial Noise Policy* (INP) (NSW EPA 2000), the *NSW Road Noise Policy* (RNP) (NSW DECCW 2011), and the *Interim Construction Noise Guideline* (ICNG) (NSW DECC 2009) are all relevant to the assessment of noise generated by this project. In all these policies there is discussion of the need to balance the economic and social benefits of activities that may generate noise with the protection of the community from the adverse effects of noise. The noise assessment criteria adopted relate to levels of noise that can be tolerated or permitted above background before some adverse effect (annoyance, discomfort, sleep disturbance or complaints) occurs.

For the assessment of noise impacts from the project a range of guidelines and criteria have been adopted for the assessment of:

- Construction – including ground-borne noise, vibration and blasting

- Operations – relevant to road noise.

The following sections provide an overview of the guidelines adopted for each of these aspects. In particular the basis for the guidelines and relevance to the protection of health and well-being is noted.

8.4.2 Construction noise criteria

People are usually more tolerant to noise and vibration during the construction phase of proposals than during normal operation. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, acceptable noise and vibration levels are normally higher during construction than during operations.

Construction often requires the use of heavy machinery which can generate high noise and vibration levels at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration levels, the time at which the construction works are undertaken, and the character of the noise or vibration emissions.

The ICNG has been adopted for the assessment of noise during construction works (NSW DECC 2009). These guidelines require that noise impacts from the project be predicted at sensitive receivers. These noise levels are then compared with the project specific criteria, referred to as management levels, which are based on an increase above background levels. Where an exceedance occurs, the guidelines require that the proponent must apply all feasible and reasonable work practices to minimise impacts. The management levels are based on levels of noise above background that may result in reactions (or complaints) by the community. The levels are based on some reaction (noise affected) and a strong reaction (highly noise affected).

Levels of noise allowable outside standard work hours, particularly at night, are lower than those permitted during normal work hours. Where construction works are planned to extend over more than two consecutive nights a sleep disturbance assessment is required to be undertaken. Based on the available information on the levels of noise that result in sleep disturbance, a maximum internal noise level below 50–55 dB(A) is considered unlikely to cause awakening. The project has considered that a closed window provides up to 10 dB(A) attenuation of noise, and hence an upper limit of outside noise of 65 dB(A) has been adopted in these guidelines for the assessment of sleep disturbance.

The assessment of noise impacts during construction has been undertaken based on 21 noise catchment areas (assumed to have background noise levels consistent with the background noise monitoring location within each catchment area).

The ICNG provides an approach for determining LAeq (15minute) NML at residential receivers along the alignment applying the measured LAF90 (15minute) rating background noise levels (RBL).

Where construction would be undertaken during the night-time period the potential for sleep disturbance should be assessed. The current approach to identifying potential sleep disturbance impacts is to set a screening criterion 15 dB(A) above the RBL during the night-time period (10pm–7am).

8.4.3 Ground-borne noise criteria

The ICNG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne construction noise levels such as might occur during tunnelling. The ICNG provides ground-borne noise levels at residences for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home. The following ground-borne noise levels are applicable for residences:

- Evening 40 dB(A) LAeq (15minute)
- Night-time 35 dB(A) LAeq (15minute)

These guidelines are applicable during tunnelling and other construction activities that require rock breaking.

8.4.4 Vibration criteria

Guidelines for vibration from construction activities that are based on structural damage and human comfort (as tactile vibration or regenerated noise) have been adopted in the assessment.

Most commonly specified 'safe' structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

In terms of the most recent relevant vibration damage criteria, British Standard 7385:Part 2-1993 *Evaluation and Measurement for Vibration in Buildings Part 2* (British Standard 1993) is an internationally accepted standard against which the likelihood of building damage from ground vibration can be assessed. This is the Standard recommended in Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* (Australian Standards 1998) as the vibration guideline values and assessment methods 'applicable to Australian conditions'.

The German Standard DIN 4150:Part 3-1999 (DIN 1999) also provides guidelines for evaluating the effects of vibration on structures.

Using these guidance documents goals for vibration have been set in the NVIA for residential and commercial buildings as well as for heritage buildings.

In relation to human comfort, intermittent vibration has been evaluated on the basis of the EPA guideline *Assessing Vibration: A Technical Guideline* (NSW DEC 2006), which is based on vibration dose values (VDV). The criteria for VDV are based on the potential for annoyance (based on the level of vibration over the assessment period). Guidelines for continuous and impulsive vibration are dependent on the time of day they occur and the activity taking place that could be affected.

8.4.5 Blasting criteria

Guidance in relation to acceptable overpressure and vibration from blasting is provided in the ICNG, which specifies that the assessment should be based on the levels in the *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZEC 1990). To assess the potential for vibration damage from blasting, Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 (Australian Standards 1998).

8.4.6 Operational noise criteria

Operational noise impacts have been evaluated on the basis of the RNP, with additional guidance and criteria provided within Roads and Maritime's *Noise Criteria Guideline* (NCG) (NSW DECCW 2011; NSW Roads and Maritime 2015). The principles underlying the guidance documents are:

- Criteria are based on the road development type a residence is affected by due to the road project
- Adjacent and nearby residences should not have significantly different criteria for the same road
- Criteria for the surrounding road network are assessed where a road project generates an increase in traffic noise greater than 2dB(A) on the surrounding road network
- Existing quiet areas are to be protected from excessive changes in amenity due to traffic noise.

The project consists of both new and redeveloped roads or road sections according to the definitions in the guidance documents and so both road types need to be considered in developing project-specific limits.

The current approach to assessing potential sleep disturbance is to apply an initial screening criterion of background (or RBL) plus 15 dB(A) (as described in the Application Notes to the INP), and to undertake further analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period. Where the screening criterion cannot be met, additional analysis should consider the level of exceedance as well as factors such as:

- How often high noise events would occur
- The time of day (normally between 10pm and 7am)
- Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).

Other guidelines that contain additional advice relating to potential sleep disturbance impacts should also be considered, including the RNP (NSW DECCW 2011). The RNP provides a review of research into sleep disturbance. From the research to date, the RNP concludes that:

- Maximum internal noise levels of 50–55 dB(A) LAFmax are unlikely to awaken people from sleep
- One or two events per night, with maximum internal noise levels of 65 to 70 dB(A) LAFmax, are not likely to affect health and wellbeing significantly.

It is generally accepted that internal noise levels in a dwelling, with the windows open are 10 dB(A) lower than external noise levels. Based on a worst case minimum attenuation, with windows open, of 10 dB(A), the first conclusion above suggests that short term external noises of 60 dB(A) to 65 dB(A) are unlikely to cause awakening reactions. The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dB(A) to 80 dB(A) LAFmax are not likely to affect health and wellbeing significantly.

8.5 Overview of noise and vibration assessment

8.5.1 Construction impacts

Construction Noise

Noise during construction has been assessed on the basis of the proposed project and the level of noise likely to be generated from all the equipment to be used in the project. In addition information on local terrain and existing buildings and structures considered. A worst case assessment has been used in accordance with the ICNG, assuming no mitigation measures are implemented. For each area assessed, the noise levels at the most affected receiver have been used to represent the whole area.

Noise impacts in excess of the criteria have been identified at a number of receivers during site establishment works, temporary road closures and intersection modifications, works within the various construction compounds, construction of surface roadways, tunnelling works, demolition of acquired structures and construction of fixed facilities. Hence a range of mitigation measures will be required to mitigate and manage impacts.

It is likely that the screening criterion for sleep disturbance will be exceeded for night works adjacent to residential receivers for most works scenarios. The level of noise predicted for the project is typical for construction works using noise intensive equipment in built up areas. Construction works will be undertaken during daytime hours wherever possible. Further consideration of the need for noise mitigation measures where works are required at night will be undertaken during future detailed design works for the project.

Cumulative noise impacts

Assessing cumulative noise impacts is the process of checking whether different activities occurring in a similar area all contribute noise at the same receiver which could result in a greater than predicted level of noise using the normal assessment procedures. Such an assessment is technically difficult given the number of noise sources that are part of this project and estimating the timing of activities to check whether they are really likely to coincide.

If activities coincide it is likely to increase the number of 15 minute time periods where worst case noise impacts occur. As there is a more detailed design phase still to occur for this project the noise assessment has developed exceedance categories and guidance to be applied to manage cumulative noise.

Potential noise impacts from movement of construction vehicles

Potential increases in noise for sensitive receivers due to construction traffic has been assessed separately from the assessment of noise from other construction activities.

Heavy vehicles involved in construction are expected to travel via the existing arterial road network (M4, Parramatta Road, Wattle Street and Concord Road). Access and use of more local roads has been evaluated in the NVIA. The assessment found that Short Street East and Powell Street in Homebush Bay were the most affected local roads proposed to carry heavy construction vehicles. Other local roads will be around the construction ancillary facilities will be much less affected.

Ground-borne construction noise

Detailed three-dimensional modelling has been undertaken for the project to predict potential elevated noise due to ground-borne noise. Ground-borne noise occurs when works are being undertaken under the ground surface or in some other fashion that results in the vibrations from noise moving through the ground rather than the air. This project involves tunnelling so many of the more significant noise activities will be present at depth (approximately 40 metres below ground level).

The modelling has addressed the worst case situation when the tunnelling is occurring immediately beneath a sensitive receiver. The tunnelling equipment will move at about 30 metres per week so will be directly underneath a sensitive receiver for a relatively short time (a number of days).

The worst-case ground-borne noise levels are predicted to be compliant with the more stringent 35 dB(A) LAeq(15minute) night-time criterion at the majority of receivers which are potentially affected by ground-borne noise from tunnelling works.

At locations near interchanges where the tunnel rises to meet surface roads (Homebush Bay Drive, Concord Road, Wattle Street and Parramatta Road) some exceedance of the evening and night-time noise criteria may occur.

Vibration impacts

A range of the equipment to be used in construction will have the potential to cause unacceptable levels of vibration. Managing the potential for such vibration to actually cause discomfort or structural damage at sensitive receiver locations is based on ensuring suitable separation distances between the equipment and the receiver locations.

The assessment undertaken indicates a low risk of annoyance from the proposed tunnelling works using a roadheader with all receivers outside the nominated safe working distance except three receivers in NCA02 near the tunnel dives.

Assessment of the proposed roadworks using a large rock breaker may result in a significant number of receivers (just fewer than 500 residential receivers across the project) within the nominated safe working distance for human comfort vibration.

In relation to human comfort (response), the safe working distances relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted.

Receivers adjacent to construction areas have been identified as likely to perceive vibration impacts at times during construction works. This is expected to be primarily due to works associated with rock breakers and other high vibration plant items such as heavy vibratory rollers. In practice vibration impacts from most construction activities would be intermittent within the duration of the proposal and generally tend to move along the alignment such that impacts at any given receiver are for a far shorter duration. The required locations for vibration intensive equipment should be reviewed during detailed design when more specific information is available

Blasting Impacts

It has not yet been determined if blasting will be required for this project. If it is required, detailed analysis will be undertaken in the detailed design phase of the project to determine compliance with the relevant criteria. Blasting activities, if required, will only occur underground during standard daytime hours only (except where approved by the relevant authority). These works will be managed such that the criteria are not exceeded. Building condition surveys will be required for nearby buildings where it is identified that there may be potential for exceedances of the vibration criteria related to blasting.

8.5.2 Mitigation measures during construction

Noise mitigation measures will be required in order to manage the potential noise levels from the project. Construction Noise and Vibration Management Plans (CNVMPs) are proposed to be developed to outline specific measures required to mitigate noise impacts during the construction phase. The objectives of the CNVMP will be:

- Assist in ensuring that the noise emissions during the construction works comply with the NML and goals developed for the project
- Determine noise and vibration monitoring, reporting and response procedures
- Describe specific mitigation treatments, management methods and procedures to be implemented to control noise and vibration during construction
- Describe construction timetabling to minimise noise impacts including time and duration restrictions, respite periods and frequency
- Describe procedures for notifying residents of construction activities likely to affect their amenity through noise and vibration
- Define contingency plans to be implemented in the event of non-compliances and/or noise complaints.

A summary of the proposed project noise mitigation measures to be implemented where practical and appropriate and the potential noise benefit is presented in **Table 8.2**.

Table 8.2 Construction noise mitigation summary

Construction noise mitigation measures	Potential noise reduction
Schedule construction works within the standard construction hours.	No reduction during standard construction hours Minimises Out of Hours noise impacts
Schedule a respite period (eg one hour for every three hours of continuous construction activity) where required for high noise generating activities.	n/a
Schedule high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm where appropriate and agreed with the community.	n/a
Restrict construction vehicle movements during the night-time along local roads to light vehicles only, subject to further investigation of potential night-time maximum noise events during detailed design.	n/a
As far as reasonable practicable, limit heavy vehicle movements outside of standard construction hours associated with tunnel support works (spoil removal, concrete delivery and other heavy vehicle movements) to access and egress directly to and from the major road network.	n/a
Undertake spoil removal during the day as far as reasonable practicable.	n/a

Construction noise mitigation measures	Potential noise reduction
Minimise the number of consecutive nights work impacting the same receivers where practicable – likely to only apply to the moving corridor works and not the civil and tunnel sites.	n/a
Noisy activities should be scheduled outside normal school hours, where practicable.	n/a
Acoustic enclosure around tunnelling shafts – subject to detailed construction planning.	Typically around 15 to 22 dB(A)
Temporary acoustic fencing/barriers – subject to detailed construction planning.	Typically around 5 to 10 dB(A)
Portable temporary enclosures.	Up to around 15 dB(A)
Construct operational noise barriers early in the construction program where feasible and reasonable.	5–10 dB(A)
Install operational property treatments where required	Improved reduction of internal noise levels within habitable rooms of dwellings
Maximise offset distance between noisy plant items and nearby noise sensitive receivers where practicable	Approximately 6 dB(A) reduction per doubling of offset distance
Loading and unloading should be carried out away from sensitive receivers where practicable	Approximately 6 dB(A) reduction per doubling of offset distance
Avoid the coincidence of noisy plant working simultaneously close together, where practicable.	Up to 3 dB(A) for halving the number of similar dominant plant items working together.
Shut down equipment when not in use.	Negligible reduction in comparison to worst-case predictions, however eliminates noise source during less noise intensive works.
Maximise offset distance between noisy plant items and nearby noise sensitive receivers where practicable.	Approximately 6 dB(A) reduction per doubling of offset distance.
Regular compliance checks on the noise emissions.	n/a
Ongoing noise monitoring during construction at sensitive receivers.	n/a
Where practicable, heavy vehicle movements should be limited to daytime hours.	n/a
Non-tonal reversing alarms where practicable.	n/a
Equipment with directional noise emissions should be oriented away from sensitive receivers.	n/a

Impacts associated with vibration will be addressed, mitigated or managed, using measures to be outlined in the CNVMP. In general, mitigation measures that will be considered in developing the management plan include:

- Relocate vibration generating plant and equipment to areas within the site in order to lower the vibration impacts
- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment to less sensitive construction periods
- Use lower vibration generating items of excavation plant and equipment eg smaller capacity rockbreaker hammers as far as reasonably practicable
- Minimise consecutive works in the same locality (if applicable)
- Use dampened rockbreakers and/or ‘city’ rockbreakers to minimise the impacts associated with rockbreaking works where a larger breaker may result in adverse vibration impacts
- If vibration intensive works are required within the safe working distances, vibration monitoring or attended vibration trials would be undertaken to ensure that levels remain below the cosmetic damage criterion

- Building condition surveys would be completed both before and after the works to identify existing damage and any damage due to the works
- Measurements of existing ambient vibration levels will be undertaken at receivers with vibration sensitive equipment during the detailed design phase. This information would be used to inform the site-specific CNVMPs for works near these locations.

8.5.3 Noise impacts during operation

Noise impacts during operation of the project have been assessed for the years 2021 and 2031. The modelling has considered noise impacts in the community both without the project and with the project.

The assessment identified that many of the receivers located adjacent to the project are subject to significant existing noise impacts from existing road traffic (which in many cases already exceed the noise criteria). **Figure 8.3** presents the change in noise levels predicted at receptors located adjacent to the road corridor that are associated with the operation of the project.

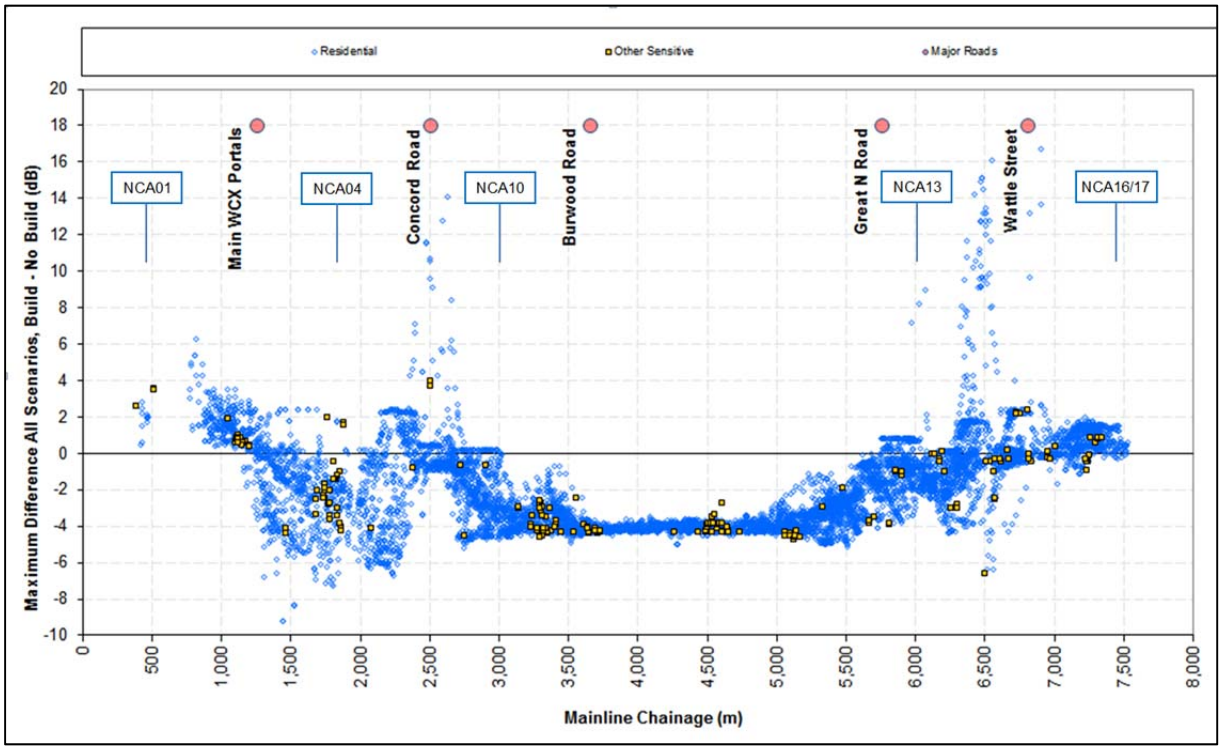


Figure 8.3 Predicted change in noise levels associated with the project: without mitigation (NVIA, SLR 2015)

The noise assessment identified the following:

- The project is predicted to result in an overall decrease in the number of receivers with an exceedance of the NCG criteria across the study area as a whole during both the daytime and night-time periods. This is mainly due to areas where traffic is forecast to reduce as part of the project (such as the unmodified section of the M4, east of the proposed portals and Parramatta Road east of Concord Road)
- The project is predicted to result in a reduction in noise levels at approximately 78 percent of the receivers within the study area (including those on Parramatta Road between the assessment areas)
- A minor (less than 2.0 dB) increase in noise levels is predicted at approximately 18 percent of the receivers. This magnitude of noise increase is noted in the RNP as being barely perceptible to the average person

- Large reductions in noise (up to around -8 dB) are identified in NCA04 (north of the M4, east of the new portals) where the project is forecast to significantly reduce traffic on the M4 carriageways
- Large increases in noise (up to around +16 dB) are identified in NCA07 to NCA09 (near the Concord Road interchange) and NCA14 to NCA18 (near the Wattle Street interchange) where the project adds new lanes/ramps closer to receivers in combination with removing existing building screening due to property acquisitions.

The relatively minor change in noise levels at the majority of receivers means that the requirement for the project to provide additional noise mitigation in most areas is due to high existing noise levels (ie cumulative limit exceedances).

Mitigation measures have been considered to reduce noise levels in those locations where it will be above guidance values. The use of low noise pavement and noise barriers has been considered. Mitigation measures are required at 400 receivers/floors (306 lots) in the project area as shown on **Figure 8.4** and **Figure 8.5**.

There will be properties that remain affected even after the installation of these mitigation measures. For these properties, individual treatment of buildings to attenuate noise is proposed. A total of 310 receivers (247 lots) have been assessed as needing at-property treatments.

8.5.4 Summary of impacts

Table 8.3 presents a summary of the noise and vibration impacts predicted in each NCA during construction and operation.



SLR
2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
www.slrconsulting.com

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Project No.:	610.13569
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Sheet Size:	@ A4
Projection:	GDA 1994 MGA Zone 56

N

0 100 200 300 400 m

Proposed Design
Acquired Buildings
Noise Barriers

Triggered Receivers

>2.0 dB Increase
Cumulative Limit
Both
Residential
Other Sensitive

Indicative Noise Contours - Maximum Increase (All Scenarios)

2 dB
4 dB
6 dB

Figure 8.4 Location of receivers considered for additional noise mitigation during operation: western part (SLR 2015)



SLR
2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
www.slrconsulting.com

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Figure 8.5 Location of receivers considered for additional noise mitigation during operation: eastern part (SLR 2015)

Table 8.3 Summary of noise impacts (from NVIA)

Noise catchment area	Existing noise Levels	Construction impacts Noise	Vibration	Management measures required	Operational impacts Impacts	Mitigation
NCA01	Dominated by M4 and Parramatta Road with noise levels between 55 and 65 dBA daytime and 50 and 65 dBA night time with levels above 65 dBA very close to the M4.	Noise impacts from corridor and Homebush Bay Drive compound predicted. Exceedance of guideline by up to and over 20 dBA at closest receivers.	Vibration impacts may occur at outer extents of roadworks area.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 53 receivers (31 buildings)	Required. With low noise pavement and noise barriers, 22 receivers (22 buildings) may require property treatment
NCA02	Dominated by M4 with noise levels around 70 dBA during the day and 60 dBA close to the motorway and 55 dBa (day) and 50 dBA (night) further from the motorway.	Noise impacts from general activities in the corridor, activities at the Pomeroy Street compound, construction of the western ventilation facility and demolition of acquired houses predicted. Exceedance of guideline by over 25 dBA (during site establishment), 20 dBA (demolition) and 10 dBA (other works) predicted at closest receivers.	Vibration impacts may occur at outer extents of roadworks area. Vibration during tunnelling require monitoring to ensure guidelines are met.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 21 receivers (18 buildings)	Required. With low noise pavement and noise barriers, 5 receivers (5 buildings) may require property treatment
NCA03	Dominated by M4 and Parramatta Road with noise levels around 65 dBA daytime and 60 dBA night time.	Noise impacts from general activities in the corridor and activities at the Pomeroy Street compound are predicted. Exceedance of guideline by up to and over 25 dBA predicted at closest receivers during the worst case general activities in the corridor.	Vibration impacts may occur at outer extents of roadworks area.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 35 receivers (32 buildings)	Required. With low noise pavement and noise barriers, 30 receivers (28 buildings) may require property treatment

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA04	Dominated by M4 with noise levels around 60 dBA daytime and 55 dBA night time.	Noise impacts from general activities in the corridor and activities at the Underwood Road compound as well as the Western ventilation facility and demolition of properties are predicted. Exceedance of guideline by up to and over 25 dBA.	No vibration impacts expected.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 5 receivers (4 buildings)	Required. With low noise pavement and noise barriers, five receivers (four buildings) may require property treatment
NCA05	Dominated by M4 and Parramatta Road with noise levels around 65 dBA during day and 60 dBA the night.	Noise impacts from general activities in the corridor and activities at the Powells Creek compound, the Underwood Road compound and the Underwood Road tunnel site are predicted. Exceedance of guideline by up to and over 20 dBA predicted at closest receivers.	Vibration impacts may occur at outer extents of roadworks area.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 14 receivers (eight buildings)	Required. 14 receivers (eight buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA06	Dominated by M4, Sydney Street and Concord Road with noise levels greater than 65 dBA during day and night time.	Noise impacts from general activities in the corridor and activities at the Concord Road civil and tunnel site are predicted. Exceedance of guideline by uo to and over 20 dBA predicted at closest receivers. Ground borne noise exceedances are predicted for receivers above the tunnelling near the surface which may last up to 2 weeks for the most affected receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 11 receivers (11 buildings)	Required. 11 receivers (11 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA07	Dominated by Concord Road with noise levels greater than 65 dBA during day and night time.	Noise impacts from general activities in the corridor and activities at the Concord Road civil and tunnel site are predicted. Exceedance of guideline by up to and over 20 dBA predicted at closest receivers. Ground borne noise exceedances are predicted for receivers above the tunnelling near the surface which may last up to 2 weeks for the most affected receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 70 receivers (56 buildings)	Required. 70 receivers (56 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA08 and NCA09	These two areas are located to the east of the Concord Road interchange and existing noise is dominated by Concord Road and the M4. Noise levels are up to 55 dBA during the day and 50 dBA during the night.	Noise impacts from general activities in the corridor and activities at the Concord Road civil and tunnel site are predicted. Exceedance of guideline by up to and over 20 dBA predicted at closest receivers. Ground borne noise exceedances are predicted for receivers above the tunnelling near the surface which may last up to 2 weeks for the most affected receivers.	Vibration impacts may occur at outer extents of roadworks area.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 2 receivers (2 buildings)	Required. Noise barriers are proposed. One receiver may require property treatment.
NCA10	Dominated by Parramatta Road and Ada Street with noise levels around 65 dBA during the day and 60 dBA during the night.	Noise impacts from general corridor construction works for the Concord Road interchange and at the Concord Road tunnel and civil site are predicted. Exceedances of up to 10 dBA are predicted for most receivers in most of this area. Exceedances of up to 20 dBA may occur for a small number of receivers near the Concord Road compound.	No vibration impacts expected.	Required, to be outlined in the CNVMP	No exceedances have been identified	None required

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA11	Dominated by Parramatta Road with noise levels greater than 65 dBA during day and night time.	Noise impacts from general corridor construction works for the Concord Road interchange and at the Concord Road tunnel and civil site are predicted. Exceedances of only up to 10 dBA are predicted for most receivers in most of this area. A small number of receivers near the Concord Road interchange may experience higher exceedances during site establishment works, property demolitions. Exceedances of up to 20 dBA may occur for a small number of receivers due to the tunnelling.	Vibration impacts may occur at outer extents of roadworks area.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 14 receivers (8 buildings)	Required. 14 receivers (eightbuildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA12	Dominated by Parramatta Road	Noise impacts may occur due to the construction of the fresh air supply facility at Cintra Park and the tunnelling site at Cintra Park. Exceedances of up to and greater than 20 dBA may occur at the closes receivers. Ground borne noise exceedances are predicted for some receivers east of Burwood Road above the tunnelling which is closer to the surface at this location.	No vibration impacts expected.	Required, to be outlined in the CNVMP	None identified	None required

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA13	Dominated by Parramatta Road	Noise impacts may occur due to general construction works, demolition works, construction of the eastern ventilation facility and works at Northcote Street tunnel site, Parramatta Road ventilation facility site and Parramatta Road civil site. Exceedances of up to a greater than 20 dBA may occur at closes receivers. Ground borne noise exceedances are predicted for some receivers east of Burwood Road above the tunnelling which is closer to the surface at this location. These noise exceedances are expected to only last for about 4 days at each receiver.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	None identified	Four receivers (two buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA14	Dominated by Parramatta Road and Wattle Street with noise levels around 60 dBA daytime and 55 dBA night time.	Noise impacts may occur due to general construction works, demolition works and works at Northcote Street tunnel site and Parramatta Road ventilation facility site. Exceedances of up to and greater than 20 dBA may occur at closes receivers. Ground borne noise exceedances are predicted for some receivers above the tunnelling.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 17 receivers (15 buildings)	Required. With low noise pavement and noise barriers (nine buildings) may require property treatment
NCA15	Dominated by Parramatta Road and Wattle Street with noise levels around 65 dBA during the day and night.	Noise impacts may occur due to general construction works, demolition works and works at Wattle Street and Walker Ave civil site. Exceedances of up to and greater than greater than 20 dBA may occur at closes receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 28 receivers (26 buildings)	17 receivers (15 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA16	Dominated by Wattle Street and Ramsay Street with noise levels above 65 dBA during the day and night in receivers fronting Wattle Street and noise levels around 60 dBA during the day and 55 dBA during the night in other parts of this area.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at Wattle Street and Walker Ave civil site. Exceedances of up to and greater than 20 dBA may occur at the closest receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 17 receivers (15 buildings)	Required: 17 receivers (15 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA17	Dominated by Wattle Street traffic with noise levels above 65 dBA during the day and night.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at Wattle Street and Walker Ave civil site. Exceedances of up to and greater than 20 dBA may occur at the closest receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 32 receivers (27 buildings)	25 receivers (20 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA18	Dominated by Wattle Street and Parramatta Road with noise levels above 65 dBA during the day and 60 dBA during the night near the Wattle Street/Ramsay Stree intersection and 60 dBA during the day and 55 dBA during the night in other parts of the area.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at Wattle Street and Walker Ave civil site and the Parramatta Road ventilation facility site. Exceedances of up to and greater than 20 dBA may occur at the closest receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 13 receivers (10 buildings)	Eight receivers (6 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA19	Dominated by Parramatta Road with noise levels around 65 dBA during the day and 60 dBA during the night.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at Wattle Street and Walker Ave civil site and the Parramatta Road civil site. Exceedances of up to and greater than 25 dBA may occur at closes receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at two receivers (two buildings)	Two receivers (two buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.

Noise catchment area	Existing noise Levels	Construction impacts			Operational impacts	
		Noise	Vibration	Management measures required	Impacts	Mitigation
NCA20	Dominated by Parramatta Road with noise levels greater than 65 dBA during day and night time fronting Parramatta Road and around 65 dBA during the day and 60 dBA during the night for other parts.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at the Parramatta Road civil site. Exceedances of up to and greater than 25 dBA may occur at the closest receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 18 receivers (14 buildings)	17 receivers (13 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.
NCA21	Dominated by Parramatta Road with noise levels around 65 dBA during the day and 60 dBA during the night.	Noise impacts may occur due to general construction works, demolition works, temporary road modifications and works at the Parramatta Road civil site. Exceedances of up to and greater than 25 dBA may occur at the closest receivers.	Vibration impacts may occur at outer extents of roadworks area during tunnelling.	Required, to be outlined in the CNVMP	Exceedance of road noise criteria at 37 receivers (22 buildings)	37 receivers (21 buildings) may require property treatment. Noise barriers and low noise pavement not relevant/feasible for this area.

8.6 Health outcomes relevant to noise

Environmental noise has been identified (I-INCE 2011; WHO 2011) as a growing concern in urban areas because it has negative effects on quality of life and well-being and it has the potential for causing harmful physiological health effects. With increasingly urbanised societies impacts of noise on communities have the potential to increase over time.

Deciding on the most effective noise management options in a specific situation is not just a matter of defining noise control actions to achieve the lowest noise levels or meeting arbitrarily chosen criteria for exposure to noise. The goal should be designed to achieve the best available compromise between the benefits to society of reduced exposure to community noise versus the costs and technical feasibility of achieving the desired exposure levels given the project. On the one hand there are the rights of the community to enjoy an acceptably quiet and healthy environment. On the other hand there are the needs of the society for new or upgraded facilities, industries, roads, recreation opportunities etc, all of which typically produce more community noise (I-INCE 2011; WHO 2011).

Sound is a natural phenomenon that only becomes noise when it has some undesirable effect on people or animals. Unlike chemical pollution, noise energy does not accumulate either in the body or in the environment but it can have both short-term and long-term adverse effects on people. These health effects include (WHO 1999, 2011):

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)
- Annoyance
- Hearing impairment
- Interference with speech and other daily activities
- Children's school performance (through effects on memory and concentration)
- Cardiovascular health.

Other effects for which evidence of health impacts exists, but for which the evidence is weaker, include:

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Tinnitis (which can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Some evidence of indirect effects such as impacts on the immune system.

Within a community the severity of the health effects of exposure to noise and the number of people who may be affected are schematically illustrated in **Figure 8.6**.

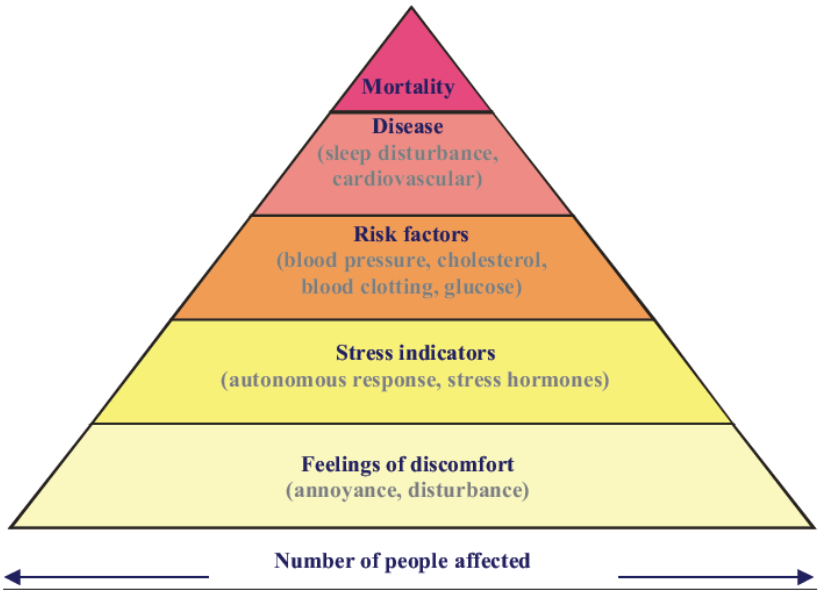


Figure 8.6 **Schematic of severity of health effects of exposure to noise and the number of people affected (WHO 2011)**

Often, annoyance is the major consideration because it reflects the community's dislike of noise and their concerns about the full range of potential negative effects, and it affects the greatest number of people in the population.

There are many possible reasons for noise annoyance in different situations. Noise can interfere with speech communication or other desired activities. Noise can contribute to sleep disturbance, which can obviously be very annoying and has the potential to lead to long-term health effects. Sometimes noise is just perceived as being inappropriate in a particular setting without there being any objectively measurable effect at all. In this respect, the context in which sound becomes noise can be more important than the sound level itself.

Different individuals have different sensitivities to types of noise and this reflects differences in expectations and attitudes more than it reflects any differences in underlying auditory physiology. A noise level that is perceived as reasonable by one person in one context (for example in their kitchen when preparing a meal) may be considered completely unacceptable by that same person in another context (for example in their bedroom when they are trying to sleep). In this case the annoyance relates, in part, to the intrusion from the noise. Similarly a noise level, which is considered to be completely unacceptable by one person, may be of little consequence to another even if they are in essentially the same room. In this case the annoyance depends almost entirely on the personal preferences, lifestyles and attitudes of the listeners concerned.

It is against this background that regulators in various communities have established sound level criteria above which noise is deemed to be unacceptable and below which it is deemed to be acceptable. Any assessment of noise impacts needs to consider the relevant criteria established for a new or existing (or upgraded) facility or activity. Where there are impacts in excess of these guidelines, an assessment of noise mitigation is required to be undertaken.

In relation to this project, potential noise impacts have been assessed against Australian (more specifically New South Wales) criteria that have been established on the basis of the relationship between noise and health impacts. The criteria developed for use in the assessment for control of noise come from policy documents developed by the NSW Government including the INP, the NSW Interim Construction Noise Policy, and the RNP (NSW DECC 2009; NSW DECCW 2011; NSW EPA 2000). All of these policies are based on the health effects of noise outlined in the reviews published by the following organisations:

- World Health Organisation – *Guidelines on Community Noise – Health effects of noise* (WHO 1999)
- World Health Organisation – *Night Noise Guidelines for Europe* (WHO 2009)
- International Institute of Noise Control Engineering – *Guidelines for Community Noise Impact Assessment and Mitigation* (I-INCE 2011)
- Environmental Health Council of Australia – The health effects of environmental noise – other than hearing loss (enHealth 2004).

Various attempts have been made to assess the effect (measured by average reported annoyance, sleep disturbance or a similar type of effect) from community noise (measured by long term average sound levels) to develop exposure-response relationships. As individual reactions to noise are so varied, these studies need large sample sizes to obtain reasonable correlation between the noise exposure and the response. Any dose-response relationship determined from large studies over a range of communities and cultures will not necessarily represent the reaction of individuals or small communities. These exposure-response relationships are of value for macro-scale (ie whole urban environment scale) strategic assessment purposes where individual differences are not important, however, they are not as useful when considering potential impacts to a small population located close to a specific project/activity. Hence these macro-scale relationships cannot be easily applied (in any meaningful way) in this assessment.

As guidelines/criteria that are based on the protection of health (including annoyance) are available to assess construction and operational noise impacts associated with this project, the assessment of potential health impacts has focused on whether the guidelines/criteria established can be met. Where the guidelines cannot be met then there is the potential for the above adverse health effects to occur in the community adjacent to the project.

In most cases, when developing management limits for the project, it has been assumed that there is a 10 dB(A) difference between noise inside and outside of a building with windows open. This assumption, although unreferenced, appears to have been sourced from the RNP. Further consideration of this assumption raises a number of issues including:

- Internal noise levels are defined in the RNP as those measured in the centre of a habitable room so if activities (like sleeping or concentrating) happen at the edge of a room they may be more impacted by noise than might be expected
- The RNP refers to windows being open sufficient to provide adequate ventilation as discussed in the Building Code of Australia. The Building Code of Australia does not require that residential buildings have significant levels of ventilation and, as a result, opening a window sufficient to provide the minimum ventilation required is unlikely to mean that the window is completely open or even that more than one window in a room is opened. Sufficient ventilation may result from the existing drafts in a building (with no windows open) or the opening of two windows only for the entire building. Assuming that the 10 dB(A) change in noise applies for all situations where windows are open is not appropriate
- Consequently, the use of this assumption in setting noise management limits for this project may need to be reviewed.

The worst case assessment predicts that noise criteria and vibration criteria will be exceeded (in some cases by quite large increments) at a number of properties adjacent to the project during construction and operation without mitigation measures, as summarised in **Table 8.3**.

During construction of the project, noise levels are estimated to exceed NML by large amounts during some works in specific locations. Some sensitive receivers will be close enough to these sites that noise, ground-borne noise and/or vibration due to the construction of the project will be significantly elevated above the criteria. The worst-case levels estimated in this assessment are sufficiently high for some receivers during some works that health impacts are likely to occur. Loss of use of outdoor areas, disturbance of sleep, reduced capacity for concentration, interference with speech and other activities are all likely with potential for effects on cardiovascular health if the elevated noise at a particular location occurs for extended periods. Annoyance and increased stress levels will also occur. Consequently, significant mitigation of noise and vibration during the construction phase of the project will be essential.

The detailed design for the mitigation measures will be outlined in the CNVMP. The aim of the mitigation measures should be to reduce noise and vibration to levels that comply with the management goals established in this assessment. If it is not possible to achieve compliance with these goals, health impacts for the affected community are likely.

Without the detailed design for the mitigation measures it is not possible to evaluate whether health effects are likely, how significant they will be or where they may occur during the construction phase of the project.

During operation of the project, most receivers living and working around the project will experience the same or slightly lower levels of noise than they experience currently. In the area north of the M4 in Homebush and Sydney Olympic Park significant decreases in noise are expected due to surface traffic entering the tunnels instead of remaining at the surface. Increases in noise (without installation of mitigation measures) are expected near the interchanges at Concord Road (Strathfield/Concord), at Wattle Street (Haberfield) and Parramatta Road (Ashfield) due to additional traffic lanes, increased traffic and removal of some buildings which currently screen other buildings located behind. The impacted properties are shown on **Figure 8.4** and **Figure 8.5**.

Mitigation measures during operation are likely to include use of low noise pavement for surface roads, installation of noise barriers and at property treatments on some buildings. While these mitigation measures are required to ensure that the environment where people spend most of the day (i.e. indoors) is not associated with adverse health impacts from excessive noise, it does assume that residents take up these measures and where they do, they keep external windows and doors shut and have minimal use of outdoor areas.

In urban areas particularly where noise is dominated by road traffic noise, access to outdoor green-space areas that are not (perceived to be) impacted by noise (eg where there is a quiet side of a specific property or there is access to a quiet green space areas close to the residential home) have been found to significantly improve well-being and lower levels of stress (Gidlöf-Gunnarsson & Öhrström 2007). Impacts on the use and enjoyment of outdoor areas due to increased noise may result in increased levels of stress at individual properties.

Where specific residents/properties do not take up the recommended at property treatments to mitigate noise indoors there is the potential for noise levels at these properties to exceed the relevant guidelines/criteria. In these situations there is the potential for adverse health effects, particularly annoyance and sleep disturbance, to occur.

Community consultation will be an important part of the process in addressing noise impacts for the project as there are a number of individual homes where at property treatment will be required to enable the noise criteria to be met, and minimise the potential for adverse health effects associated with the project. However, such treatments may have other effects which will also need to be managed/ considered.

9 Assessment of social impacts on health

9.1 General

The World Health Organisation defines health as ‘a (dynamic) state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity’. Hence the assessment of health should include both the traditional/medical definition that focuses on illness and disease as well as the more broad social definition that includes the general health and wellbeing of a population.

The assessment of changes in air quality and noise on the health of the local community (presented in sections 7 and 8) addressed key aspects that have the potential to directly affect health.

There are, however a range of other impacts associated with the project that can affect the health and well-being of the community in a more indirect way. In addition changes within a community that may be associated with the project may be differentially distributed. This may affect population group that may be advantaged or disadvantaged based on age, gender, socioeconomic status, geographic location, cultural background, aboriginality, and current health status and existing disability. This aspect relates to the equity of the impacts in the local community.

This section has more specifically evaluated changes in the community that have the potential to indirectly affect the health and well-being of the community. In addition this section has provided a review of whether there are any impacts that are likely to be more significant in any section of the community, and if these areas may result in inequitable impacts on the health of the population. The evaluation presented in this section provides a qualitative evaluation of potential health impacts on the community.

The section refers to the SIA conducted by AECOM and GHD (2015) which is included in **Appendix M** of the EIS.

9.2 Changes in traffic

The study area includes urban transport corridors that are contained within the LGAs of Auburn, Strathfield, Burwood, Ashfield, Canada Bay and Leichardt. The main Parramatta Road transport corridor accommodates a mix of travel demand characteristics that range from short local trips to longer strategic through vehicle movements.

The study area currently comprises an urbanised area dominated by heavy traffic volumes on the M4, Parramatta Road and local roads. The project aims to redirect through vehicle movements off the surface road network into the tunnel. While this is intended to result in improvements in local traffic once completed, the project does involve some impacts to local traffic and access during construction.

Construction

A number of changes to local roads are proposed during the construction phase of works. While it is expected that access to all properties on the local roads will be maintained during the construction works, temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area.

Major construction works would be primarily accessed from Parramatta Road and the M4. Construction ancillary facilities would be located to provide the most direct access for heavy vehicles to and from arterial roads such as Parramatta Road, M4, Concord Road, Sydney Street and Wattle Street and to avoid or minimise use of local roads.

In addition a number of bus stops located at or near construction ancillary facilities at Underwood Road, Concord Road, Cintra Park and Parramatta Road will be relocated.

It is expected that during construction there will some impact to the local community as a result of increased travel times for vehicles, cyclists and bus passengers; reduced pedestrian roadside safety due to an increase in traffic; reduction in pedestrian and cyclist amenity.

These changes have the potential to result in increased levels of stress and anxiety in the local community. These impacts, however, are expected to occur during the period of construction only.

Operations

However once the project is complete it is expected to result in large reductions in vehicle delays along the corridor between Homebush Bay Drive in the west, and City West Link and Haberfield/Leichardt in the east. This is evident both within the new project tunnel which will ultimately provide connectivity to the M4–M5 Link, and also on the existing Parramatta Road despite the reduction in capacity due to the provision of kerbside bus lanes. The assessment has also identified benefits on the parallel route along Queens Road and Gipps Street. This improvement will enhance connectivity regionally.

Public Transport

A limited number of bus routes currently use Parramatta Road within the study area of the project. However, Transport for NSW has identified the potential for a new high frequency bus route between Burwood and the CBD which would be provided following delivery of the project. The traffic study has also indicated that the project could deliver significant travel time savings for buses (between 3 and 15 minutes during peak periods) between Burwood and Chandos Street as a result of the project, with a dedicated bus lane provided east from Burwood on Parramatta Road.

Improvements in public transport availability and especially efficiency will have broad social benefits. The use of public transport includes incidental exercise (eg walking to and from bus or train stops) increasing the chance of travellers meeting recommended daily physical activity targets.

Pedestrian and Cycle Access

The existing pedestrian network is varied, with residential areas located off the main roadways providing good pedestrian facilities. Parramatta Road currently favours high volume traffic movements which impacts accessibility and travel times for pedestrians.

Some pedestrian footpaths will be closed during construction, however these closures will only affect one side of the road (allowing access to remain on the other side of the road). Where required safe alternate pedestrian access routes will be identified. Pedestrian access will be restored once construction is complete. Additional crossings will be provided at the off ramp location on Concord Road and Powells Creek. In addition changes to signal timings due to changes in traffic volumes and distribution may lower the time taken to cross major intersections, potentially improving travel times and accessibility.

The existing cycle network comprises limited dedicated cycleways (targeted at leisure trips rather than commuter trips) and a mix of on-road options. There are significant gaps in north-south connections due to Parramatta Road and the M4. During construction, works will be undertaken to ensure that connectivity is maintained for cyclists. This will involve cycleway detours from the M4 onto local roads and other cycleways. Once the project is completed reduced traffic volumes would provide opportunities to improve cycling routes through the study area and these are being investigated as part of the Parramatta Road Urban Transformation Program.

Improved urban amenity and cycling infrastructure could likely attract more people to both recreational and commute cycling, with consequent positive health benefits.

9.3 Changes in air quality

As discussed in **section 6**, the project will result in improved air quality (i.e. decrease in total pollutant concentrations) within much of the local community. The redistribution of surface traffic in the area will result in an increase in pollutants at some locations, however the risks to health posed by these changes range from negligible to tolerable/acceptable.

Review of the changes in air quality associated with the project has not identified impacts that significantly affect specific areas of disadvantage (refer to **Figure 6.4** for the distribution of changes in $PM_{2.5}$ concentrations in the community). In relation to changes in air quality impacts associated with the project, changes in $PM_{2.5}$ are of most relevance. The areas where increases in $PM_{2.5}$ concentrations are predicted are adjacent to existing roadways, where changes in traffic volumes associated with the project are predicted to result in a small increase in $PM_{2.5}$ exposure.

Suburbs in the study area that, based on the 2011 Census Data, are slightly more disadvantaged (in relation to the Socio-Economic Index for Areas (SEIFA)) include Homebush West and Burwood.

- In Homebush West there are some areas where the project will result in decreased $PM_{2.5}$ impacts, however there are few small areas where the project will result in increased $PM_{2.5}$ impacts. The increase only affects a small number of residential homes/buildings located in this area (located close to existing roadways) and there is no significant increase affecting the whole population. The calculated increase in risk associated with exposure to the increased concentrations of $PM_{2.5}$ in air at these locations (assessed in **section 6**) were considered to be tolerable/acceptable.
- In Burwood there are areas located in the vicinity of Parramatta Road where the project will result in a decreased $PM_{2.5}$ impacts. There are no increases in $PM_{2.5}$ concentrations predicted in this area.

Other areas where small increases in $PM_{2.5}$ were predicted are located in the suburbs of Haberfield and Leichardt, which are both areas of low socioeconomic disadvantage.

Hence the changes in air quality associated with the project is not considered to adversely affect areas of lower socioeconomic disadvantage.

It is noted that in many urban areas housing prices are lower on main roadways. However in the study area the median house prices are high, so the effect of changes in price based on proximity to main roads is not a significant factor. Some public housing is located in the study area, however these properties are mixed in with privately owned property such that there are no specific areas with higher populations of public housing tenants. Hence there are no social equity issues identified in relation to the change in air quality in the local community.

9.4 Changes in noise

As discussed in **section 8**, the project will result in lower noise levels in many areas with some areas, located close to new road infrastructure, experiencing an increase in noise. In addition where no mitigation measures are implemented the predicted change in noise levels associated with various construction activities are likely to result in adverse health impacts. These impacts include disturbance of sleep, reduced capacity for concentration, interference with speech and other activities and the loss of the use of outdoor space are all likely with potential for effects on cardiovascular health if the elevated noise at a particular location occurs for extended periods. Annoyance and increased stress levels will also occur. Consequently, significant mitigation of noise and vibration impacts is required to be implemented during the construction phase of the project to ensure there are no impacts on the health and wellbeing of the local community.

Road noise changes predicted for the project will require the implementation of mitigation measures (low noise pavement and some noise barriers) with some properties also requiring treatment to lower noise levels inside the home to a level where health impacts are minimised. For properties where noise treatment is identified, these measures are effective in minimising impacts of noise on health if they are taken up by the property owner and windows and doors are kept closed. Where this does not occur there is the potential for health impacts to occur as a result of increased road noise (particularly in the evening and at night-time). In addition it is noted that for these properties comfortable use of outdoor areas may change (due to increased noise impacts) and affect the access and use of outdoor garden areas. Where alternate quite outdoor areas are accessible such impacts are not considered to be significant, however for some members of the community it may not be possible or practical to travel to other outdoor areas. Where this is the case the change in property use (as a result of noise impacts) may result in increased levels of stress and anxiety and decreased wellbeing.

Properties where noise mitigation measures are required for the operation of the project are primarily located adjacent to existing main roadways: M4, Concord Road and Wattle Street. There are some properties that are not located adjacent to existing major roadways. A number of these properties are already affected by elevated levels of road noise and the mitigation measures proposed may reduce overall impacts of road noise at these locations. Review of the areas where noise impacts are predicted has not identified impacts that affect specific areas of disadvantage.

9.5 Changes in community

9.5.1 General

Changes in the urban environment have the potential to result in impacts to health, primarily due to increased levels of stress and anxiety associated with rapid changes in the community. In relation to this project many of the changes relate to property acquisitions and access to community facilities, visual impacts and changes in community cohesion.

9.5.2 Property acquisitions and access

The project involves the acquisition of approximately 166 lots and partial acquisition of approximately 17 lots comprising private property and land owned by councils, public authorities or the State of NSW.

Assessment of the social impacts of property acquisitions presented in the SIA concluded that it is anticipated that the social impacts of relocating for many of the directly affected households will be a major short term impact. Whilst for some, if they desire but are unable to relocate locally, the social impact may involve an extended recovery time.

The project will involve the acquisition of some community facilities (Strathfield Girl Guides Hall (to be relocated), Powells Creek/Arnotts Reserve, Zongde Buddhist Temple (to be relocated) and Concord Uniting Church (part acquisition only)).

Dusing construction a loss of access to other facilities (Bill Boyce Reserve at Pomeroy Street, parts of Reg Coady Reserve at Wattle Street, vacant land located west of Powells Creek and Cintra Park Hockey Complex) will occur. Community access to these facilities and open space areas will be returned after construction is complete.

In relation to property acquisitions, the following can be noted from the SIA for specific areas within the community:

- Homebush area: residents living in the properties proposed to be acquired (on Ismay Avenue, Allen and Short Streets and Underwood Road) are not considered to be vulnerable and hence the project is not expected to disproportionately disadvantage residents in this area
- Concord area: a number of the properties proposed to be acquired are in locations adjacent to existing major roadways (affected by existing noise and amenity impacts). Two of the properties are public housing properties. These tenants may be at a greater disadvantage and may be more vulnerable to health issues associated with relocation
- Cintra Park area: no residential properties will be acquired in this area. The only impacts relate to and use of Cintra Park stadium land and parking areas for construction activities. These impacts are temporary
- Wattle Street area: a large number of properties are proposed to be acquired (along Wattle Street, Parramatta Road, and include some adjoining properties in Wolseley, Northcote, Ramsay and Martin Streets and Walker Avenue). While these acquisition are not expected to disadvantage any particular group the project will have some impact on the cohesion of the local community
- Parramatta Road area: the properties proposed to be acquired in this area (primarily front the southern side of Parramatta Road and adjoining areas of Chandos Street) are at greater socio-economic disadvantage and may be more vulnerable to health issues associated with relocation.

Moving house is known to be a significant stressor that can have a negative short-term impact on the health of individuals. WDA is providing access for affected households to a counselling service, WestConnex Assist to support them in negotiating the land acquisition process. This service provides short-term, results-focussed support to help people adapt to changes brought by the property acquisition process, and can also on-refer clients to other service providers as required. This service will assist in minimising health impacts associated with property acquisitions.

9.5.3 Visual changes

Changes in visual amenity are predicted to occur during construction for a number of residents where the property overlooks a construction ancillary facility or work site. Once completed new road infrastructure (ramps and tunnel) will be landscaped to reduce long-term visual impacts of the project.

The project is located in a highly modified urban environment and does not involve clearing of remnant native vegetation. Small areas of planted vegetation would be removed with mitigation measures proposed to minimise indirect impacts.

Noise mitigation measures will result in the installation of noise barriers in some locations which will affect visual amenity. In addition some properties will be located closer to new road infrastructure. These impacts are primarily along the M4 corridor in Homebush at the Western and Eastern ventilation facilities, Concord Road interchange, and Parramatta Road and Wattle Street interchanges. Project design and landscaping plans aim to minimise visual intrusion of project elements and respect and respond to the existing character of these areas.

Changes to the amenity and of a street or suburb can negatively impact a sense of belonging and identity of its residents and consequently their community cohesion.

9.6 Overall assessment

Within an urban environment there are a wide range of complex factors (acting and interacting at different scales) that can affect health and wellbeing. This is conceptualised in **Figure 9.1** (presented by the International Council for Science and similar to that defined by the WHO) (ICSU 2011). The factors identified may result in either positive or negative impacts on health and wellbeing. It is noted that no single element or determinant acts in isolation. Health and wellbeing in the urban environment depends on the sum of the total interactions between many factors.

Potential impacts related to this project are summarised on the figure, showing both positive and negative impacts. The figure illustrates the complexity of making definitive conclusions in relation to health impacts in the community. However it is noted that where negative impacts have been identified, these impacts are either short-term (during construction only) and/or appropriate mitigation or management measures have been identified to minimise impacts on the community.

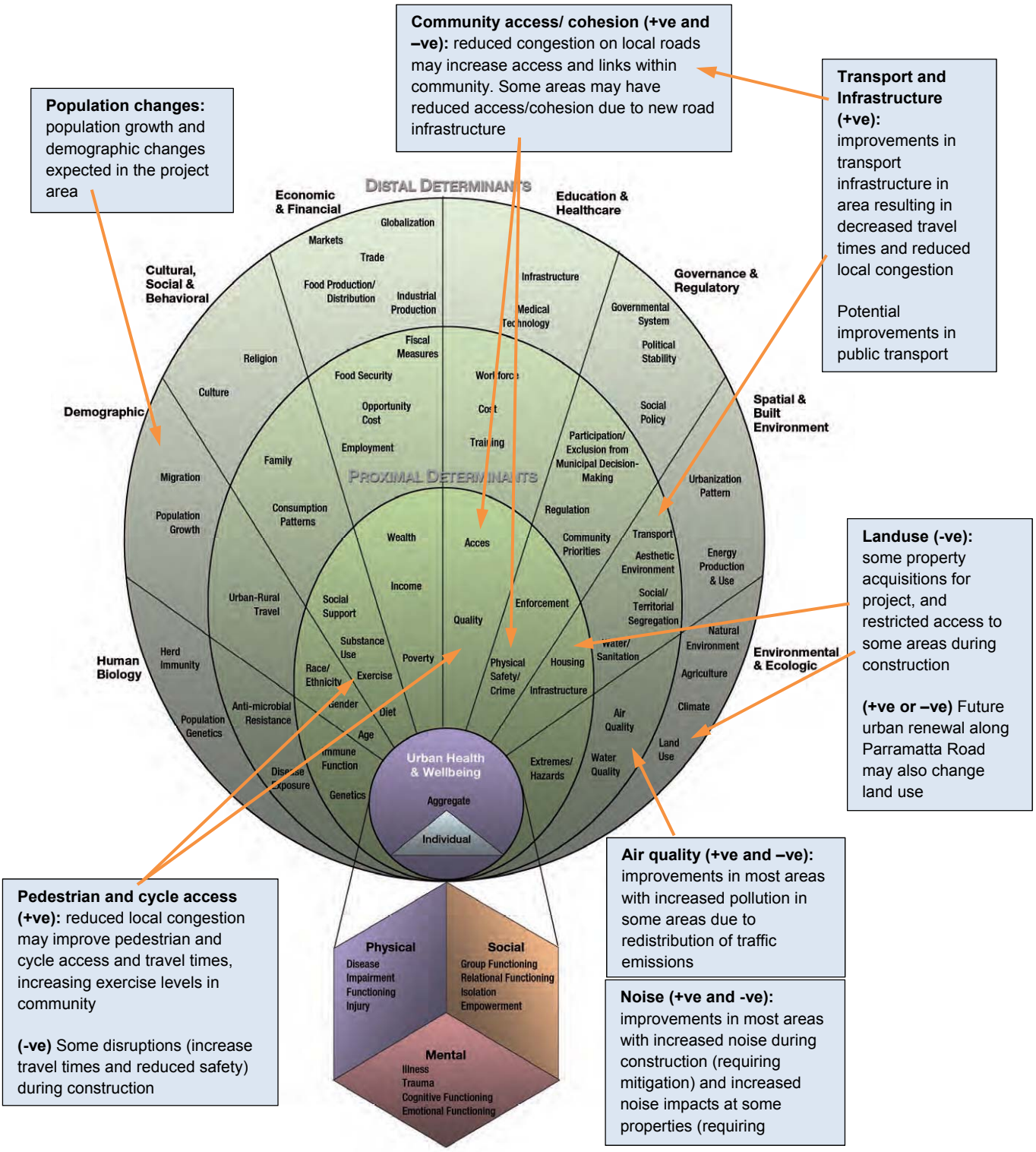


Figure 9.1 **Conceptual framework for determinants of health and wellbeing in the urban environment and potential impacts from project. (ICSU 2011)**

10 Conclusions

An assessment of health impacts associated with emissions to air and noise and vibration resulting from the construction and operation of the project has been undertaken. In addition the assessment has also considered impacts on health associated with social changes associated with the project.

Based on the assessment undertaken and presented in this report the following has been concluded:

- In relation to air quality:
  - Impacts in the community outside the tunnel: the project is expected to result in a decrease in total pollutant levels in the community. The project is expected to result in a redistribution of impacts associated with vehicle emissions. For much of the community this will result in an improvement (ie decreased concentrations and health impacts), however for a number of areas a small increase in pollutant concentration may occur. Potential health impacts associated with changes in air quality (specifically nitrogen dioxide and particulates) within the local community have been assessed and are considered to be low and essentially negligible
  - Impacts within the tunnel: while concentrations of pollutants from vehicle emissions are higher within the tunnel (compared with outside the tunnel) the time spent exposed to these pollutants is very short (minutes). Where health based guidelines are available, exposures within the tunnel are expected to be below these guidelines. However for nitrogen dioxide and particulates there are no health based guidelines and exposure to pollutants derived from congested traffic (including within tunnels) may increase the risk of adverse health effects. Drivers who regularly use tunnels or drive in congested traffic in Sydney can minimise exposure to vehicle emissions by keeping windows up and air conditioning on recirculation when in tunnels or heavy traffic conditions. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent
- In relation to noise and vibration, potential impacts during construction and operation have been considered:
  - Construction: without implementation of mitigation measures there is the potential for noise and vibration impacts associated with a range of construction activities to result in adverse health effects in the community. Hence it is important that management and/or mitigation measures are implemented throughout the construction period to minimise the potential for adverse health effects. These management and mitigation measures (including the requirement for noise monitoring) are to be outlined in detail within the Construction Noise and Vibration Management Plan
  - Operation: during the operational phase of the project a number of properties have been identified where road noise has the potential to be elevated and adversely affect health. For these properties mitigation measures are required to protect the health of occupants. These mitigation measures may include low noise pavement, noise barriers and/or noise treatments on individual properties. The recommended mitigation measures would ensure that the levels of road traffic noise experienced by residents would be reduced as low as feasible and reasonable
- Changes in the urban environment associated with the project have the potential to result in a range of impacts on health and wellbeing of the community. The potential for changes to result in impacts on health and wellbeing is complex. Changes that may occur have the potential to result in both positive and negative impacts. Negative impacts may occur as a result of traffic changes during construction, property acquisitions, visual changes, noise impacts and changes in access/cohesion of local areas. These may result in increased levels of stress and anxiety. In many cases the impacts identified are either short-term (associated with construction only) and/or mitigation/management measures have been identified to minimise the impacts on the community.

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Appendix A Approach to risk assessment using exposure-response relationships

Mortality and morbidity health endpoints

A quantitative assessment of risk for these endpoints uses a mathematical relationship between an exposure concentration (ie concentration in air) and a response (namely a health effect). This relationship is termed an exposure-response relationship and is relevant to the range of health effects (or endpoints) identified as relevant (to the nature of the emissions assessed) and robust (as identified in the main document). An exposure-response relationship can have a threshold, where there is a safe level of exposure, below which there are no adverse effects; or the relationship can have no threshold (and is regarded as linear) where there is some potential for adverse effects at any level of exposure.

In relation to the health effects associated with exposure to nitrogen dioxide and particulate matter, no threshold has been identified. Non-threshold exposure-response relationships have been identified for the health endpoints considered in this assessment.

The assessment of potential risks associated with exposure to particulate matter involves the calculation of a relative risk (RR). For the purpose of this assessment the shape of the exposure response function used to calculate the relative risk is assumed to be linear[10]. The calculation of a relative risk based on the change in relative risk exposure concentration from baseline/existing (ie based on incremental impacts from the project) can be calculated on the basis of the following equation (Ostro 2004):

Equation 1 $RR = \exp[\beta(X-X0)]$

Where:
X-X0 = the change in particulate matter concentration to which the population is exposed (µg/m^3)
β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per 1 µg/m^3 increase in particulate matter exposure.

Based on this equation, where the published studies have derived relative risk values that are associated with a 10 micrograms per cubic metre increase in exposure, the β coefficient can be calculated using the following equation:

Equation 2 $$\beta = \frac{\ln(RR)}{10}$$

Where:
RR = relative risk for the relevant health endpoint as published (µg/m^3)
10 = increase in particulate matter concentration associated with the RR (where the RR is associated with a 10 µg/m^3 increase in concentration).

10 Some reviews have identified that a log-linear exposure response function may be more relevant for some of the health endpoints considered in this assessment. Review of outcomes where a log-linear exposure-response function has been adopted (Ostro 2004) for $PM_{2.5}$ identified that the log-linear relationship calculated slightly higher relative risks compared with the linear relationship within the range 10–30 micrograms per cubic metre,(relevant for evaluating potential impacts associated with air quality goals or guidelines) but lower relative risks below and above this range. For this assessment (where impacts from a particular project are being evaluated) the impacts assessed relate to concentrations of $PM_{2.5}$ that are well below 10 micrograms per cubic metre and hence use of the linear relationship is expected to provide a more conservative estimate of relative risk.

Quantification of impact and risk

The assessment of health impacts for a particular population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004)[11] where the exposure-response relationships identified have been directly considered on the basis of the approach outlined below.

The calculation of changes in health endpoints associated with exposure to nitrogen dioxide and particulate matter as outlined by the WHO (Ostro 2004) has considered the following four elements:

- Estimates of the changes in particulate matter exposure levels (ie incremental impacts) due to the project for the relevant modelled scenarios
- Estimates of the number of people exposed to particulate matter at a given location
- Baseline incidence of the key health endpoints that are relevant to the population exposed
- Exposure-response relationships expressed as a percentage change in health endpoint per microgram per cubic metre change in NO_2 or particulate matter exposure, where a relative risk (RR) is determined (refer to Equation 1).

From the above, the increased incidence of a health endpoint corresponding to a particular change in particulate matter concentrations can be calculated using the following approach:

The attributable fraction/portion (AF) of health effects from air pollution, or impact factor, can be calculated from the relative risk (calculated for the incremental change in concentration considered as per Equation 1) as:

Equation 3 $$AF=\frac{RR-1}{RR}$$

The total number of cases attributable to exposure to particulate matter (where a linear dose-response is assumed) can be calculated as:

Equation 4 $$E=AF \times B \times P$$

Where:
B = baseline incidence of a given health effect (eg mortality rate per person per year)
P = relevant exposed population

The above approach (while presented slightly differently) is consistent with that presented in Australia (Burgers & Walsh 2002), US (OEHHA 2002; USEPA 2005a, 2010) and Europe (Martuzzi et al. 2002; Sjoberg et al. 2009).

The calculation of an increased incidence (ie number of cases) of a particular health endpoint is not relevant to a specific individual, rather this is relevant to a statistically relevant population. This calculation has been undertaken for populations within the suburbs surrounding the proposed project.

11 For regional guidance, such as that provided for Europe by the WHO (WHO 2006a) regional background incidence data for relevant health endpoints are combined with exposure-response functions to present an impact function, which is expressed as the number/change in incidence/new cases per 100,000 population exposed per microgram per cubic metre change in particulate matter exposure. These impact functions are simpler to use than the approach adopted in this assessment, however in utilising this approach it is assumed that the baseline incidence of the health effects is consistent throughout the whole population (as used in the studies) and is specifically applicable to the sub-population group being evaluated. For the assessment of exposures in the areas evaluated surrounding the project it is more relevant to utilise local data in relation to baseline incidence rather than assume that the population is similar to that in Europe (where these relationships are derived).

When considering the potential impact of the project on the population, the calculation has been undertaken using the following:

- Equation 1 has been used to calculate a relative risk. The relative risk has been calculated for a population weighted annual average incremental increase in concentrations. The population weighted average has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics within a suburb (ie mesh blocks – which are small blocks that cover an area of approximately 30 urban residences). For each mesh block in a suburb the average incremental increase in concentration has been calculated and multiplied by the population living in the mesh block (data available from the ABS for the 2011 census year). The weighted average has been calculated by summing these calculations for each mesh block in a suburb and dividing by the total population in the suburb (ie in all the mesh block)
- Equation 3 has been used to calculate an attributable fraction
- Equation 4 has been used to calculate the increased number of cases associated with the incremental impact evaluated. The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered and the population (for the relevant age groups) present in the suburb.

The above approach can be simplified (mathematically, where the incremental change in particulate concentration is low, less than one microgram per cubic metre) as follows:

Equation 5 $E=\beta \times B \times \sum_{mesh}(\Delta X_{mesh} \times P_{mesh})$

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m^3 change in exposure concentration
B = baseline incidence of a given health effect per person (eg annual mortality rate)
ΔXmesh = change (increment) in exposure concentration in µg/m^3 as an average within a small area defined as a mesh block (from the ABS – where many mesh blocks make up a suburb)
Pmesh = population (residential – based on data form the ABS) within each small mesh block

An additional risk can then be calculated as:

Equation 6 $Risk=\beta \times \Delta X \times B$

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m^3 change in exposure
ΔX = change (increment) in exposure concentration in µg/m^3 relevant to the project at the point of exposure
B = baseline incidence of a given health effect per person (eg annual mortality rate)

This calculation provides an annual risk for individuals exposed to changes in air quality from the project at specific locations (such as the maximum, or at specific sensitive receiver locations). The calculated risk does not take into account the duration of exposure at any one location and hence is considered to be representative of a population risk.

Quantification of short-and long-term effects

The concentration-response functions adopted for the assessment of exposure are derived from long and short-term studies and relate to short or long-term effects endpoints (eg change in incidence from daily changes in nitrogen dioxide or particulate matter, or chronic incidence from long-term exposures to particulate matter).

Long-term or chronic effects are assessed on the basis of the identified exposure-response function and annual average concentrations. These then allow the calculation of a chronic incidence of the assessed health endpoint.

Short-term effects are also assessed on the basis of an exposure-response function that is expressed as a percentage change in endpoint per microgram per cubic metre change in concentration. For

short-term effects, the calculations relate to daily changes in nitrogen dioxide and particulate matter exposures to calculate changes in daily effects endpoints. While it may be possible to measure daily incidence of the evaluated health endpoints in a large population study specifically designed to include such data, it is not common to collect such data in hospitals nor are effects measurable in smaller communities. Instead these calculations relate to a parameter that is measurable, such as annual incidence of hospitalisations, mortality or lung cancer risks. The calculation of an annual incidence or additional risk can be undertaken using two approaches (Ostro 2004; USEPA 2010):

- Calculate the daily incidence or risk at each receiver location over every 24-hour period of the year (based on the modelled incremental 24-hour average concentration for each day of the year and daily baseline incidence data) and then sum the daily incidence/risk to get the annual risk
- Calculate the annual incidence/risk based on the incremental annual average concentration at each receiver (and using annual baseline incidence data).

In the absence of a threshold, and assuming a linear concentration-response function (as is the case in this assessment), these two approaches result in the same outcome mathematically (calculated incidence or risk). Given that it is much simpler computationally to calculate the incidence (for each receiver) based on the incremental annual average, compared with calculating effects on each day of the year and then summing, this is the preferred calculation method. It is the recommended method outlined by the WHO (Ostro 2004).

The use of the simpler approach, based on annual average concentrations should not be taken as implying or suggesting that the calculation is quantifying the effects of long-term exposure.

Hence for the calculations presented in this technical working paper that relate to the expected use of the project tunnel, for both long-term and short-term effects, annual average concentrations of nitrogen dioxide and particulate matter have been utilised.

Where short-term worst-case exposures are assessed (such as those related to a breakdown in the tunnel) short-term, daily, calculations have been undertaken to assessed short-term health endpoints. This has been undertaken as the exposure being assessed relates to an infrequent short-duration event. It will not occur each day of the year and hence it is not appropriate to assess on the basis of an annual average.

Appendix B Approach to assessment of diesel particulate matter

Diesel exhaust (DE) is emitted from 'on-road' diesel engines (vehicle engines) and can be formed from the gaseous compounds emitted by diesel engines (secondary particulate matter). After emission from the exhaust pipe, diesel exhaust undergoes dilution and chemical and physical transformations in the atmosphere, as well as dispersion and transport in the atmosphere. The atmospheric lifetime for some compounds present in diesel exhaust ranges from hours to days.

Data from the USEPA (USEPA 2002) indicates that diesel exhaust as measured as diesel particulate matter made up about six per cent of the total ambient/urban air $PM_{2.5}$. In this project, emissions to air from the operation of the tunnel include a significant proportion of diesel powered vehicles. Available evidence indicates that there are human health hazards associated with exposure to diesel particulate matter. The hazards include acute exposure-related symptoms, chronic exposure related non-cancer respiratory effects, and lung cancer.

In relation to non-carcinogenic effects, acute or short-term (eg episodic) exposure to diesel particulate matter can cause acute irritation (eg eye, throat, bronchial), neurophysiological symptoms (eg light-headedness, nausea), and respiratory symptoms (cough, phlegm). There also is evidence for an immunologic effect–exacerbation of allergenic responses to known allergens and asthma-like symptoms. Chronic effects include respiratory effects. The review of these effects (USEPA 2002) identified a threshold concentration for the assessment of chronic non-carcinogenic effects. The review conducted by the USEPA also concluded that exposures to diesel particulate matter also consider $PM_{2.5}$ goals (as these also address the presence of diesel particulate matter in urban air environments). The review found that the diesel particulate matter chronic guideline will also be met if the $PM_{2.5}$ guideline was met.

Review of exposures to diesel particulate matter (USEPA 2002) identified that such exposures are 'likely to be carcinogenic to humans by inhalation'. A more recent review by IARC (Attfield et al. 2012; IARC 2012; Silverman et al. 2012) classified diesel engine exhaust as carcinogenic to humans (Group 1) based on sufficient evidence that exposure is associated with an increased risk for lung cancer. In addition, outdoor air pollution and particulate matter (that includes diesel particulate matter) have been classified by IARC as carcinogenic to humans based on sufficient evidence of lung cancer.

Many of the organic compounds present in diesel exhaust are known to have mutagenic and carcinogenic properties and hence it is appropriate that a non-threshold approach is considered for the quantification of lung-cancer endpoints.

In relation to quantifying carcinogenic risks associated with exposure to diesel exhaust, the USEPA (USEPA 2002) has not established a non-threshold value (due to uncertainties identified in the available data).

WHO has used data from studies in rats to estimate unit risk values for cancer (WHO 1996). Using four different studies where lung cancer was the cancer endpoint, WHO calculated a range of 1.6×10^{-5} to 7.1×10^{-5} per $\mu g/m^3$ (mean value of 3.4×10^{-5} per $\mu g/m^3$). This would suggest that an increase in lifetime exposure to diesel particulate matter between 0.14 and 0.625 $\mu g/m^3$ could result in a one in one hundred thousand excess risk of cancer.

The California Environmental Protection Agency has proposed a unit lifetime cancer risk of 3.0×10^{-4} per $\mu g/m^3$ diesel particulate matter (OEHHA 1998). This was derived from data on exposed workers and based on evidence that suggested unit risks between 1.5×10^{-4} and 15×10^{-4} per $\mu g/m^3$. This would suggest that an increase in lifetime exposure to diesel particulate matter of 0.033 $\mu g/m^3$ could result in a one in one hundred thousand excess risk of cancer. This estimate has been widely criticised as overestimating the risk and hence has not been considered in this assessment.

On the basis of the above, the WHO cancer unit risk value (mean value of 3.4 x 10^{-5} per µg/m^3) has been used to evaluate potential excess lifetime risks associated with incremental impacts from diesel particulate matter exposures. Diesel particulate matter has not been specifically modelled in the AQAR; rather diesel particulate matter is part of the $PM_{2.5}$ assessment. For the purpose of this assessment it has been conservatively assumed that 100 per cent of the incremental $PM_{2.5}$ (from the project only) is derived from diesel sources. This is conservative as not all the vehicles using the tunnel (and emitting $PM_{2.5}$) would be diesel powered (as currently there is a mix of petrol, diesel, LPG and hybrid-electric powered vehicles with the proportion of alternative fuels rising in the future).

For the assessment of potential lung cancer risks associated with exposure to diesel particulate matter, a non-threshold cancer risk is calculated. Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows for inhalation exposures (USEPA 2009b):

Equation 7 Carcinogenic Risk (inhalation) = Concentration in Air x Inhalation Unit Risk x AF

Exposure adjustment factor (AF):

The above calculation assume the receptor is exposed at the same location for 24 hours of the day, every day, for a lifetime (which is assumed to be 70 years). This assumption is overly conservative for residents and workers in the community surrounding the project. Residents do not live in the one home for a lifetime. Guidance from enHealth indicates that an appropriate assumption for the time living in the one home is 35 years (enHealth 2012b). For residents it is assumed that they may be at home for 24 hours per day for 365 days of the year, for 35 years. This results in an adjustment factor of 0.5 (35 years/70 years). This factor has been adopted for the assessment of all exposures regardless of whether these are residential areas, schools, recreational areas or workplaces.

Appendix C Acceptable risk levels

General

The acceptability of an additional population risk is the subject of some discussion as there are currently no guidelines available in Australia, or internationally, in relation to an acceptable level of population risk associated with exposure to particulate matter. More specifically there are no guidelines available that relate to an acceptable level of risk for a small population (associated with impacts from a specific activity or project) compared with risks that are relevant to whole urban populations (that are considered when deriving guidelines). The following provides additional discussion in relation to evaluating calculated risk levels.

'The solution to developing better criteria for environmental contaminants is not to adopt arbitrary thresholds of 'acceptable risk' in an attempt to manage the public's perception of risk, or develop oversimplified tools for enforcement or risk assessment. Rather, the solution is to standardize the process by which risks are assessed, and to undertake efforts to narrow the gap between the public's understanding of actual vs. perceived risk. A more educated public with regard to the actual sources of known risks to health, environmental or otherwise, will greatly facilitate the regulatory agencies' ability to prioritize their efforts and standards to reduce overall risks to public health.' (Kelly 1991).

Most human activities that have contributed to economic progress present also some disadvantages, including risks of different kinds that adversely affect human health. These risks include air or water pollution due to industrial activities (coal power generation, chemical plants, and transportation), food contaminants (pesticide residues, additives), and soil contamination (hazardous waste). Despite all possible efforts to reduce these threats, it is clear that the zero risk objective is unobtainable or simply not necessary for human and environmental protection and that a certain level of risk in a given situation is deemed 'acceptable' as the effects are so small as to be negligible or undetectable. Risk managers need to cope with some residual risks and thus must adopt some measure of an acceptable risk.

Much has been written about how to determine the acceptability of risk. The general consensus in the literature is that 'acceptability' of a risk is a judgment decision properly made by those exposed to the hazard or their designated health officials. It is not a scientifically derived value or a decision made by outsiders to the process. Acceptability is based on many factors, such as the number of people exposed, the consequences of the risk, the degree of control over exposure, and many other factors.

The USEPA (Hoffman 1988) 'surveyed a range of health risks that our society faces' and reviewed acceptable-risk standards of government and independent institutions. The survey found that 'No fixed level of risk could be identified as acceptable in all cases and under all regulatory programs...,' and that: '...the acceptability of risk is a relative concept and involves consideration of different factors'. Considerations may include:

- The certainty and severity of the risk
- The reversibility of the health effect
- The knowledge or familiarity of the risk
- Whether the risk is voluntarily accepted or involuntarily imposed
- Whether individuals are compensated for their exposure to the risk
- The advantages of the activity
- The risks and advantages for any alternatives.

To regulate a technology in a logically defensible way, one must consider all its consequences, i.e. both risks and benefits.

10^{-6} as an 'acceptable' risk level?

The concept of $1x10^{-6}$ (10^{-6}) was originally an arbitrary number, finalised by the US Food and Drug Administration (FDA) in 1977 as a screening level of 'essentially zero' or de minimus risk. The term de minimus is an abbreviation of the legal concept, 'de minimus non curat lex: the law does not concern itself with trifles.' In other words, 10^{-6} was developed as a level of risk below which risk was considered a 'trifle' and not of concern in a legal case.

This concept was traced back to a 1961 proposal by two scientists from the National Cancer Institute regarding methods to determine 'safety' levels in carcinogenicity testing. The FDA applied the concept in risk assessment in its efforts to deal with diethylstilboestrol as a growth promoter in cattle. The threshold of one-in-a-million risk of developing cancer was established as a screening level to determine what carcinogenic animal drug residues merited further regulatory consideration. In the FDA legislation, the regulators specifically stated that this level of 'essentially zero' was not to be interpreted as equal to an acceptable level of residues in meat products. Since then, the use of risk assessment and 10^{-6} (or variations thereof) have been greatly expanded to almost all areas of chemical regulation, to the point where today one-in-a-million (10^{-6}) risk means different things to different regulatory agencies in different countries. What the FDA intended to be a lower regulatory level of 'zero risk' below which no consideration would be given as to risk to human health, for many regulators it somehow came to be considered a maximum or target level of 'acceptable' risk (Kelly 1991).

When evaluating human health risks, the quantification of risk can involve the calculation of an increased lifetime chance of cancer (as is calculated for diesel particulate matter in this assessment) or an increased probability of some adverse health effect (or disease) occurring, over and above the baseline incidence of that health effect/disease in the community (as is calculated for exposure to particulate matter).

In the context of human health risks, 10^{-6} is a shorthand description for an increased chance of 0.000001 in 1 (one chance in a million) of developing a specific adverse health effect due to exposure (over a lifetime or a shorter duration as relevant for particulate matter) to a substance. The number 10^{-5} represents 1 chance in 100,000, and so on.

Where cancer may be considered, lifetime exposure to a substance associated with a cancer risk of $1x10^{-6}$ would increase an individual's current chances of developing cancer from all causes (which is 40 per cent, or 0.4 – the background incidence of cancer in a lifetime) from 0.4 to 0.400001, an increase of 0.00025 per cent.

For other health indicators considered in this assessment, such as cardiovascular hospitalisations for people aged 65 years and older (for example), an increased risk of 10^{-6} (one chance in a million) would increase an individual's (aged 65 years and older) chance of hospitalisation for cardiovascular disease (above the baseline incidence of 23 per cent, or 0.23) from 0.23 to 0.230001, an increase of 0.00043 per cent.

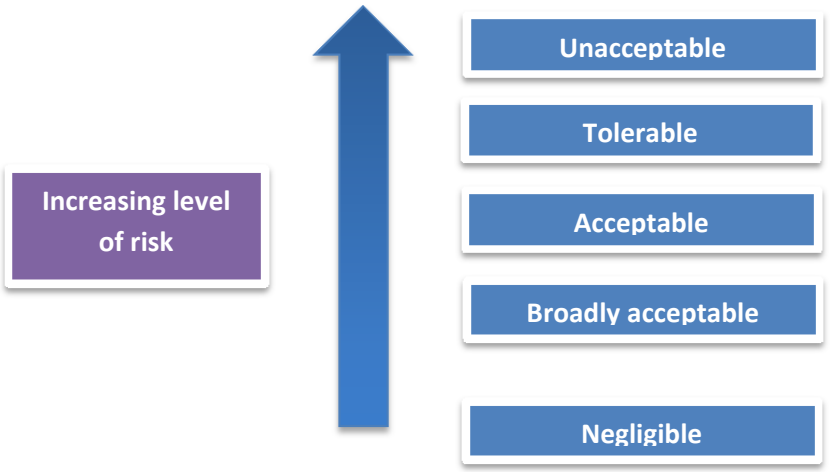
To provide more context in relation to the concept of a one in a million risk, the following presents a range of everyday life occurrences. The activity and the time spent undertaking the activity that is associated with reaching a risk of one in a million for mortality are listed below (Higson 1989; NSW Planning 2011):

- Motor vehicle accident – 2.5 days spent driving a motor vehicle to reach one in a million chance of having an accident that causes mortality (death)
- Home accidents – 3.3 days spent within a residence to reach a one in a million chance of having an accident at home that causes mortality
- Pedestrian accident (being struck by vehicles) – 10 days spent walking along roads to reach a one in a million chance of being struck by a vehicle that causes mortality
- Train accident – 12 days spent travelling on a train to reach a one in a million chance of being involved in an accident that causes mortality

- Falling down stairs [1] – 66 days spent requiring the use of stairs in day-to-day activities to reach a one in a million chance of being involved in a fall that causes mortality
- Falling objects – 121 days spent in day-to-day activities to reach a one in a million chance of being hit by a falling object that causes mortality.

This risk level should also be considered in the context that everyone has a cumulative risk of death that ultimately must equal one and the annual risk of death for most of one's life is about one in 1000.

While various terms have been applied, it is clear that the two ends of what is a spectrum of risk are the 'negligible' level and the 'unacceptable' level. Risk levels intermediate between these are frequently adopted by regulators with varying terms often used to describe the levels. When considering a risk derived for an environmental impact it is important to consider that the level of risk that may be considered acceptable will lie somewhere between what is negligible and unacceptable, as illustrated below.



The calculated individual lifetime risk of death or illness due to an exposure to a range of different environmental hazards covers many orders of magnitude, ranging from well less than 10^{-6} to levels of 10^{-3} and higher (in some situations). However, most figures for an acceptable or a tolerable risk range between 10^{-6} to 10^{-4}, used for either one year of exposure or a whole life exposure. It is noteworthy that 10^{-6} as a criterion for 'acceptable risk' has not been applied to all sources of exposure or all agents that pose risk to public health.

A review of the evolution of 10^{-6} reveals that perception of risk is a major determinant of the circumstances under which this criterion is used. The risk level 10^{-6} is not consistently applied to all environmental legislation. Rather, it seems to be applied according to the general perception of the risk associated with the source being regulated and where the risk is being regulated (with different levels selected in different countries for the same sources).

[1] Mortality risks as presented by: http://www.riskcomm.com/visualaids/riskscale/datasources.php

A review of acceptable risk levels at the USEPA (Schoeny 2008) points out that risk assessors can identify risks and possibly calculate their value but cannot determine what is acceptable. Acceptability is a value judgment that varies with type of risk, culture, voluntariness and many other factors. Acceptability may be set by convention or law. The review also states that the USEPA aims for risk levels between 10^{-6} and 10^{-4} for risks calculated to be linear at low dose, while for other endpoints, not thought to be linear at low dose, the risk is compared to Reference Dose/Concentrations or guideline levels. The USEPA typically uses a target reference risk range of 10^{-4} to 10^{-6} for carcinogens in drinking water, which is in line with World Health Organization (WHO) guidelines for drinking water quality which, where practical, base guideline values for genotoxic carcinogens on the upper bound estimate of an excess lifetime cancer risk of 10^{-5}.

There are many different ways to define acceptable risk and each way gives different weight to the views of different stakeholders in the debate. No definition of 'acceptable' will be acceptable to all stakeholders. Resolving such issues, therefore, becomes a political (in the widest sense) rather than a strictly health process.

The following is a list of standpoints that could be used as a basis for determining when a risk is acceptable or, perhaps, tolerable. The WHO (Fewtrell & Bartram 2001) address standards related to water quality. They offer the following guidelines for determining acceptable risk. A risk is acceptable when:

- It falls below an arbitrary defined probability
- It falls below some level that is already tolerated
- It falls below an arbitrary defined attributable fraction of total disease burden in the community
- The cost of reducing the risk would exceed the costs saved
- The cost of reducing the risk would exceed the costs saved when the 'costs of suffering' are also factored in
- The opportunity costs would be better spent on other, more pressing, public health problems
- Public health professionals say it is acceptable
- The general public say it is acceptable (or more likely, do not say it is not)
- Politicians say it is acceptable.

In everyday life individual risks are rarely considered in isolation. It could be argued that a sensible approach would be to consider health risks in terms of the total disease burden of a community and to define acceptability in terms of it falling below an arbitrary defined level. A problem with this approach is that the current burden of disease attributable to a single factor, such as air pollution, may not be a good indicator of the potential reductions available from improving other environmental health factors. For diseases such as cardiovascular disease where causes are multifactorial, reducing the disease burden by one route may have little impact on the overall burden of disease.

Overall

It is not possible to provide a rigid definition of acceptable risk due to the complex and context-driven nature of the challenge. It is possible to propose some general guidelines as to what might be an acceptable risk for specific development projects.

If the level of 10^{-6} (one chance in a million) were retained as a level of increased risk that would be considered as a negligible risk in the community, then the level of risk that could be considered to be tolerable would lie between this level and an upper level that is considered to be unacceptable.

While there is no guidance available on what level of risk is considered to be unacceptable in the community, a level of 10^{-4} for increased risk (one chance in 10,000) has been generally adopted by health authorities as a point where risk is considered to be unacceptable in the development of drinking water guidelines (that impact on whole populations) (for exposure to carcinogens as well as for annual risks of disease (Fewtrell & Bartram 2001)) and in the evaluation of exposures from pollutants in air (NSW DEC 2005).

Between an increased risk level considered negligible (10^{-6}) and unacceptable (10^{-4}) lie risks that may be considered to be tolerable or even acceptable. Tolerable risks are those that can be tolerated (and where the best available, and most appropriate, technology has been implemented to minimise exposure) in order to realise some benefit.

In a societal context, risks are inevitable and any new development will be accompanied by risks which are not amenable or economically feasible to reduce below a certain level. It is not good policy to impose an arbitrary risk level to such developments without consideration of the myriad factors that should be brought into play to determine what is 'tolerable'.

When considering the impacts associated with this project, it is important to note that there are a range of benefits associated with the project and the design of the project has incorporated measures to minimise exposures to traffic-related emissions in the local areas. Hence for this project the calculated risks have been considered to be tolerable when in the range of 10^{-6} and 10^{-4} of increased risk and where the increased incidence of the health impacts are considered to be insignificant.

Determination of significance of population impacts

The assessment of potential health impacts associated with emissions to air from the project has not only calculated an increased annual risk, relevant to the health endpoints considered, but also a change in the incidence, ie the additional (or saving of) number of cases, of the adverse effects occurring within the population potentially exposed. The calculated change in incidence need to be considered in terms of what may be significant.

In relation to the calculated change in incidence of an adverse health effect occurring in a population, the following is noted for the primary health indicators (based on statistics available from NSW Health):

- In relation to mortality (all causes), the health statistics available show that for the year 2011/2012 the variability in all admissions data reported (based on the 95 per cent confidence interval for data reported in Sydney) is around ± 2.5 per cent. This is the variability in the data reported in one year. Each year the mortality rate also varies with around one per cent variability reported in the mortality rate (number reported for all causes) between 2010/11 and 2011/12. Based on the population considered in this assessment and the baseline incidence, a one per cent variability results in ± 10 cases per year. Changes in mortality within this range would not be detected (above normal variability) in the health statistics.
- In relation to cardiovascular disease hospitalisations, the health statistics available show that for the year 2013/2014 the variability in all admissions data reported (based on the 95 percent confidence interval for data reported in Sydney) is around ± two percent. This is the variability in the data reported in one year. Each year the rate of hospitalisations (all ages) also varies with around 2 to 3 per cent variability reported in the number of hospitalisations for people aged 65 years and older in each year between 2010/11 and 2013/14. Based on the baseline incidence of cardiovascular hospitalisations considered in this assessment for individuals aged 65 years and the population considered in this assessment a variability of two per cent equates to ± 40 cases per year. Changes in cardiovascular hospitalisations in the population aged 65 years and older within this range would not be detected (above normal variability) in the health statistics.
- In relation to respiratory disease hospitalisations, the health statistics available show that for the year 2013/2014 the variability in all admissions data reported (based on the 95 percent confidence interval for data reported in Sydney) is around ± six percent. This is the variability in the data reported in one year. Each year the rate of hospitalisations (all ages) also varies with around 3–4 per cent variability reported in the number of hospitalisations (all ages) in each year between 2011 and 2014. Based on the baseline incidence of respiratory hospitalisations considered in this assessment for individuals aged 65 years and older, and the population evaluated in this assessment, a variability of three per cent equates to ± 25 cases per year. Changes in respiratory hospitalisations in the population aged 65 years and older within this range would not be detected (above normal variability) in the health statistics.

Where changes in air quality associated with this project are well below 10 cases per year they are considered to be within the normal variability of health statistics. For evaluating impacts form this project a 10 fold margin of safety has been included to determine what changes in incidence may be considered negligible within the study population. This means that changes in the population incidence of any health effect evaluated that is less than 1 case per year are considered negligible.

Appendix D Risk calculations: change in nitrogen dioxide concentrations

Quantification of Effects - NO2
M4 East

	2021			2031			2031 Cumulative		
Air quality indicator:	**NO2**	**NO2**	**NO2**	**NO2**	**NO2**	**NO2**	**NO2**	**NO2**	**NO2**
Endpoint:	**Mortality - All Causes**	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**	**Mortality - All Causes**	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**	**Mortality - All Causes**	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**
Effect Exposure Duration:	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term
Age Group:	30+	All ages	1-14 years	30+	All ages	1-14 years	30+	All ages	1-14 years
β (change in effect per 1 µg/m³ PM) (as per Table 6.12)	0.00188	0.00426	0.00115	0.00188	0.00426	0.00115	0.00188	0.00426	0.00115
Annual Baseline Incidence (per 100,000) (as per Table 4.4)	56.9	51.5	1220.7	56.9	51.5	1220.7	56.9	51.5	1220.7
Baseline Incidence (per person per year)	0.000569	0.000515	0.012207	0.000569	0.000515	0.012207	0.000569	0.000515	0.012207

Sensitive Receptors		**Increase in Annual Average NO2 Concentration (µg/m³)**	**Risk**	**Risk**	**Risk**	**Increase in Annual Average NO2 Concentration (µg/m³)**	**Risk**	**Risk**	**Risk**	**Increase in Annual Average NO2 Concentration (µg/m³)**	**Risk**	**Risk**	**Risk**
Maximum Receptor													
Maximum (any landuse)		**2.0**	**2E-06**	**4E-06**	**3E-05**	**1.7**	**2E-06**	**4E-06**	**2E-05**	**3.10**	**3E-06**	**7E-06**	**4E-05**
Maximum Residential		**1.8**	**2E-06**	**4E-06**	**3E-05**	**1.7**	**2E-06**	**4E-06**	**2E-05**	**3.10**	**3E-06**	**7E-06**	**4E-05**
Maximum Commercial		**1.8**	**2E-06**	**4E-06**	**3E-05**	**1.2**	**2E-06**	**4E-06**	**3E-05**	**1.68**	**2E-06**	**4E-06**	**3E-05**
Community Receptors													
Peek-A-Boo Early Learning	Childcare	-1.8	-2E-06	-4E-06	-2E-05	-1.8	-2E-06	-4E-06	-3E-05	-2.2	-2E-06	-5E-06	-3E-05
Aiya Medical Centre	Medical	-0.37	-4E-07	-8E-07	-5E-06	0.25	3E-07	6E-07	4E-06	-0.17	-2E-07	-4E-07	-2E-06
St John of God Burwood Hospital	Medical	-1.3	-1E-06	-3E-06	-2E-05	-1.9	-2E-06	-4E-06	-3E-05	-1.3	-1E-06	-3E-06	-2E-05
MLC School Sydney	School	-1.4	-2E-06	-3E-06	-2E-05	-1.0	-1E-06	-2E-06	-1E-05	-0.97	-1E-06	-2E-06	-1E-05
Southern Cross Catholic Vocational College	School	-0.98	-1E-06	-2E-06	-1E-05	-1.2	-1E-06	-3E-06	-2E-05	-1.3	-1E-06	-3E-06	-2E-05
Burwood ENT Surgery	Medical	-3.1	-3E-06	-7E-06	-4E-05	-2.4	-3E-06	-5E-06	-3E-05	-2.1	-2E-06	-5E-06	-3E-05
Burwood Chest Clinic	Medical	-3.3	-4E-06	-7E-06	-5E-05	-2.3	-2E-06	-5E-06	-3E-05	-2.3	-2E-06	-5E-06	-3E-05
Homebush Boys Highschool	School	-0.67	-7E-07	-1E-06	-9E-06	-0.26	-3E-07	-6E-07	-4E-06	-0.13	-1E-07	-3E-07	-2E-06
Homebush Public School	School	-0.89	-1E-06	-2E-06	-1E-05	0.14	1E-07	3E-07	2E-06	-0.25	-3E-07	-5E-07	-3E-06
Homebush Medical Centre	Medical	-0.32	-3E-07	-7E-07	-4E-06	0.068	7E-08	1E-07	1E-06	-0.25	-3E-07	-6E-07	-4E-06
Pre-Uni New College	School	-0.46	-5E-07	-1E-06	-6E-06	-0.34	-4E-07	-7E-07	-5E-06	-0.11	-1E-07	-2E-07	-2E-06
McDonald College	School	0.14	2E-07	3E-07	2E-06	0.21	2E-07	5E-07	3E-06	0.28	3E-07	6E-07	4E-06
Light House Child Care	Childcare	-0.88	-9E-07	-2E-06	-1E-05	-0.44	-5E-07	-1E-06	-6E-06	-0.44	-5E-07	-1E-06	-6E-06
MLC School Sydney	School	-0.88	-9E-07	-2E-06	-1E-05	-1.4	-2E-06	-3E-06	-2E-05	-1.0	-1E-06	-2E-06	-1E-05
Strathfield Private Hospital	Medical	-0.62	-7E-07	-1E-06	-9E-06	-0.53	-6E-07	-1E-06	-7E-06	-0.86	-9E-07	-2E-06	-1E-05
St Mary's Catholic Primary	School	-3.6	-4E-06	-8E-06	-5E-05	-3.3	-3E-06	-7E-06	-5E-05	-3.3	-3E-06	-7E-06	-5E-05
Rosebank College	School	-3.0	-3E-06	-7E-06	-4E-05	-1.6	-2E-06	-4E-06	-2E-05	-1.7	-2E-06	-4E-06	-2E-05
Little VIPs	Childcare	-3.5	-4E-06	-8E-06	-5E-05	-2.4	-3E-06	-5E-06	-3E-05	-2.3	-2E-06	-5E-06	-3E-05
Ella Community Child Care Centre	Childcare	-0.60	-6E-07	-1E-06	-8E-06	-0.62	-7E-07	-1E-06	-9E-06	-0.56	-6E-07	-1E-06	-8E-06
Ramsay Street Medical Center	Medical	0.33	4E-07	7E-07	5E-06	-0.20	-2E-07	-4E-07	-3E-06	-0.58	-6E-07	-1E-06	-8E-06
St. John of Arc Catholic School	School	-1.1	-1E-06	-2E-06	-1E-05	-0.06	-6E-08	-1E-07	-8E-07	-0.24	-3E-07	-5E-07	-3E-06
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	-0.44	-5E-07	-1E-06	-6E-06	-0.44	-5E-07	-1E-06	-6E-06	-0.74	-8E-07	-2E-06	-1E-05
Dobroyd Point Public School	School	0.31	3E-07	7E-07	4E-06	0.49	5E-07	1E-06	7E-06	-0.16	-2E-07	-4E-07	-2E-06
Domremy College	School	-0.17	-2E-07	-4E-07	-2E-06	-0.0091	-1E-08	-2E-08	-1E-07	-0.38	-4E-07	-8E-07	-5E-06
The Infants Home	Childcare	-1.8	-2E-06	-4E-06	-3E-05	-0.61	-7E-07	-1E-06	-9E-06	-0.76	-8E-07	-2E-06	-1E-05
Lucas Gardens School	School	-1.9	-2E-06	-4E-06	-3E-05	-1.6	-2E-06	-3E-06	-2E-05	-1.5	-2E-06	-3E-06	-2E-05
Educare Playschool	Childcare	-1.6	-2E-06	-4E-06	-2E-05	-0.79	-8E-07	-2E-06	-1E-05	-0.71	-8E-07	-2E-06	-1E-05
Goodstart Early Learning	Childcare	-0.68	-7E-07	-1E-06	-1E-05	-0.97	-1E-06	-2E-06	-1E-05	-1.0	-1E-06	-2E-06	-1E-05
Haberfield Public School	School	-0.61	-6E-07	-1E-06	-8E-06	-1.1	-1E-06	-2E-06	-1E-05	-1.2	-1E-06	-3E-06	-2E-05
Happy Little Campers	Childcare	-0.35	-4E-07	-8E-07	-5E-06	-0.21	-2E-07	-5E-07	-3E-06	-0.51	-5E-07	-1E-06	-7E-06
Burwood Girls High School	School	-0.29	-3E-07	-6E-07	-4E-06	-1.0	-1E-06	-2E-06	-1E-05	-0.85	-9E-07	-2E-06	-1E-05
St Mary's Nursing Home	Aged care	-3.1	-3E-06	-7E-06	-4E-05	-2.6	-3E-06	-6E-06	-4E-05	-2.6	-3E-06	-6E-06	-4E-05
Linburn Nursing Home	Aged care	-0.62	-7E-07	-1E-06	-9E-06	-1.2	-1E-06	-3E-06	-2E-05	-0.96	-1E-06	-2E-06	-1E-05
Redleaf Manor Aged Care	Aged care	-0.42	-4E-07	-9E-07	-6E-06	-0.44	-5E-07	-1E-06	-6E-06	-0.02	-2E-08	-5E-08	-3E-07
BUPA Aged Care	Aged care	-0.82	-9E-07	-2E-06	-1E-05	-0.48	-5E-07	-1E-06	-7E-06	-0.35	-4E-07	-8E-07	-5E-06
Presbyterian Aged Care Haberfield	Aged care	0.29	3E-07	6E-07	4E-06	0.020	2E-08	4E-08	3E-07	-0.87	-9E-07	-2E-06	-1E-05
Wyoming Aged Care	Aged care	0.42	4E-07	9E-07	6E-06	-0.26	-3E-07	-6E-07	-4E-06	-0.66	-7E-07	-1E-06	-9E-06
Woodfield Aged Care	Aged care	0.16	2E-07	4E-07	2E-06	0.35	4E-07	8E-07	5E-06	-1.9	-2E-06	-4E-06	-3E-05

Appendix E Risk calculations: change in $PM_{2.5}$ and PM_{10} concentrations

Quantification of Effects - PM2.5 and PM10, 2021
M4 East

Particulate Fraction:	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5	Incremental Risk - DPM
Endpoint:	Mortality - All Causes	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All Causes	Mortality - All Causes	Mortality - Cardiopulmonary	Mortality - Cardiovascular	Mortality - Respiratory	Morbidity - Asthma ED Admissions	
Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation Unit Risk
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	(refer to Appendix B)
Baseline Incidence (per 100,000) (as per Table 4.4)	976.6	9064.6	3905.1	522.3	522.3	392.4	152.4	51.5	1220.7	
Baseline Incidence (per person)	0.009766	0.090646	0.039051	0.005223	0.005223	0.003924	0.001524	0.000515	0.012207	

Sensitive Receptors		Change in Annual Average PM10 Concentration (µg/m^3)	Change in Annual Average PM2.5 Concentration (µg/m^3)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk
Maximum Receptor													
Maximum (any landuse)		**0.65**	**0.46**	**3E-05**	**3E-05**	**7E-06**	**2E-06**	**2E-06**	**2E-05**	**7E-07**	**5E-07**	**8E-06**	**8E-06**
Maximum Residential		**0.65**	**0.43**	**2E-05**	**3E-05**	**7E-06**	**2E-06**	**2E-06**	**2E-05**	**6E-07**	**4E-07**	**8E-06**	**7E-06**
Maximum Commercial		**0.50**	**0.25**	**1E-05**	**2E-05**	**4E-06**	**8E-07**	**1E-06**	**1E-05**	**4E-07**	**2E-07**	**5E-06**	**4E-06**
Community Receptors													
Peek-A-Boo Early Learning	Childcare	-0.80	-0.45	-3E-05	-3E-05	-7E-06	-3E-06	-2E-06	-2E-05	-7E-07	-4E-07	-8E-06	-8E-06
Aiya Medical Centre	Medical	-0.13	-0.12	-7E-06	-9E-06	-2E-06	-4E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
St John of God Burwood Hospital	Medical	-0.63	-0.34	-2E-05	-2E-05	-5E-06	-2E-06	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-6E-06
MLC School Sydney	School	-0.44	-0.24	-1E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-4E-07	-2E-07	-4E-06	-4E-06
Southern Cross Catholic Vocational College	School	-0.31	-0.16	-9E-06	-1E-05	-3E-06	-1E-06	-8E-07	-8E-06	-2E-07	-2E-07	-3E-06	-3E-06
Burwood ENT Surgery	Medical	-0.92	-0.64	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-3E-05	-1E-06	-6E-07	-1E-05	-1E-05
Burwood Chest Clinic	Medical	-1.5	-0.80	-5E-05	-6E-05	-1E-05	-5E-06	-4E-06	-4E-05	-1E-06	-8E-07	-1E-05	-1E-05
Homebush Boys Highschool	School	-0.17	-0.12	-7E-06	-9E-06	-2E-06	-5E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
Homebush Public School	School	-0.35	-0.097	-6E-06	-7E-06	-2E-06	-1E-06	-5E-07	-5E-06	-1E-07	-1E-07	-2E-06	-2E-06
Homebush Medical Centre	Medical	-0.14	-0.081	-5E-06	-6E-06	-1E-06	-4E-07	-4E-07	-4E-06	-1E-07	-8E-08	-1E-06	-1E-06
Pre-Uni New College	School	0.048	-0.070	-4E-06	-5E-06	-1E-06	2E-07	-3E-07	-4E-06	-1E-07	-7E-08	-1E-06	-1E-06
McDonald College	School	-0.16	-0.14	-8E-06	-1E-05	-2E-06	-5E-07	-7E-07	-7E-06	-2E-07	-1E-07	-3E-06	-2E-06
Light House Child Care	Childcare	-0.17	-0.041	-2E-06	-3E-06	-7E-07	-5E-07	-2E-07	-2E-06	-6E-08	-4E-08	-7E-07	-7E-07
MLC School Sydney	School	-0.27	-0.23	-1E-05	-2E-05	-4E-06	-9E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
Strathfield Private Hospital	Medical	-0.20	-0.033	-2E-06	-2E-06	-5E-07	-6E-07	-2E-07	-2E-06	-5E-08	-3E-08	-6E-07	-6E-07
St Mary's Catholic Primary	School	-1.3	-0.79	-4E-05	-6E-05	-1E-05	-4E-06	-4E-06	-4E-05	-1E-06	-8E-07	-1E-05	-1E-05
Rosebank College	School	-0.76	-0.50	-3E-05	-4E-05	-8E-06	-2E-06	-2E-06	-3E-05	-7E-07	-5E-07	-9E-06	-8E-06
Little VIPs	Childcare	-1.1	-0.77	-4E-05	-6E-05	-1E-05	-3E-06	-4E-06	-4E-05	-1E-06	-8E-07	-1E-05	-1E-05
Ella Community Child Care Centre	Childcare	0.086	0.026	1E-06	2E-06	4E-07	3E-07	1E-07	1E-06	4E-08	3E-08	5E-07	4E-07
Ramsay Street Medical Center	Medical	-0.22	-0.073	-4E-06	-5E-06	-1E-06	-7E-07	-4E-07	-4E-06	-1E-07	-7E-08	-1E-06	-1E-06
St. John of Arc Catholic School	School	-0.31	0.042	2E-06	3E-06	7E-07	-1E-06	2E-07	2E-06	6E-08	4E-08	8E-07	7E-07
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	-0.0053	-0.061	-3E-06	-4E-06	-1E-06	-2E-08	-3E-07	-3E-06	-9E-08	-6E-08	-1E-06	-1E-06
Dobroyd Point Public School	School	0.11	0.14	8E-06	1E-05	2E-06	4E-07	7E-07	7E-06	2E-07	1E-07	2E-06	2E-06
Domremy College	School	-0.070	-0.19	-1E-05	-1E-05	-3E-06	-2E-07	-9E-07	-1E-05	-3E-07	-2E-07	-3E-06	-3E-06
The Infants Home	Childcare	-0.60	-0.22	-1E-05	-2E-05	-4E-06	-2E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
Lucas Gardens School	School	-0.47	-0.32	-2E-05	-2E-05	-5E-06	-1E-06	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-5E-06
Educare Playschool	Childcare	-0.16	-0.15	-9E-06	-1E-05	-2E-06	-5E-07	-8E-07	-8E-06	-2E-07	-2E-07	-3E-06	-3E-06
Goodstart Early Learning	Childcare	-0.20	-0.18	-1E-05	-1E-05	-3E-06	-6E-07	-9E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Haberfield Public School	School	-0.57	-0.34	-2E-05	-2E-05	-5E-06	-2E-06	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-6E-06
Happy Little Campers	Childcare	-0.12	-0.067	-4E-06	-5E-06	-1E-06	-4E-07	-3E-07	-3E-06	-1E-07	-7E-08	-1E-06	-1E-06
Burwood Girls High School	School	-0.47	-0.19	-1E-05	-1E-05	-3E-06	-1E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-3E-06
St Mary's Nursing Home	Aged care	-1.1	-0.74	-4E-05	-5E-05	-1E-05	-3E-06	-4E-06	-4E-05	-1E-06	-7E-07	-1E-05	-1E-05
Linburn Nursing Home	Aged care	-0.37	-0.25	-1E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-4E-07	-2E-07	-5E-06	-4E-06
Redleaf Manor Aged Care	Aged care	-0.14	-0.058	-3E-06	-4E-06	-9E-07	-4E-07	-3E-07	-3E-06	-9E-08	-6E-08	-1E-06	-1E-06
BUPA Aged Care	Aged care	-0.29	-0.13	-7E-06	-9E-06	-2E-06	-9E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	-2E-06
Presbyterian Aged Care Haberfield	Aged care	-0.23	-0.18	-1E-05	-1E-05	-3E-06	-7E-07	-9E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Wyoming Aged Care	Aged care	-0.21	-0.033	-2E-06	-2E-06	-5E-07	-7E-07	-2E-07	-2E-06	-5E-08	-3E-08	-6E-07	-6E-07
Woodfield Aged Care	Aged care	0.073	-0.000090	-5E-09	-7E-09	-1E-09	2E-07	-4E-10	-5E-09	-1E-10	-9E-11	-2E-09	-2E-09

Quantification of Effects - PM2.5 and PM10, 2031
M4 East

Particulate Fraction:	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5	Incremental Risk - DPM
Endpoint:	**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Mortality - All Causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovascular**	**Mortality - Respiratory**	**Morbidity - Asthma ED Admissions**	
Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation Unit Risk
β (change in effect per 1 µg/m³ PM) (as per Table 6.18)	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	(refer to Appendix B)
Baseline Incidence (per 100,000) (as per Table 4.4)	976.6	9064.6	3905.1	522.3	522.3	392.4	152.4	51.5	1220.7	
Baseline Incidence (per person)	0.009766	0.090646	0.039051	0.005223	0.005223	0.003924	0.001524	0.000515	0.012207	

Sensitive Receptors		Change in Annual Average PM10 Concentration (µg/m³)	Change in Annual Average PM2.5 Concentration (µg/m³)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk
Maximum Receptor													
Maximum (any landuse)		**0.61**	**0.51**	**3E-05**	**4E-05**	**8E-06**	**2E-06**	**3E-06**	**3E-05**	**8E-07**	**5E-07**	**9E-06**	**9E-06**
Maximum Residential		**0.61**	**0.51**	**3E-05**	**4E-05**	**8E-06**	**2E-06**	**3E-06**	**3E-05**	**8E-07**	**5E-07**	**9E-06**	**9E-06**
Maximum Commercial		**0.46**	**0.31**	**2E-05**	**2E-05**	**5E-06**	**1E-06**	**2E-06**	**2E-05**	**5E-07**	**3E-07**	**6E-06**	**5E-06**
Community Receptors													
Peek-A-Boo Early Learning	Childcare	-0.63	-0.51	-3E-05	-4E-05	-8E-06	-2E-06	-3E-06	-3E-05	-8E-07	-5E-07	-9E-06	-9E-06
Aiya Medical Centre	Medical	0.089	-0.25	-1E-05	-2E-05	-4E-06	3E-07	-1E-06	-1E-05	-4E-07	-2E-07	-5E-06	-4E-06
St John of God Burwood Hospital	Medical	-0.59	-0.56	-3E-05	-4E-05	-9E-06	-2E-06	-3E-06	-3E-05	-8E-07	-5E-07	-1E-05	-1E-05
MLC School Sydney	School	-0.39	-0.27	-2E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-4E-07	-3E-07	-5E-06	-5E-06
Southern Cross Catholic Vocational College	School	-0.14	-0.18	-1E-05	-1E-05	-3E-06	-5E-07	-9E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Burwood ENT Surgery	Medical	-0.82	-0.50	-3E-05	-4E-05	-8E-06	-3E-06	-2E-06	-3E-05	-7E-07	-5E-07	-9E-06	-8E-06
Burwood Chest Clinic	Medical	-1.1	-0.59	-3E-05	-4E-05	-9E-06	-3E-06	-3E-06	-3E-05	-9E-07	-6E-07	-1E-05	-1E-05
Homebush Boys Highschool	School	-0.063	0.055	3E-06	4E-06	9E-07	-2E-07	3E-07	3E-06	8E-08	5E-08	1E-06	9E-07
Homebush Public School	School	-0.11	-0.079	-4E-06	-6E-06	-1E-06	-3E-07	-4E-07	-4E-06	-1E-07	-8E-08	-1E-06	-1E-06
Homebush Medical Centre	Medical	-0.21	0.0073	4E-07	5E-07	1E-07	-7E-07	4E-08	4E-07	1E-08	7E-09	1E-07	1E-07
Pre-Uni New College	School	-0.18	-0.13	-7E-06	-9E-06	-2E-06	-6E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
McDonald College	School	-0.15	-0.0053	-3E-07	-4E-07	-8E-08	-5E-07	-3E-08	-3E-07	-8E-09	-5E-09	-9E-08	-9E-08
Light House Child Care	Childcare	-0.038	0.0074	4E-07	5E-07	1E-07	-1E-07	4E-08	4E-07	1E-08	7E-09	1E-07	1E-07
MLC School Sydney	School	-0.39	-0.16	-9E-06	-1E-05	-3E-06	-1E-06	-8E-07	-8E-06	-2E-07	-2E-07	-3E-06	-3E-06
Strathfield Private Hospital	Medical	-0.35	-0.12	-7E-06	-8E-06	-2E-06	-1E-06	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
St Mary's Catholic Primary	School	-1.4	-0.87	-5E-05	-6E-05	-1E-05	-4E-06	-4E-06	-4E-05	-1E-06	-9E-07	-2E-05	-1E-05
Rosebank College	School	-0.57	-0.41	-2E-05	-3E-05	-7E-06	-2E-06	-2E-06	-2E-05	-6E-07	-4E-07	-7E-06	-7E-06
Little VIPs	Childcare	-1.3	-0.56	-3E-05	-4E-05	-9E-06	-4E-06	-3E-06	-3E-05	-8E-07	-5E-07	-1E-05	-1E-05
Ella Community Child Care Centre	Childcare	0.15	0.15	8E-06	1E-05	2E-06	5E-07	7E-07	7E-06	2E-07	1E-07	3E-06	2E-06
Ramsay Street Medical Center	Medical	-0.25	-0.12	-7E-06	-9E-06	-2E-06	-8E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
St. John of Arc Catholic School	School	0.021	0.086	5E-06	6E-06	1E-06	7E-08	4E-07	4E-06	1E-07	8E-08	2E-06	1E-06
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	0.050	0.00065	4E-08	5E-08	1E-08	2E-07	3E-09	3E-08	1E-09	6E-10	1E-08	1E-08
Dobroyd Point Public School	School	-0.023	0.066	4E-06	5E-06	1E-06	-7E-08	3E-07	3E-06	1E-07	7E-08	1E-06	1E-06
Domremy College	School	-0.045	-0.061	-3E-06	-4E-06	-1E-06	-1E-07	-3E-07	-3E-06	-9E-08	-6E-08	-1E-06	-1E-06
The Infants Home	Childcare	-0.67	-0.29	-2E-05	-2E-05	-5E-06	-2E-06	-1E-06	-1E-05	-4E-07	-3E-07	-5E-06	-5E-06
Lucas Gardens School	School	-0.48	-0.41	-2E-05	-3E-05	-7E-06	-1E-06	-2E-06	-2E-05	-6E-07	-4E-07	-7E-06	-7E-06
Educare Playschool	Childcare	-0.49	-0.21	-1E-05	-2E-05	-3E-06	-2E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
Goodstart Early Learning	Childcare	-0.17	-0.25	-1E-05	-2E-05	-4E-06	-5E-07	-1E-06	-1E-05	-4E-07	-2E-07	-4E-06	-4E-06
Haberfield Public School	School	-0.49	-0.22	-1E-05	-2E-05	-4E-06	-2E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
Happy Little Campers	Childcare	-0.15	-0.042	-2E-06	-3E-06	-7E-07	-5E-07	-2E-07	-2E-06	-6E-08	-4E-08	-8E-07	-7E-07
Burwood Girls High School	School	-0.29	-0.20	-1E-05	-1E-05	-3E-06	-9E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-3E-06
St Mary's Nursing Home	Aged care	-0.98	-0.71	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-4E-05	-1E-06	-7E-07	-1E-05	-1E-05
Linburn Nursing Home	Aged care	-0.51	-0.16	-9E-06	-1E-05	-3E-06	-2E-06	-8E-07	-8E-06	-2E-07	-2E-07	-3E-06	-3E-06
Redleaf Manor Aged Care	Aged care	-0.20	-0.063	-4E-06	-5E-06	-1E-06	-6E-07	-3E-07	-3E-06	-9E-08	-6E-08	-1E-06	-1E-06
BUPA Aged Care	Aged care	-0.19	-0.17	-1E-05	-1E-05	-3E-06	-6E-07	-8E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Presbyterian Aged Care Haberfield	Aged care	-0.060	-0.035	-2E-06	-3E-06	-6E-07	-2E-07	-2E-07	-2E-06	-5E-08	-3E-08	-6E-07	-6E-07
Wyoming Aged Care	Aged care	-0.040	-0.061	-3E-06	-4E-06	-1E-06	-1E-07	-3E-07	-3E-06	-9E-08	-6E-08	-1E-06	-1E-06
Woodfield Aged Care	Aged care	0.042	0.083	5E-06	6E-06	1E-06	1E-07	4E-07	4E-06	1E-07	8E-08	1E-06	1E-06

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Appendix F Calculations: change in population incidence for change in $PM_{2.5}$ concentrations in community

Assessment of Increased Incidence - PM2.5, 2021
M4 East

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Baseline Incidence (per 100,000) (as per Table 4.4)	976.6	9064.6	3905.1	522.3	392.4	152.4	51.5	1220.7
Baseline Incidence (per person)	0.009766	0.090646	0.039051	0.005223	0.003924	0.001524	0.000515	0.012207
Strathfield - Burwood - Ashfield								
Total Population in study area:	102796	102796	102796	102796	102796	102796	102796	102796
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (µg/m^3):	-0.064	-0.064	-0.064	-0.064	-0.064	-0.064	-0.064	-0.064
Relative Risk:	0.999631	0.999949	0.999974	0.999940	0.999173	0.999938	0.999879	0.999906
Attributable fraction (AF):	-3.7E-04	-5.1E-05	-2.6E-05	-6.0E-05	-8.3E-04	-6.2E-05	-1.2E-04	-9.4E-05
Increased number of cases in population:	-0.22	-0.062	-0.014	-0.032	-0.20	-0.0097	-0.0064	-0.017
Risk:	-3.6E-06	-4.6E-06	-1.0E-06	-3.1E-07	-3.2E-06	-9.4E-08	-6.2E-08	-1.2E-06
Canada Bay								
Total Population in study area:	59191	59191	59191	59191	59191	59191	59191	59191
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (µg/m^3):	-0.039	-0.039	-0.039	-0.039	-0.039	-0.039	-0.039	-0.039
Relative Risk:	0.999772	0.999968	0.999984	0.999963	0.999488	0.999962	0.999925	0.999942
Attributable fraction (AF):	-2.3E-04	-3.2E-05	-1.6E-05	-3.7E-05	-5.1E-04	-3.8E-05	-7.5E-05	-5.8E-05
Increased number of cases in population:	-0.084	-0.024	-0.0052	-0.011	-0.075	-0.0034	-0.0023	-0.0065
Risk:	-2.2E-06	-2.9E-06	-6.3E-07	-1.9E-07	-2.0E-06	-5.8E-08	-3.9E-08	-7.1E-07
Leichhardt								
Total Population in study area:	2538	2538	2538	2538	2538	2538	2538	2538
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (µg/m^3):	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054
Relative Risk:	0.999969	0.999996	0.999998	0.999995	0.999930	0.999995	0.999990	0.999992
Attributable fraction (AF):	-3.1E-05	-4.3E-06	-2.2E-06	-5.1E-06	-7.0E-05	-5.2E-06	-1.0E-05	-8.0E-06
Increased number of cases in population:	-0.00052	-0.00010	-0.000022	-0.000067	-0.00047	-0.000020	-0.000013	-0.000037
Risk:	-3.1E-07	-3.9E-07	-8.6E-08	-2.6E-08	-2.7E-07	-8.0E-09	-5.3E-09	-9.7E-08
Bankstown (includes Auburn)								
Total Population in study area:	2495	2495	2495	2495	2495	2495	2495	2495
% population in assessment age-group:	58%	14%	14%	100%	58%	100%	100%	20%
Population weighted Δx (µg/m^3):	-0.0091	-0.0091	-0.0091	-0.0091	-0.0091	-0.0091	-0.0091	-0.0091
Relative Risk:	0.999947	0.999993	0.999996	0.999991	0.999881	0.999991	0.999983	0.999986
Attributable fraction (AF):	-5.3E-05	-7.3E-06	-3.7E-06	-8.6E-06	-1.2E-04	-8.9E-06	-1.7E-05	-1.4E-05
Increased number of cases in population:	-0.00075	-0.00023	-0.000050	-0.00011	-0.00067	-0.000034	-0.000022	-0.000084
Risk:	-5.2E-07	-6.6E-07	-1.5E-07	-4.5E-08	-4.7E-07	-1.4E-08	-8.9E-09	-1.7E-07
Total population incidence - All Suburbs	**-0.3**	**-0.09**	**-0.02**	**-0.04**	**-0.3**	**-0.01**	**-0.009**	**-0.02**

Assessment of Increased Incidence - PM2.5, 2031
M4 East

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Baseline Incidence (per 100,000) (as per Table 4.4)	976.6	9064.6	3905.1	522.3	392.4	152.4	51.5	1220.7
Baseline Incidence (per person)	0.009766	0.090646	0.039051	0.005223	0.003924	0.001524	0.000515	0.012207
Strathfield - Burwood - Ashfield								
Total Population in study area:	102796	102796	102796	102796	102796	102796	102796	102796
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (µg/m^3):	-0.063	-0.063	-0.063	-0.063	-0.063	-0.063	-0.063	-0.063
Relative Risk:	0.999632	0.999949	0.999974	0.999940	0.999176	0.999939	0.999880	0.999906
Attributable fraction (AF):	-3.7E-04	-5.1E-05	-2.6E-05	-6.0E-05	-8.2E-04	-6.1E-05	-1.2E-04	-9.4E-05
Increased number of cases in population:	-0.22	-0.062	-0.014	-0.032	-0.20	-0.0096	-0.0064	-0.017
Risk:	-3.6E-06	-4.6E-06	-1.0E-06	-3.1E-07	-3.2E-06	-9.4E-08	-6.2E-08	-1.1E-06
Canada Bay								
Total Population in study area:	59191	59191	59191	59191	59191	59191	59191	59191
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (µg/m^3):	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037
Relative Risk:	0.999785	0.999970	0.999985	0.999965	0.999519	0.999964	0.999930	0.999945
Attributable fraction (AF):	-2.1E-04	-3.0E-05	-1.5E-05	-3.5E-05	-4.8E-04	-3.6E-05	-7.0E-05	-5.5E-05
Increased number of cases in population:	-0.079	-0.022	-0.0049	-0.011	-0.071	-0.0032	-0.0021	-0.0061
Risk:	-2.1E-06	-2.7E-06	-5.9E-07	-1.8E-07	-1.9E-06	-5.5E-08	-3.6E-08	-6.7E-07
Leichhardt								
Total Population in study area:	2538	2538	2538	2538	2538	2538	2538	2538
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (µg/m^3):	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Relative Risk:	1.000056	1.000008	1.000004	1.000009	1.000126	1.000009	1.000018	1.000014
Attributable fraction (AF):	5.6E-05	7.8E-06	4.0E-06	9.1E-06	1.3E-04	9.4E-06	1.8E-05	1.4E-05
Increased number of cases in population:	0.00094	0.00018	0.000040	0.00012	0.00084	0.000036	0.000024	0.000066
Risk:	5.5E-07	7.0E-07	1.6E-07	4.8E-08	4.9E-07	1.4E-08	9.5E-09	1.8E-07
Bankstown (includes Auburn)								
Total Population in study area:	2495	2495	2495	2495	2495	2495	2495	2495
% population in assessment age-group:	58%	14%	14%	100%	58%	100%	100%	20%
Population weighted Δx (µg/m^3):	-0.0058	-0.0058	-0.0058	-0.0058	-0.0058	-0.0058	-0.0058	-0.0058
Relative Risk:	0.999966	0.999995	0.999998	0.999995	0.999925	0.999994	0.999989	0.999991
Attributable fraction (AF):	-3.4E-05	-4.6E-06	-2.4E-06	-5.5E-06	-7.5E-05	-5.6E-06	-1.1E-05	-8.6E-06
Increased number of cases in population:	-0.00047	-0.00014	-0.000032	-0.000071	-0.00043	-0.000021	-0.000014	-0.000053
Risk:	-3.3E-07	-4.2E-07	-9.3E-08	-2.8E-08	-3.0E-07	-8.6E-09	-5.7E-09	-1.0E-07
Total population incidence - All Suburbs	**-0.3**	**-0.08**	**-0.02**	**-0.04**	**-0.3**	**-0.01**	**-0.009**	**-0.02**

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Appendix G Risk calculations: change in $PM_{2.5}$ and PM_{10} concentrations for cumulative scenario

Quantification of Effects - PM2.5 and PM10, 2031 Cumulative
M4 East

Particulate Fraction:	PM2.5	PM2.5	PM2.5	PM10	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5	Incremental Risk - DPM
Endpoint:	**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Mortality - All Causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovascular**	**Mortality - Respiratory**	**Morbidity - Asthma ED Admissions**	
Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation Unit Risk
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	(refer to Appendix B)
Baseline Incidence (per 100,000) (as per Table 4.4)	976.6	9064.6	3905.1	522.3	522.3	392.4	152.4	51.5	1220.7	
Baseline Incidence (per person)	0.009766	0.090646	0.039051	0.005223	0.005223	0.003924	0.001524	0.000515	0.012207	

Sensitive Receptors		Change in Annual Average PM10 Concentration (µg/m^3)	Change in Annual Average PM2.5 Concentration (µg/m^3)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk
Maximum Receptor													
Maximum (any landuse)		**1.0**	**0.75**	**4E-05**	**5E-05**	**1E-05**	**3E-06**	**4E-06**	**4E-05**	**1E-06**	**7E-07**	**1E-05**	**1E-05**
Maximum Residential		**1.0**	**0.75**	**4E-05**	**5E-05**	**1E-05**	**3E-06**	**4E-06**	**4E-05**	**1E-06**	**7E-07**	**1E-05**	**1E-05**
Maximum Commercial		**0.90**	**0.70**	**4E-05**	**5E-05**	**1E-05**	**2E-06**	**3E-06**	**4E-05**	**1E-06**	**7E-07**	**1E-05**	**1E-05**
Community Receptors													
Peek-A-Boo Early Learning	Childcare	-0.64	-0.50	-3E-05	-4E-05	-8E-06	-2E-06	-2E-06	-3E-05	-7E-07	-5E-07	-9E-06	-8E-06
Aiya Medical Centre	Medical	0.068	-0.13	-7E-06	-9E-06	-2E-06	2E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
St John of God Burwood Hospital	Medical	-0.56	-0.47	-3E-05	-3E-05	-7E-06	-2E-06	-2E-06	-2E-05	-7E-07	-5E-07	-8E-06	-8E-06
MLC School Sydney	School	-0.42	-0.31	-2E-05	-2E-05	-5E-06	-1E-06	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-5E-06
Southern Cross Catholic Vocational College	School	-0.25	-0.20	-1E-05	-1E-05	-3E-06	-8E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-3E-06
Burwood ENT Surgery	Medical	-0.97	-0.57	-3E-05	-4E-05	-9E-06	-3E-06	-3E-06	-3E-05	-8E-07	-6E-07	-1E-05	-1E-05
Burwood Chest Clinic	Medical	-1.2	-0.57	-3E-05	-4E-05	-9E-06	-4E-06	-3E-06	-3E-05	-8E-07	-6E-07	-1E-05	-1E-05
Homebush Boys Highschool	School	0.15	0.028	2E-06	2E-06	4E-07	5E-07	1E-07	1E-06	4E-08	3E-08	5E-07	5E-07
Homebush Public School	School	0.0025	0.030	2E-06	2E-06	5E-07	8E-09	1E-07	2E-06	4E-08	3E-08	5E-07	5E-07
Homebush Medical Centre	Medical	-0.0037	-0.010	-5E-07	-7E-07	-2E-07	-1E-08	-5E-08	-5E-07	-1E-08	-9E-09	-2E-07	-2E-07
Pre-Uni New College	School	-0.17	-0.087	-5E-06	-6E-06	-1E-06	-5E-07	-4E-07	-4E-06	-1E-07	-8E-08	-2E-06	-1E-06
McDonald College	School	0.11	-0.018	-1E-06	-1E-06	-3E-07	4E-07	-9E-08	-9E-07	-3E-08	-2E-08	-3E-07	-3E-07
Light House Child Care	Childcare	-0.051	0.010	6E-07	7E-07	2E-07	-2E-07	5E-08	5E-07	2E-08	1E-08	2E-07	2E-07
MLC School Sydney	School	-0.34	-0.18	-1E-05	-1E-05	-3E-06	-1E-06	-9E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Strathfield Private Hospital	Medical	-0.43	-0.22	-1E-05	-2E-05	-3E-06	-1E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
St Mary's Catholic Primary	School	-1.2	-0.91	-5E-05	-7E-05	-1E-05	-4E-06	-4E-06	-5E-05	-1E-06	-9E-07	-2E-05	-2E-05
Rosebank College	School	-0.73	-0.45	-3E-05	-3E-05	-7E-06	-2E-06	-2E-06	-2E-05	-7E-07	-4E-07	-8E-06	-8E-06
Little VIPs	Childcare	-0.93	-0.69	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-3E-05	-1E-06	-7E-07	-1E-05	-1E-05
Ella Community Child Care Centre	Childcare	0.011	-0.10	-6E-06	-8E-06	-2E-06	3E-08	-5E-07	-5E-06	-2E-07	-1E-07	-2E-06	-2E-06
Ramsay Street Medical Center	Medical	-0.098	-0.12	-7E-06	-8E-06	-2E-06	-3E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
St. John of Arc Catholic School	School	-0.17	0.057	3E-06	4E-06	9E-07	-5E-07	3E-07	3E-06	8E-08	6E-08	1E-06	1E-06
Saint Joan of Arc's Catholic Church Haberfield	Place of worship	-0.096	-0.055	-3E-06	-4E-06	-9E-07	-3E-07	-3E-07	-3E-06	-8E-08	-5E-08	-1E-06	-9E-07
Dobroyd Point Public School	School	0.16	-0.057	-3E-06	-4E-06	-9E-07	5E-07	-3E-07	-3E-06	-8E-08	-6E-08	-1E-06	-1E-06
Domremy College	School	-0.20	-0.048	-3E-06	-3E-06	-8E-07	-6E-07	-2E-07	-2E-06	-7E-08	-5E-08	-9E-07	-8E-07
The Infants Home	Childcare	-0.58	-0.23	-1E-05	-2E-05	-4E-06	-2E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	-4E-06
Lucas Gardens School	School	-0.36	-0.30	-2E-05	-2E-05	-5E-06	-1E-06	-1E-06	-2E-05	-4E-07	-3E-07	-5E-06	-5E-06
Educare Playschool	Childcare	-0.49	-0.13	-7E-06	-9E-06	-2E-06	-2E-06	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	-2E-06
Goodstart Early Learning	Childcare	-0.23	-0.32	-2E-05	-2E-05	-5E-06	-7E-07	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-5E-06
Haberfield Public School	School	-0.38	-0.39	-2E-05	-3E-05	-6E-06	-1E-06	-2E-06	-2E-05	-6E-07	-4E-07	-7E-06	-7E-06
Happy Little Campers	Childcare	-0.26	-0.066	-4E-06	-5E-06	-1E-06	-8E-07	-3E-07	-3E-06	-1E-07	-6E-08	-1E-06	-1E-06
Burwood Girls High School	School	-0.24	-0.17	-1E-05	-1E-05	-3E-06	-8E-07	-8E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
St Mary's Nursing Home	Aged care	-0.93	-0.68	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-3E-05	-1E-06	-7E-07	-1E-05	-1E-05
Linburn Nursing Home	Aged care	-0.51	-0.18	-1E-05	-1E-05	-3E-06	-2E-06	-9E-07	-9E-06	-3E-07	-2E-07	-3E-06	-3E-06
Redleaf Manor Aged Care	Aged care	-0.14	0.000079	4E-09	6E-09	1E-09	-4E-07	4E-10	4E-09	1E-10	8E-11	1E-09	1E-09
BUPA Aged Care	Aged care	0.10	-0.069	-4E-06	-5E-06	-1E-06	3E-07	-3E-07	-4E-06	-1E-07	-7E-08	-1E-06	-1E-06
Presbyterian Aged Care Haberfield	Aged care	-0.39	-0.29	-2E-05	-2E-05	-5E-06	-1E-06	-1E-06	-1E-05	-4E-07	-3E-07	-5E-06	-5E-06
Wyoming Aged Care	Aged care	-0.12	-0.13	-7E-06	-9E-06	-2E-06	-4E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	-2E-06
Woodfield Aged Care	Aged care	-0.57	-0.32	-2E-05	-2E-05	-5E-06	-2E-06	-2E-06	-2E-05	-5E-07	-3E-07	-6E-06	-5E-06

Appendix H Risk calculations: regulatory worst-case

Quantification of Effects - Worst-Case Short Term Changes in NO2
M4 East

	Worst-Case Emissions from M4 East		
Air quality indicator:	**NO2**	**NO2**	**NO2**
Endpoint:	**Mortality - All Causes**	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**
Effect Exposure Duration:	Short-term	Short-term	Short-term
Age Group:	30+	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6.12)	0.00188	0.00426	0.00115
Annual Baseline Incidence (per 100,000) (as per Table 4.4)	56.9	51.5	1220.7
Baseline Incidence (per person per hour)	6.49543E-08	5.879E-08	1.39349E-06

	Worst-Case Emissions from M4 East and M4-M5		
NO2	**NO2**	**NO2**	**NO2**
Mortality - All Causes	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**	
Short-term	Short-term	Short-term	
30+	All ages	1-14 years	
0.00188	0.00426	0.00115	
56.9	51.5	1220.7	
6.49543E-08	5.879E-08	1.39349E-06	

Sensitive Receptors	**Increase in 1-hour average NO2 concentration (µg/m^3)**	**Risk**	**Risk**	**Risk**	**Increase in 1-hour average NO2 concentration (µg/m^3)**	**Risk**	**Risk**	**Risk**
Maximum Receptor								
Maximum (any landuse)	**9.5**	**1E-09**	**2E-09**	**2E-08**	**18**	**2E-09**	**5E-09**	**3E-08**
Maximum Residential	**9.5**	**1E-09**	**2E-09**	**2E-08**	**18**	**2E-09**	**5E-09**	**3E-08**
Maximum Commercial	**8.9**	**1E-09**	**2E-09**	**1E-08**	**18**	**2E-09**	**5E-09**	**3E-08**
Change in maximum risk for 8 hour event								
Maximum		**9E-09**	**2E-08**	**1E-07**		**2E-08**	**4E-08**	**2E-07**
Change in maximum risk for 8 hour event, 52 days per year								
Maximum		**5E-07**	**1E-06**	**6E-06**		**9E-07**	**2E-06**	**1E-05**

Quantification of Effects - PM2.5, Short-term impacts Worst-Case scenario
M4 East

Particulate Fraction:	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5
Endpoint:	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All Causes	Mortality - Cardiovascular	Mortality - Respiratory	Morbidity - Asthma ED Admissions
Effect Exposure Duration:	Short-term	Short-term	Short-Term	Short-Term	Short-Term	Short-Term
Age Group:	≥ 65 years	≥ 65 years	All ages	All ages	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0008	0.00041	0.00094	0.00097	0.0019	0.00148
Annual Baseline Incidence (per 100,000) (as per Table 4.4)	9064.6	3905.1	522.3	152.4	51.5	1220.7
Baseline Incidence (per person per day)	0.000256062	0.000110314	1.47542E-05	4.30508E-06	1.4548E-06	3.44831E-05

Sensitive Receptors	Increase in 24-Hour Average PM2.5 Concentration (µg/m^3)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)
Maximum Receptor							
Maximum (any landuse)	1.4	3E-07	6E-08	2E-08	6E-09	4E-09	7E-08
Maximum Residential	1.4	3E-07	6E-08	2E-08	6E-09	4E-09	7E-08
Maximum Commercial	1.3	3E-07	6E-08	2E-08	6E-09	4E-09	7E-08
Change in risk for 52 events per year							
Maximum		1E-05	3E-06	1E-06	3E-07	2E-07	4E-06

M4 East and M4-M5

Particulate Fraction:	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5	PM2.5
Endpoint:	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All Causes	Mortality - Cardiovascular	Mortality - Respiratory	Morbidity - Asthma ED Admissions
Effect Exposure Duration:	Short-term	Short-term	Short-Term	Short-Term	Short-Term	Short-Term
Age Group:	≥ 65 years	≥ 65 years	All ages	All ages	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6.18)	0.0008	0.00041	0.00094	0.00097	0.0019	0.00148
Annual Baseline Incidence (per 100,000) (as per Table 4.4)	9064.6	3905.1	522.3	152.4	51.5	1220.7
Baseline Incidence (per person per day)	0.000256062	0.000110314	1.47542E-05	4.30508E-06	1.4548E-06	3.44831E-05

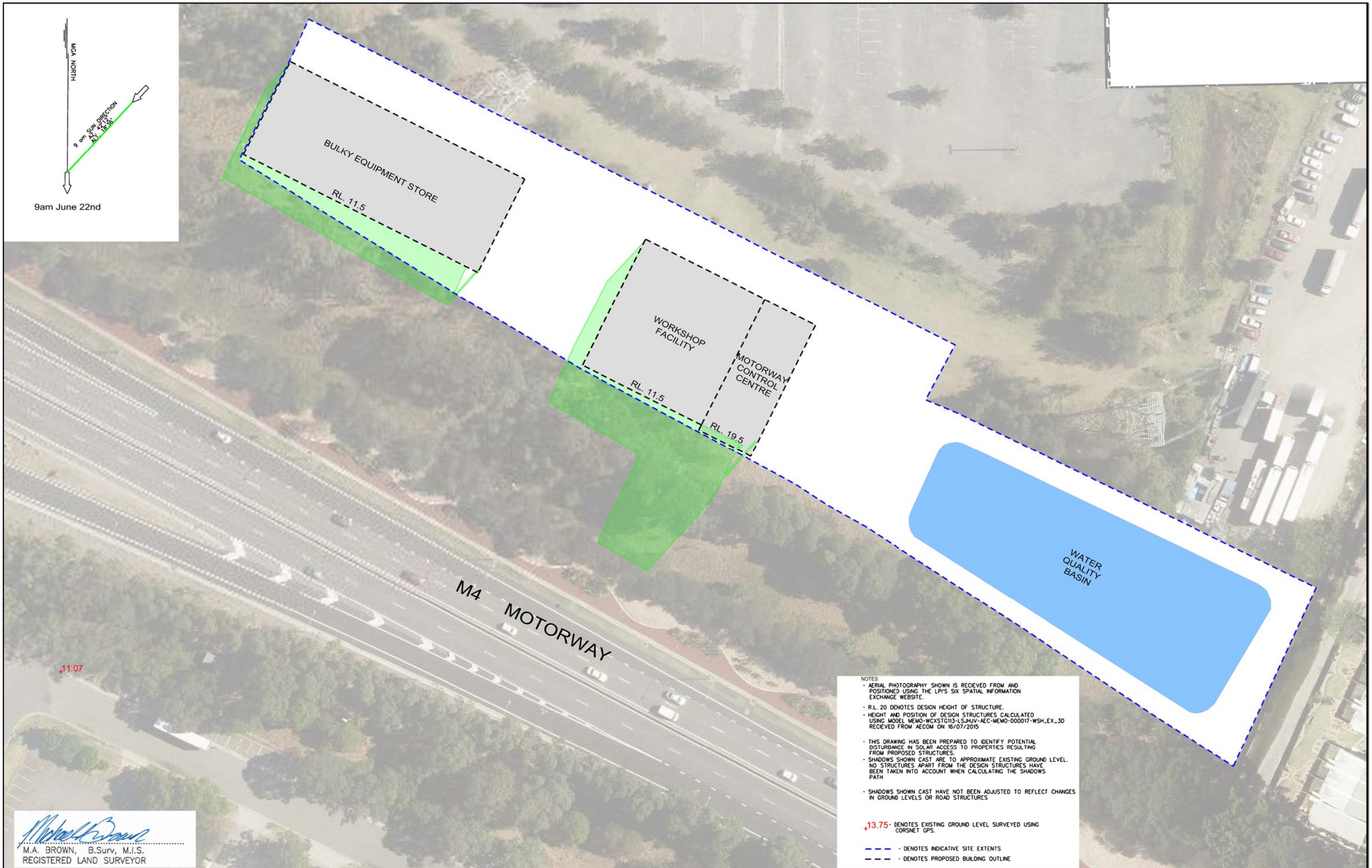
Sensitive Receptors	Increase in 24-Hour Average PM2.5 Concentration (µg/m^3)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)	Risk (Equation 6)
Maximum Receptor							
Maximum (any landuse)	2.8	6E-07	1E-07	4E-08	1E-08	8E-09	1E-07
Maximum Residential	2.8	6E-07	1E-07	4E-08	1E-08	8E-09	1E-07
Maximum Commercial	2.7	6E-07	1E-07	4E-08	1E-08	7E-09	1E-07
Change in risk for 52 events per year							
Maximum		3E-05	7E-06	2E-06	6E-07	4E-07	7E-06

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Appendix K

Shadow diagrams

WestConnex



NOTES:
- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING MODEL MEMO-WCXSTG113-LS_HJV-AEC-MEMO-000017-WSH_EX_3D RECIEVED FROM AECOM ON 16/07/2015
- THIS DRAWING HAS BEEN PREPARED TO IDENTIFY POTENTIAL DISTURBANCE IN SOLAR ACCESS TO PROPERTIES RESULTING FROM PROPOSED STRUCTURES.
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- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

SUBDIVISION | STRATA PLANS | STRATUM SUBDIVISION | LEASE PLANS | TOPOGRAPHIC SURVEYS | GPS SURVEYS | 3D MODELLING | RACECOURSE DESIGN | PROJECT MANAGEMENT | SUN SHADOW DIAGRAMS

SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-9am		-	1 OF 7 SHEETS

MGA NORTH

10 am SUN DIRECTION
AZ 29°07'
ALT 29°05

10am June 22nd

BULKY EQUIPMENT STORE

RL. 11.5

WORKSHOP FACILITY

RL. 11.5

MOTORWAY CONTROL CENTRE

RL. 19.5

WATER QUALITY BASIN

M4 MOTORWAY

+11.07

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893

Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897

a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

SUBDIVISION | STRATA PLANS | STRATUM SUBDIVISION | LEASE PLANS | TOPOGRAPHIC SURVEYS | GPS SURVEYS | 3D MODELLING | RACECOURSE DESIGN | PROJECT MANAGEMENT | SUN SHADOW DIAGRAMS

SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

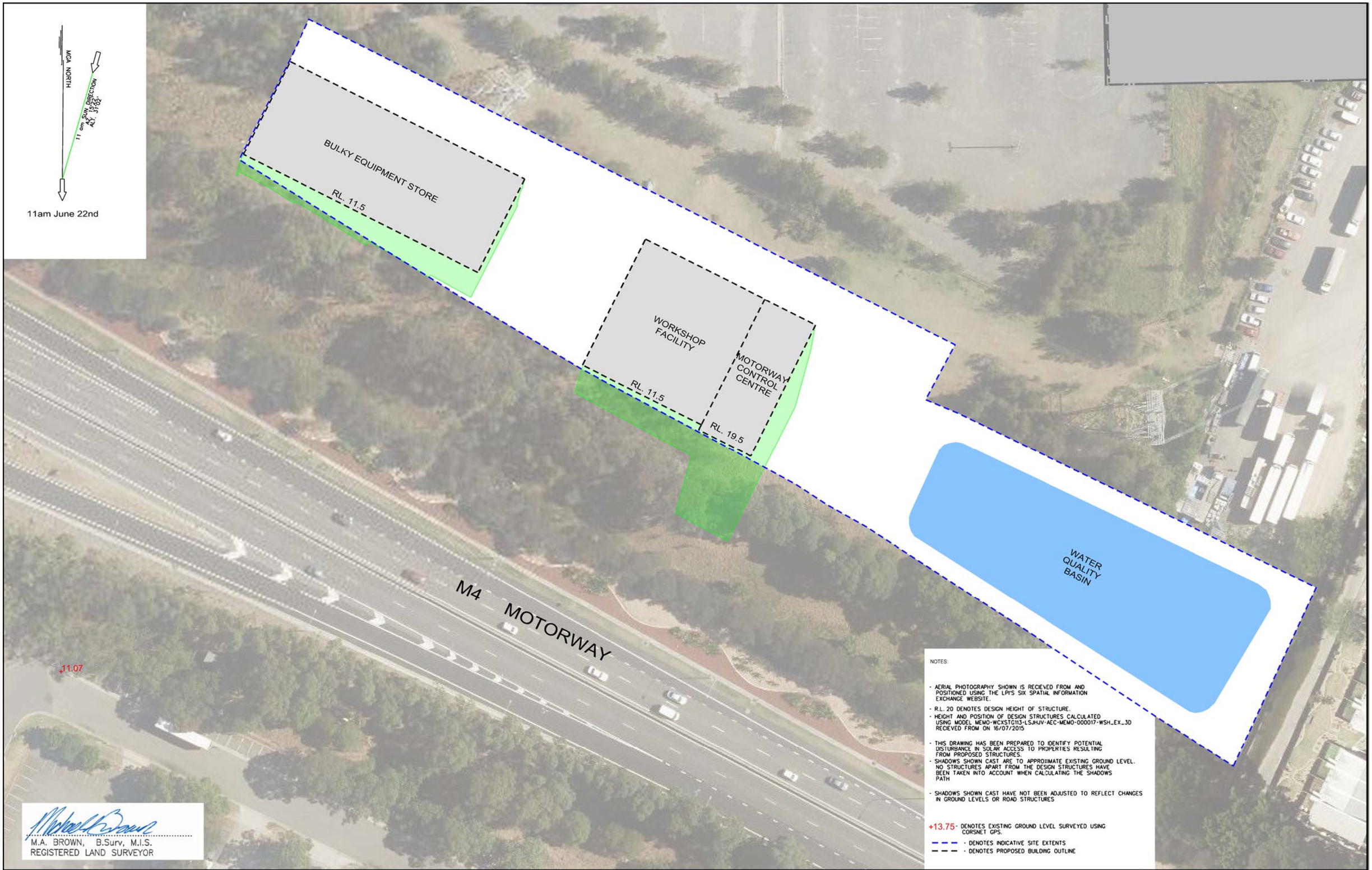
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-10am		-	2 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — REDUCTION RATIO 1: 800 @ A3 — 40

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893

Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897

a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

11am ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON SUN DIRECTION
ALT. 32°51'

12noon June 22nd

BULKY EQUIPMENT STORE

RL. 11.5

WORKSHOP FACILITY

RL. 11.5

MOTORWAY CONTROL CENTRE

RL. 19.5

WATER QUALITY BASIN

M4 MOTORWAY

+11.07

NOTES:

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- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING MODEL MEMO-WCXSTG113-LSJHJV-AEC-MEMO-000017-WSH_EX_3D RECIEVED FROM AECOM ON 16/07/2015
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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-12nocn		-	4 OF 7 SHEETS

MGA NORTH

PM SUN DIRECTION
AZ. 315°08'
AL. 31°02'

1pm June 22nd

BULKY EQUIPMENT STORE

RL. 11.5

WORKSHOP FACILITY

RL. 11.5

MOTORWAY CONTROL CENTRE

RL. 19.5

WATER QUALITY BASIN

M4 MOTORWAY

+11.07

NOTES:

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+13.75 · DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

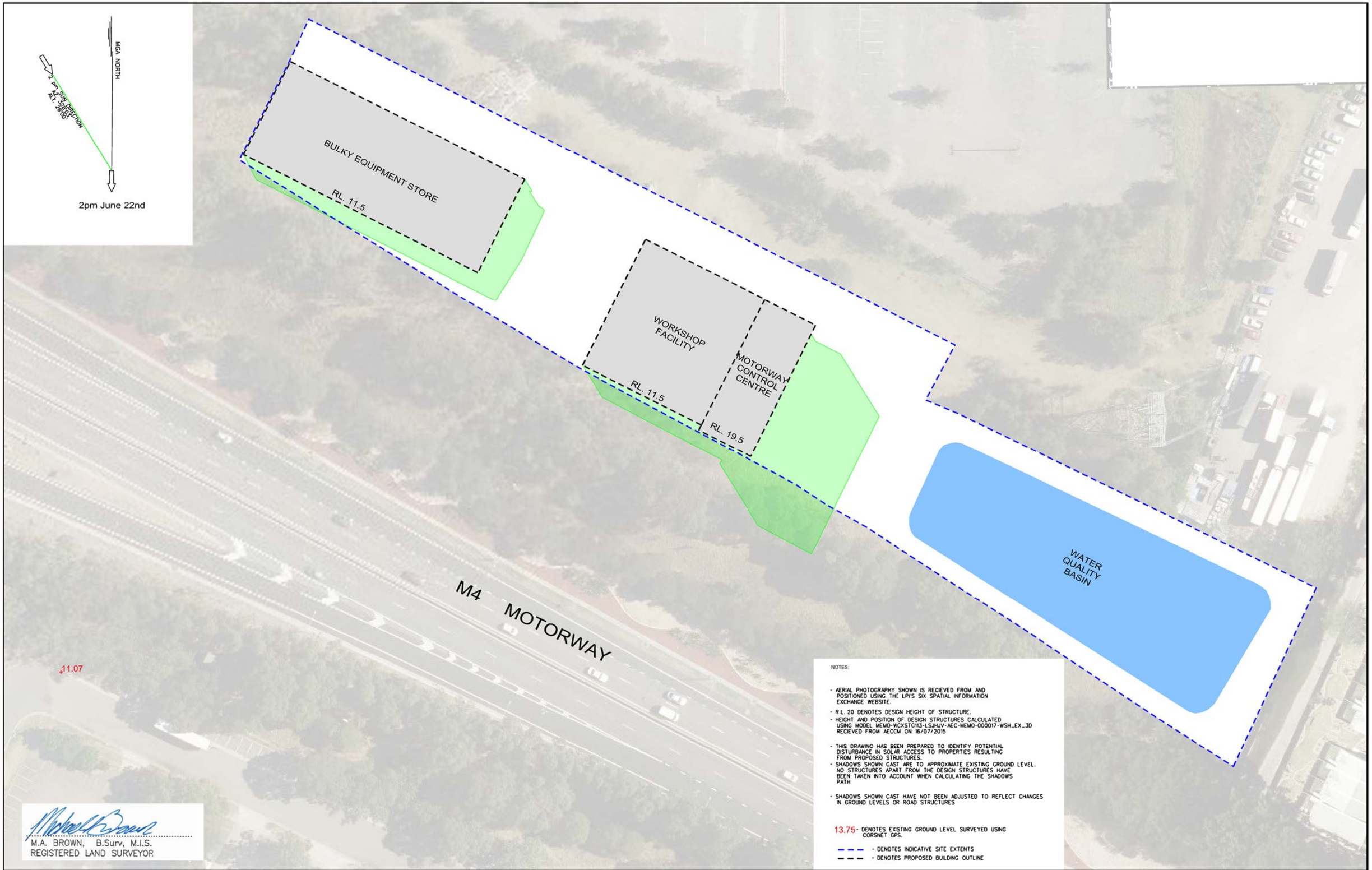
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-1pm		-	5 OF 7 SHEETS



NOTES:

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13.75 · DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

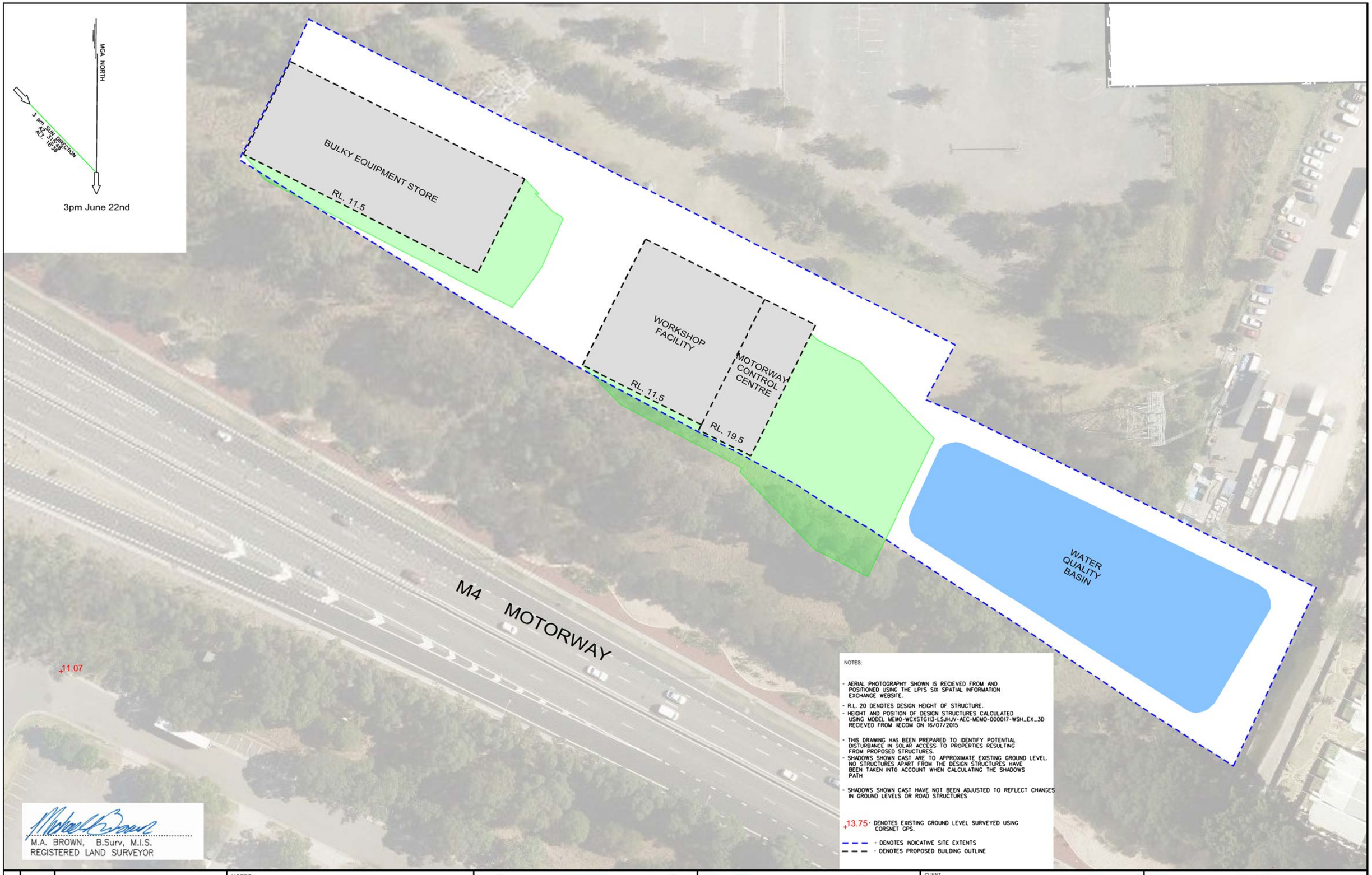
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

2pm ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-2pm		-	6 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — REDUCTION RATIO 1: 800 — 40 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm ANALYSIS
MOTORWAY OPERATIONS COMPLEX
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-MOC-3pm		-	7 OF 7 SHEETS



NOTES:

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- - - - DENOTES INDICATIVE SITE EXTENTS

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M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

AECOM

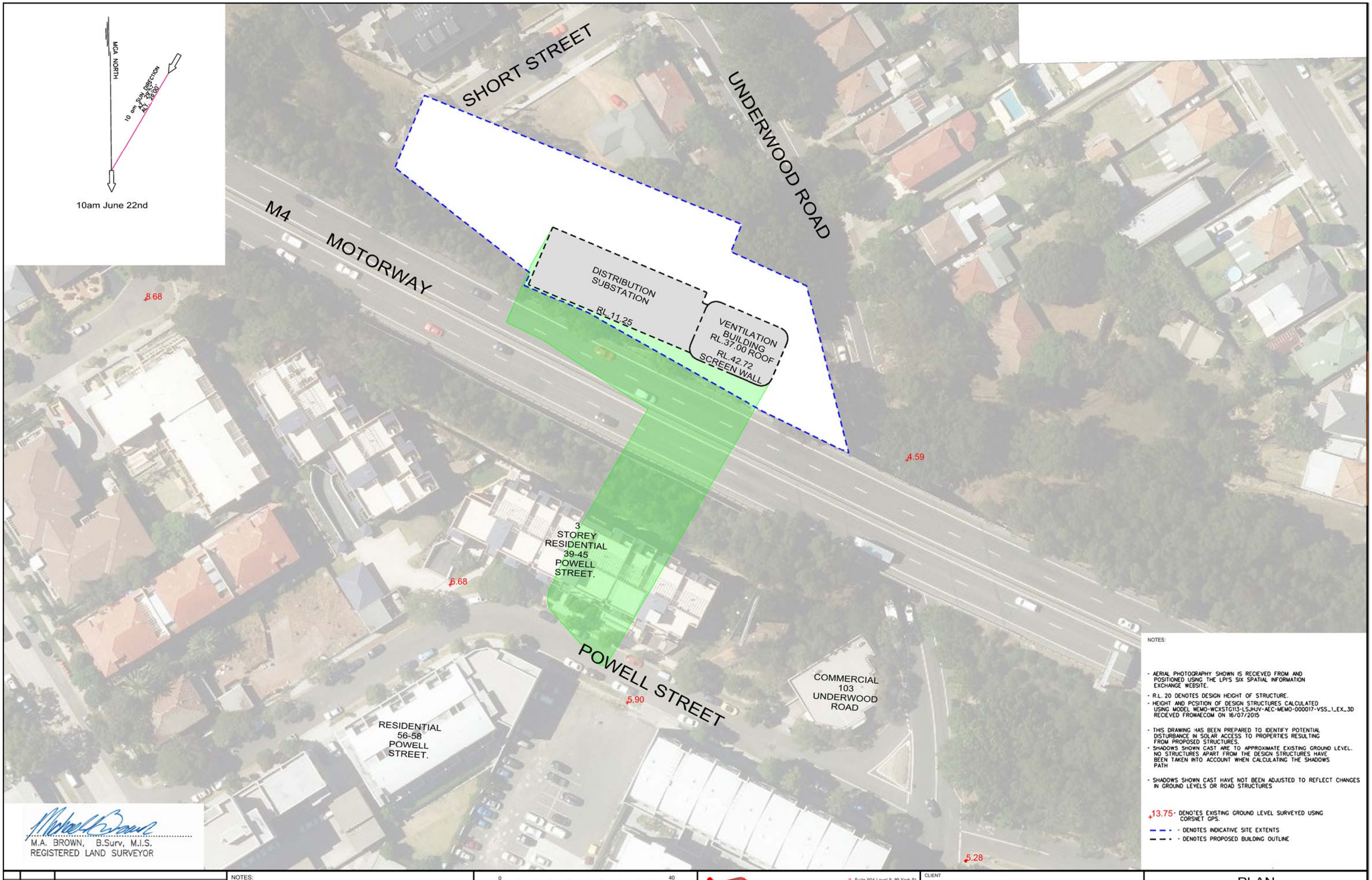
LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN

9am ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-9am		-	1 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

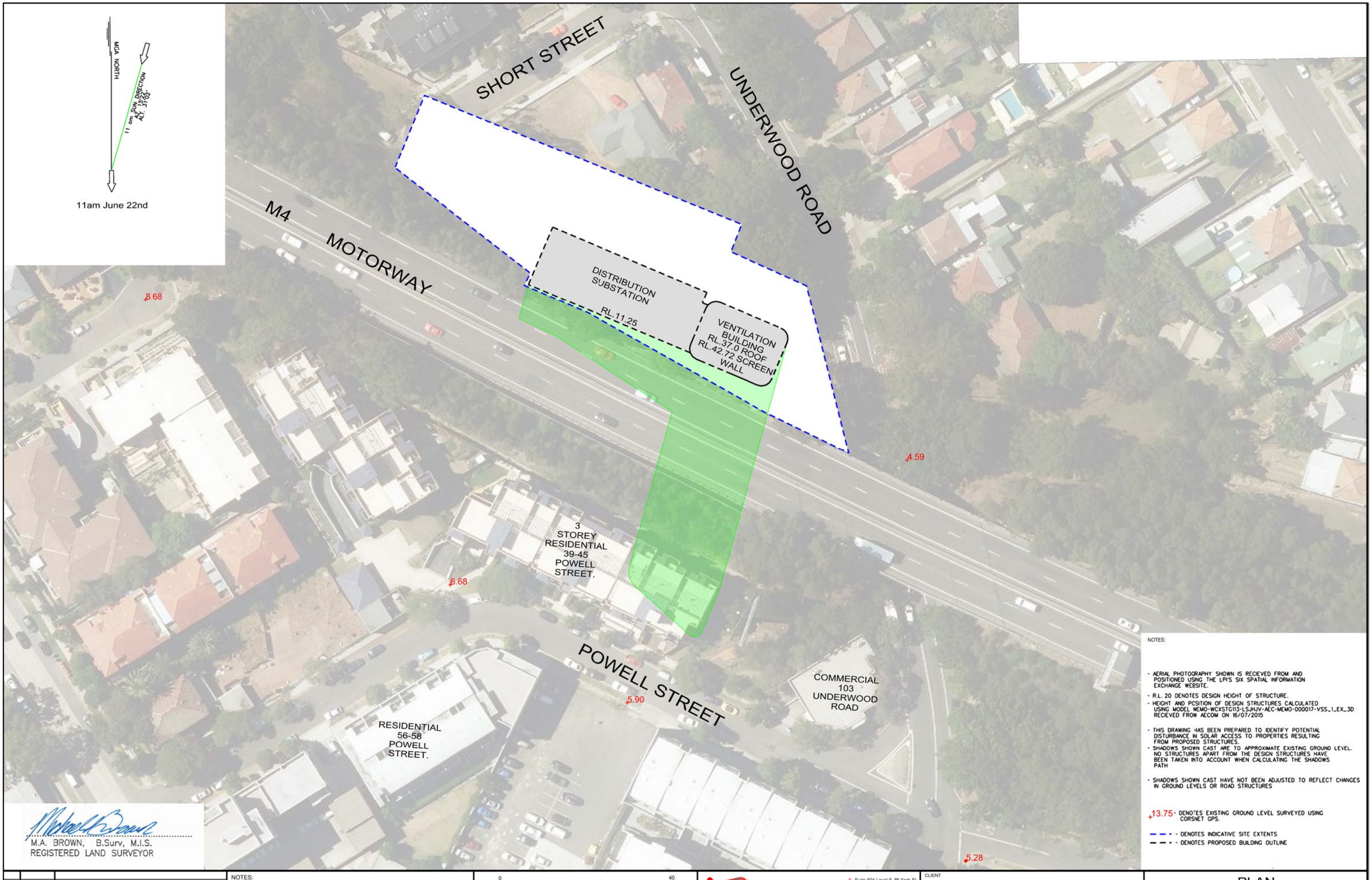
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVC-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON 'SUN DIRECTION'
AZ. 359°00'
ALT. 32°01'

12noon June 22nd

SHORT STREET

UNDERWOOD ROAD

M4 MOTORWAY

DISTRIBUTION SUBSTATION
RL.11.25

VENTILATION BUILDING
RL.37.00 ROOF
RL.42.72
SCREEN WALL

3 STOREY RESIDENTIAL 39-45 POWELL STREET.

POWELL STREET

RESIDENTIAL 56-58 POWELL STREET.

COMMERCIAL 103 UNDERWOOD ROAD

+8.68
+4.59
+6.68
+5.90
+5.28

NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING MODEL MEMO-WCXSTG113-LSJHJV-AEC-MEMO-000017-VSS_1_EX_3D RECIEVED FROM ANDREW COOK OF AECOM ON 16/07/2015
- THIS DRAWING HAS BEEN PREPARED TO IDENTIFY POTENTIAL DISTURBANCE IN SOLAR ACCESS TO PROPERTIES RESULTING FROM PROPOSED STRUCTURES.
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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893

Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897

a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-NOON		-	4 OF 7 SHEETS



NOTES:

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13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.
- - - - DENOTES INDICATIVE SITE EXTENTS
- - - - DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

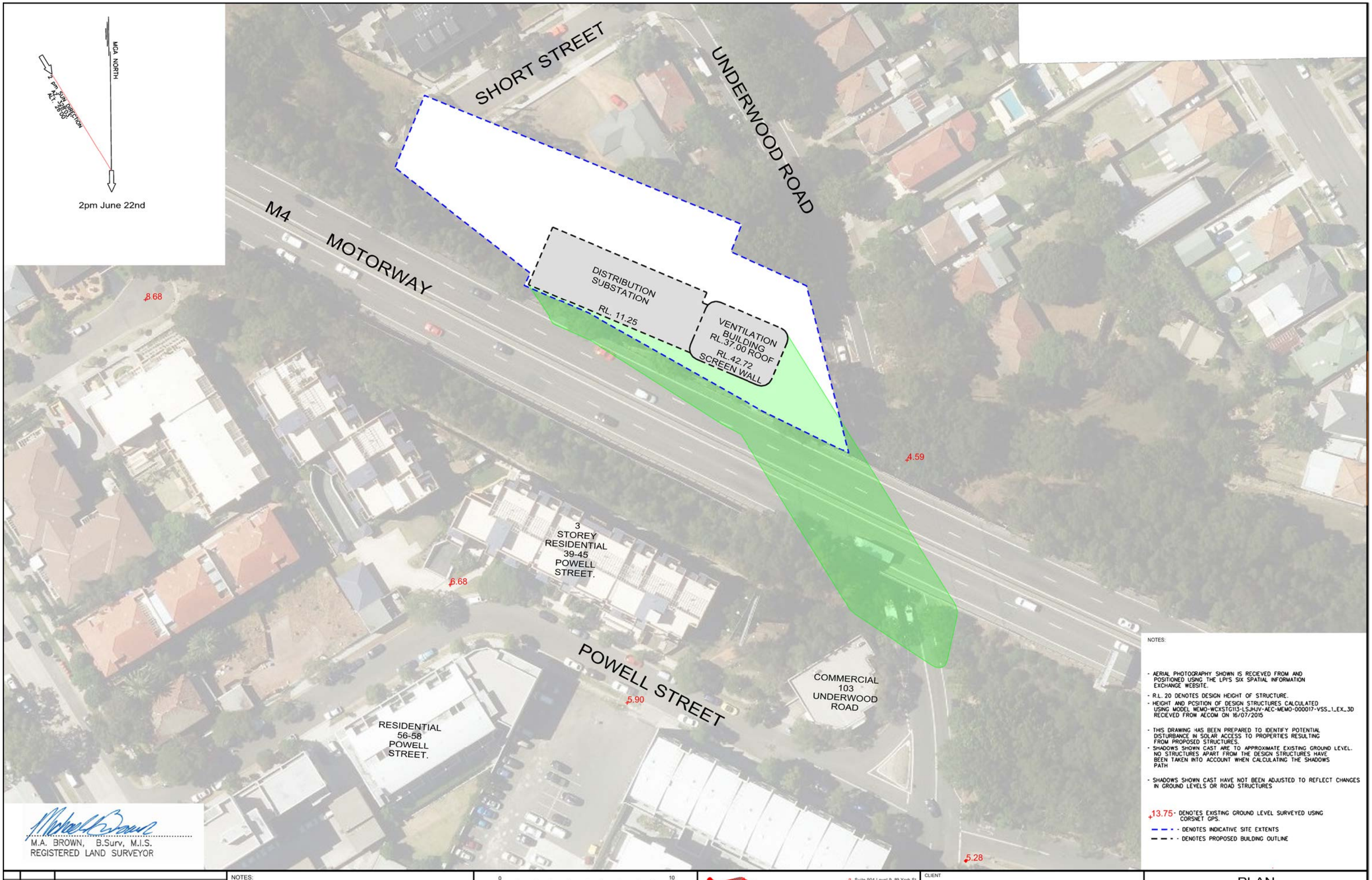
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-1pm		-	5 OF 7 SHEETS



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- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 10
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

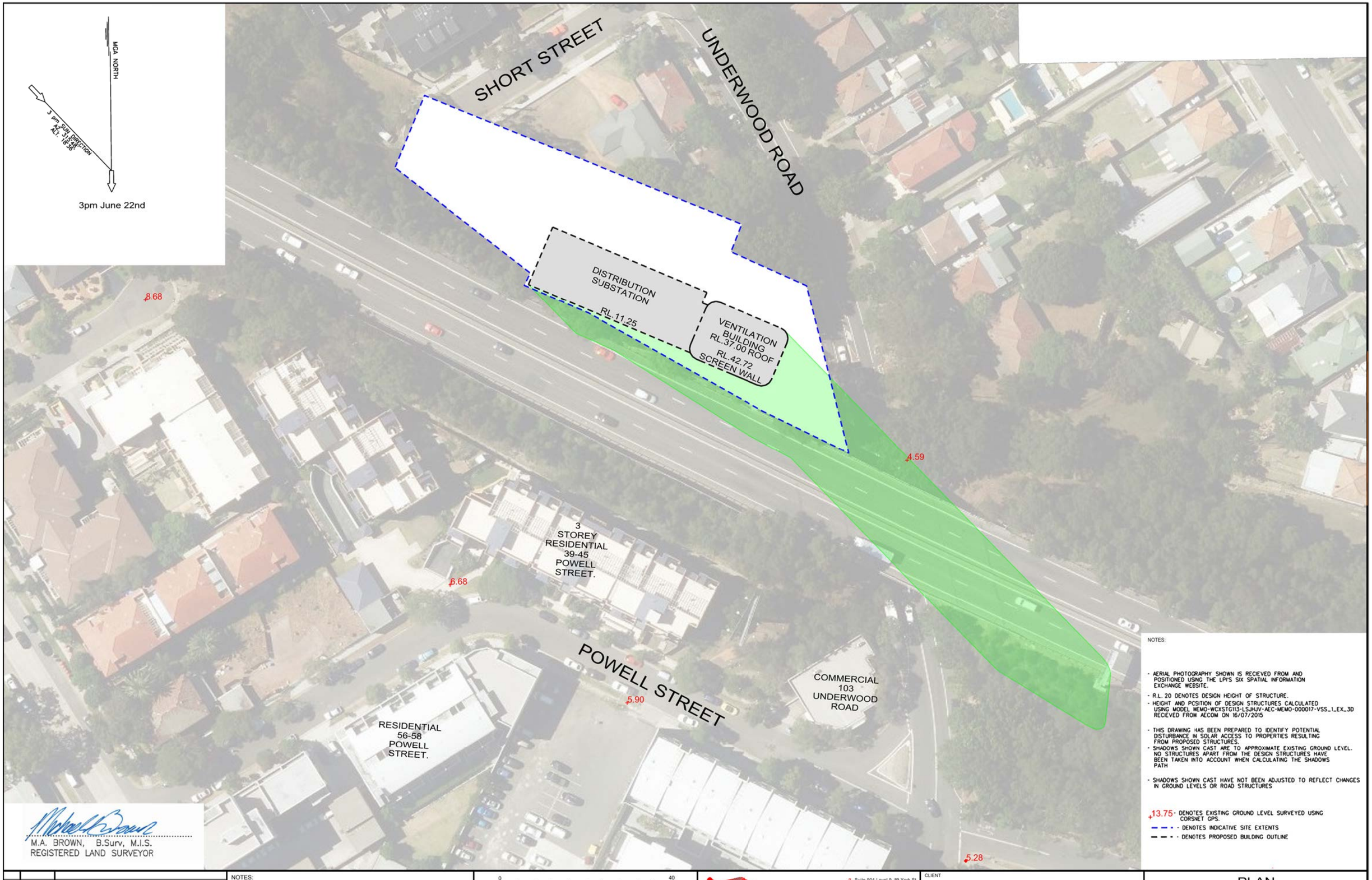
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-2pm		-	6 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 89 York St Sydney NSW 2000
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm ANALYSIS
WESTERN VENTILATION FACILITY
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF-3pm		-	7 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
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p +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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- - - DENOTES INDICATIVE SITE EXTENTS
— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1:800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM
LOCALITY: WESTCONNEX M4 EAST PROJECT
L.G.A.: -

PLAN

10am SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM
LOCALITY: WESTCONNEX M4 EAST PROJECT
L.G.A.: -

PLAN

11am SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-11am		-	3 OF 7 SHEETS



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REGISTERED LAND SURVEYOR

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REV.	DATE	AMENDMENTS

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0 — 40
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DATUM : -

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-12		-	4 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING MODEL MEMO-WCXSTG113-LSJHJV-AEC-MEMO-000017-VSS_1_EX_3D RECIEVED FROM AECOM ON 16/07/2015
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- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.
- - - DENOTES INDICATIVE SITE EXTENTS
— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

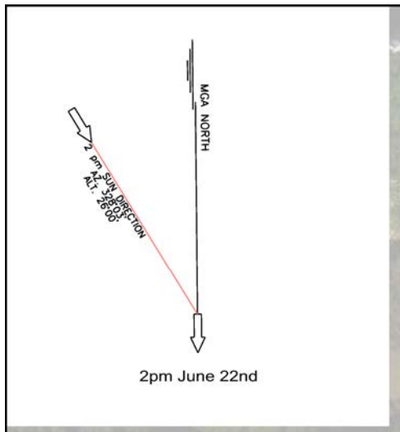
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-1pm		-	5 OF 7 SHEETS



ALLEN STREET

ISMAY AVENUE

POWELLS CREEK

4.76

SUBSTATION

RL 11.70

FIRE PUMP ROOM AND TANKS

RL 11.70

M4 MOTORWAY

5.28

POWELL STREET

7.83

9.02

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75 · DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

AECOM

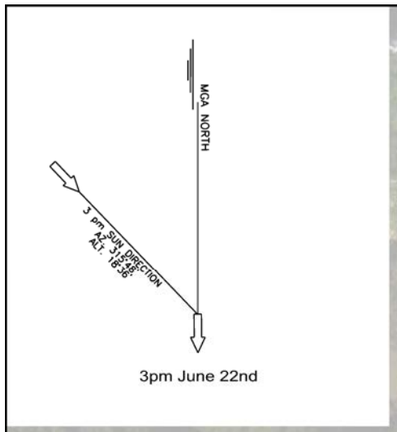
LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN

2pm SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-2pm		-	6 OF 7 SHEETS



ALLEN STREET

ISMAY AVENUE

POWELLS CREEK

M4 MOTORWAY

POWELL STREET

SUBSTATION

RL 11.70

FIRE PUMP ROOM AND TANKS

RL 11.70

4.76

5.28

7.83

9.02

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.
- - - DENOTES INDICATIVE SITE EXTENTS
— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYING SINCE 1893
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P.W. Rygate & West
ABN 61 001 204 897
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p +61 2 9262 6800
f +61 2 9262 6843
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOWING ANALYSIS
ISMAY AVENUE
HOMEBUSH/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WVF2-3pm		-	7 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — · — DENCTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
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p +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM
LOCALITY: WESTCONNEX M4 EAST PROJECT
L.G.A.: -

PLAN
10am SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-10am		-	2 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — · — DENCTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-11am		-	3 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENCTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

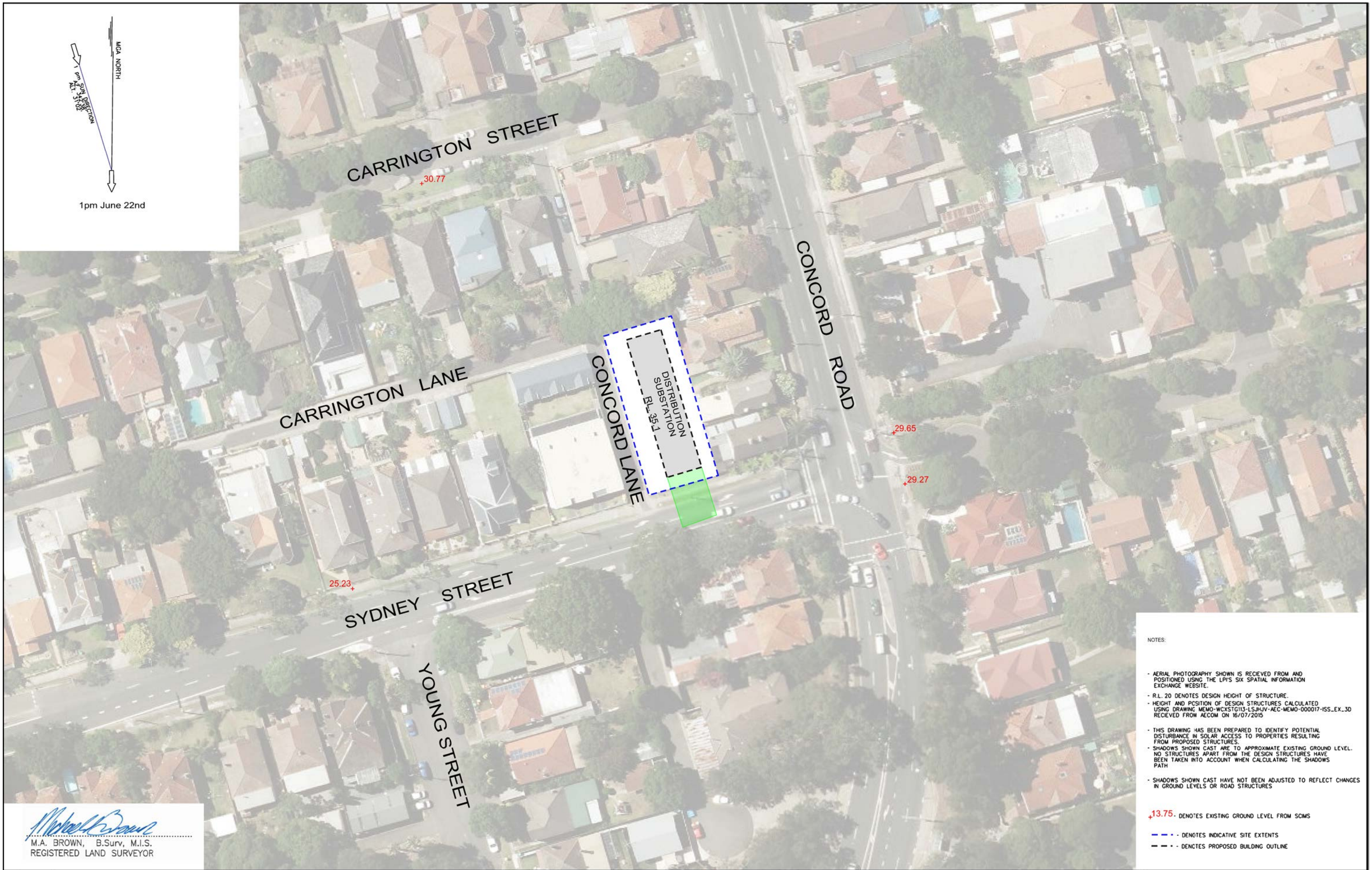
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-12noon		-	4 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENCTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-1pm		-	5 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENCTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

AECOM

LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN
2pm SHADOW ANALYSIS SUBSTATION AT CONCORD ROAD INTERCHANGE CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-2pm		-	6 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENCTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
SUBSTATION AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-3pm		-	7 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL SCIMS

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
CINTRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - DENOTES INDICATIVE SITE EXTENTS
— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
CITNRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
CITNRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-11am		-	3 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
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P.W. Rygate & West
ABN 61 001 204 897
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
CITNRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-12noon		-	4 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
CINTRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-1pm		-	5 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm SHADOW ANALYSIS
CITNRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-2pm		-	6 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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- - - DENOTES INDICATIVE SITE EXTENTS

— — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
CITNRA PARK
CONCORD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CPC-3pm		-	7 OF 7 SHEETS



NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING M4E-HSL-5000-UD-SK-4000-511[W] RECIEVED FROM AECOM ON 16/07/2015
- THIS DRAWING HAS BEEN PREPARED TO IDENTIFY POTENTIAL DISTURBANCE IN SOLAR ACCESS TO PROPERTIES RESULTING FROM PROPOSED STRUCTURES.
- SHADOWS SHOWN CAST ARE TO APPROXIMATE EXISTING GROUND LEVEL. NO STRUCTURES APART FROM THE DESIGN STRUCTURES HAVE BEEN TAKEN INTO ACCOUNT WHEN CALCULATING THE SHADOWS PATH
- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE BOUNDARY

— — — DENOTES PROPOSED BUILDING

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1: 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE. DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1 400 @ A1

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

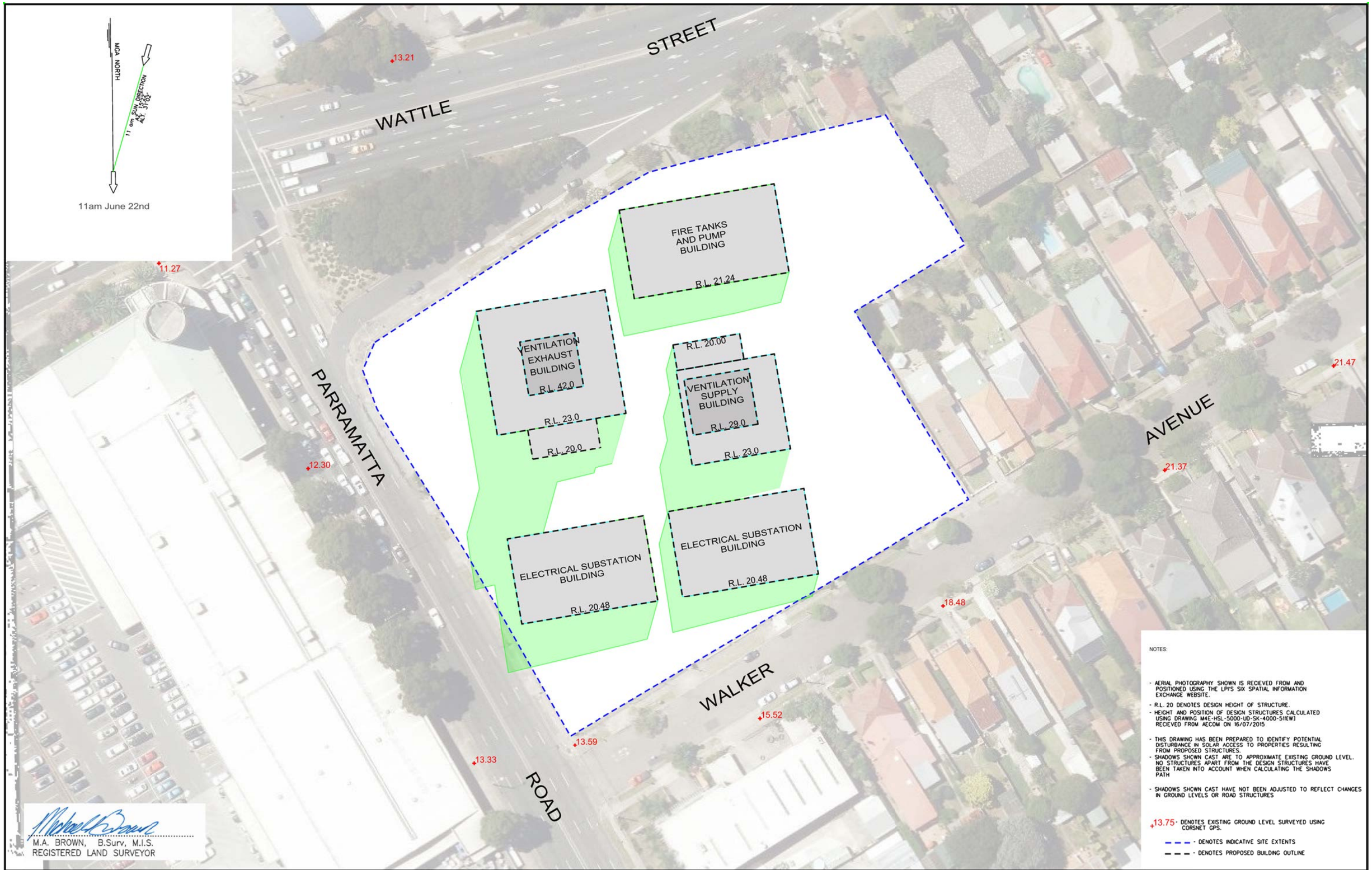
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

10am SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING M4E-HSL-5000-UD-SK-4000-511[W1 RECIEVED FROM AECOM ON 16/07/2015
- THIS DRAWING HAS BEEN PREPARED TO IDENTIFY POTENTIAL DISTURBANCE IN SOLAR ACCESS TO PROPERTIES RESULTING FROM PROPOSED STRUCTURES.
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+13.75 · DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - · DENOTES INDICATIVE SITE EXTENTS

— — — · DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
f +61 2 9262 6843
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

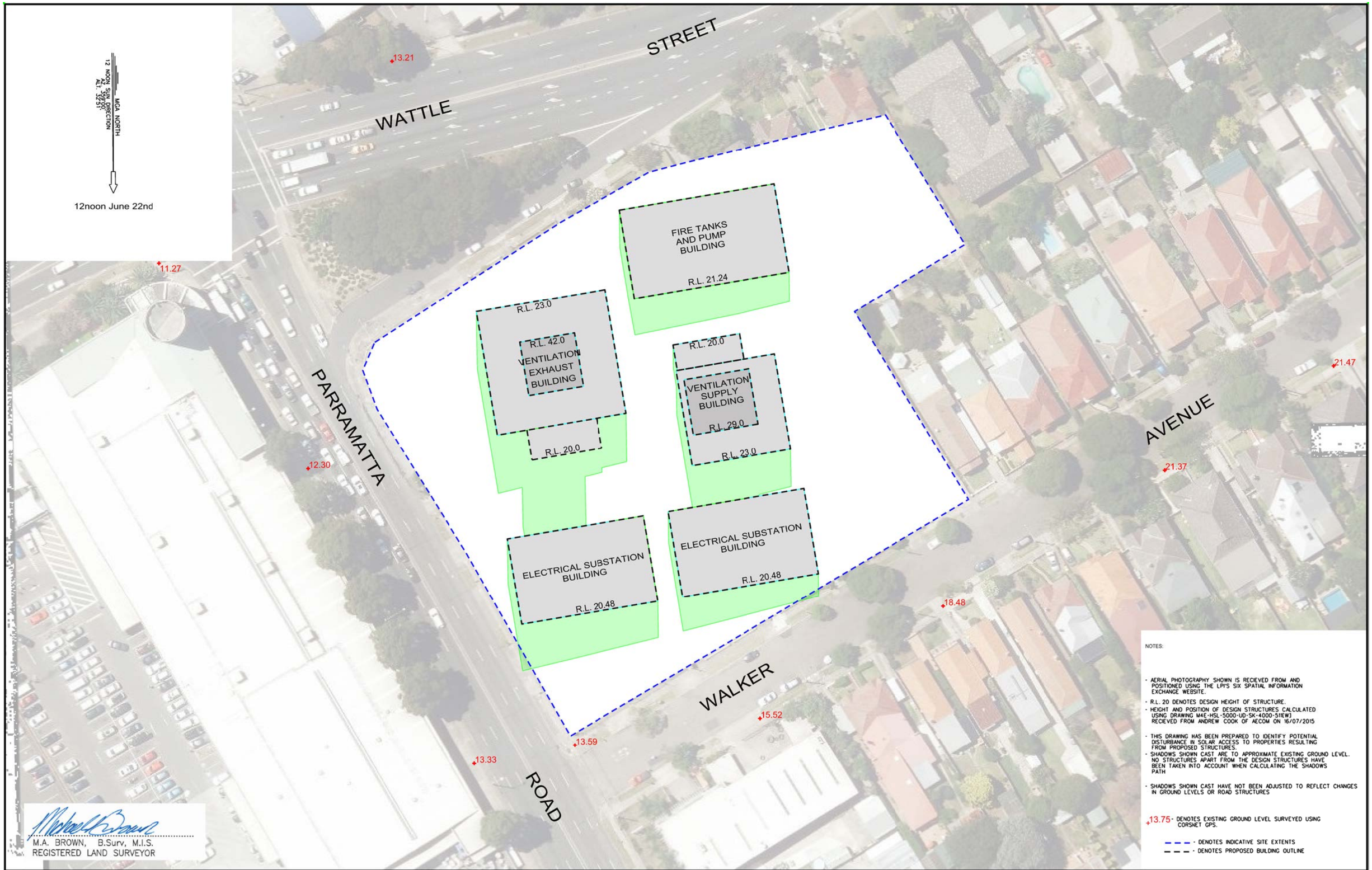
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-11am		-	3 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- R.L. 20 DENOTES DESIGN HEIGHT OF STRUCTURE.
- HEIGHT AND POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING M4E-HSL-5000-UD-SK-4000-51[W] RECIEVED FROM ANDREW COOK OF AECOM ON 16/07/2015
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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1 800 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

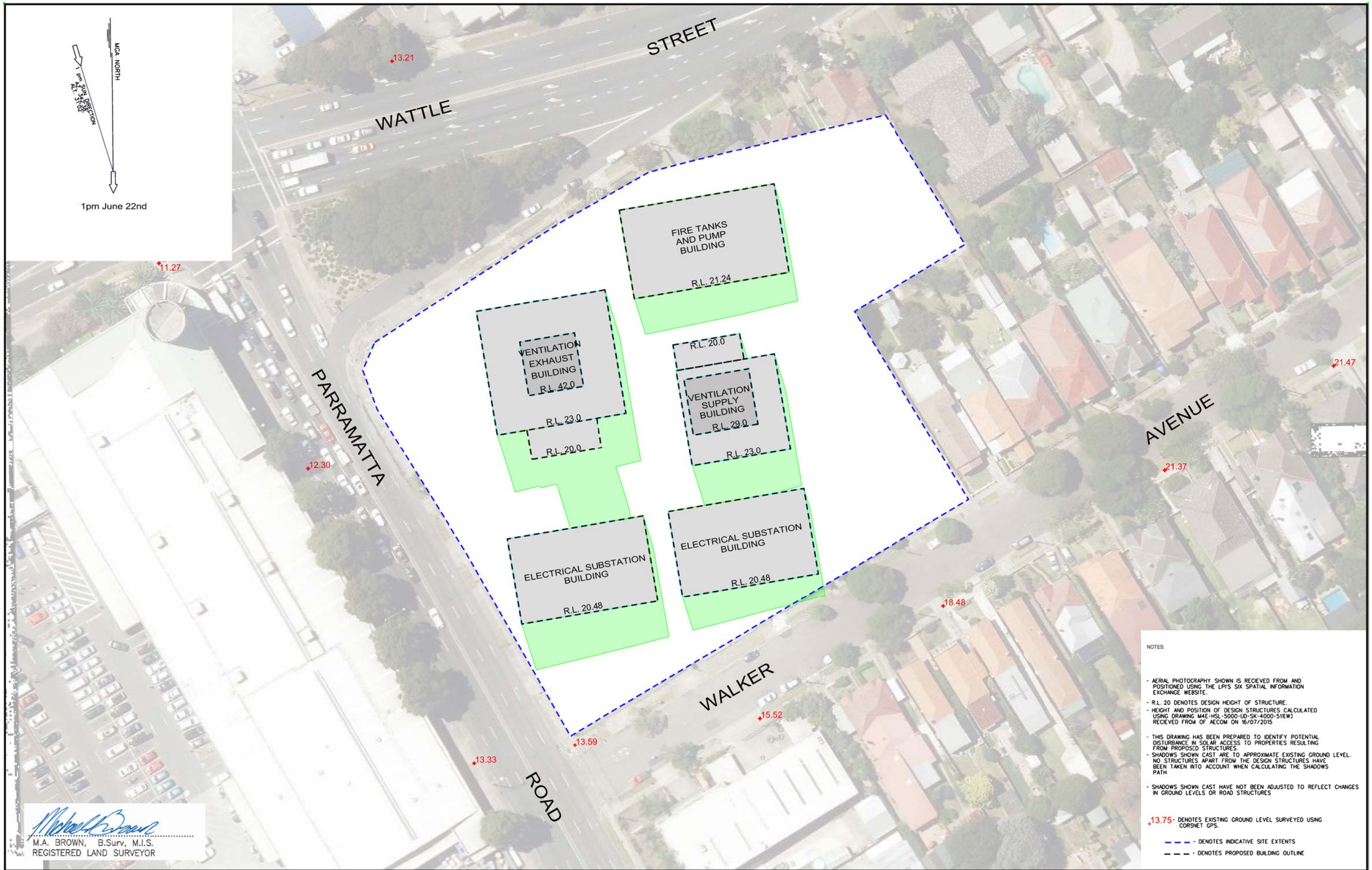
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-12noon		-	4 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
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ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

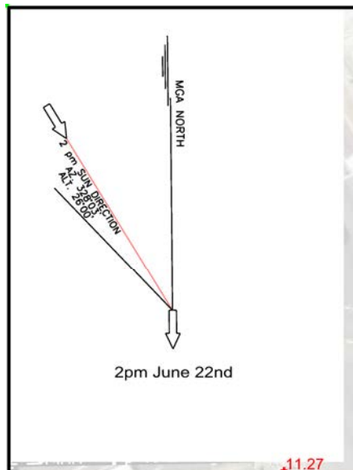
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-1pm		-	5 OF 7 SHEETS



2pm June 22nd

STREET

WATTLE

PARRAMATTA

ROAD

WALKER

AVENUE

13.21

11.27

12.30

21.47

21.37

18.48

15.52

13.59

13.33

FIRE TANKS AND PUMP BUILDING
R.L. 21.24

R.L. 23.0
R.L. 42.0
VENTILATION EXHAUST BUILDING
R.L. 20.00

R.L. 20.00
VENTILATION SUPPLY BUILDING
R.L. 29.0
R.L. 23.0

ELECTRICAL SUBSTATION BUILDING
R.L. 20.48

ELECTRICAL SUBSTATION BUILDING
R.L. 20.48

NOTES:

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13.75 DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - DENOTES INDICATIVE SITE EXTENTS

- - DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	RM	MAB	ACD

CLIENT: AECOM

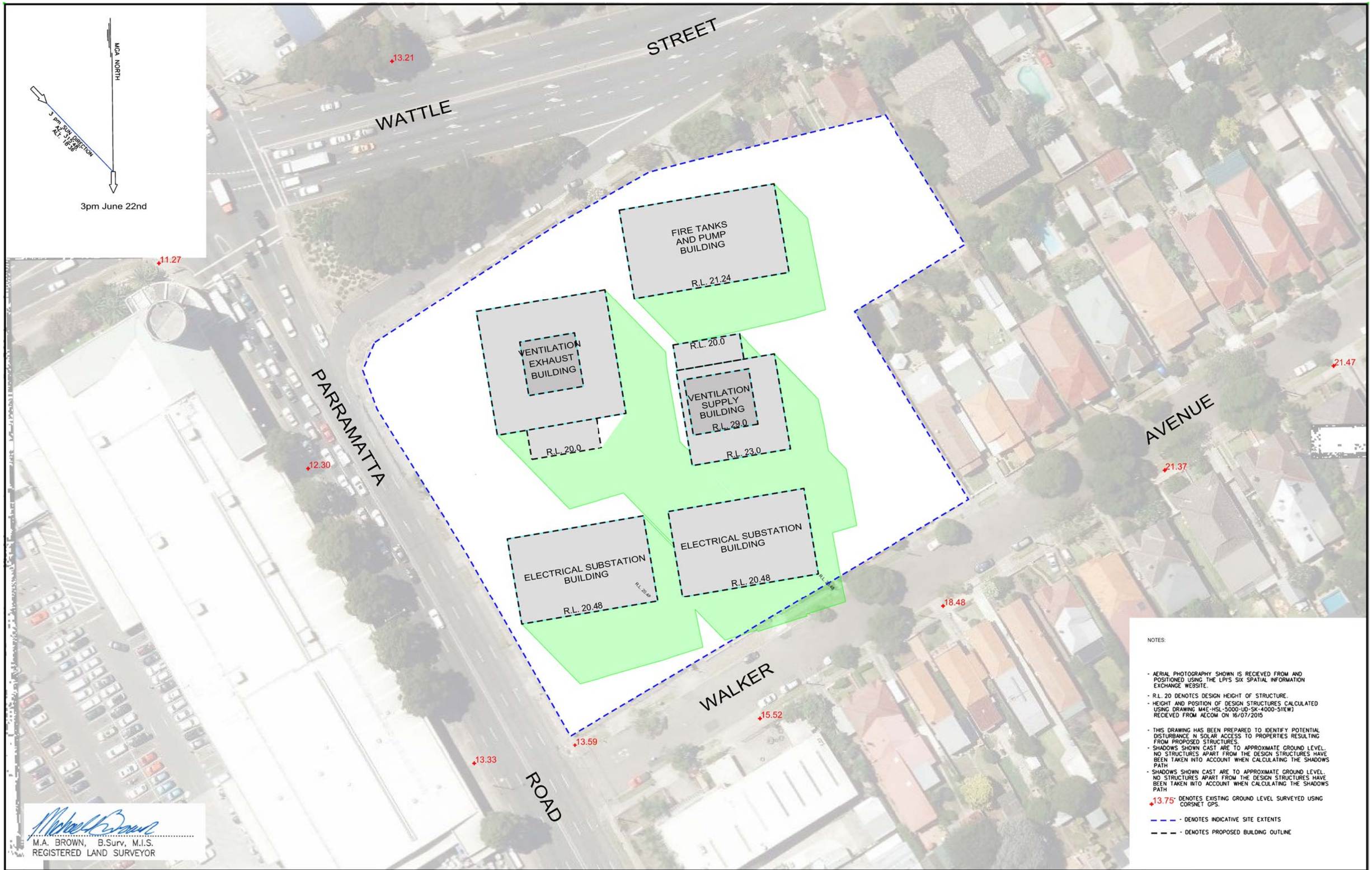
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-2pm		-	6 OF 7 SHEETS



NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
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13.75 DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS.

- - - - DENOTES INDICATIVE SITE EXTENTS

— — — DENOTES PROPOSED BUILDING OUTLINE

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

NOTES:

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0 — 40
REDUCTION RATIO 1 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

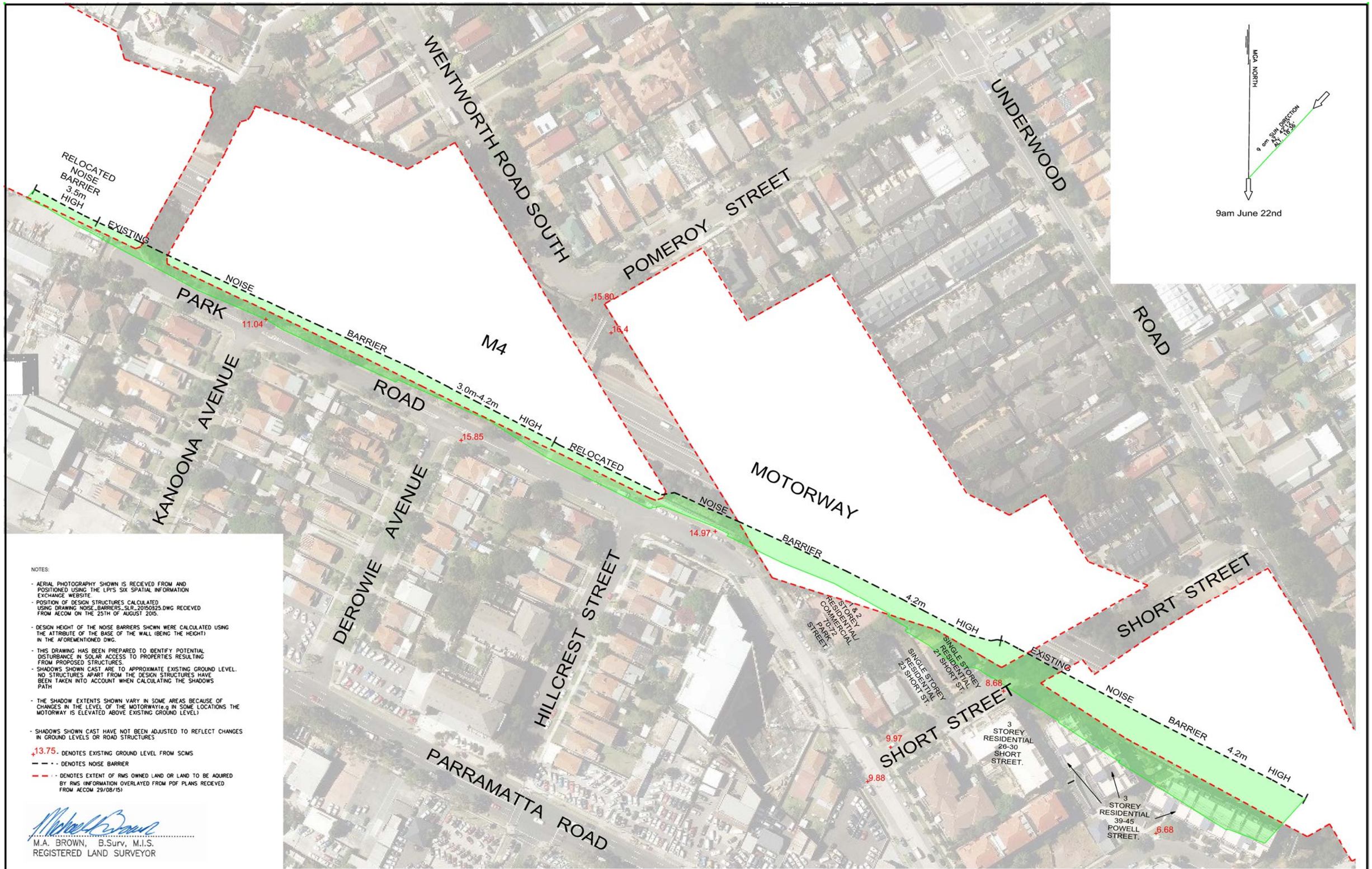
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
EASTERN VENTILATION FACILITY
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-EVF-3pm		-	7 OF 7 SHEETS



NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE
- POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING NOISE_BARRIERS_SLR_20150825.DWG RECIEVED FROM AECOM ON THE 25TH OF AUGUST 2015.
- DESIGN HEIGHT OF THE NOISE BARRIERS SHOWN WERE CALCULATED USING THE ATTRIBUTE OF THE BASE OF THE WALL (BEING THE HEIGHT) IN THE AFOREMENTIONED DWG.
- THIS DRAWING HAS BEEN PREPARED TO IDENTIFY POTENTIAL DISTURBANCE IN SOLAR ACCESS TO PROPERTIES RESULTING FROM PROPOSED STRUCTURES.
- SHADOWS SHOWN CAST ARE TO APPROXIMATE EXISTING GROUND LEVEL. NO STRUCTURES APART FROM THE DESIGN STRUCTURES HAVE BEEN TAKEN INTO ACCOUNT WHEN CALCULATING THE SHADOWS PATH
- THE SHADOW EXTENTS SHOWN VARY IN SOME AREAS BECAUSE OF CHANGES IN THE LEVEL OF THE MOTORWAY(e.g IN SOME LOCATIONS THE MOTORWAY IS ELEVATED ABOVE EXISTING GROUND LEVEL)
- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75. DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES NOISE BARRIER

— — — DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

NOTES:

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0 — 80
REDUCTION RATIO 1 1600 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 39 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

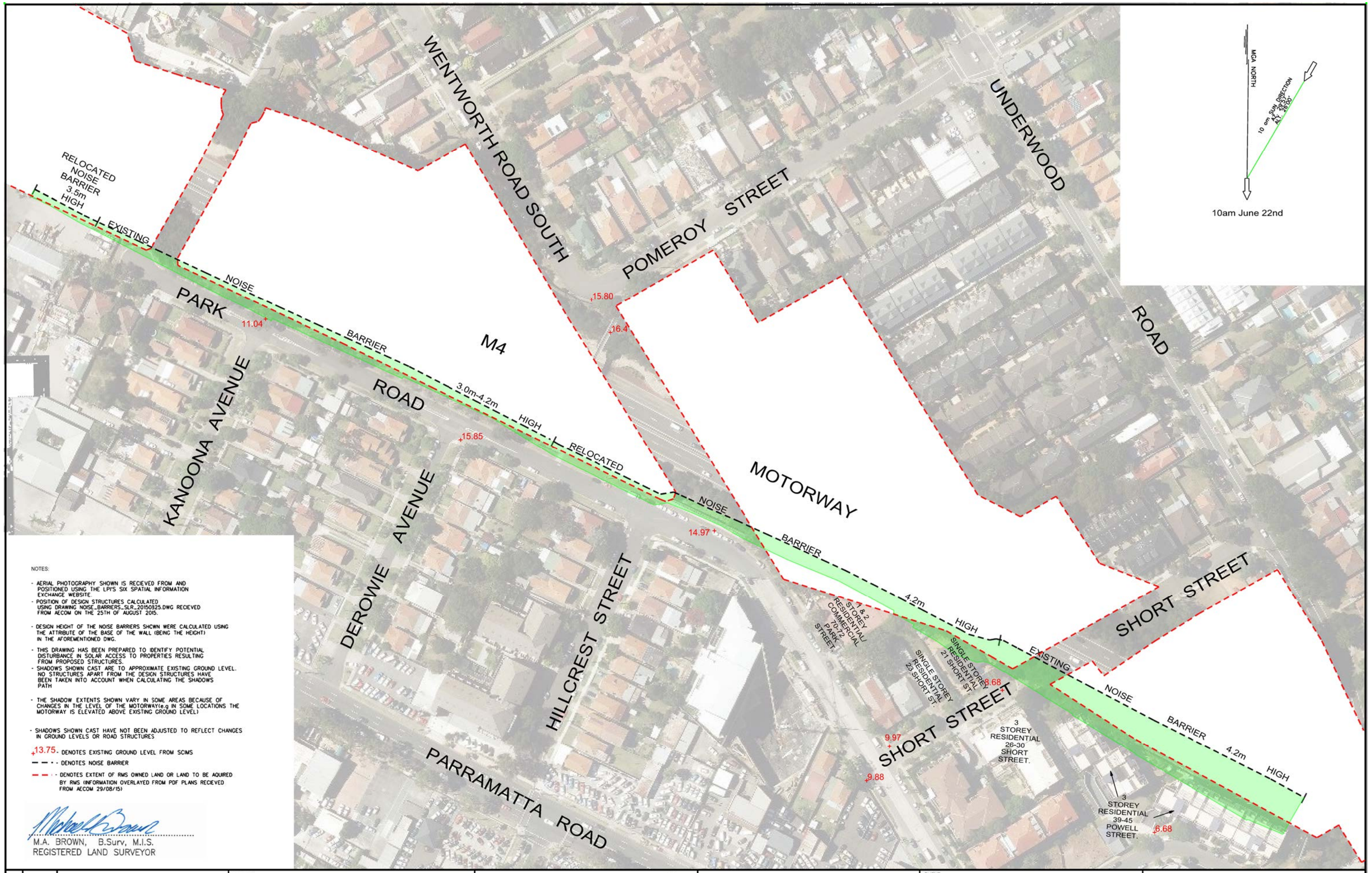
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
NOISE BARRIER
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-9am		-	1 OF 7 SHEETS



NOTES:

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- DESIGN HEIGHT OF THE NOISE BARRIERS SHOWN WERE CALCULATED USING THE ATTRIBUTE OF THE BASE OF THE WALL (BEING THE HEIGHT) IN THE AFOREMENTIONED DWG.
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+13.75. DENOTES EXISTING GROUND LEVEL FROM SCIMS

DENOTES NOISE BARRIER

DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

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Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
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e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

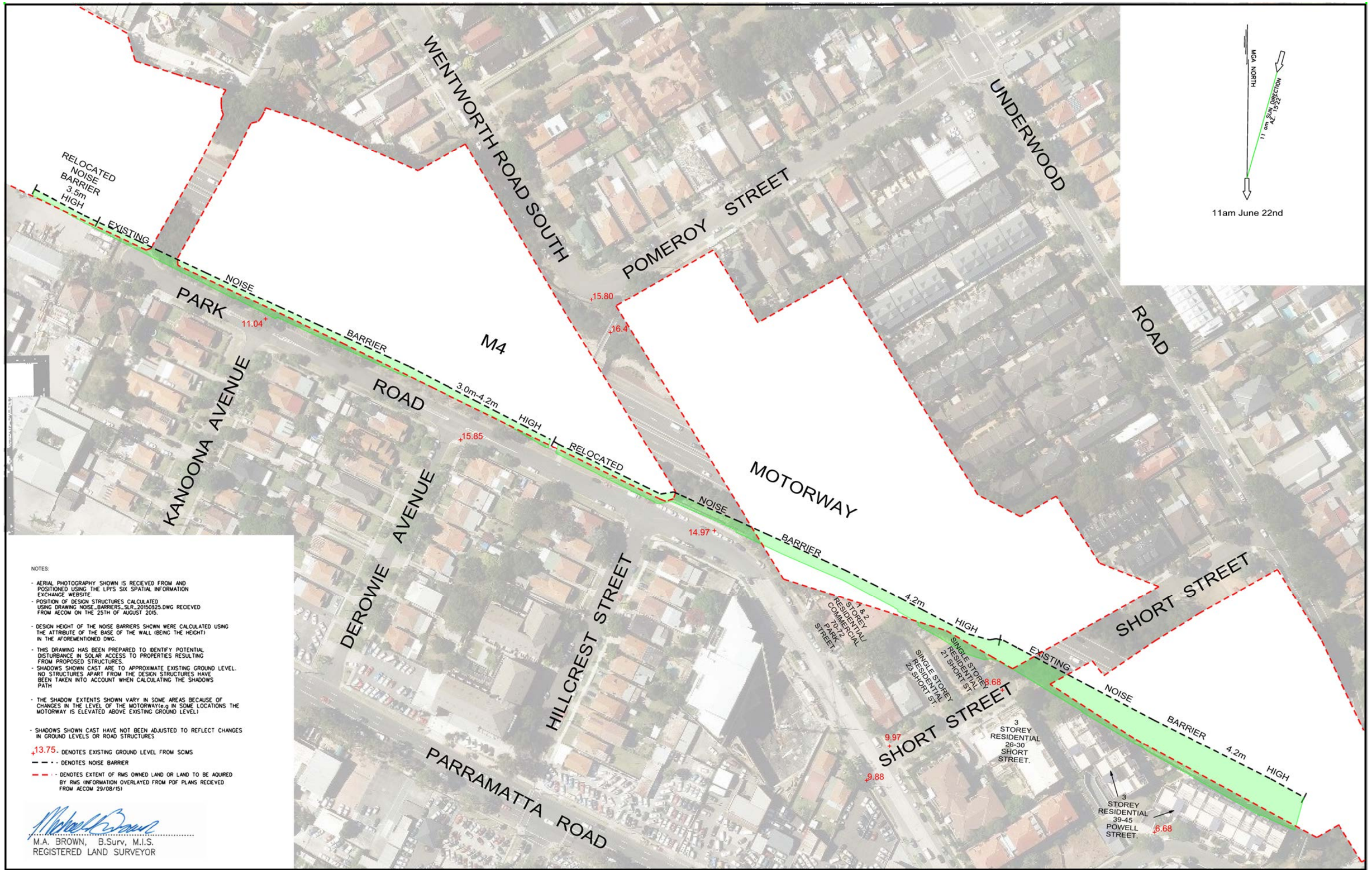
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-10am		-	2 OF 7 SHEETS



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e surveyors@rygate.com.au
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

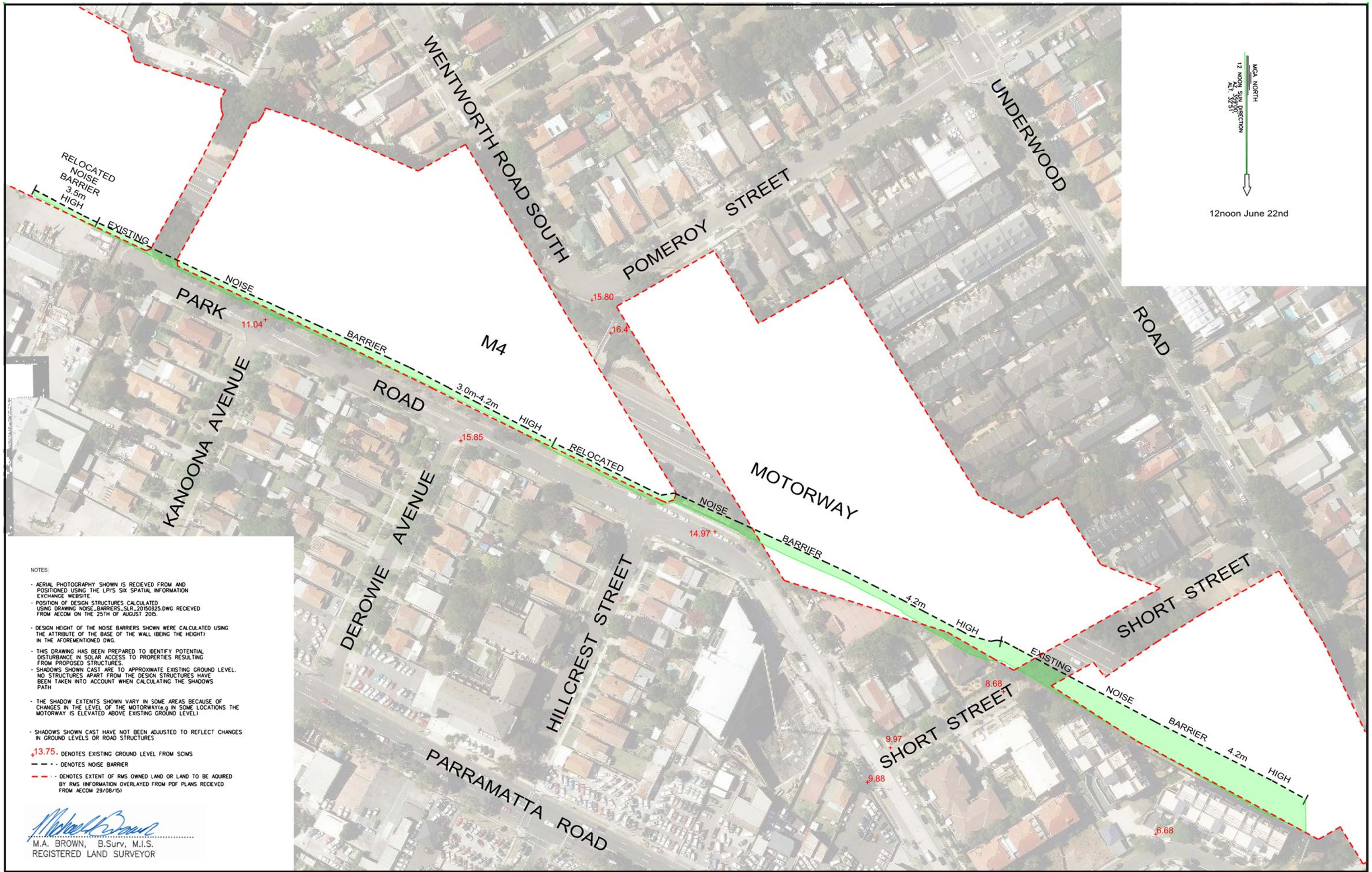
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-11am		-	3 OF 7 SHEETS



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DENOTES NOISE BARRIER

DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
Suite 904 Level 9, 39 York St Sydney NSW 2000
D +61 2 9262 6800
f +61 2 9262 6843
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

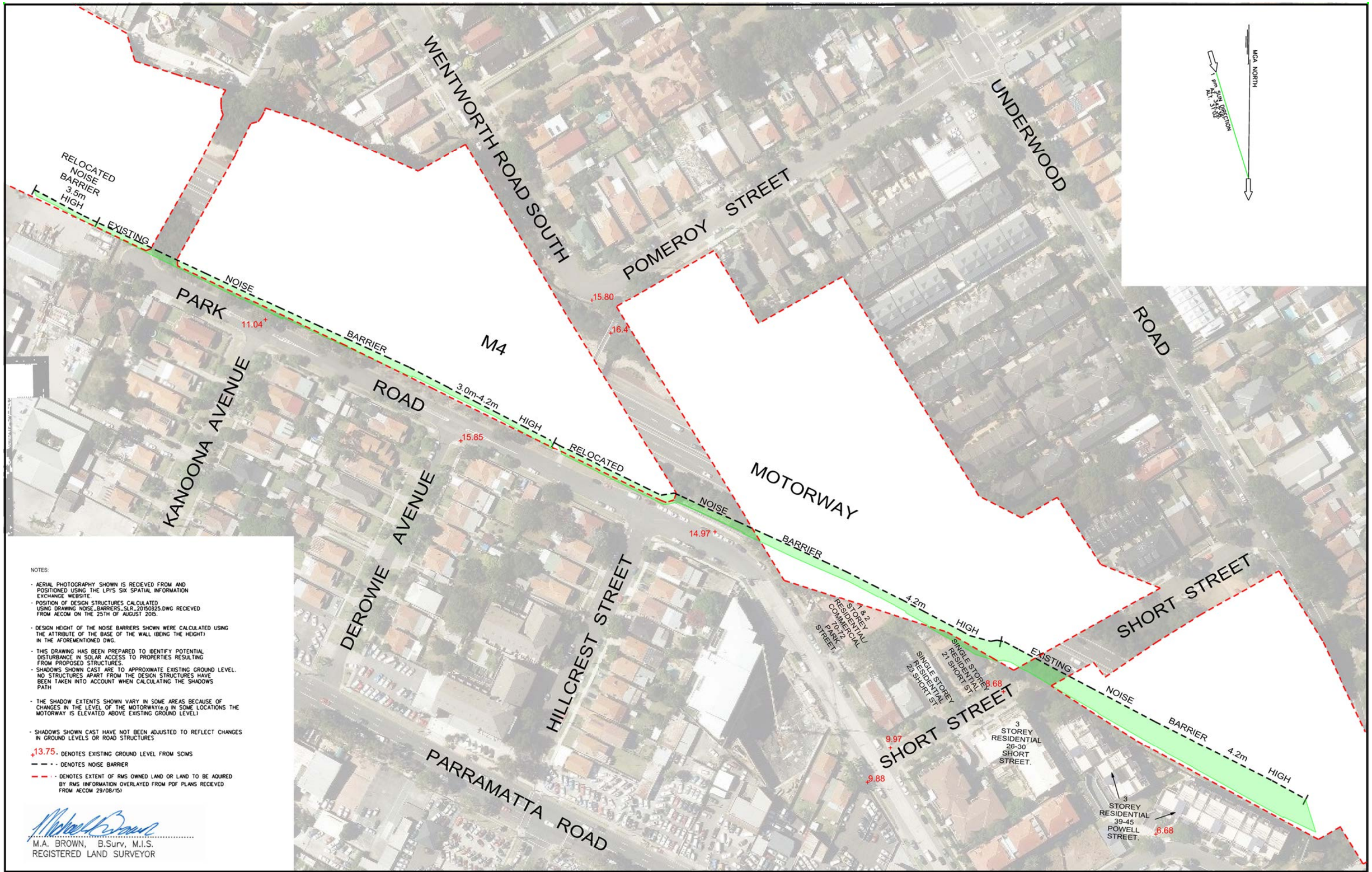
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

12noon SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-12		-	4 OF 7 SHEETS



NOTES:

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+13.75. DENOTES EXISTING GROUND LEVEL FROM SCIMS

DENOTES NOISE BARRIER

DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

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REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 80
REDUCTION RATIO 1 1600 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

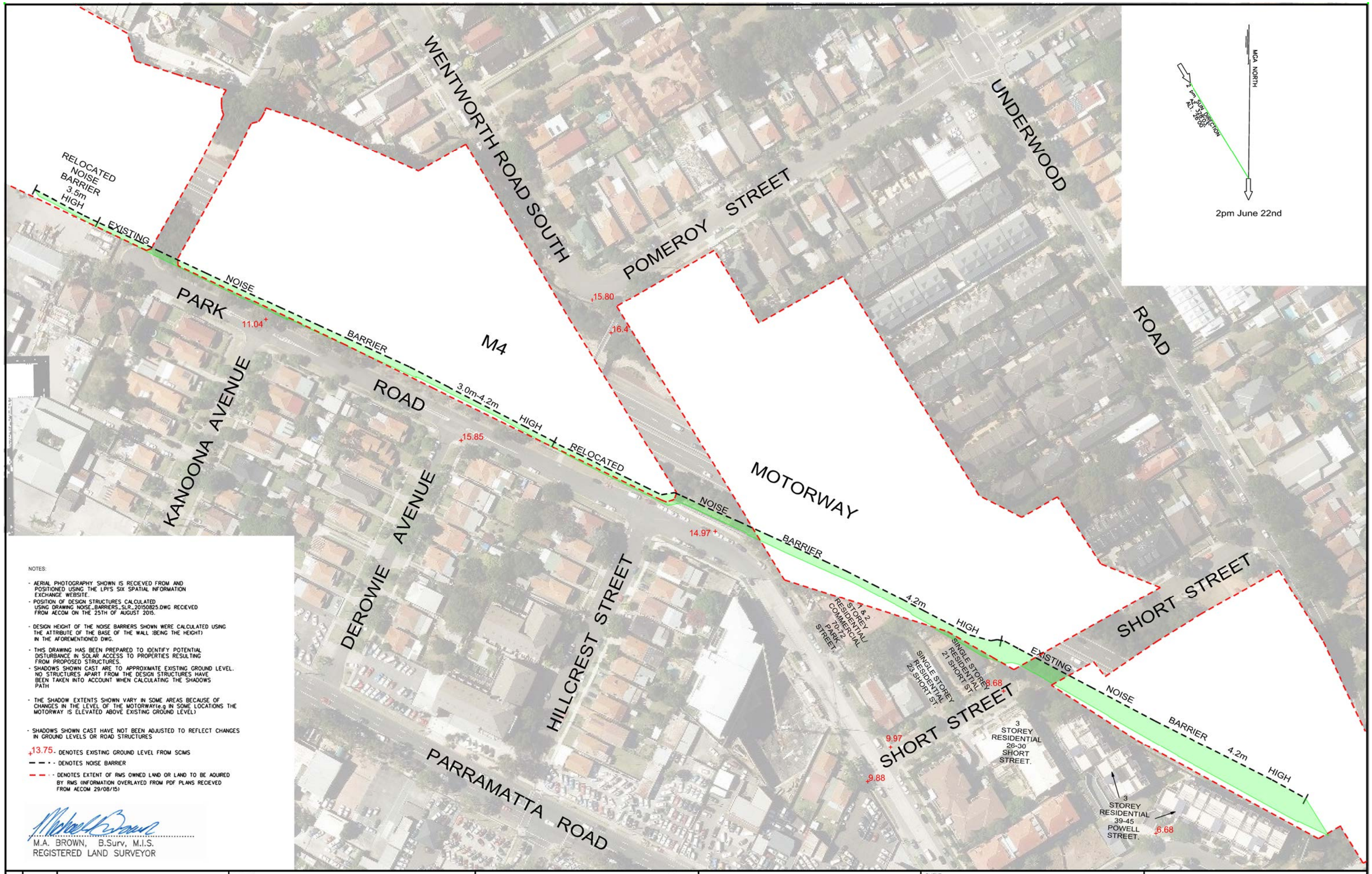
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-1pm		-	5 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES NOISE BARRIER

— — · · DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

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REV.	DATE	AMENDMENTS

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0 — 80
REDUCTION RATIO 1 1600 @ A3

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DATUM : -
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

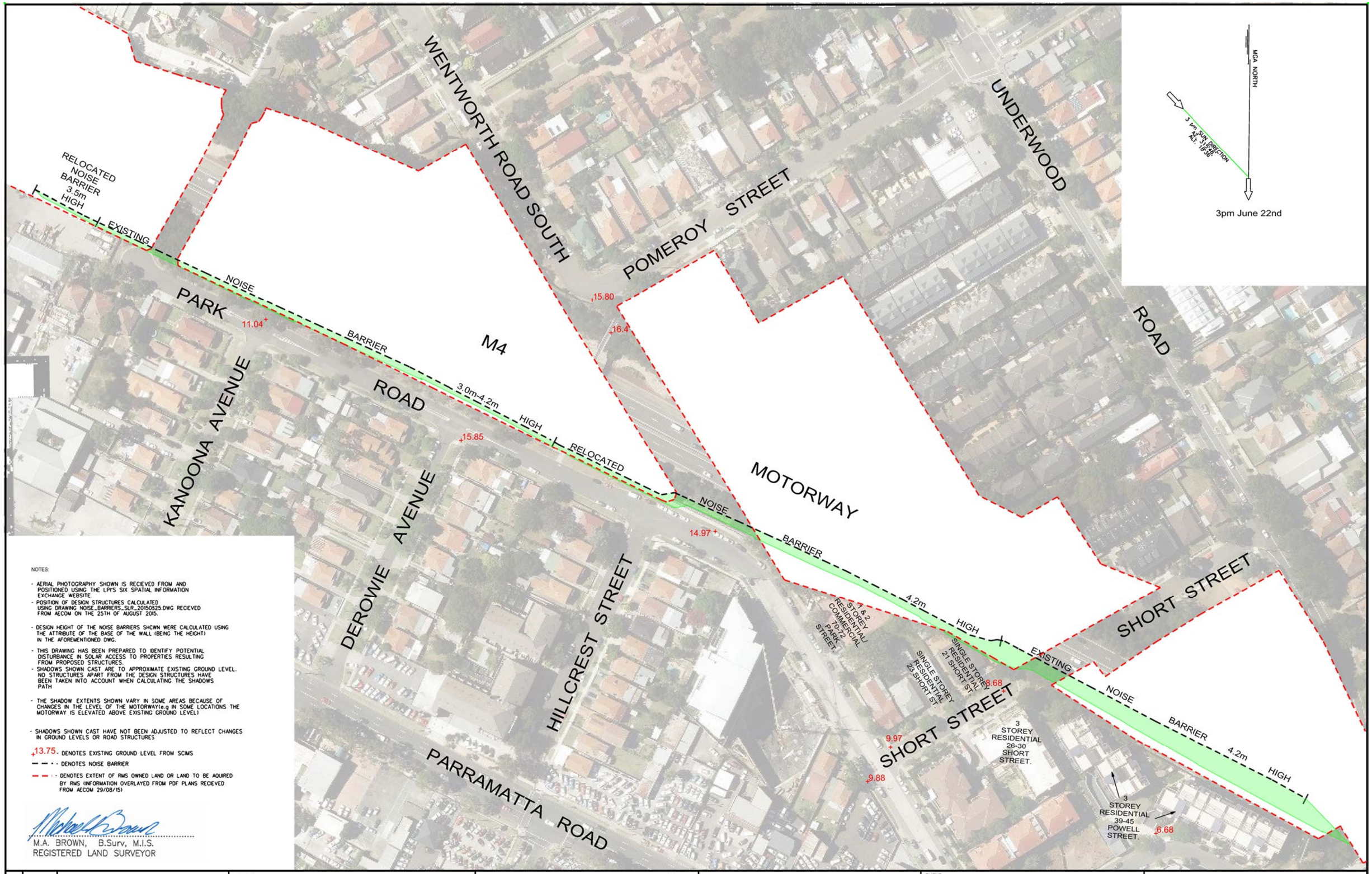
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

2pm SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-2pm		-	6 OF 7 SHEETS



NOTES:

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DENOTES NOISE BARRIER

DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

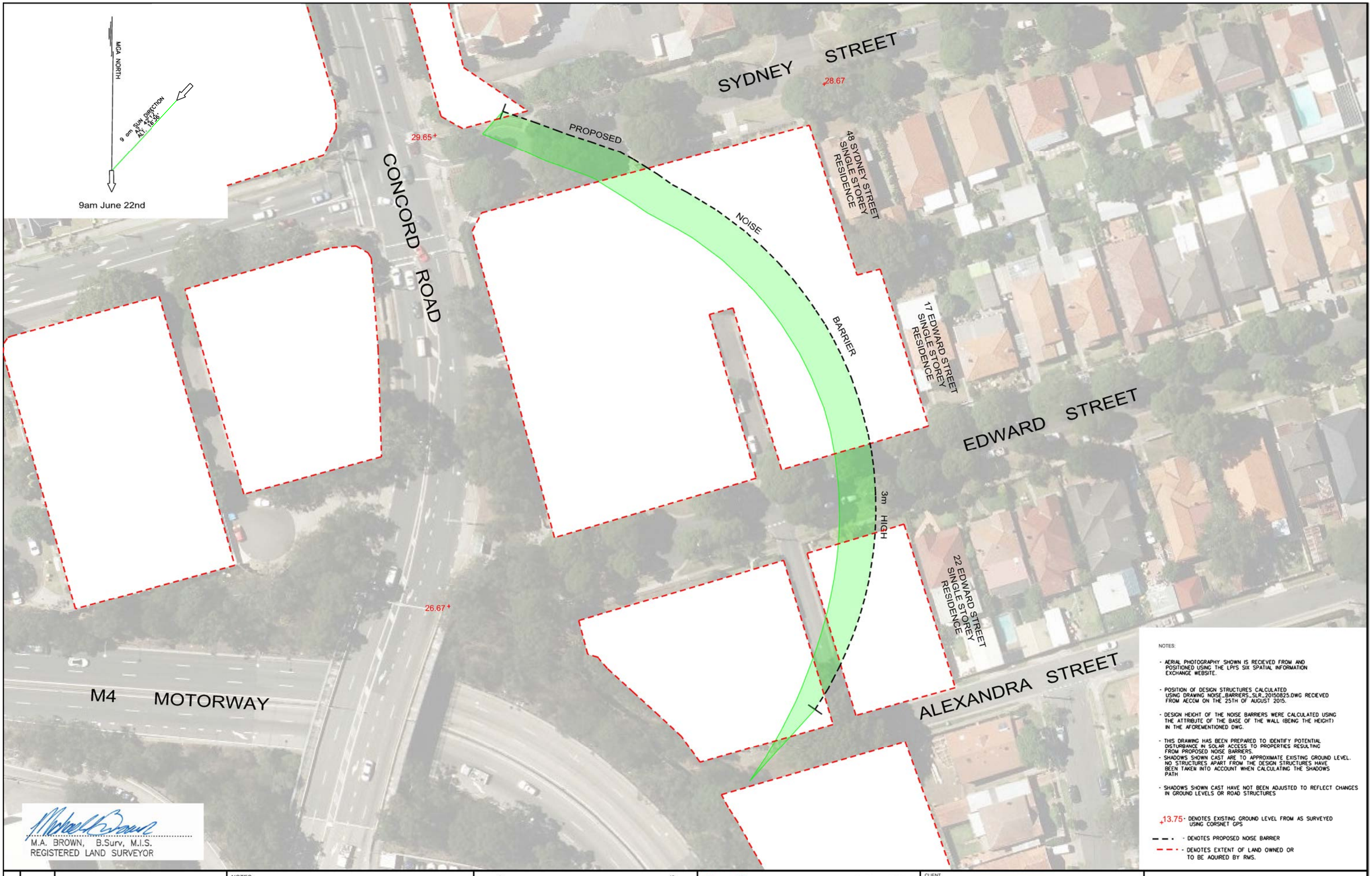
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

9am SHADOW ANALYSIS
NOISE BARRIERS
M4 MOTORWAY
HOMEBUSH

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-PARKRD-3pm		-	7 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 · DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

– – – DENOTES PROPOSED NOISE BARRIER

– – · – DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

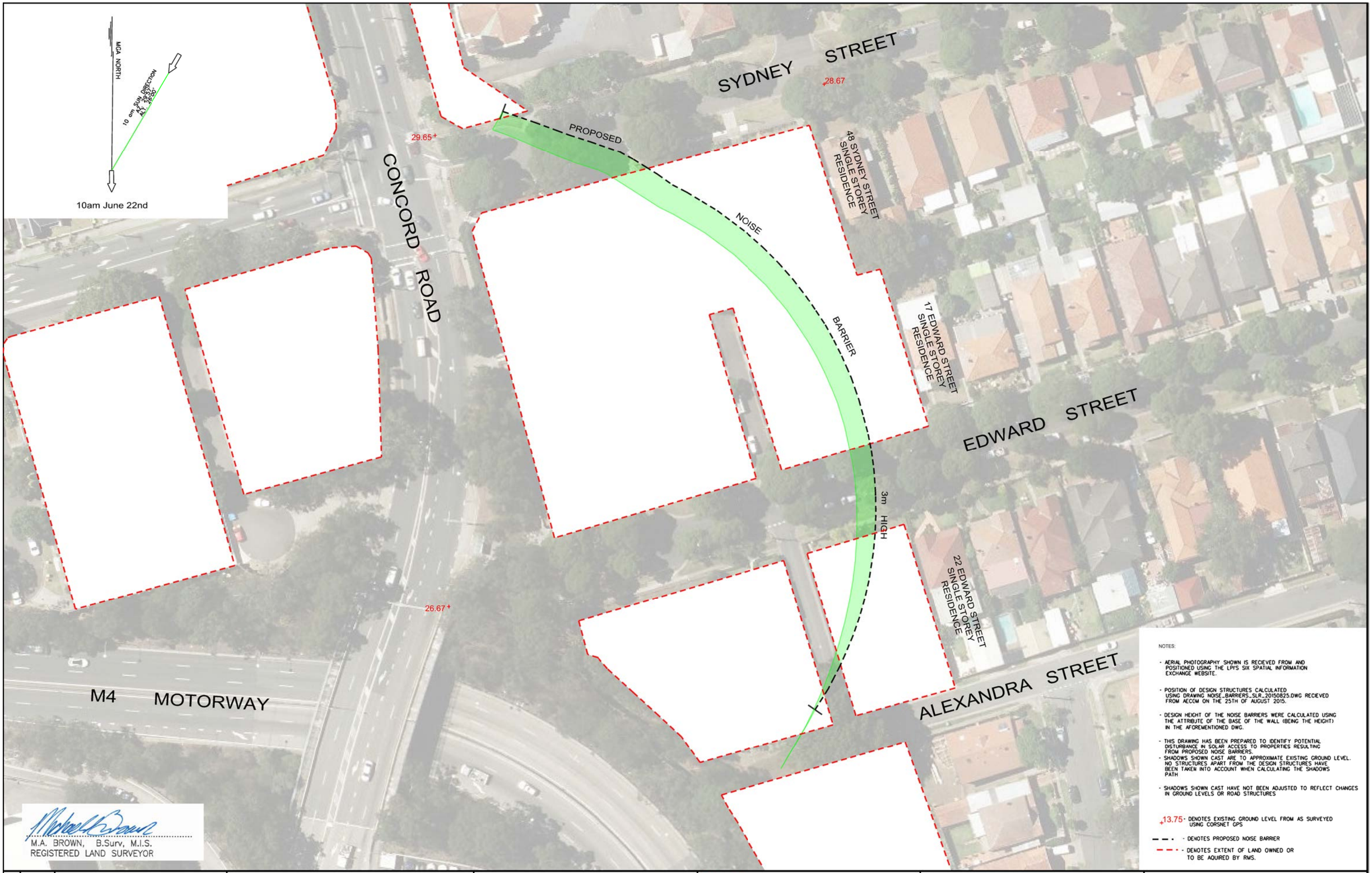
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-9am		-	1 OF 7 SHEETS



NOTES:

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+13.75 · DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

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– – · – DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

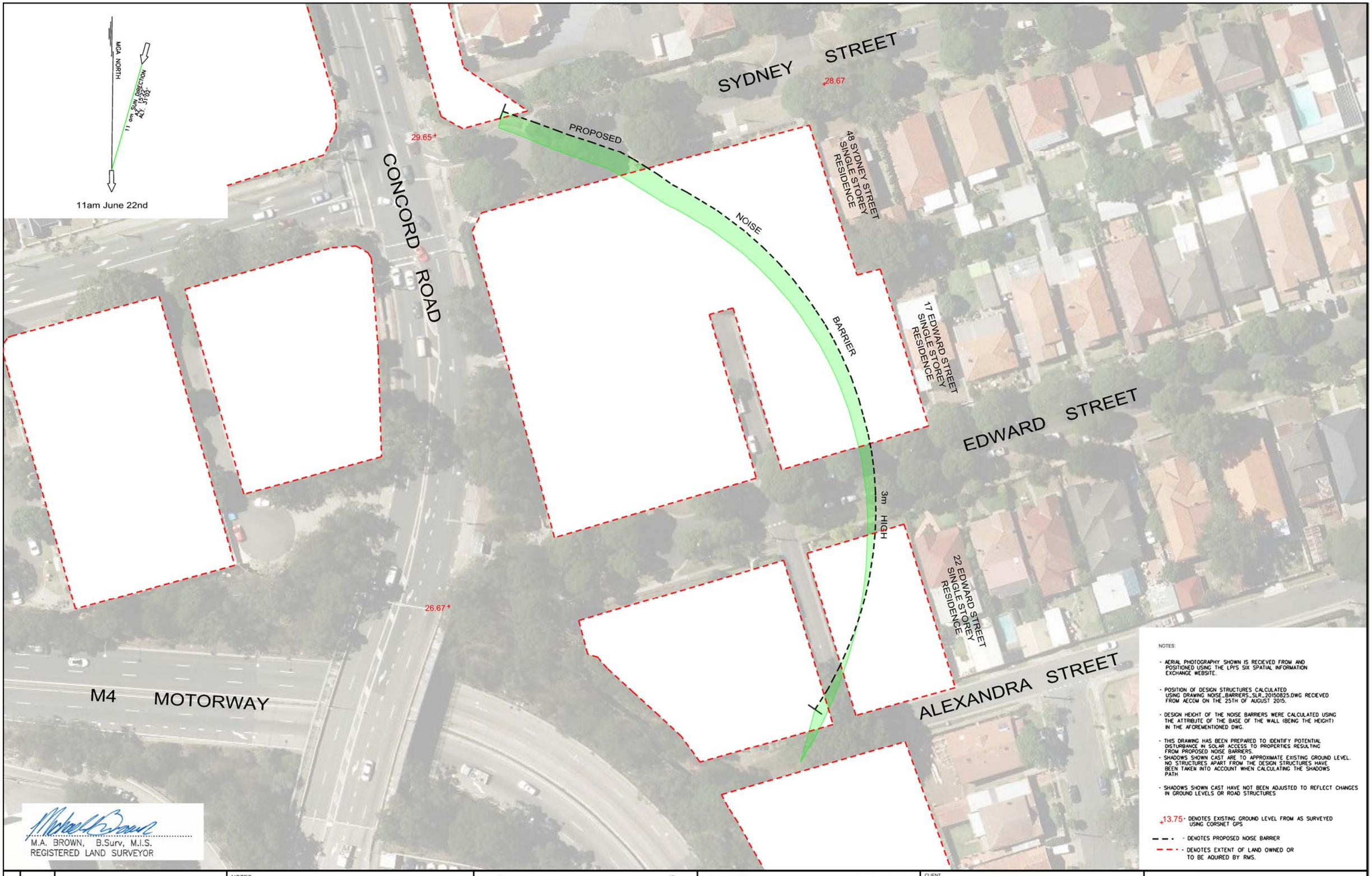
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
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REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-11am		-	3 OF 7 SHEETS

MGA NORTH
12 NOON SUN DIRECTION
ALT. 32.91°

12noon June 22nd

SYDNEY STREET

28.67+

29.65+

PROPOSED

NOISE

BARRIER

3m HIGH

CONCORD ROAD

48 SYDNEY STREET SINGLE STOREY RESIDENCE

17 EDWARD STREET SINGLE STOREY RESIDENCE

EDWARD STREET

22 EDWARD STREET SINGLE STOREY RESIDENCE

26.67+

M4 MOTORWAY

ALEXANDRA STREET

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REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

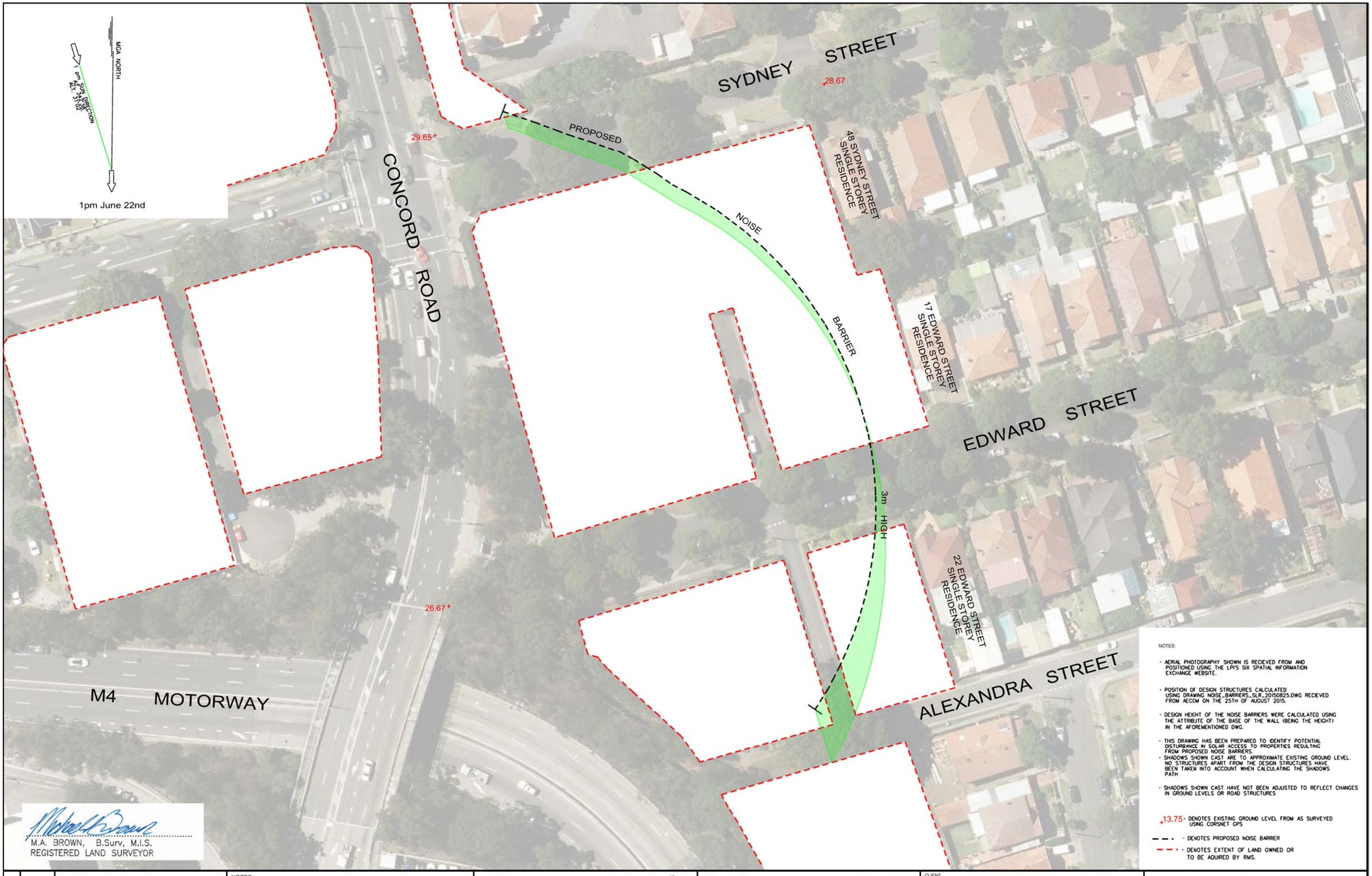
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-12		-	4 OF 7 SHEETS



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– – · – DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
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ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
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w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

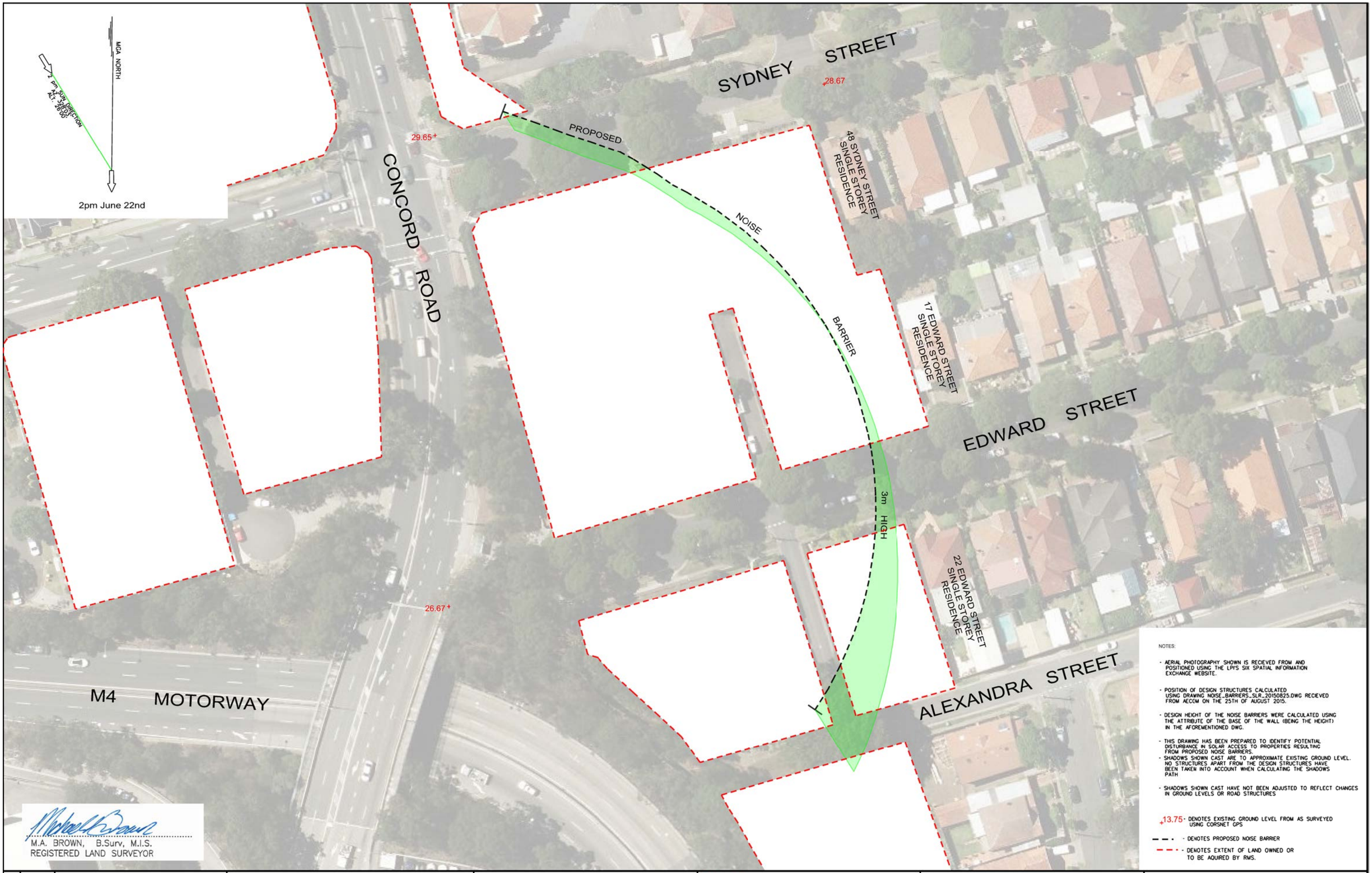
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-1pm		-	5 OF 7 SHEETS



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REGISTERED LAND SURVEYOR

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REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

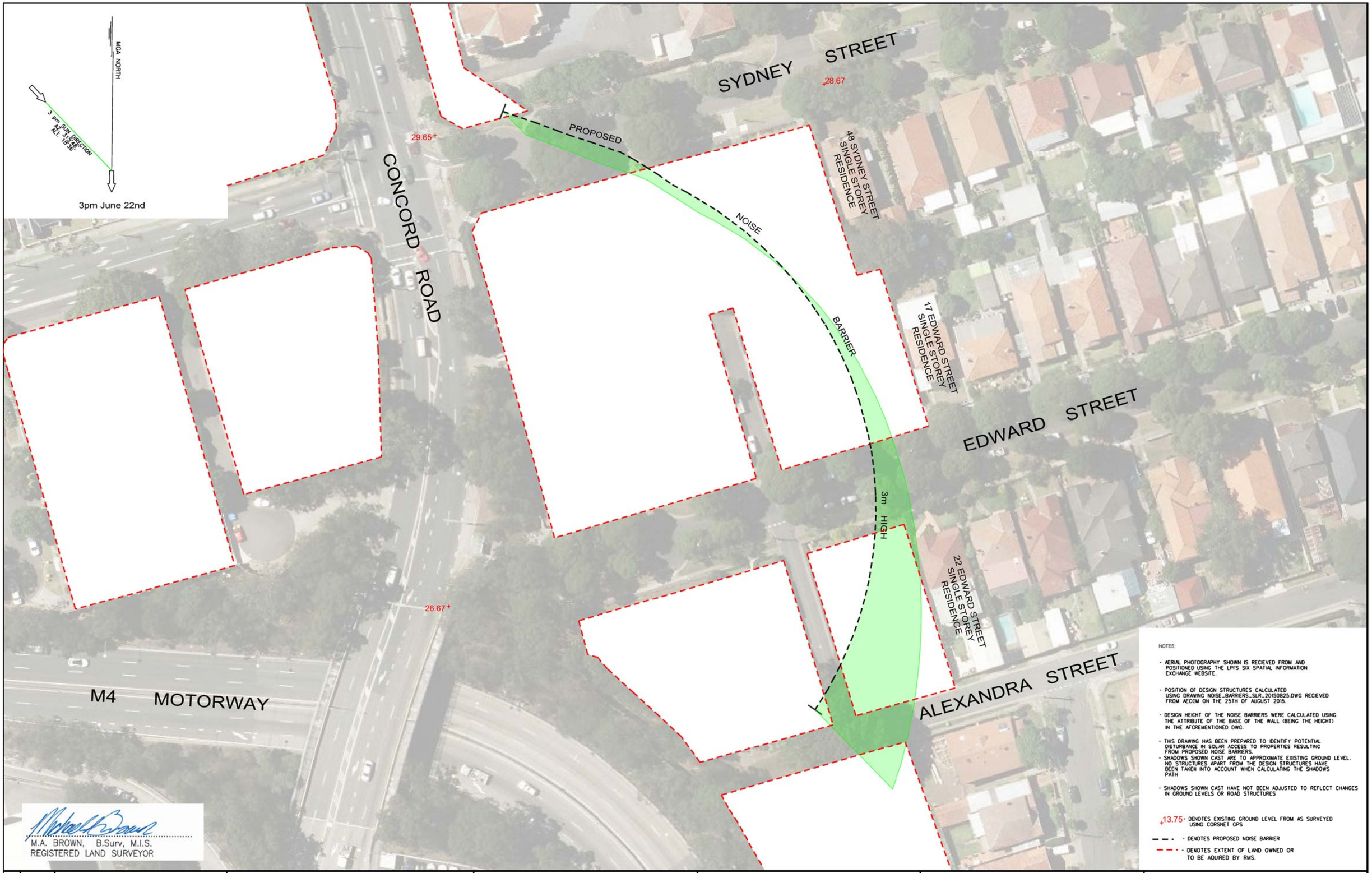
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-2pm		-	6 OF 7 SHEETS



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0 — 40
REDUCTION RATIO 1: 800 @ A3

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CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

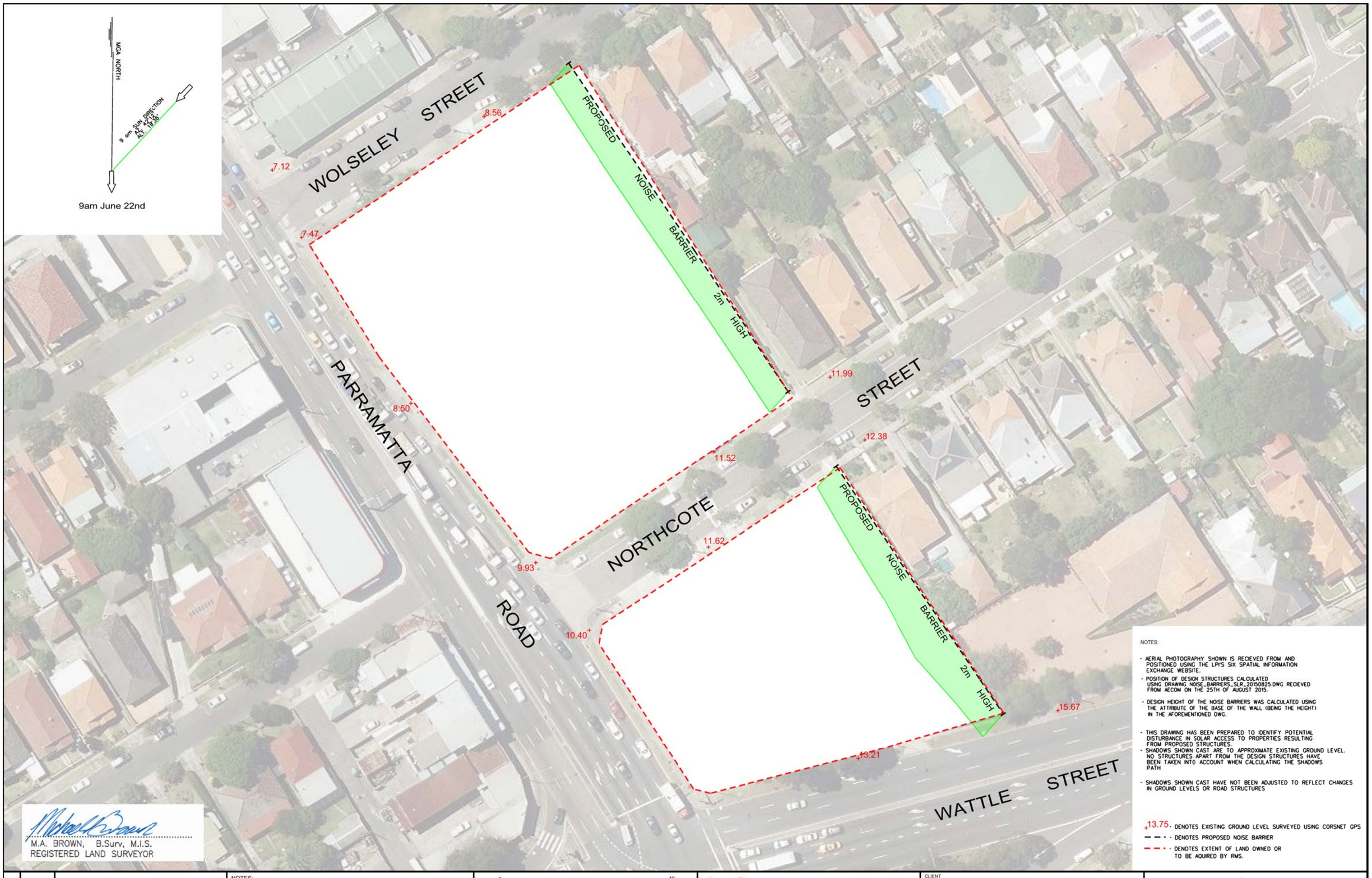
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
NOISE BARRIER
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-NB-3pm		-	7 OF 7 SHEETS



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REGISTERED LAND SURVEYOR

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REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-9am		-	1 OF 7 SHEETS



NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING NOISE_BARRIERS_SLR_20150825.DWG RECIEVED FROM AECOM ON THE 25TH OF AUGUST 2015.
- DESIGN HEIGHT OF THE NOISE BARRIERS WERE CALCULATED USING THE ATTRIBUTE OF THE BASE OF THE WALL (BEING THE HEIGHT) IN THE AFOREMENTIONED DWG.
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- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS

- - - - DENOTES PROPOSED NOISE BARRIER

— — — DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
Rygate & Company Pty Limited
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p +61 2 9262 6800
f +61 2 9262 6843
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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- SHADOWS SHOWN CAST HAVE NOT BEEN ADJUSTED TO REFLECT CHANGES IN GROUND LEVELS OR ROAD STRUCTURES

+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS
- - - - DENOTES PROPOSED NOISE BARRIER
- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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Rygate & Company Pty Limited
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON SUN DIRECTION
AZ. 359°00'
AL. 32°51'

12noon June 22nd

WOLSELEY STREET

PARRAMATTA ROAD

NORTHCOTE STREET

WATTLE STREET

PROPOSED NOISE BARRIER 2m HIGH

PROPOSED NOISE BARRIER 2m HIGH

8.56
7.12
7.47
8.50
11.99
12.38
11.52
11.62
9.93
10.40
15.67
13.21

NOTES:

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+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS

- - - - DENOTES PROPOSED NOISE BARRIER

- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT
AECOM

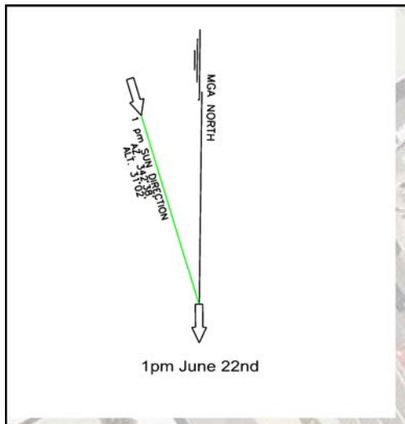
LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN

12noon SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-12		-	4 OF 7 SHEETS



WOLSELEY STREET

PARRAMATTA ROAD

NORTHCOTE STREET

WATTLE STREET

PROPOSED NOISE BARRIER 2m HIGH

PROPOSED NOISE BARRIER 2m HIGH

8.56
7.12
7.47
8.50
11.99
12.38
11.52
11.62
9.93
10.40
15.67
13.21

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS

- - - - DENOTES PROPOSED NOISE BARRIER

- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
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w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
PROPOSED NOISEBARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-1pm		-	5 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS
- - - - DENOTES PROPOSED NOISE BARRIER
- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYING SINCE 1893
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT
AECOM

LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN
2pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WOLSELEY STREET AND NORTHCOTE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-2pm		-	6 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75. DENOTES EXISTING GROUND LEVEL SURVEYED USING CORSNET GPS
- - - - DENOTES PROPOSED NOISE BARRIER
- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM
LOCALITY: WESTCONNEX M4 EAST PROJECT
L.G.A.: -

PLAN
3pm SHADOW ANALYSIS PROPOSED NOISE BARRIERS WOLSELEY STREET AND NORTHCOTE STREET HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT1-3pm		-	7 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - - DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

- - - - DENOTES PROPOSED NOISE BARRIER

REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - - DENOTES EXTENT OF RMS OWNED LAND OR LAND TO BE AQUIRED BY RMS (INFORMATION OVERLAYED FROM PDF PLANS RECIEVED FROM AECOM 29/08/15)

- - - - DENOTES PROPOSED NOISE BARRIER

REV.	DATE	AMENDMENTS

NOTES:

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

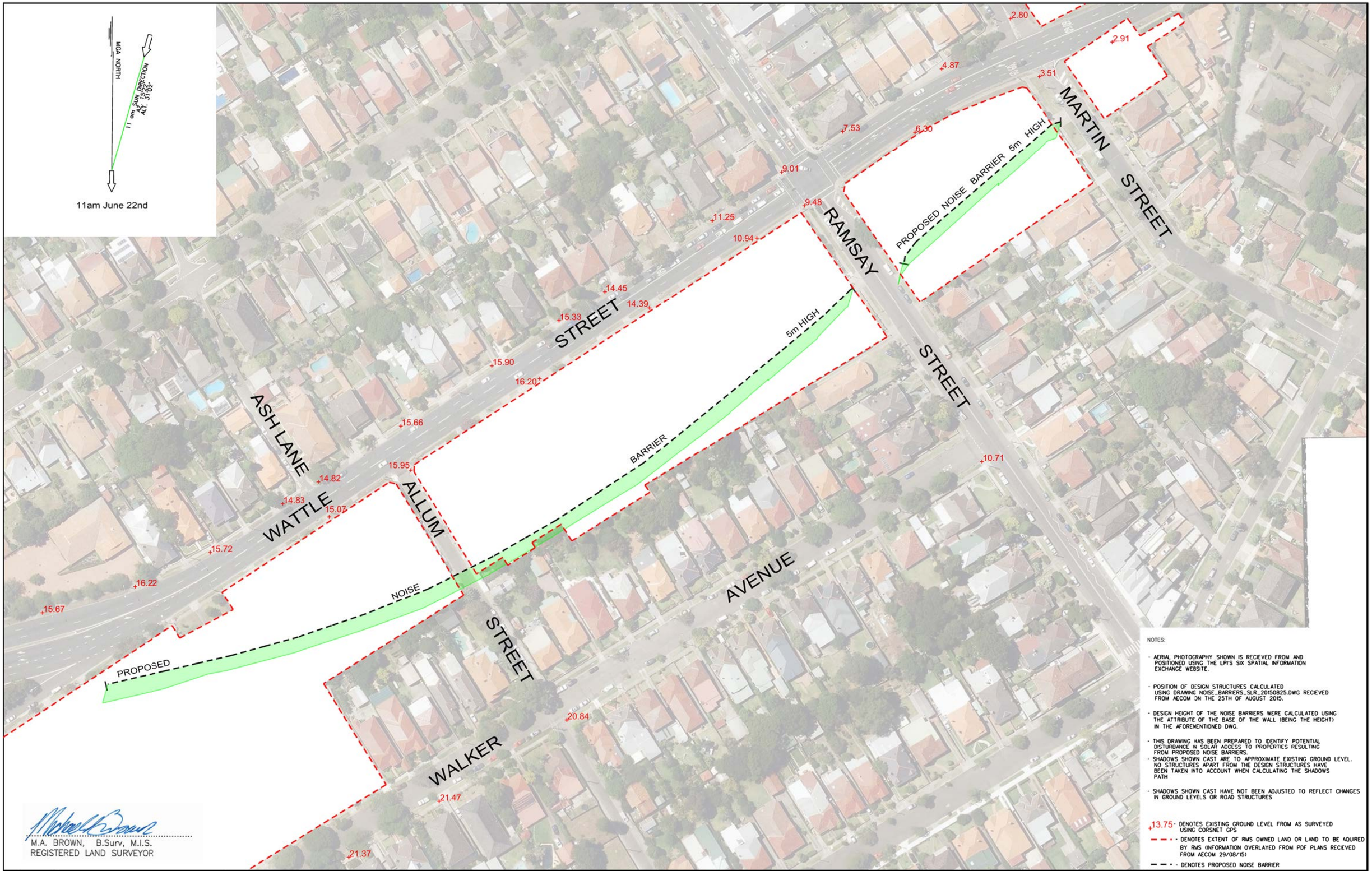
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT10am		-	2 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON SUN DIRECTION
ALT. 32.51°
AZ. 359.59°

12noon June 22nd

RAMSAY STREET

MARTIN STREET

PROPOSED NOISE BARRIER 5m HIGH

5m HIGH BARRIER

ASH LANE

WATTLE STREET

ALLUM STREET

PROPOSED NOISE BARRIER

WALKER AVENUE

+2.80
+2.91
+4.87
+3.51
+7.53
+6.30
+9.01
+9.48
+11.25
10.94+
+14.45
14.39+
+15.33
+15.90
16.20+
+15.66
15.95+
+14.82
+14.83
15.07+
+15.72
+16.22
+15.67
+10.71
+20.84
+21.47
+21.37

NOTES:

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- - - - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

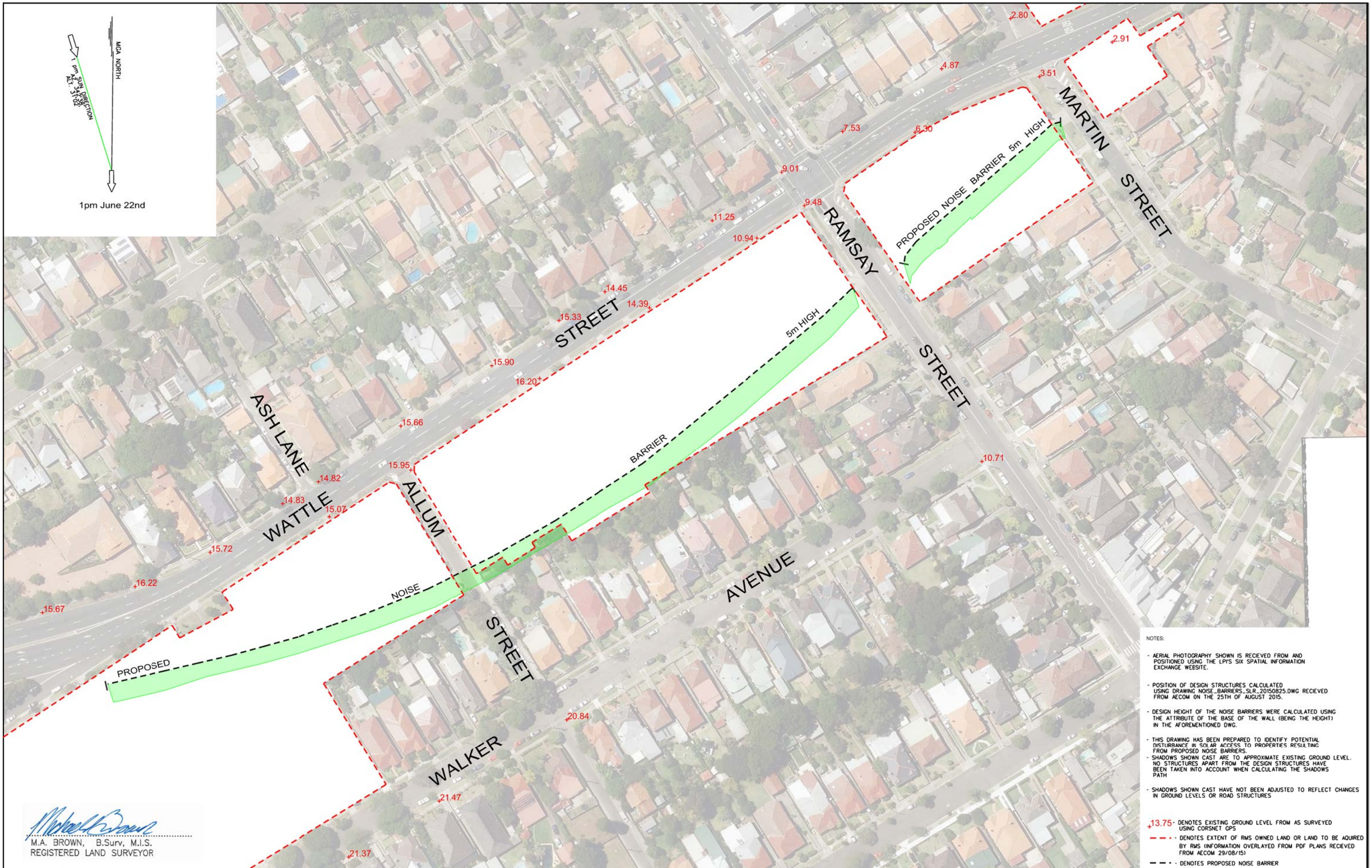
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-12		-	4 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

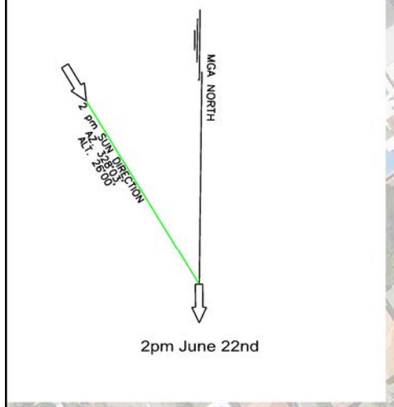
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

1pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-1pm		-	5 OF 7 SHEETS



2pm June 22nd

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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- - - - DENOTES PROPOSED NOISE BARRIER

REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-2pm		-	6 OF 7 SHEETS



NOTES:

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— — - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 75
REDUCTION RATIO 1: 1500 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
WATTLE STREET
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-WAT-3pm		-	7 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - · - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

9am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-9am		-	1 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - · - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
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w rygate.com.au

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-10am		-	2 OF 7 SHEETS



NOTES:

- AERIAL PHOTOGRAPHY SHOWN IS RECIEVED FROM AND POSITIONED USING THE LPI'S SIX SPATIAL INFORMATION EXCHANGE WEBSITE.
- POSITION OF DESIGN STRUCTURES CALCULATED USING DRAWING NOISE_BARRIERS_SLR_20150825.DWG RECIEVED FROM AECOM ON THE 25TH OF AUGUST 2015.
- DESIGN HEIGHT OF THE NOISE BARRIERS WERE CALCULATED USING THE ATTRIBUTE OF THE BASE OF THE WALL (BEING THE HEIGHT) IN THE AFOREMENTIONED DWG.
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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - · - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON SUN DIRECTION
AZ. 359°00'
ALT. 32°51'

12noon June 22nd

(IRON COVE CREEK)

CANAL

PARADE

DOBROYD

DOBROYD

DOBROYD

PARADE

LOUDEN

AVENUE

CRANE

AVENUE

WARATAH
STREET

5m HIGH BARRIER

NOISE

PROPOSED

+2.99
+2.06
+1.72
+2.85
+1.69
+1.66
+2.22
+1.97
+2.20

NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - · · - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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REDUCTION RATIO 1: 800 @ A3

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-12		-	4 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - · - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM
LOCALITY: WESTCONNEX M4 EAST PROJECT
L.G.A.: -

PLAN
1pm SHADOW ANALYSIS PROPOSED NOISE BARRIERS DOBROYD PARADE HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-1pm		-	5 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — REDUCTION RATIO 1: 800 @ A3 — 40

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

2pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-2pm		-	6 OF 7 SHEETS



NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM AS SURVEYED USING CORSNET GPS

- - - - DENOTES PROPOSED NOISE BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
PROPOSED NOISE BARRIERS
DOBROYD PARADE
HABERFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-DOB-3pm		-	7 OF 7 SHEETS



NOTES:

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\+

+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – • – – - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT
AECOM

LOCALITY
WESTCONNEX M4 EAST PROJECT

L.G.A.
-

PLAN
9am SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-POW-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

— — • - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-POW-10am		-	2 OF 7 SHEETS



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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – • – – - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-pow-11am		-	3 OF 7 SHEETS

MGA NORTH

12 NOON SUN DIRECTION
ALT. 75°00'
AZ. 322°51'

12noon June 22nd

15.65 TB

8.07

M4 MOTORWAY

PROPOSED ON-RAMP (ELEVATED)

14.72 TB

11.42 TB

10.13 TB

8.26 TB

6.44

2-10 POWELL STREET
5 STOREY RESIDENTIAL

STREET

POWELL

17-35 PARRAMATTA ROAD
SINGLE STOREY
COMMERCIAL

9.59

6.06

PARRAMATTA ROAD

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

NOTES:

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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – • – – - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

REV.	DATE	AMENDMENTS

NOTES:

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

RYGATE SURVEYORS
SURVEYING SINCE 1893
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
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w rygate.com.au
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

12noon SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-POW-12		-	4 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

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\+ 13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – • – – - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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RYGATE SURVEYORS
Rygate & Company Pty Limited
P.W. Rygate & West
ABN 61 001 204 897
SURVEYING SINCE 1893
a Suite 904 Level 9, 89 York St Sydney NSW 2000
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

1pm SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-POW-1pm		-	5 OF 7 SHEETS



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\+ 13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – • – – - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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P.W. Rygate & West
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A. -

PLAN

2pm SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CR-2pm		-	6 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
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+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

— — • - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

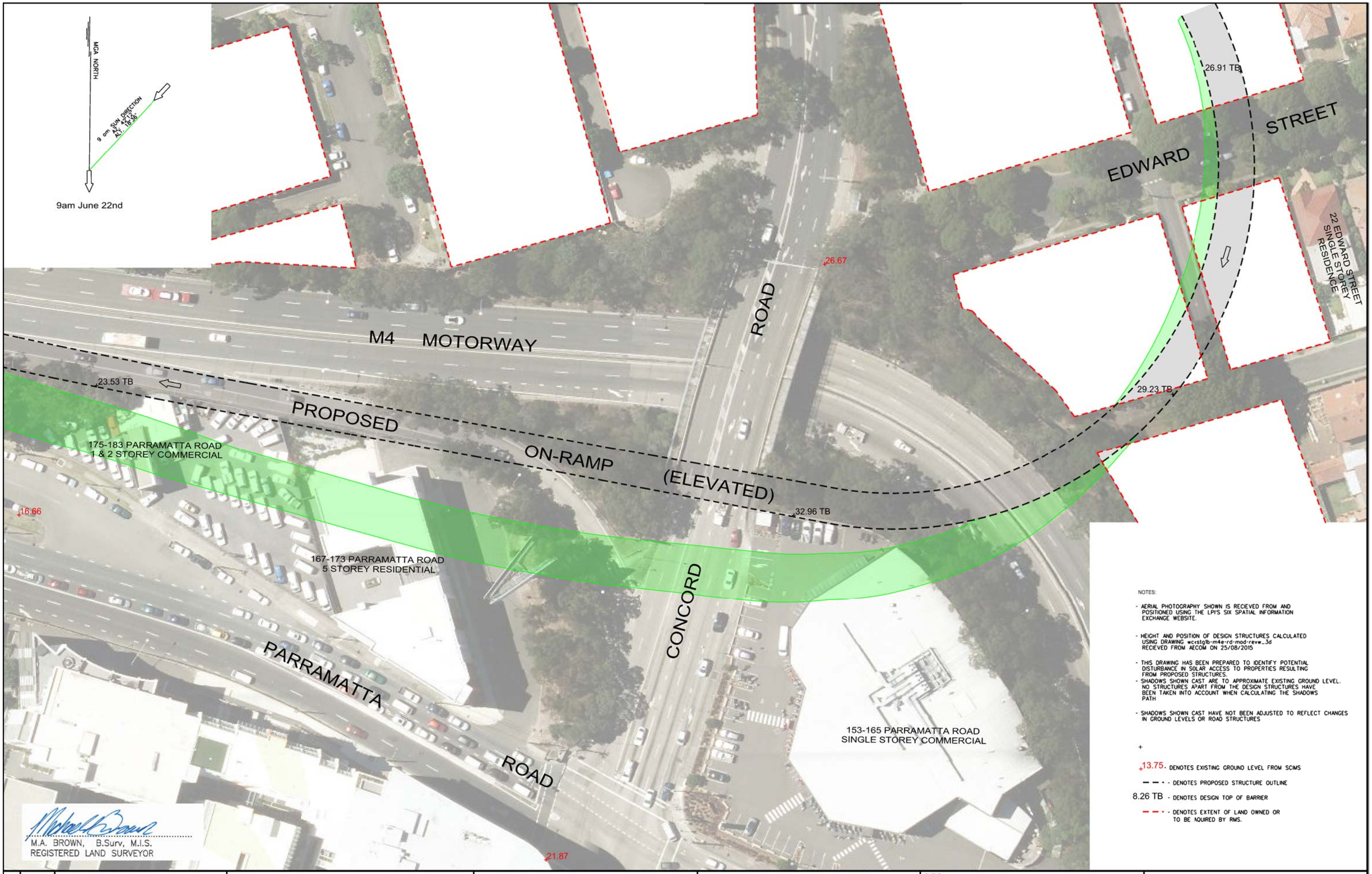
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

3pm SHADOW ANALYSIS
PROPOSED M4 MOTORWAY ON-RAMP
POWELLS CREEK
NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CR-3pm		-	7 OF 7 SHEETS



NOTES:

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\+ 13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

— — - - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

— — - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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0 — 40
REDUCTION RATIO 1: 800 @ A3

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DATUM : -

CONTOUR INTERVAL : N/A

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

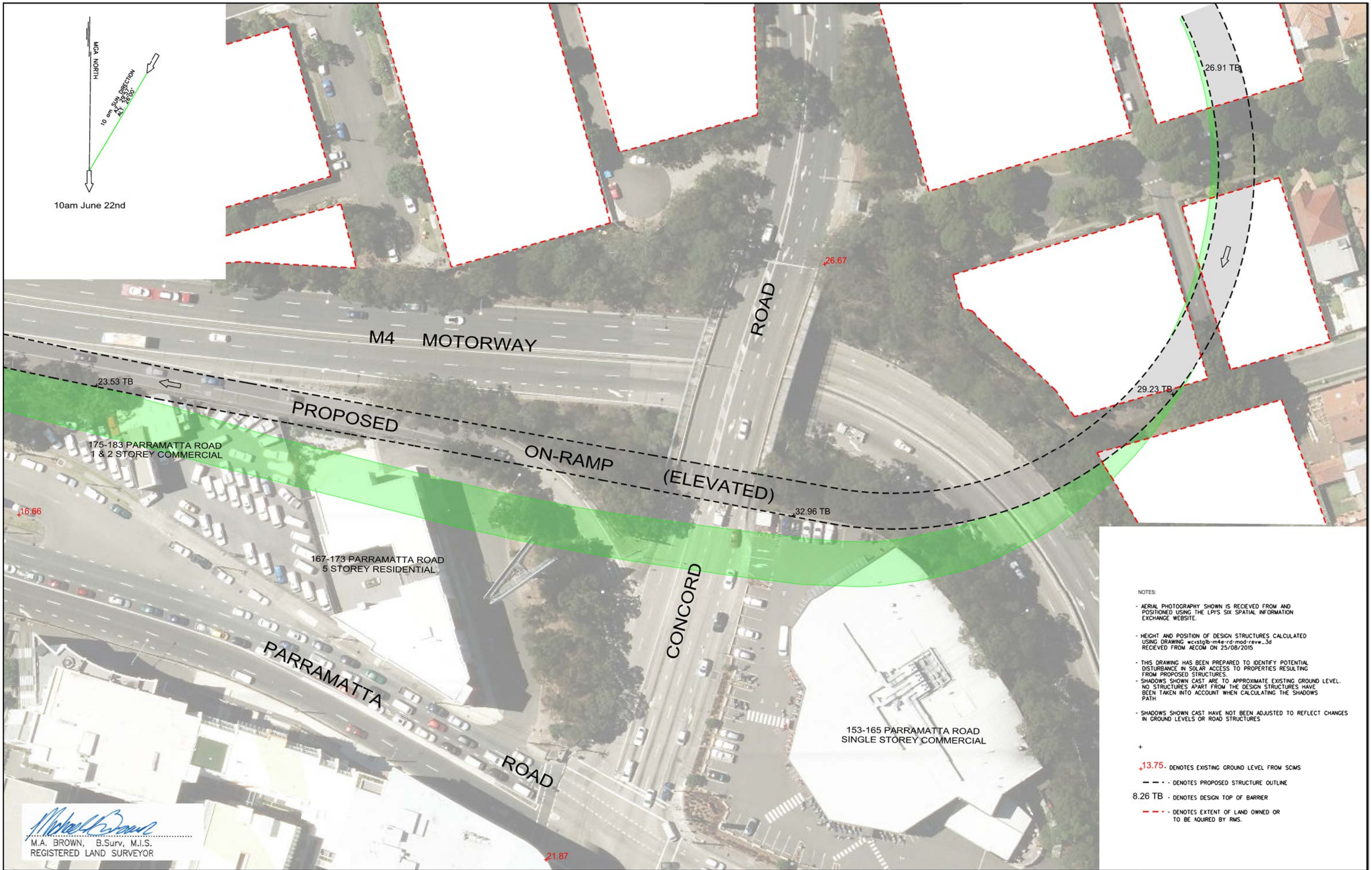
CLIENT: AECOM

LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN
9am SHADOW ANALYSIS
ON-RAMP AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-9am		-	1 OF 7 SHEETS



M.A. BROWN, B.Surv, M.I.S.
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\+

13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

\- - - - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

\- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

REV.	DATE	AMENDMENTS

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0 — 40
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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

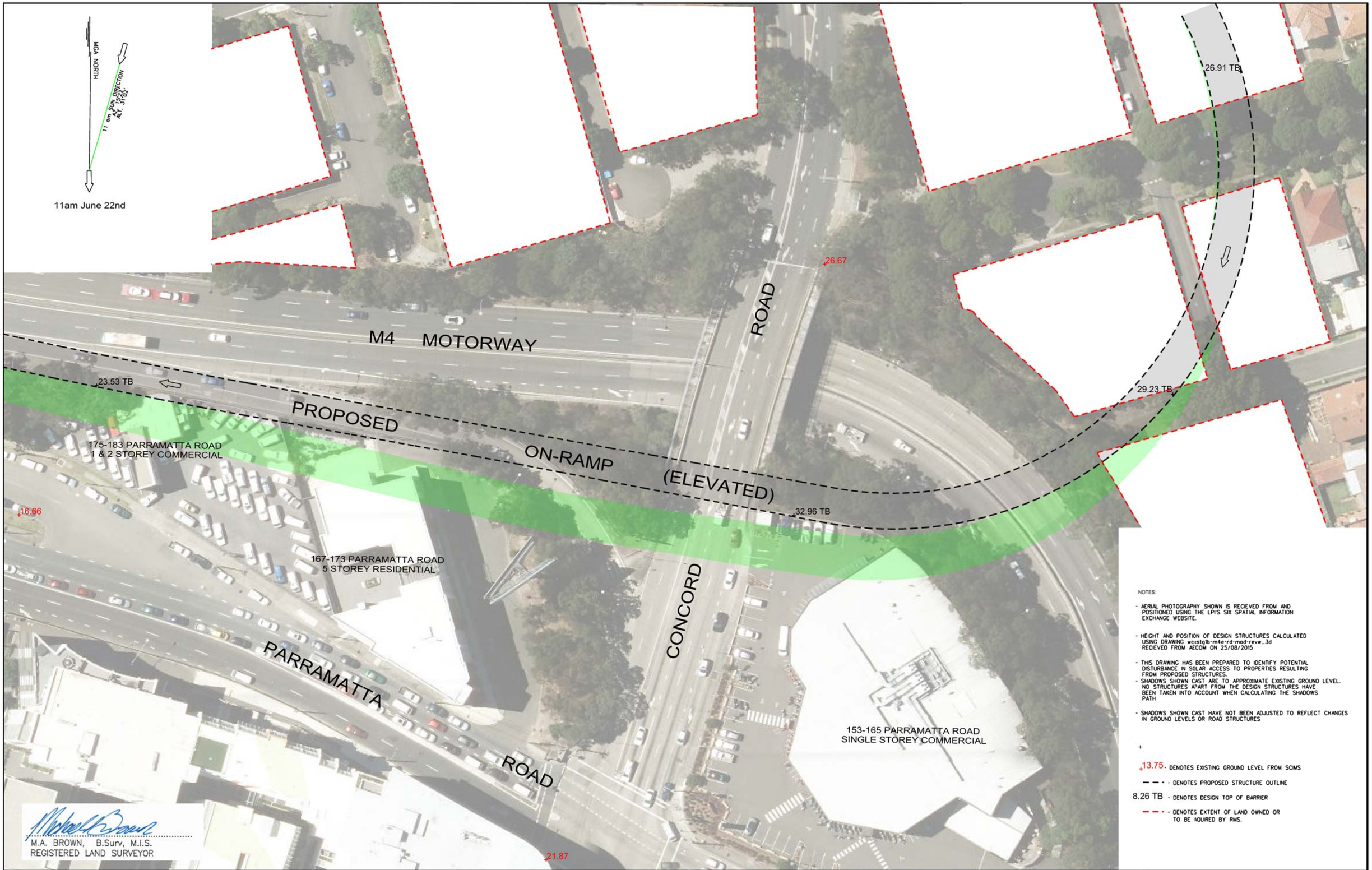
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

10am SHADOW ANALYSIS
ON-RAMP AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-10am		-	2 OF 7 SHEETS



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+

+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

– – · – – DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

– – · – – DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
CO-ORDINATES: MGA ZONE 56

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SURVEYOR	DRAWN	CHECKED	APPROVED
MAB	MB	MAB	ACD

CLIENT: AECOM

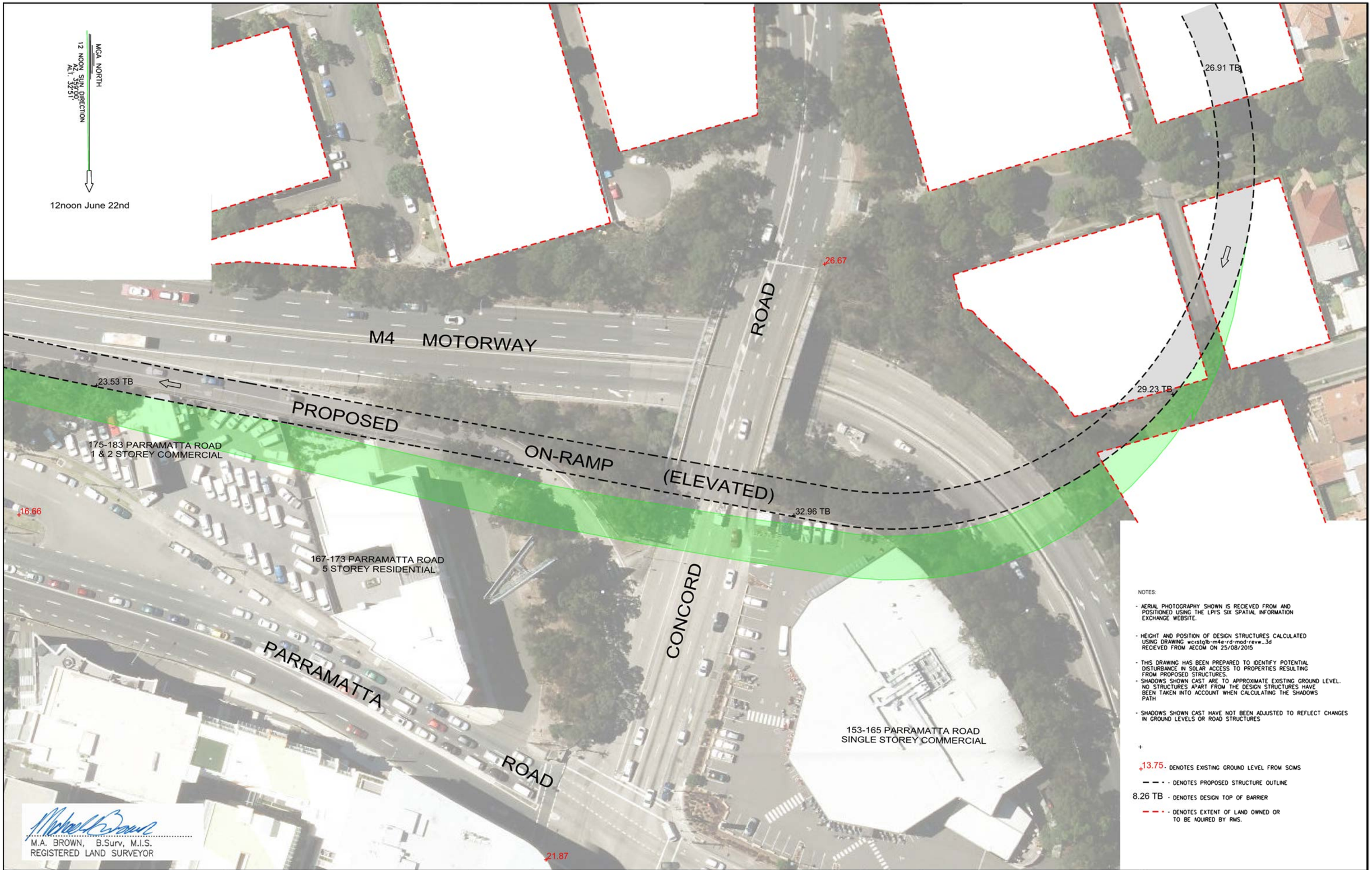
LOCALITY: WESTCONNEX M4 EAST PROJECT

L.G.A.: -

PLAN

11am SHADOW ANALYSIS
ON-RAMP AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

REFERENCE No.	PLAN No.	DATE	SHEET No.
76976-CRI-11am		-	3 OF 7 SHEETS



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+

+13.75 - DENOTES EXISTING GROUND LEVEL FROM SCIMS

- - - - DENOTES PROPOSED STRUCTURE OUTLINE

8.26 TB - DENOTES DESIGN TOP OF BARRIER

- - - - DENOTES EXTENT OF LAND OWNED OR TO BE AQUIRED BY RMS.

M.A. BROWN, B.Surv, M.I.S.
REGISTERED LAND SURVEYOR

REV.	DATE	AMENDMENTS

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DATUM : -

CONTOUR INTERVAL : N/A

ORIGIN OF LEVELS : APPROX (A.H.D.)
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P.W. Rygate & West
ABN 61 001 204 897
a Suite 904 Level 9, 89 York St Sydney NSW 2000
p +61 2 9262 6800
f +61 2 9262 6843
e surveyors@rygate.com.au
w rygate.com.au

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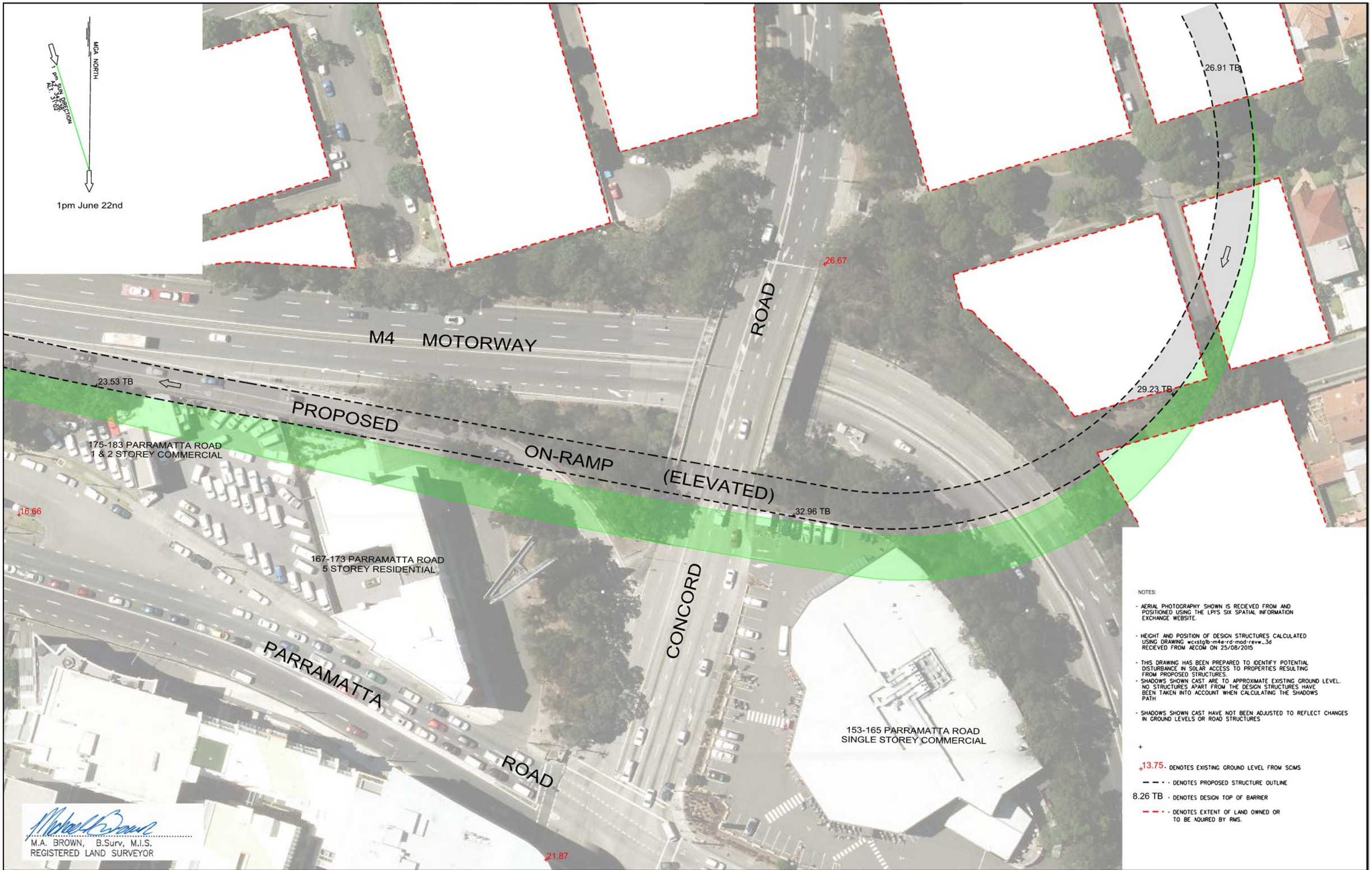
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12noon SHADOW ANALYSIS
ON-RAMP AT
CONCORD ROAD INTERCHANGE
CONCORD/NORTH STRATHFIELD

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a Suite 904 Level 9, 89 York St Sydney NSW 2000
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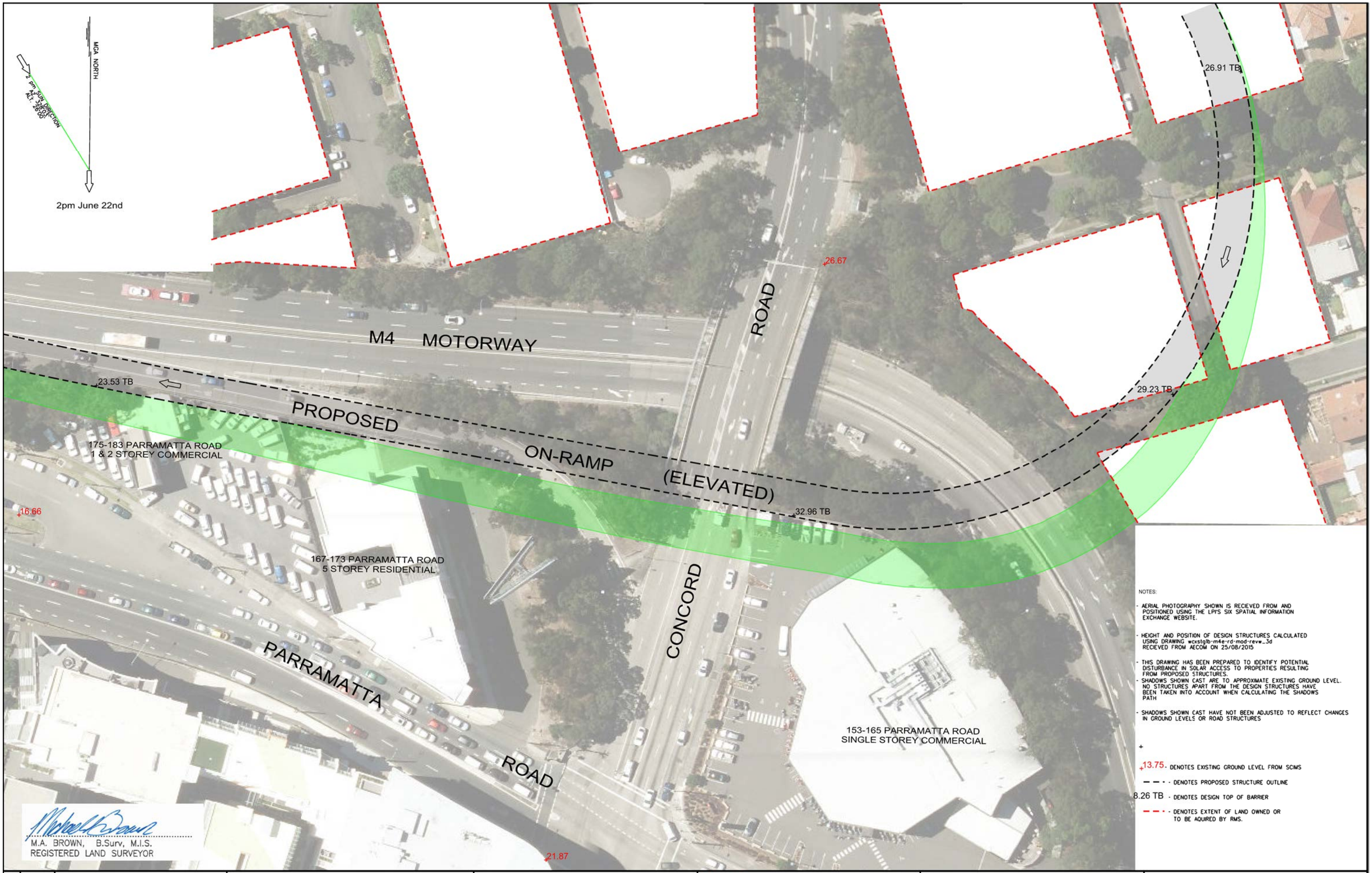
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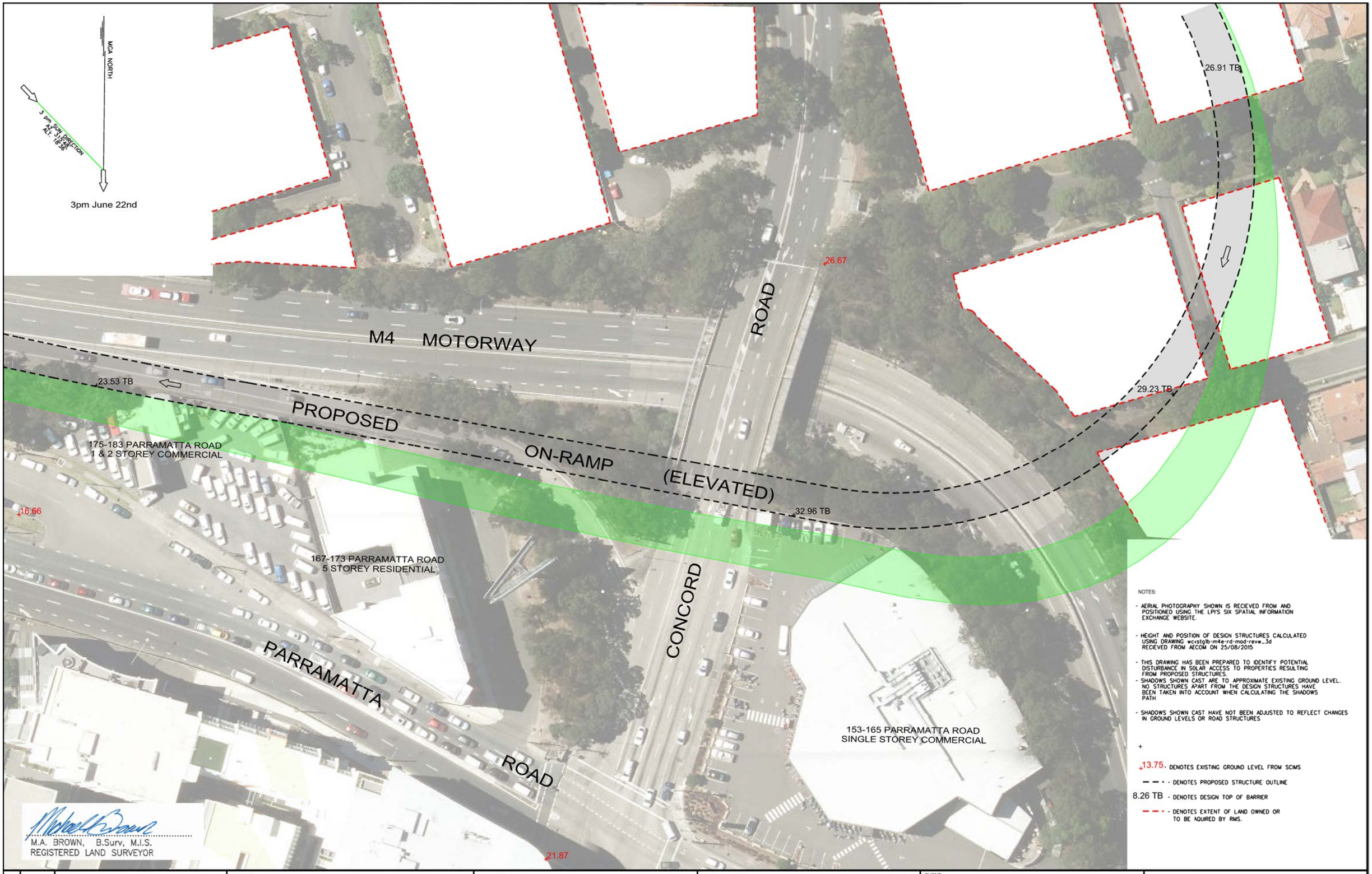
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a Suite 904 Level 9, 89 York St Sydney NSW 2000
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Appendix L

Urban design, landscape character and visual impact assessment

WestConnex

WestConnex Delivery Authority

WestConnex M4 East

Urban Design, Landscape Character and Visual Impact Assessment

September 2015

Prepared for

WestConnex Delivery Authority

Prepared by

AECOM Australia

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Accepted on behalf of the RMS by:	Jay Stricker Industry Director – Transport
Signed:	
Date	05 September 2015

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Glossary of terms and abbreviations

Term	Meaning
CBD	Central business district
Construction footprint	The total area required for construction of the project
CPTED	Crime prevention through environmental design
EIS	Environmental Impact Statement
EIAG	Roads and Maritime *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (2013)
GIS	Geographic information system
GPT	Gross pollutant trap
GLVIA	*Guidelines for Landscape and Visual Impact Assessment* (2013) (third edition)
HCA	Heritage conservation area
LCZ	Landscape character zone
LGA	Local government area
M4	M4 Motorway
SHR	State heritage register
Roads and Maritime	Roads and Maritime Services
VEM	Visual envelope mapping
WDA	WestConnex Delivery Authority
WUDF or WestConnex Urban Design Framework	*Westconnex Motorway Urban Design Framework: WestConnex – "City Shaping Infrastructure"* (September 2013)
WSUD	Water sensitive urban design initiatives

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Executive summary

The WestConnex Delivery Authority (WDA) is seeking approval to upgrade and extend the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield, in inner western Sydney. These proposed works are described as the M4 East project (the project).

The Secretary of the NSW Department of Planning and Environment issued a set of environmental assessment requirements for the project; referred to as Secretary's environmental assessment requirements (SEARs). This report responds to these requirements as they relate to urban design and visual amenity matters.

- The objective of the urban and landscape design for the project is focused on achieving the objectives of the draft WestConnex Motorway Urban Design Framework (WUDF) to deliver benefits to road users and the community. Therefore the WUDF is considered the benchmark for assessing the urban and landscape design proposal.
- The WUDF's vision statement states that 'a "whole of corridor" design approach shall be adopted, to ensure the realisation of a memorable motorway experience that is legible, identifiable and integrated into the existing urban fabric'. The successful project 'integration within the existing urban fabric' is critical to a well-managed response to potential visual impact and is of direct relevance to this assessment.

To meet the WUDF vision statement, a review of the urban design and landscape implications was undertaken of the project components, including supporting infrastructure, during construction and operation. Key elements of this process included:

- Identification of urban and landscape design objectives of the project to enhance the interchanges, tunnels, 'cut and cover' and 'slot' arrangements.
- Provision of an overview description of urban design and landscape concept for the project.
- Consideration of residual land and treatments, including identification of opportunities to utilise surplus or residual land, and utilise key structures (such as stacks) for multiple uses.
- Identification of measures to create, promote and enhance connectivity across Parramatta Road, where impacts to connectivity are associated with the project.
- Demonstration of how the proposed urban and landscape design elements would be consistent with the existing and desired future character of the area.

Potential impacts on nearby sensitive receptors were assessed using the methods and techniques described in the *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (Roads and Maritime, 2013).

The existing environment of the project is highly urbanised, comprising broadly of:

- Major roads such as the M4, Concord Road, Parramatta Road and Wattle Street.
- Residential areas including established low density residential areas in North Strathfield, Haberfield and Ashfield, and medium density and high density residential development including North Strathfield, Strathfield, Homebush, Haberfield and Ashfield.
- Commercial and industrial areas, predominantly alongside the M4 Motorway and fronting onto Parramatta Road.

A total of 15 Landscape Character Zones (LCZ) were identified as having the potential to be impacted by the surface components of the project. The LCZs reflect the differences in character that are inherent in such a densely urbanised setting, due to factors such as: mix and period of housing types; interweaving of land uses, and the number of different land uses.

Key landscape character and visual amenity issues arising from the assessment include a loss of a substantial corridor of vegetative screening to the existing M4, and change in character of the motorway to a much wider hardscape development that provides limited opportunities for landscape integration between the carriageways and along parts of the boundary.

Potential impacts were considered across the 15 LCZs. The assessment found that high visual impacts would only occur at three of the identified LCZs; those being the Concord Oval precinct, Haberfield precinct and the Yasmar Juvenile Training Facility.

Potential impacts on visual amenity were considered across four different user groups; residents, pedestrians, recreational users and motorists. High potential visual amenity impacts were considered likely for the residential user group. To minimise the potential impacts identified, site compounds and work areas would be screened, organised and managed. Vegetation clearance would be minimised where possible and built structures would be designed consistent with the objectives and design principles set by the WestConnex Urban Design Guidelines and Roads and Maritime Design Guidelines. Notwithstanding the application of mitigation, construction activities would still be visible from some locations. However, construction impacts are temporary and therefore the residual impacts are considered to be low.

Within the context of limited opportunities for substantial landscape integration between the carriageways, the design and execution of the urban design associated with the project works will be critical to the visual outcomes of the project. The urban design and landscape assessment considered elements of the project, including key structures (such as ventilation facilities) with reference to the WUDF, and with consideration of the visual amenity implications of the project upon the surrounding areas.

While the transformational potential of the project is likely to depend upon the delivery of the whole WestConnex program, that success would be founded on the quality of its constituent parts, including this project. The assessment was therefore particularly mindful of the design objectives, and of the need for sensitive integration within the project setting, and the impact of that upon communities and liveability.

The assessment found that the preferred design is generally consistent with the objectives and design principles set by the WUDF and Roads and Maritime design guidelines. However, it is difficult, at this early stage of the design resolution, to be conclusive with regard to all of the required elements. Where exceptions exist it is generally due to the lack of detailed design resolution rather than inappropriate design.

The assessment considered the potential for the project to enhance connectivity across Parramatta Road. To this end, the design commitments include continued and careful consideration of future public transport, pedestrian and cycle links with Parramatta Road, with reference to the objectives of the Parramatta Road Urban Transformation Program.

The assessment also considered the residual land proposed by the project. However, there is no detail at this stage as to the potential future uses of those lands, other than defined areas of public amenity. The design commitments therefore include further investigation of potential land uses supported by outline development guidelines, such as future building heights, setbacks and densities, to better define the future character of these sites. The future desired character of these lands is based on existing relevant Local Government Authority planning strategies.

1 Introduction

1.1 Overview of the project

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to upgrade and extend the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield. This includes twin tunnels about 5.5 kilometres long and associated surface works to connect to the existing road network. These proposed works are described as the M4 East project (the project). The location of the project is shown in .

Approval is being sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). The project was declared by the Minister for Planning to be State significant infrastructure and critical State significant infrastructure and an environmental impact statement (EIS) is therefore required.

The project is a component of WestConnex, which is a proposal to provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. The location of WestConnex is shown in . The individual components of WestConnex are:

- M4 Widening – Pitt Street at Parramatta to Homebush Bay Drive at Homebush (planning approval granted and under construction)
- M4 East (the subject of this report)
- New M5 – King Georges Road at Beverly Hills to St Peters (planning application lodged and subject to planning approval)
- King Georges Road Interchange Upgrade (planning approval granted and work has commenced)
- M4–M5 Link – Haberfield to St Peters, including the Southern Gateway and Southern Extension (undergoing concept development and subject to planning approval).

Separate planning applications will be lodged for each individual component project. Each project will be assessed separately, but the impacts of each project will also be considered in the context of the wider WestConnex.

The NSW Government has established the WestConnex Delivery Authority (WDA) to deliver WestConnex. WDA has been established as an independent public subsidiary corporation of Roads and Maritime. Its role and functions are set out in Part 4A of the *Transport Administration (General) Regulation 2013* (NSW). WDA is project managing the planning approval process for the project on behalf of Roads and Maritime. However, for the purpose of the planning application for the project, Roads and Maritime is the proponent.

1.2 Project location

The project is generally located in the inner west region of Sydney within the Auburn, Strathfield, Canada Bay, Burwood and Ashfield local government areas (LGAs). The project travels through 10 suburbs: Sydney Olympic Park, Homebush West, Homebush, North Strathfield, Strathfield, Concord, Burwood, Croydon, Ashfield and Haberfield.

The project is generally located within the M4 and Parramatta Road corridor, which links Broadway at the southern end of the Sydney central business district (CBD) and Parramatta in Sydney's west, about 20 kilometres to the west of the Sydney CBD. This corridor also provides the key link between the Sydney CBD and areas further west of Parramatta (such as Penrith and western NSW).

The western end of the project is located at the interchange between Homebush Bay Drive and the M4, about 13 kilometres west of the Sydney CBD. The project at this location would tie in with the M4 Widening project in the vicinity of Homebush Bay Drive.

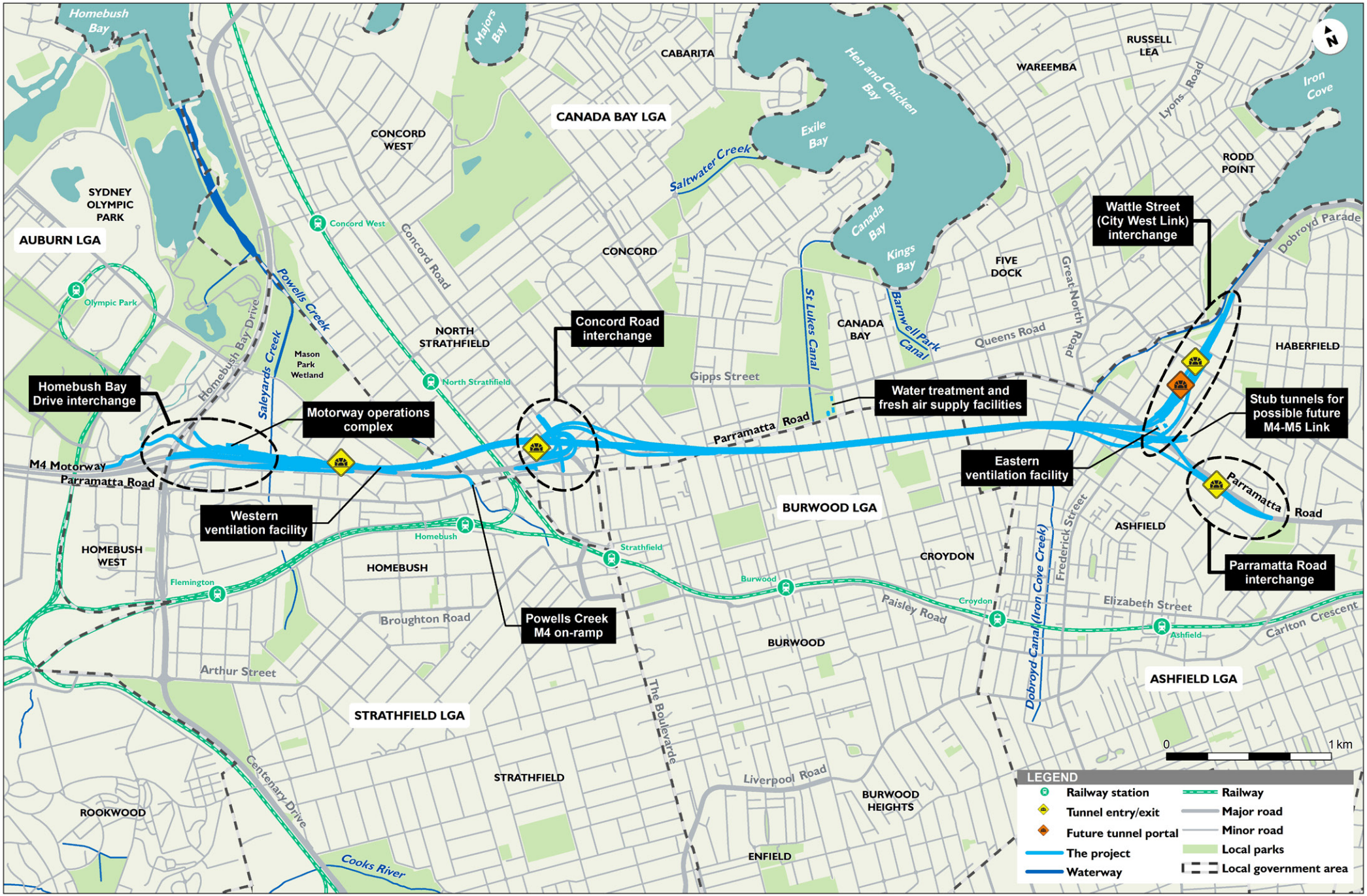


Figure 1.1 Local context of the project

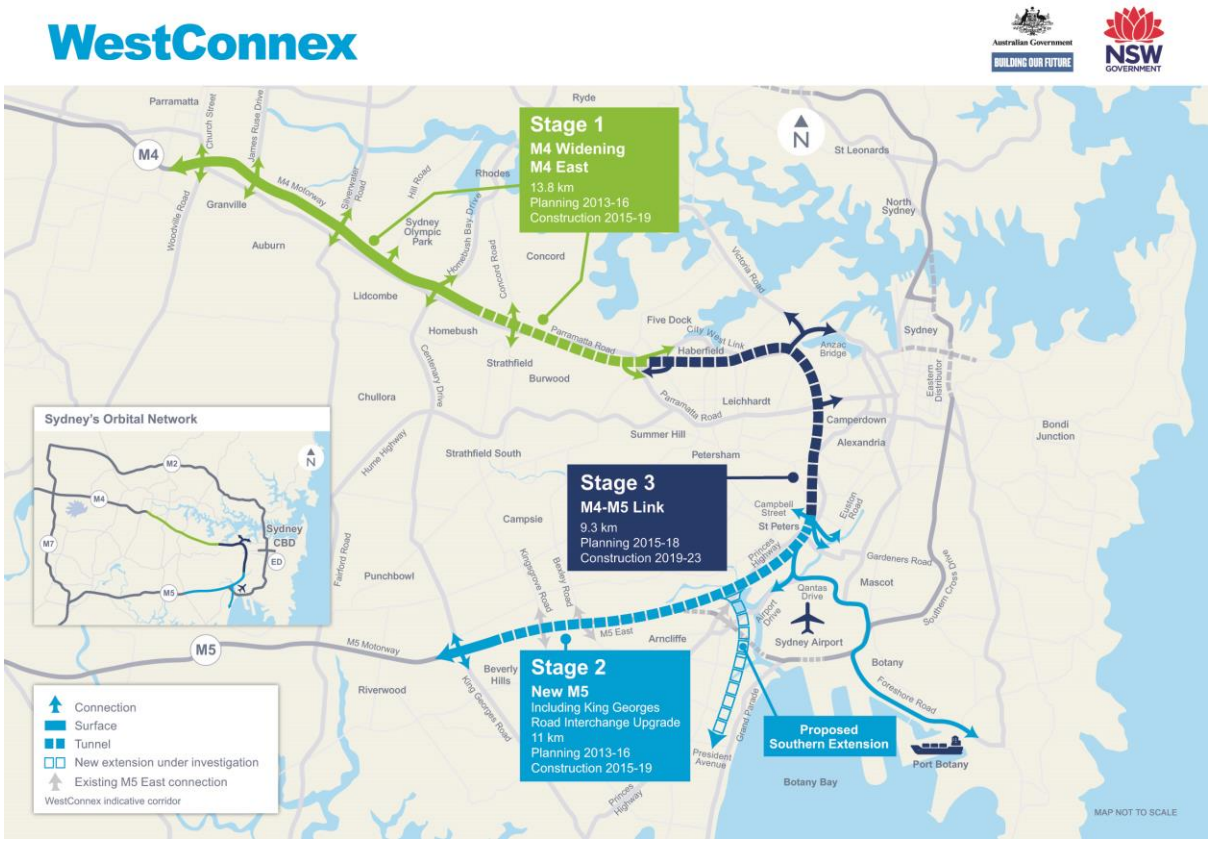


Figure 1.2 WestConnex

The tunnel dive structures would start at the centre of the M4, west of the existing pedestrian footbridge over the M4 at Pomeroy Street, and would continue underground to the north of the existing M4 and Parramatta Road, before crossing beneath Parramatta Road at Broughton Street at Burwood. The tunnels would continue underground to the south of Parramatta Road until the intersection of Parramatta Road and Wattle Street at Haberfield. Ramps would connect the tunnels to Parramatta Road and Wattle Street (City West Link) at the eastern end of the project. The tunnels would end in a stub connection to the possible future M4–M5 Link (M4–M5 Link), near Alt Street at Haberfield.

The project would include interchanges between the tunnels and the above ground road network, along with other surface road works, at the following locations:

- M4 and Homebush Bay Drive interchange at Sydney Olympic Park and Homebush (Homebush Bay Drive interchange)
- Powells Creek, near George Street at North Strathfield (Powells Creek M4 on-ramp)
- Queen Street, near Parramatta Road at North Strathfield (Queen Street cycleway westbound on-ramp)
- M4 and Sydney Street, Concord Road and Parramatta Road interchange at North Strathfield (Concord Road interchange)
- Wattle Street (City West Link), between Parramatta Road and Waratah Street at Haberfield (Wattle Street (City West Link) interchange)
- Parramatta Road, between Bland Street and Orpington Street at Ashfield and Haberfield (Parramatta Road interchange).

1.3 Secretary's environmental assessment requirements

The NSW Department of Planning and Environment has issued a list of Secretary's Environmental Assessment Requirements (SEARs) that inform the environmental impact assessment. **Table 1.1** displays the SEARS that are specific to visual impact and urban design; and also provides a cross reference to the relevant section(s) of this report which address these requirements.

In addition, two agency letters, which accompany the SEARs and are applicable to visual impact and urban design, were issued by Strathfield Council and Ashfield Council.

Table 1.2 provides details of the visual impact and urban design requirements outlined in the agency letters and a cross reference to the relevant section(s) of this report which address these conditions.

Table 1.1 How SEARs have been addressed in this report

SEARs	
Urban design and visual amenity requirements	
Requirement	**Section where addressed in report**
a consideration of the urban design and visual amenity implications of the project, including supporting infrastructure, during construction and operation. The assessment must: – identify urban design and landscaping objectives to enhance the interchanges, tunnels, cut-and-cover and 'slot' arrangements – consider resulting residual land and treatments – demonstrate how the proposed hard and soft urban design elements of the project would be consistent with the existing and desired future character of the area	Potential impacts to visual amenity during the construction and operation phase are provided in **chapters 5** and **6**. Urban design and landscaping objectives are provided in **section 2.1**. Operational urban design is considered in **section 6.3**. Consideration of the existing and desired future character of the area is provided in section **6.1**.
consideration of the WestConnex Urban Revitalisation Project	Consideration of the Parramatta Road Urban Renewal Program has been provided in **section 1.1.1**.
identification of opportunities to utilise surplus or residual land, and utilise key structures (such as stacks) for multiple uses i.e. integration with other structures	Operational urban design is considered in **section 6.3.2**.
identification and evaluation of the visual impacts and urban design aspects of the project (and its components) on surrounding areas	Consideration and assessment of potential visual impacts on receivers is provided in **sections 6.1**.and **0**.
a consideration of impacts on views and vistas, streetscapes, key sites and buildings	Consideration and assessment of potential visual impacts on receivers is provided in in **sections 6.1**.and **0**.
identification of measures to create, promote and enhance connectivity across Parramatta Road, where impacts to connectivity are associated with the project	An assessment of connectivity measures is provided in **section 1.1.1**.
measures to manage lighting impacts both during construction and operation	Management and mitigation measures for lighting during construction and operation are provided in **Chapter 7**.
artists' impressions and perspective drawings of the proposal from a variety of locations along and adjacent to the route	Artist's impressions of the project are provided in **section 2.3**.

Table 1.2 How agency comments have been addressed in this report

Agency letters	
Strathfield Council	
Requirement	**Section where addressed in report**
5. Urban Design Report/Visual Impact Statement to assess (and mitigate) the impacts of the proposed M4 East and associated tunnelling works on the adjacent areas of the Parramatta Road Corridor. This includes the existing Medium/High Density Residential and Mixed Used zoned areas.	**Chapter 5** Assessment of construction impacts **Section 6.1** Landscape character impact assessment **Section 6.2** Desired future character assessment **Section 6.3** Urban design assessment **Section 7.1** Landscape character mitigation strategy **Section 7.2** Urban Design mitigation strategy
Ashfield Council	
Requirement	**Section where addressed in report**
The portals and their 'land cuttings' for the associated entry and exit laneways have the potential to create a poor visual setting, including for adjacent residential areas in the Haberfield Conservation area. Vehicles using entry and exit laneways are also likely to create high levels of noise for adjoining properties, including nearby residences. The following details must therefore be provided in the EIS: The design of any 'noise screening walls or devices'. The design of 'noise screening walls or devices', accompanied with a report by a qualified acoustic engineer, explaining how effective they will be in reducing noise impacts for adjoining properties. How any residual areas which are part of the portal/roadway works will be treated and designed. How any visually exposed parts of the portal/slip lanes will be visually screened, such as side walls. Landscaping treatments around portal sites and entry/exit laneways. In addition to plans and elevations, the above should be graphically demonstrated in three dimensions to enable the public to adequately evaluate the proposals.	**Section 6.1** Landscape character impact assessment **Section 6.3** Urban design assessment **Section 7.1** Landscape character mitigation strategy **Section 7.2** Urban Design mitigation strategy **Section 2.3** (Perspective images)
The DGRs should also specify a requirement for the EIS to address cumulative impacts of the proposal across all major issues – traffic, noise, vibration, social, health, visual, heritage, biodiversity, environmental, climate change, flooding, water quality, etc.	**Section 6.1** Landscape character impact assessment **Section 6.2** Desired future character assessment **Section 6.3** Urban design assessment **Section 7.1** Landscape character mitigation strategy **Section 7.2** Urban Design mitigation strategy

1.4 Purpose of this report

The purpose of this report is to inform the Environmental Impact Statement (EIS) for the project, including:

- Addressing the Secretary's environmental assessment requirements
- Provision of a landscape character and visual impact assessment that considers the potential visual impacts (adverse and beneficial) that are likely to occur as a result of the project
- Assessing the contractor's urban design and landscape concept to inform the detailed design of the project.

1.5 Structure of this report

The document has been divided into the following key sections:

- **Chapter 2** – Provides an overview of the proposed project
- **Chapter 3** – Outlines the assessment methodology undertaken
- **Chapter 4** – Describes the landscape and design framework context for the project
- **Chapter 5** – Assesses the potential visual impacts of the project during construction
- **Chapter 6** – Assesses the potential visual and landscape character impacts and urban design components of the project during operation
- **Chapter 7** – Details the proposed management measures required to mitigate impacts.
- **Chapter 8** – Provides a conclusion to the report.

2 Proposed project

2.1 Project features

The project would comprise the construction and operation of the following key features:

- Widening, realignment and resurfacing of the M4 between Homebush Bay Drive and Underwood Road at Homebush
- Upgrade of the existing Homebush Bay Drive interchange to connect the western end of the new tunnels to the existing M4 and Homebush Bay Drive, while maintaining all current surface connections
- Two new three-lane tunnels (the mainline tunnels), one eastbound and one westbound, extending from west of Pomeroy Street at Homebush to near Alt Street at Haberfield, where they would terminate until the completion of the M4–M5 Link. Each tunnel would be about 5.5 kilometres long and would have a minimum internal clearance (height) to in-tunnel services of 5.3 metres
- A new westbound on-ramp from Parramatta Road to the M4 at Powells Creek, west of George Street at North Strathfield
- An interchange at Concord Road, North Strathfield/Concord with on-ramps to the eastbound tunnel and off-ramps from the westbound tunnel. Access from the existing M4 to Concord Road would be maintained via Sydney Street. A new on-ramp would be provided from Concord Road southbound to the existing M4 westbound, and the existing on-ramp from Concord Road northbound to the existing M4 westbound would be removed
- Modification of the intersection of the existing M4 and Parramatta Road, to remove the left turn movement from Parramatta Road eastbound to the existing M4 westbound
- An interchange at Wattle Street (City West Link) at Haberfield with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. The project also includes on- and off-ramps at this interchange that would provide access to the M4–M5 Link. In addition, the westbound lanes of Wattle Street would be realigned
- An interchange at Parramatta Road at Ashfield/Haberfield, with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. In addition, the westbound lanes of Parramatta Road would be realigned
- Installation of tunnel ventilation systems, including ventilation facilities within the existing M4 road reserve near Underwood Road at Homebush (western ventilation facility) and at the corner of Parramatta Road and Wattle Street at Haberfield (eastern ventilation facility). The eastern ventilation facility would serve both the project and the M4–M5 Link project. Provision has also been made for a fresh air supply facility at Cintra Park at Concord
- Associated surface road work on the arterial and local road network, including reconfiguration of lanes, changes to traffic signalling and phasing, and permanent road closures at a small number of local roads
- Pedestrian and cycle facilities, including permanently re-routing a portion of the existing eastbound cycleway on the northern side of the M4 from west of Homebush Bay Drive to near Pomeroy Street, and a new westbound cycleway on-ramp connection from Queen Street at North Strathfield to the existing M4
- Tunnel support systems and services such as electricity substations, fire pump rooms and tanks, water treatment facilities, and fire and life safety systems including emergency evacuation infrastructure
- Motorway operations complex on the northern side of the existing M4, east of the Homebush Bay Drive interchange
- Provision of road infrastructure and services to support the future implementation of smart motorway operations (subject to separate planning approval)

- Installation of tolling gantries and traffic control systems along the length of the project
- Provision of new and modified noise walls
- Provision of low noise pavement for new and modified sections of the existing M4
- Temporary construction ancillary facilities and temporary works to facilitate the construction of the project.

An overview of the project at completion is shown in **Figure 2.1**.

The project does not include work required for reconfiguring Parramatta Road as part of the urban transformation program. The project does not include ongoing motorway maintenance activities during operation. These would be subject to separate assessment and approval as appropriate.

2.2 Construction activities

2.2.1 Overview

Construction activities associated with the project would generally include:

- Enabling and temporary works, including construction power, water supply, ancillary site establishment, demolition works, property adjustments and public transport modifications (if required)
- Construction of the road tunnels, interchanges, intersections and roadside infrastructure
- Haulage of spoil generated during tunnelling and excavation activities
- Fitout of the road tunnels and support infrastructure, including ventilation and emergency response systems
- Construction and fitout of the motorway operations complex and other ancillary operations buildings
- Realignment, modification or replacement of surface roads, bridges and underpasses
- Implementation of environmental management and pollution control facilities for the project.

The project assessed in this report does not include surveys, sampling or investigation to inform the design or assessment, such as test drilling, test excavations, geotechnical investigations, or other tests. It also does not include adjustments to, or relocation of, existing utilities infrastructure undertaken prior to commencement of construction. These would be subject to separate assessment and approval as appropriate.

2.2.2 Construction footprint

The total area required for construction of the project, including construction ancillary facilities, is referred to as the ‘construction footprint’. The construction footprint would be about 65 hectares in total, comprising about 48 hectares at the surface and about 17 hectares below ground.

In addition to below ground works, surface works would be required to support tunnelling activities and to construct surface infrastructure such as interchanges, tunnel portals, ventilation facilities, ancillary operations buildings and facilities, and new cycleway facilities near the Homebush Bay Drive interchange and Queen Street at North Strathfield.

The overall surface construction footprint generally aligns with the operational footprint, with the locations of future operational ancillary facilities being used to support construction work. Some additional areas adjacent to the operational footprint (around the portals and on- and off-ramps, and also at the tunnel mid-point) would also be required during the construction stage only to facilitate construction.

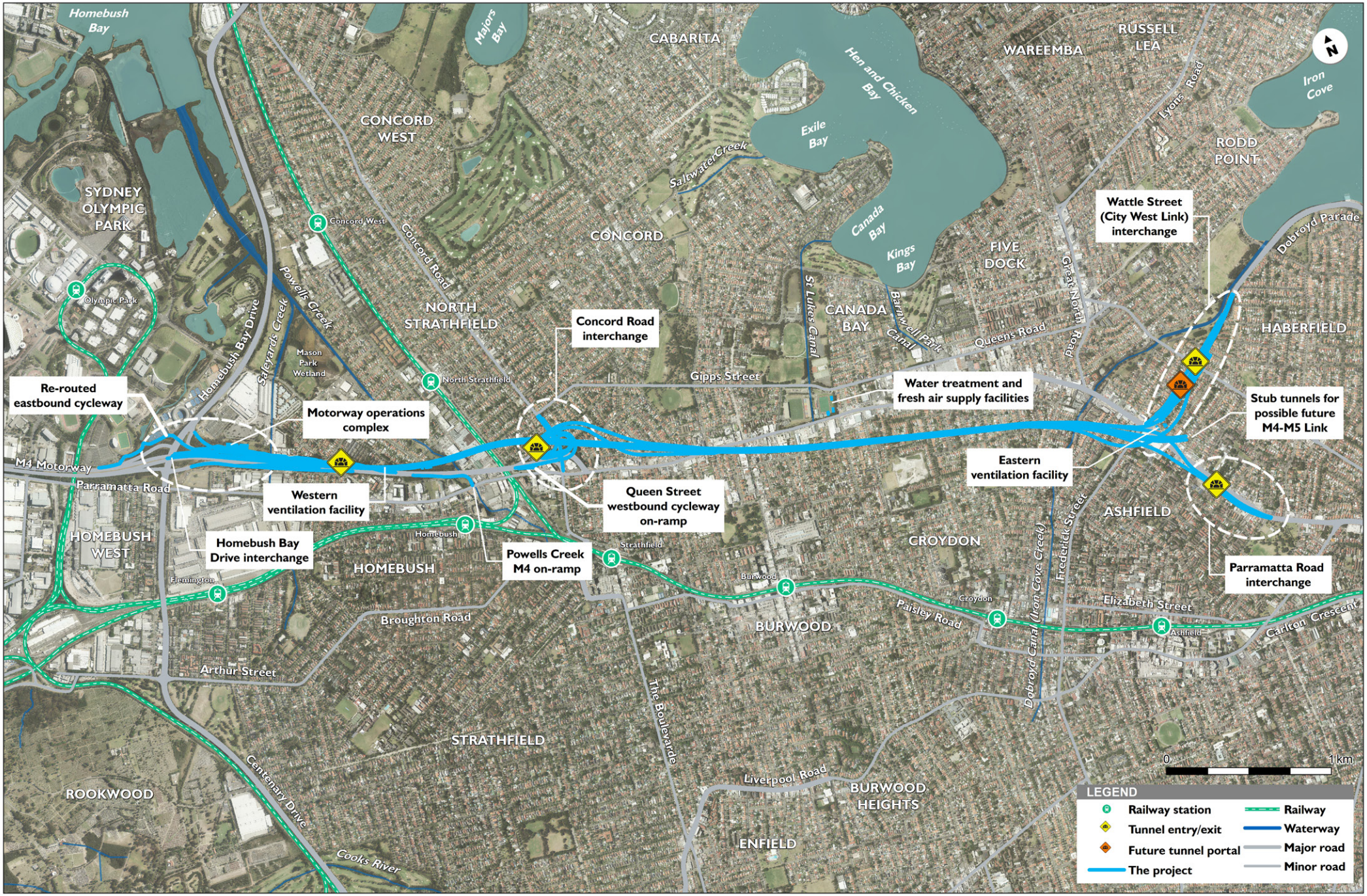


Figure 2.1 Overview of the proejct

Construction ancillary facilities currently proposed would be required at the following 10 locations:

- Homebush Bay Drive civil site (C1)
- Pomeroy Street civil site (C2)
- Underwood Road civil and tunnel site (C3)
- Powells Creek civil site (C4)
- Concord Road civil and tunnel site (C5)
- Cintra Park tunnel site (C6)
- Northcote Street tunnel site (C7)
- Eastern ventilation facility site (C8)
- Wattle Street and Walker Avenue civil site (C9)
- Parramatta Road civil site (C10).

An overview of the construction footprint is shown in .

The final size and configuration of construction ancillary facilities would be further developed during detailed design.

2.2.3 Construction program

Subject to planning approval, construction of the project is planned to start in the second quarter of 2016, with completion planned for the first quarter of 2019. The total period of construction works is expected to be around three years, including nine months of commissioning occurring concurrently with the final stages of construction. The indicative construction program is shown in .

Table 2.1 Indicative construction program overview

Construction activity	Indicative construction timeframe															
	2016				2017				2018				2019			
Construction access excavation (all sites)		■	■	■												
Tunnelling (excavation)			■	■	■	■	■	■								
Tunnel drainage and pavement works						■	■	■	■	■						
Tunnel mechanical and electrical fitout works								■	■	■	■					
Tunnel completion works											■	■	■			
Homebush Bay Drive interchange			■	■	■	■	■	■	■	■	■					
M4 surface works		■	■	■	■	■	■	■	■	■	■	■				
Western ventilation facility							■	■	■	■	■					
Powells Creek on-ramp		■	■	■	■	■										
Concord Road interchange			■	■	■	■	■	■	■	■	■	■				
Wattle Street interchange		■	■	■	■	■	■	■	■	■	■	■	■			
Parramatta Road interchange		■	■	■	■	■	■	■	■	■	■	■	■			
Eastern ventilation facility		■	■	■	■	■	■	■	■	■	■	■				
Cintra Park fresh air supply facility				■	■	■	■	■	■	■	■	■	■			
Cintra Park water treatment facility									■	■	■	■				
Motorway operations complex						■	■	■								
Mechanical and electrical fitout works							■	■	■	■	■	■				
Site rehabilitation and landscaping						■	■	■	■	■	■	■	■			

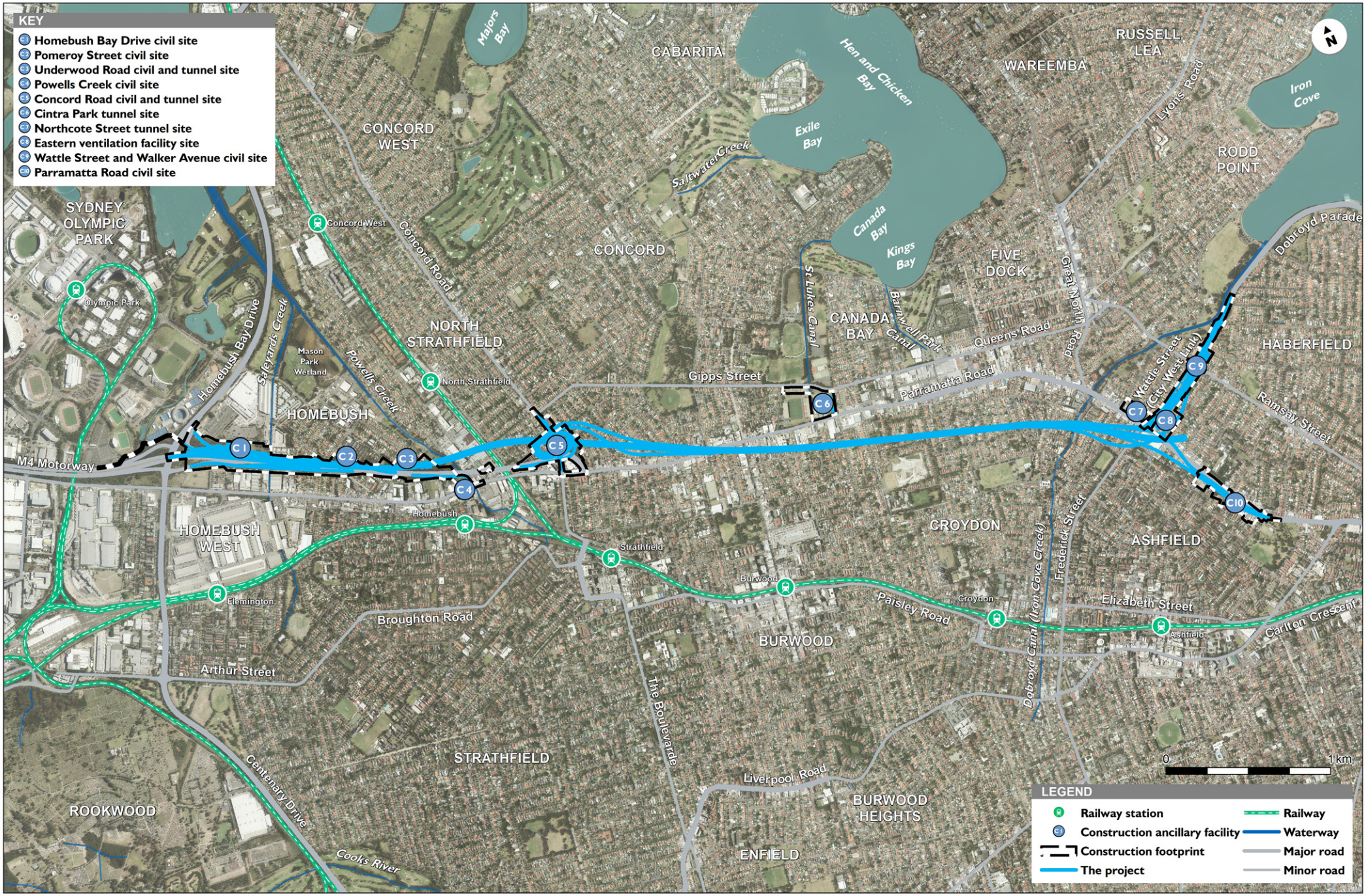


Figure 2.2 Overview of construction footprint and construction ancillary facilities

2.3 Overview of urban design proposal

The key urban and landscape design features of the project relevant to this assessment are outlined in the following sections and shown in preliminary urban design concept plans in **Appendix A**.

Homebush Bay Drive Interchange

- The existing interchange would be modified at the western end of the Motorway connecting the eastern extent of the M4 and the proposed tunnel, whilst maintaining vehicular movements between the existing M4 Motorway and Homebush Bay Drive and Concord and Parramatta Roads
- The western portal would be located between Pomeroy Street and Underwood Road and is a key element in the wider WestConnex project
- The entry and exit portals would present a memorable approach to the tunnel with architecturally designed wall and portal treatments that respond to motorway function and contribute to the motoring experience.



Figure 2.3 Artist's impression of the modified M4, looking east from Homebush Bay Drive

Motorway control centre, maintenance and ventilation facilities

- The motorway control centre and maintenance facilities proposed at Homebush Bay Drive, within the existing M4 road reservation, will provide for operations management and control systems. These would be screened from the M4 with shrub and tree plantings around the perimeter of the facility, and be accessible via the Homebush Bay Drive on-ramp.
- The western portal precinct would accommodate the architecturally designed western ventilation facility located adjacent to Underwood Road. This location would also provide an electrical distribution facility and access to tolling equipment over the eastbound on-ramp.
- Further to the east, adjacent to Ismay Avenue and north of the existing M4, would be fire pump storage tanks and a 33kV substation, all within architecturally designed facilities.



Figure 2.4 **Artist's impression of the modified M4, looking east above the western portal entry and exit ramps, with the proposed terracotta ventilation facility in the middle distance**

Concord Road interchange

- An interchange at Concord Road with northbound and southbound access to the M4 and tunnel.
- The design presents a compact solution that would minimise impacts on residential areas east of Concord Road.
- Existing pedestrian and public transport connectivity would be maintained and the proposal would establish two new pocket parks for the local community.
- An electrical distribution facility would be located above the cut-and-cover tunnel in Concord Lane accessible from Sydney Street. Land areas above the cut-and-cover tunnel would be returned for future redevelopment.



Figure 2.5 **Artist's impression of the modified Concord Road intersection, looking east across the portal entry and exit ramps**

Fresh air supply and water treatment facilities at Cintra Park

- The mid-tunnel facilities would be located at the Cintra Park next to Concord Oval and include fresh air supply and water treatment facilities, including a water treatment plant and water quality control pond.
- An electrical distribution facility designed to address the residential scale of the existing environs is proposed.



Figure 2.6 **Artist's impression of the modified Cintra Park, looking south towards Parramatta Road the fresh air supply facility would be the low rectangular building in the middle background, the other service buildings are arrayed along the left side of the picture.**

The M4 East tunnels

- A large portion of the overall project would be in tunnel, which would accommodate two new, three-lane through carriageways, extending from and connecting to the eastern extent of the project and to Parramatta Road east of Wattle Street, with interchanges at Concord Road and Wattle Street at Haberfield.
- The project provides architectural variation to vertical surfaces to visually and psychologically break up the extent of tunnel lengths.
- The proposal provides for the integration of lighting, signage and art to enhance the T\tunnel travel experience, subject to detailed design, and user and safety audits.

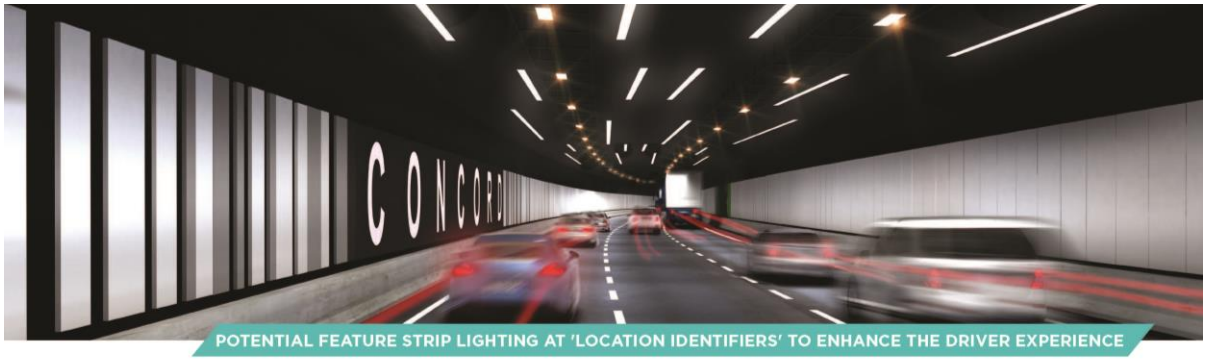




Figure 2.7 **Artist's impression of the tunnel interiors including architectural treatments that indicate location, provide visual variety and interest, and safety features.**

Wattle Street interchange

- The interchange at Wattle Street with northbound access to Wattle Street and southbound access to the M4, would include provision for access to connect with the possible future Stage 3 and continued vehicular access to Wattle Street.
- The interchange would combine the on- and off-ramps together in one portal location centrally located in the road reserve. This would allow the Wattle Street surface connections to run around the on- and off-ramps, providing a regular street edge condition to remain along both sides of Wattle Street, retaining existing pedestrian movements and connectivity.
- The proposed widened verges and widened central median area of the reconstructed Wattle Street, would present extensive new areas of landscaping, including a new turfed median, verge areas and expansive canopies of dense street tree plantings to provide shade and amenity. Much of the proposed landscaping would be located over the cut and cover structure of the Tunnel.
- Architecturally designed ventilation facilities would be located between Wattle Street and Walker Avenue, together with fresh air intakes, substations and maintenance facilities. The scale of the ventilation facility would be similar to that of the existing Bunnings building on the south west corner of the intersection opposite.
- For consistency, the on and off-ramp portal designs are proposed to be similar in to those at the western portal entry.



Figure 2.8 **Artist's impression of the Wattle Street interchange, looking south towards Parramatta Road above the portal entry and exit ramps**

Parramatta Road interchange

- An interchange on Parramatta Road between Bland Street and Ashfield Park, with eastbound access to Parramatta Road and westbound access to the M4.
- The eastern connection in Parramatta Road would combine the entry and exit portals in one location with a centrally located spatial provision for a future mass transit corridor.
- The on and off-ramp portal designs would be similar in to those at the western portal entry.
- The existing pedestrian bridge over Parramatta Road at Bland Street would be retained, however the southern stairs would be modified to accommodate the reconstructed westbound section of Parramatta Road. The existing stair would be removed and replaced with a new stair connecting to Bland Street.
- The proposal would provide a six metre wide verge with sufficient space to accommodate large shade bearing street trees. The northern and western areas of the central median would also be planted with avenues of street trees, providing shade and amenity for pedestrians and the local community.



Figure 2.9 **Artist's impression of the eastern portal at the Parramatta Road interchange, looking west towards the western ventilation stack in the middle distance**

3 Assessment methodology

3.1 Key guidelines and policies

The methodology for this landscape and visual impact assessment is undertaken in accordance with the Roads and Maritime *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (2013) (EIAG).

The EIAG states that there are two main purposes of landscape character and visual impact assessment:

- To inform the development of the preferred route and concept design so that the proposal can avoid and minimise impacts up front. It must be commenced early in the environmental impact assessment process to achieve this goal and integrated with the design process.
- To inform RMS, other agencies and the community about the landscape character and visual impact of the proposal and what avoidance, management and mitigation strategies would be implemented.

The EIAG distinguishes between landscape character impact and visual impact as:

> … landscape character assessment – the assessment of impact on the aggregate of an area's built, natural and cultural character or sense of place, and visual impact assessment – the assessment of impact on views.

Landscape character and visual assessment are equally important. Landscape character assessment helps determine the overall impact of a project on an area's character and sense of place. Visual impact assessment helps define the day to day effects of a project on people's views.

This dual assessment helps differentiate options, improve route alignment decisions and improve design outcomes.

This assessment of potential landscape and visual impacts has been undertaken on the current concept landscape and urban design of the proposed roadway and related infrastructure, within the context of the existing conditions within the project boundary. Reference has also been made to the third edition of the *Guidelines for Landscape and Visual Impact Assessment* (2013) (GLVIA), produced jointly by the (UK) Landscape Institute and the Institute of Environmental Management & Assessment.

3.2 Key assumptions

The conceptual landscape design applies only to:

- Residual land identified by the project as being dedicated for landscaping purposes (ie areas coloured green)
- M4 corridor edges where landscape remediation is required, eg above cut-and-cover elements and adjoining new infrastructure elements
- New verges to Parramatta Road, where it is assumed that existing overhead power lines would be placed underground as part of the project, making provision for street tree planting.

Given that it is unknown at this stage how residual land other than that identified for landscaping purposes would be used, these areas are assessed as being empty, grassed sites enclosed with security fencing. Additionally, proposed landscape treatments are assessed as being at an early stage of growth (12–18 months) and then at 10 years after opening, to ensure a reasonable, conservative approach to any beneficial effects of vegetative screening on the project.

On the basis of the above, it can be expected that the landscape character and visual impact assessment ratings derived within this report would improve when:

- Residual lands are developed with regard to the urban design and landscaping objectives and principles with the WUDF, other relevant planning documents for the Parramatta Road corridor, and council planning codes
- The project landscaping matures
- Mitigation measures are put in place.

Residual impacts

In accordance with the EIAG, rating of residual impacts is not undertaken. It can be expected that the impact assessment ratings would improve as a result of developing residual land; maturing of the landscape; and implementing of mitigation measures as described above. However, given that the level of success with which these elements would be implemented cannot be measured at this stage, the EIAG defers to a position of assumed likely improved outcomes only.

3.3 Methodology

3.3.1 Document review and government liaison

Key documents reviewed for this project were:

- WestConnex–M4 East, Application SSI 13_6307, 7 January 2014
- Parramatta Road: Westconnex Urban Renewal Framework; A Living Street: A Corridor of Enterprise', Hassell, 7 August 2013
- *Westconnex Motorway Urban Design Framework: WestConnex – "City Shaping Infrastructure*", Hassell in collaboration with Westconnex Delivery Authority – Roads and Maritime Services, Centre For Urban Design, 13 September 2013
- Parramatta Road Urban Renewal Project: Urban Amenity Improvement Plan, Cox/Oculus, 12 March 2014
- Parramatta Road Urban Renewal Project: Final Report, Cox/Oculus, 12 March 2014
- Parramatta Road Urban Renewal Project: Motorway Integration Plan Design Report Plan, Cox/Oculus, 8 April 2014.

Periodic liaison was undertaken with WDA and the Roads and Maritime Centre for Urban Design.

3.3.2 Existing environment

The methodology commenced with an assessment of the existing environment. For the purposes of this assessment, this was undertaken through a combination of reference to the project documentation, desktop review and site inspection.

Landscape character zones

In order to assess landscape character impact, landscape character zones (LCZ) were identified across the project boundary. The landscape character zones were defined as areas of landscape with similar properties or strongly defined spatial qualities, which are visually distinct from adjoining areas. As much of the project would comprise of tunnelled motorway, the landscape character units were focussed around areas of proposed surface works, including the proposed interchanges, the operational water treatment plant and discharge location at the Cintra Park hockey facility, and the ventilation facilities.

Existing Views

The existing visual environment along the project has been assessed through a desktop review of aerial photography, geographic information system (GIS) mapping of topography and vegetation, land use mapping and site inspections.

Key existing views were identified based on a range of criteria, some or all of which informed the decision, including:

- Where there was a significant change between the before and after view
- Where there was potential for a significant adverse visual outcome for sensitive receivers, eg residents from their homes, and local receivers participating in passive recreation such as walking along quiet, attractive streets or through parks
- Where there was potential for a significant adverse visual outcome to locations of high visual amenity
- Where there was potential for a significant adverse visual outcome to heritage listed items or Heritage Conservation Areas (HCAs)
- Where the view was representative of other similar settings, in which there was potential for a similar adverse outcome in eg on the character of a streetscape.

3.3.3 Urban and landscape design review

A review of the urban design and landscape implications was undertaken of the project components, including supporting infrastructure, during construction and operation. Key elements of this process included:

- Identification of urban and landscape design objectives of the project to enhance the interchanges, tunnels, cut-and-cover and slot arrangements
- Provision of an overview description of urban design and landscape concept for the project
- Consideration of residual land and treatments, including identification of opportunities to utilise surplus or residual land, and utilise key structures (such as stacks) for multiple uses
- Identification of measures to create, promote and enhance connectivity across Parramatta Road, where impacts to connectivity are associated with the project
- Demonstration of how the proposed urban and landscape design elements would be consistent with the existing and desired future character of the area.

3.3.4 Landscape character and visual impact assessment

Separate impact assessments were undertaken for:

- Landscape character – to evaluate the potential impact of the project on the combined quality of the built, natural and cultural aspects that make up areas within the project boundary and provide their unique sense of place
- Visual impact – to evaluate the potential impact of the project on existing views.

The method applied to measure both landscape character and visual impact comprised a sensitivity analysis of each existing landscape zones or views subject to change, and an assessment of the magnitude of change on that zone or view. Professional judgement and experience is applied on a case by case basis to identify qualitative levels of significance for each receptor (refer **Table 3.1**).

Table 3.1 Landscape character and visual impact grading matrix

Visual impact		Magnitude of change			
		High	**Moderate**	**Low**	**Negligible**
Sensitivity of receptors	**High**	High	High–moderate	Moderate	Negligible
	Moderate	High–moderate	Moderate	Moderate–low	Negligible
	Low	Moderate	Moderate–low	Low	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

Source: Roads and Maritime (March 2013)

Sensitivity

The EIAG states that:

> *Sensitivity refers to the qualities of an area, the type and number of receivers and how sensitive the existing character of the setting is to the proposed change. For example, a pristine natural environment will be more sensitive to change than a built up industrial area.*

The sensitivity of a landscape is based upon the extent to which it can accept change of a particular type and scale without adverse impacts upon its character or value. Sensitivity varies according to the type of proposed change, number of receivers and nature of the landscape, including:

- Inherent landscape value, eg its condition, perceptual qualities, and cultural importance
- The likely congruency of the proposed change, i.e. the extent to which the proposal may 'fit' or be 'visually absorbed' into the landscape, eg in relation to line, colour, texture, form, scale, etc.

The sensitivity of visual receivers and views is dependent on:

- The location and context of the viewpoint
- The expectations and occupation or activity of the receptor
- The quality of the view
- The importance of the view
- The type and number of receivers
- The temporal duration of the viewer.

The most sensitive receptors may include:

- Occupiers of residences with views affected by a proposed change
- Receivers undertaking outdoor passive recreation activities
- Communities where the development results in changes in the landscape setting or valued views enjoyed by or which hold cultural significance to the community
- An area with a high frequency and range of users, eg outdoor recreational facilities including active recreation users.

Magnitude

The magnitude of change affecting a landscape or visual receptor depends on factors such as the nature, scale and duration of the particular change that is expected to occur. In the landscape, the magnitude of change would depend on factors such as the extent of loss, change or addition of any feature, or any change in the backdrop to, or outlook from a landscape that affects its character. The magnitude of change on a view would depend on factors such as the extent of visibility of the change (refer 'visual envelope mapping' below), degree of obstruction of existing features, degree of contrast with the existing view, angle of existing view, duration of view, and distance from the change.

Visual envelope mapping

The likely visibility of the proposed elements of the project from surrounding areas has been broadly mapped, to create a visual envelope. This provides a measure of which parts of the project are likely to be viewed from large areas of surrounding development, and which may therefore be potentially more visually sensitive when compared to other components of the project where direct views may be limited.

Consideration of landscaping treatments

Landscaping treatments proposed as part of the project are considered as part of the assessment process, but for the purposes of the assessment process, have been considered only in relation to an early stage of planting (ie after 12–18 months) and then at 10 years after opening. This approach is in accordance with the EIAG. The mature landscape is however considered as a mitigation measure.

Visualisations

Photographic panoramas, created using a wide angle lens, have been used as a base for graphic visualisations which depict elements of the proposed project. Where necessary, photos were stitched together. Each panorama was then zoomed in to the area of interest within it.

Assessment of night lighting impacts

A broad assessment of the impacts of night lighting during both the construction and operation phases of the project was undertaken, by applying the methodology for assessment of visual impacts described previously.

The following assumptions are made with regard to the assessment process:

- The assessment is not based on a lighting design, but rather assumptions have been made with regard to the types and extent of lighting likely to be installed for both the construction and operation phases
- There is no assessment of existing or proposed luminance levels
- Construction lighting does not include construction vehicles entering and leaving the sites and is assumed to be:
  - In place over a period of up to four years
  - In operation seven days a week
  - At levels sufficient to meet occupational health and safety levels, and security levels.

Operational lighting is assumed to be:

- In operation seven days a week
- At levels sufficient to meet occupational health and safety levels, and security levels.

3.3.5 Mitigation measures

Upon completion of the impact assessments, a series of potential mitigation measures were developed in response to the specific impacts identified through the assessment process.

4 Existing environment

4.1 Background

4.1.1 WestConnex Motorway character areas

The *WestConnex Motorway Urban Design Framework* (WUDF) provides a corridor analysis of character areas and road user experience, identifying six character areas along the full length of the overall project (stages 1, 2 and 3). The character areas relevant to the project comprise:

- Character area 1: Industrial, commercial and retail – which runs between Parramatta and Concord. This character area incorporates the western portion of the project, broadly between Homebush Bay Drive and Concord Road
- Character area 2: Motor services and retail – which runs between Concord Road and Ashfield Park. This character area incorporates the eastern portion of the project, broadly between Concord Road and Ashfield Park.

This report develops a finer level of detail within these two character areas, and identifies a series of landscape character zones that more closely define specific landscape character types within what is a complex urban fabric.

4.1.2 Non-Aboriginal heritage

Significant heritage elements can in their own right define distinctive landscape character types within the broader urban context. Alternatively, recognition of their presence within a landscape character zone needs to be considered, as these may provide added weight when assessing receiver sensitivity to project effects.

This report identifies all State and locally listed non-Aboriginal heritage items located within or closely adjoining identified landscape character zones, and takes these into consideration when assessing the sensitivity of these zones and potential impacts to important views. Refer to Appendix B which includes mapping which locates items referred to in the body of this LVIA report.

4.2 Landscape character zones

The existing environment of the project boundary is highly urbanised, comprising broadly of:

- Major roads such as the M4, Concord Road, Parramatta Road and Wattle Street
- Residential areas including established low density residential areas in North Strathfield, Haberfield and Ashfield, and medium density and high density residential development including North Strathfield, Concord, Burwood, Croyden, Strathfield, Homebush, Haberfield and Ashfield
- Commercial and industrial areas, predominantly alongside the M4 and fronting onto Parramatta Road.

LCZs have been identified in those areas that have the potential to be impacted by the surface components of the project. The LCZs reflect the differences in character that are inherent in such a densely urbanised setting, due to factors such as the mix and period of housing types, interweaving of land uses, and the number of different land uses as described above. The following 15 LCZ have been identified within the project boundary (refer to **Figure 4.1**, **Figure 4.2** and **Figure 4.3**).

Western LCZs:

LCZ 1 – M4 Motorway (Homebush Bay Drive to Concord Road)

LCZ 2 – Homebush commercial precinct

LCZ 3 – Parramatta Road (west) precinct

LCZ 4 – Underwood Road precinct

LCZ 5 – Powells Creek precinct.

Central LCZs:

LCZ 6 – Concord Road precinct

LCZ 7 – Edward Street precinct

LCZ 8 – Concord Oval precinct.

Eastern LCZs:

LCZ 9 – Dobroyd Parade precinct

LCZ 10 – Wattle Street precinct

LCZ 11 – Parramatta Road (east) precinct

LCZ 12 – Haberfield precinct

LCZ 13 – Yasmar Juvenile Training Facility

LCZ 14 – Ashfield medium density precinct

LCZ 15 – Ashfield Park

Descriptions of each LCZ are provided in the following sections.

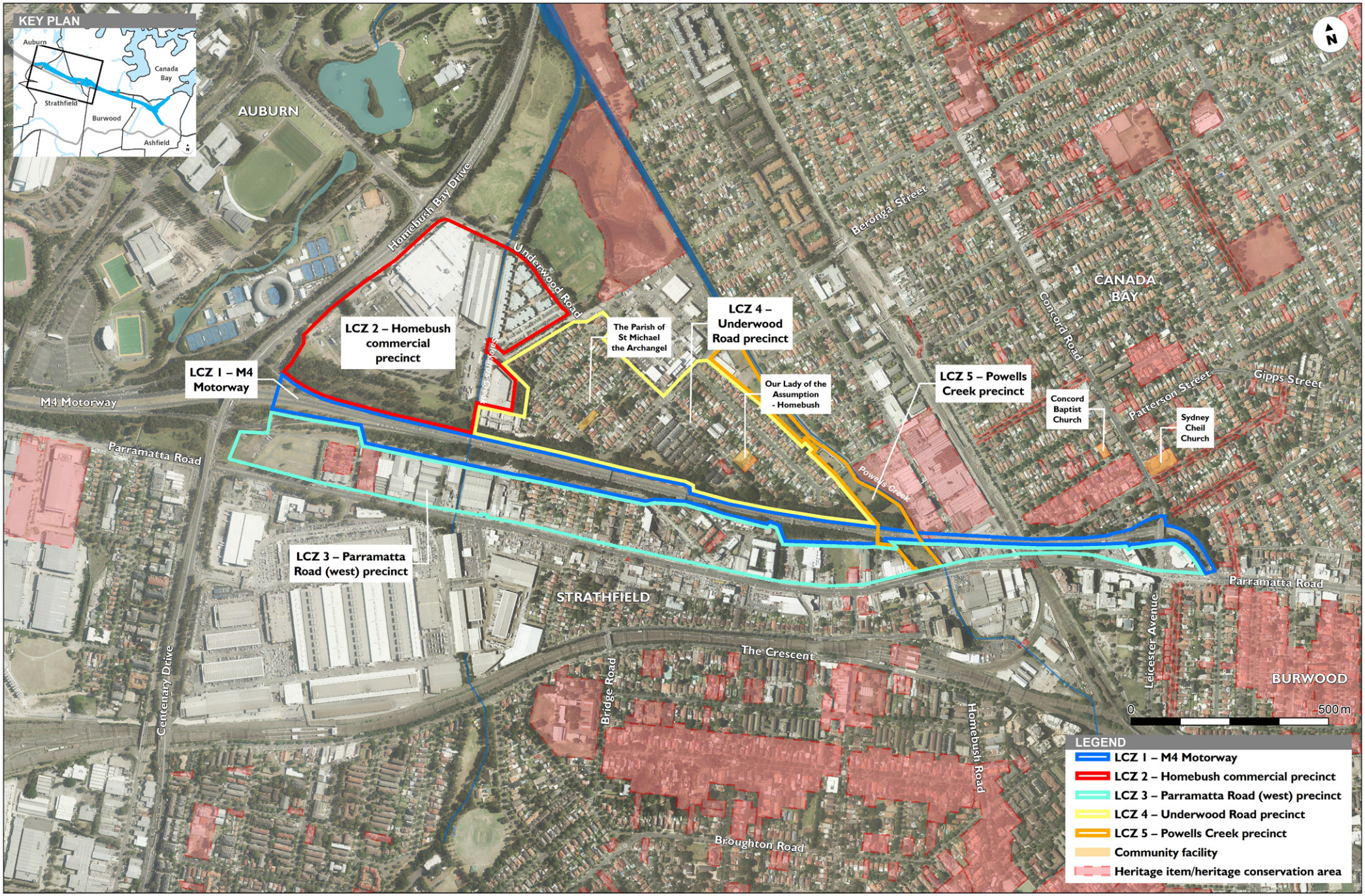


Figure 4.1 Western landscape character zones

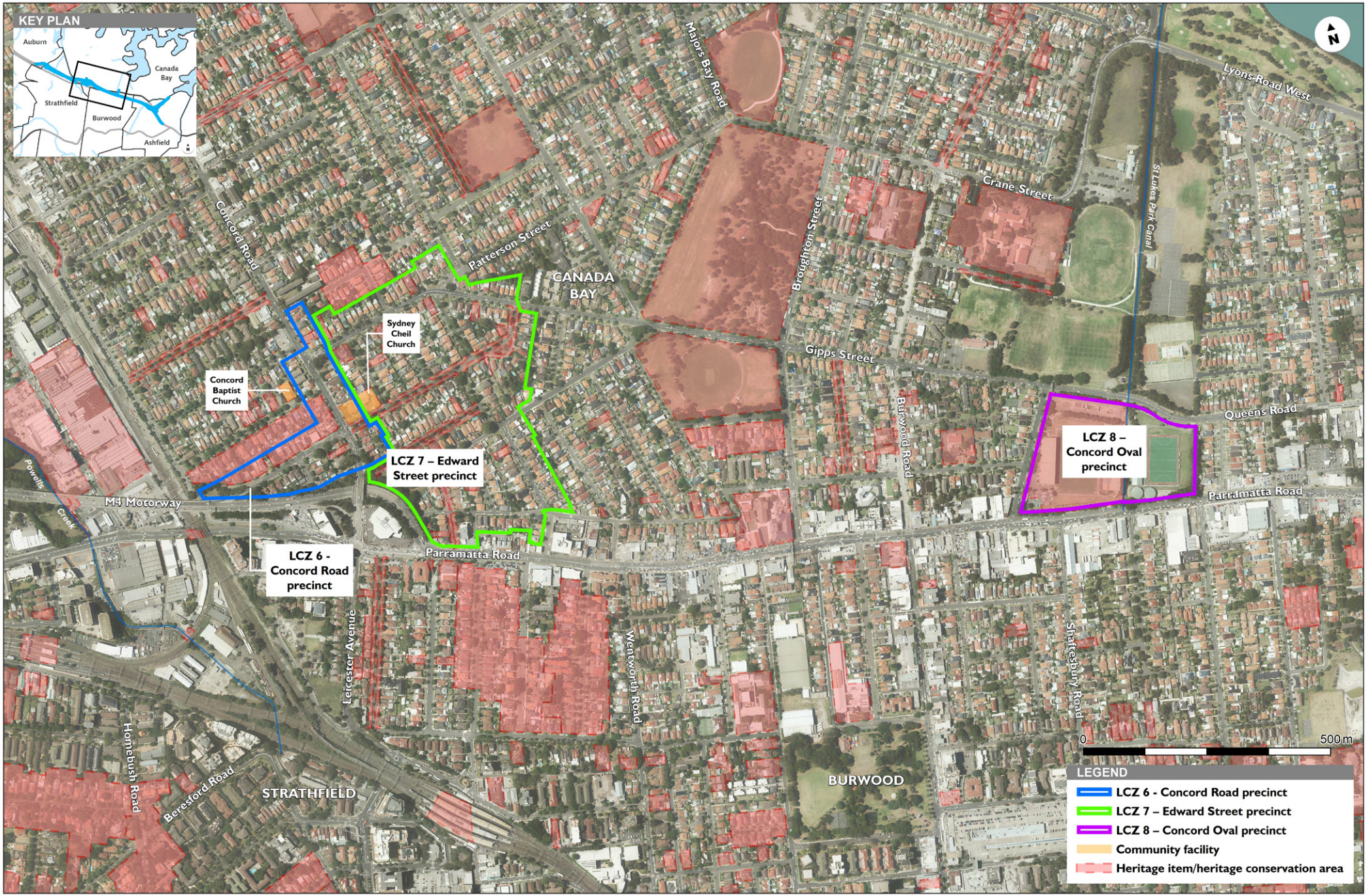


Figure 4.2 Central landscape character zones

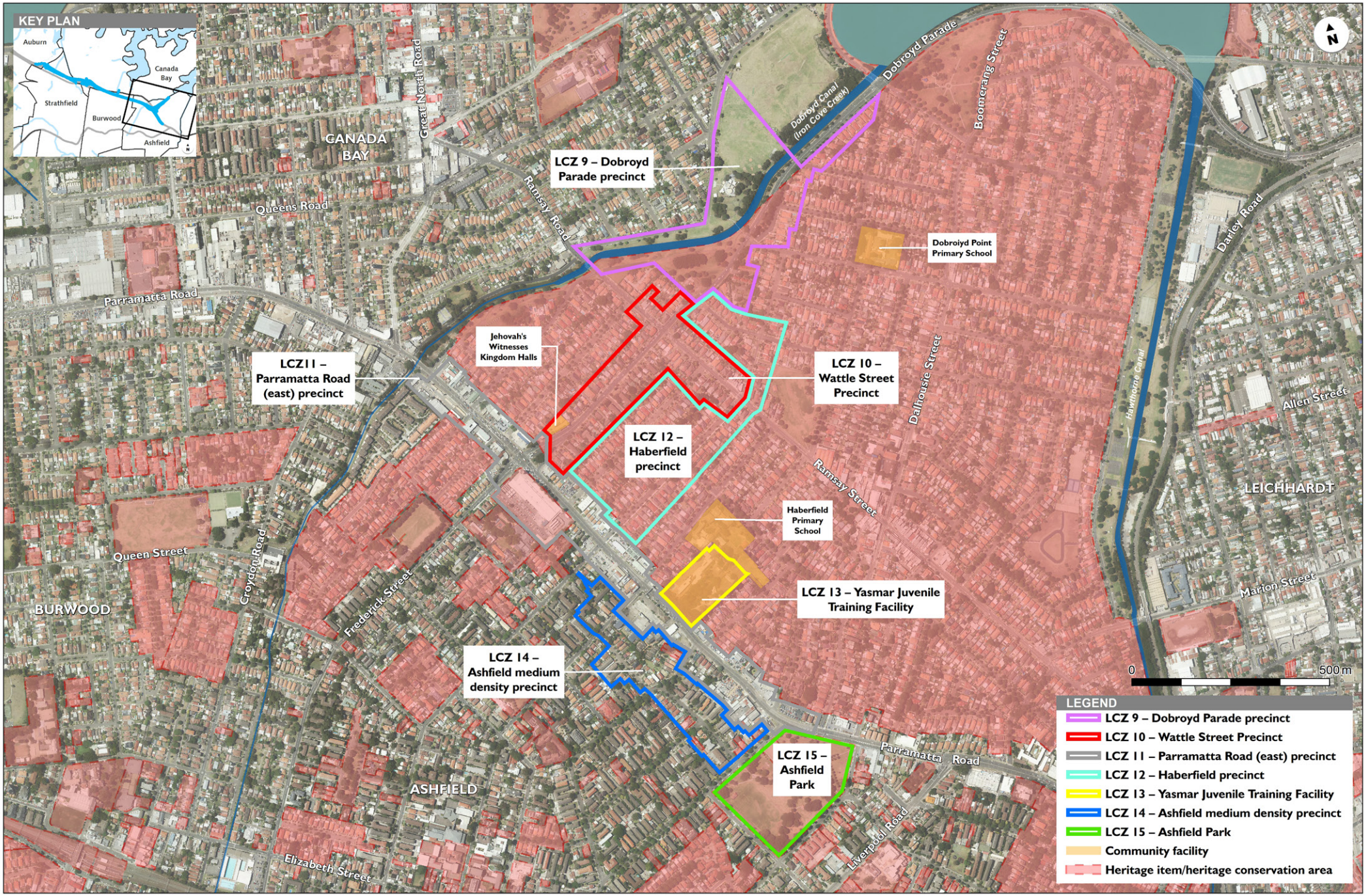


Figure 4.3 Eastern landscape character zones

4.2.1 LCZ 1 – M4 Motorway

This LCZ is characterised by the landscape of the M4. The portion of the M4 between immediately to the west of Homebush Bay Drive through to Parramatta Road has been assessed, as shown in **Figure 4.4** and **Figure 4.5**.

The western end of the LCZ extends from the Homebush Bay Drive interchange to Powells Creek and has two character sub-types as follows:

- Homebush Bay Drive interchange to about 200 metres west of Underwood Road. This section is viewed as a relatively narrow and strongly visually enclosed corridor. Screening of urban development adjoining this area is provided by steep batters around the interchange and along much of the southern edge; dense plantings of corridor edge; and a full suite of canopy and mid-stratum trees with shrub and grassy understorey. The northern edge is distinguished by a formal, sinuous landscape setting that was established for the Sydney Olympics but has since fallen into a state of disrepair (refer to **Figure 4.6**)
- From 200 metres west of Underwood Road to the M4 bridge crossing over Powells Creek. This section predominantly comprises a mix of generally narrower vegetated edges, a narrow road section with noise walls, and views periodically opening up towards the medium density residential development to the south (refer to **Figure 4.7**).

Views from the corridor then suddenly open up as the carriageway crosses a bridge of some 350 metres in length over Powells Creek and the Northern Rail Line. This provides motorists with extensive regional views across the landscape:

- To the north across North Strathfield to a mix of large office buildings and the historic Bakehouse Quarter in the foreground, with a middleground view across low density residential development characterised by substantial tree canopy interspersed with red terracotta rooves (refer to **Figure 4.8**)
- To the south, views across commercial development adjacent to the Parramatta Road corridor and high density residential development in Strathfield (refer to **Figure 4.9**)
- The eastern end of the corridor extends from the Concord Road off-take lane (Sydney Street) to the intersection with Parramatta Road. The character reflects that of the above, predominantly densely vegetated edges with an opening to the south over mixed commercial and high density residential development.

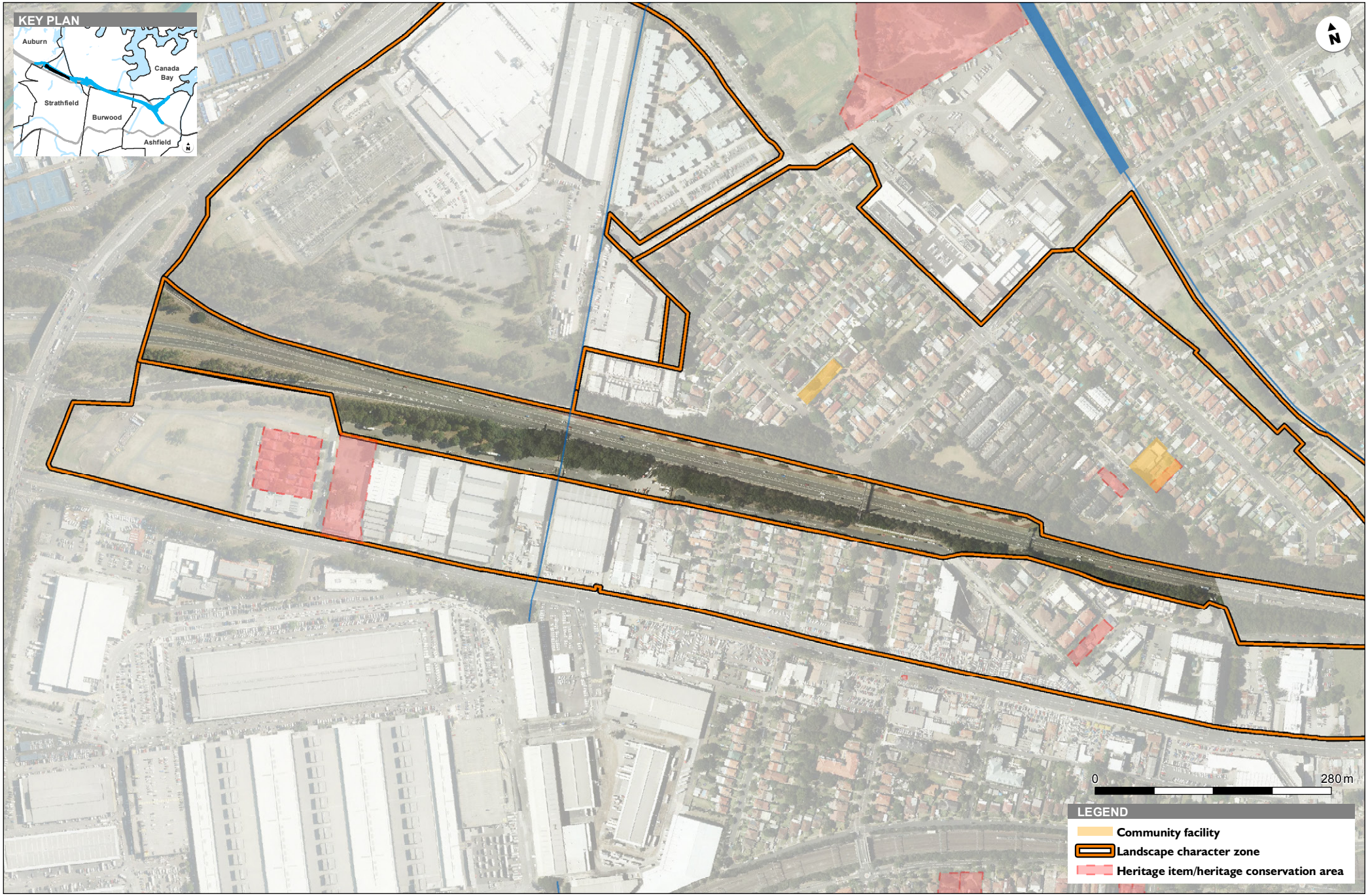


Figure 4.4 Aerial photograph of M4 precinct – north

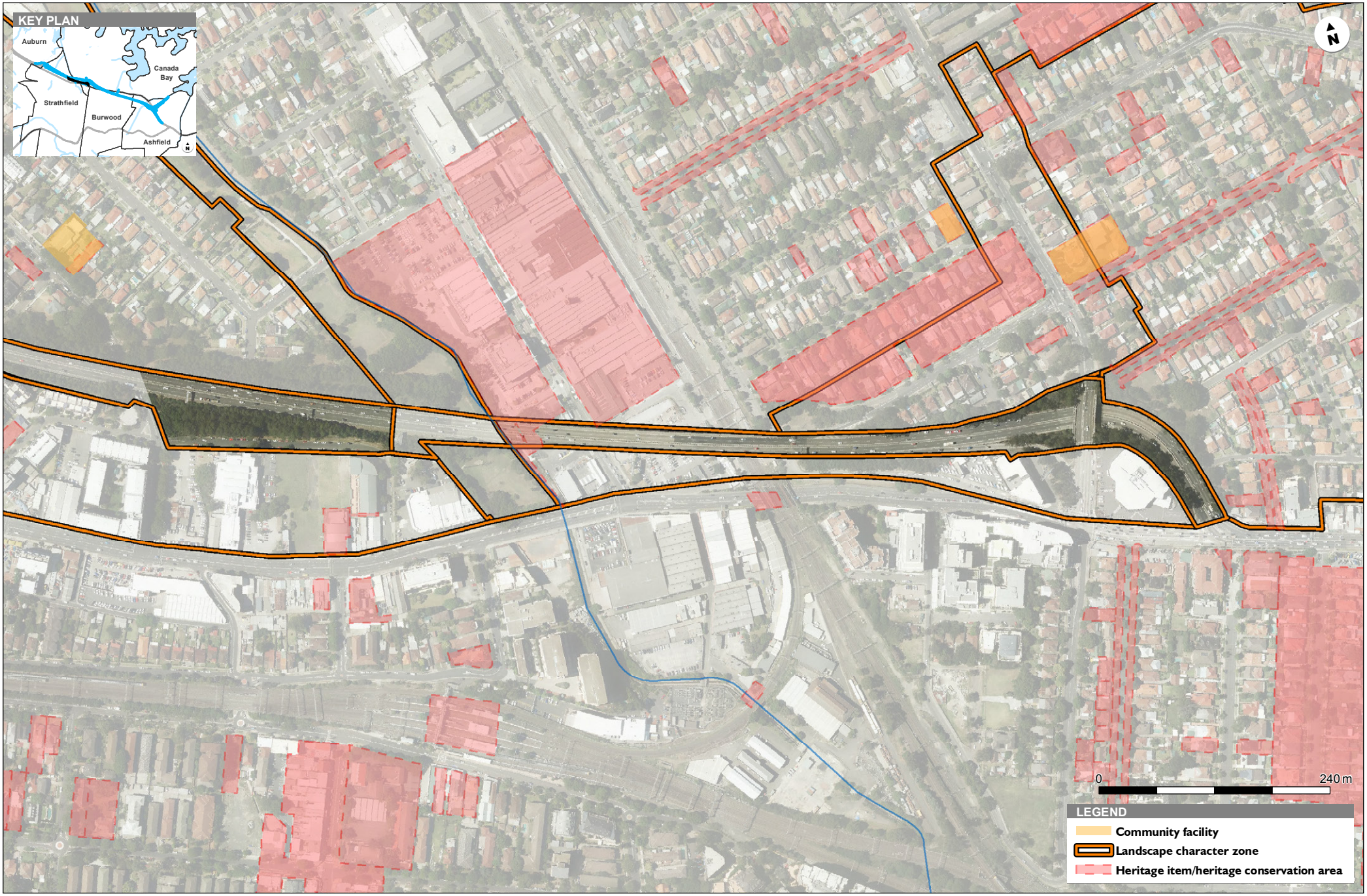


Figure 4.5 Aerial photograph of M4 precinct - south



Figure 4.6 **Typical view looking west along the M4 from the Park Road pedestrian overbridge.**



Figure 4.7 **Typical view looking east along the M4 with thinning screening vegetation and intermittent views south to residential development. (Source: AECOM)**



Figure 4.8 **View travelling east along the M4 from Powells Creek bridge, looking north across part of the historic Bakehouse Quarter to North Strathfield. (Source: AECOM)**



Figure 4.9 **View from Powells Creek bridge, travelling west along the M4 looking south to high-rise residential development in Strathfield. (Source: AECOM)**

4.2.2 LCZ 2 – Homebush commercial precinct

This precinct adjoins the M4 and lies adjacent to Sydney Olympic Park to the west and residential development to the east in the suburb of Homebush. The precinct contains a large retail development (Direct Factory Outlets) with associated car parking, a business park and electrical substation. The area between this development and the M4 comprises an open area with a moderate coverage of tree planting, creating a relatively dense visual screen to the M4 (refer to **Figure 4.10** and **Figure 4.11**)



Figure 4.10 **View looking south across DFO carpark to substantial vegetative screen edge between this precinct and the M4. (Source: AECOM)**

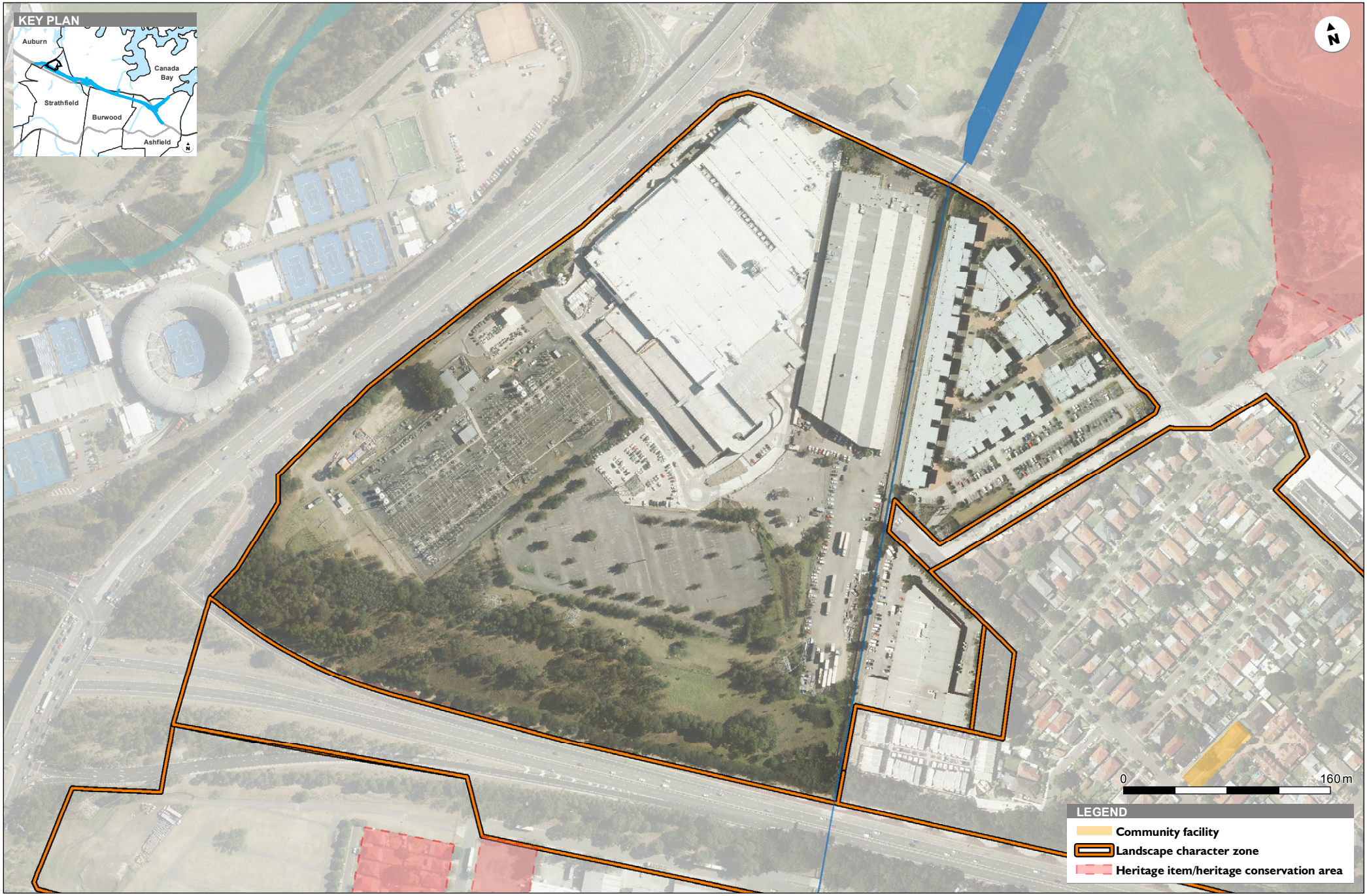


Figure 4.11 Aerial photograph of Homebush commercial precinct

4.2.3 LCZ 3 – Parramatta Road (west) precinct

This precinct is characterised by a diverse mix of uses including: low density residential development in the western and central sections of the precinct; medium density residential development in the centre; commercial development fronting Parramatta Road including the heritage listed Wentworth Hotel and Former Homebush Theatre; a block of light industrial premises towards the western end; and an undeveloped open area to the western boundary with Homebush Bay Drive. A key element defining the character of this zone is the long, narrow footprint, with the development compressed between the M4 and Parramatta Road. Additionally, the western end of the precinct comprises a strong grid pattern.

The perimeter along the M4 is subject to a dense screen of tree planting for most of its length, with the exception of the bridge crossing area between Powells Creek and the Northern Rail Line. The vegetation gradually decreases in density travelling east between Welfare Street and Underwood Road (refer to **Figure 4.12**).

The low density residential development exhibits significant homogeneity and is typical of the period of development, comprising small, red brick free-standing dwellings with terracotta rooves, and generally mature street tree plantings. The housing adjoining Park Road (and the M4) faces the north–south running residential streets, and so does not look directly towards the M4. Motorway (refer to **Figure 4.14**).

All streets within this residential precinct visually link to Parramatta Road at the southern boundary, with some of the streets blocked to traffic, and the M4 noise wall to the north, which is only partially screened by planting due to growing restrictions imposed by overhead power lines (refer to **Figure 4.15**.

Non-Aboriginal heritage

Non-Aboriginal heritage located within this LCZ is listed in **Table 4.1**.

Table 4.1 LCZ 3 non-Aboriginal heritage

Item reference	Name	Significance	Description
01*	Houses within Welfare Street Precinct Group	Local	2–14 Welfare Street. Developed about 1920s, the houses are presumed to be cottages for abattoir staff as this land remained in the ownership of the abattoir.
03*	Wentworth Hotel	Local	195 Parramatta Road. Wentworth Hotel is a privately owned Hotel built on the corner of Flemington Street and Parramatta Road in 1886 and rebuilt in the 1930s.
10*	Former Homebush Theatre	Local	55–57 Parramatta Road
13*	Spanish Mission House and Garden	Local	80 Park Road (formerly 80 Wentworth Road)
16	Shops	Local	16-18 George Street

Item reference	Name	Significance	Description
17*	Bakehouse Quarter (former Arnott's complex)	Local	11 George Street. The Bakehouse Quarter includes the former Arnott's biscuit factory and related buildings that are of substantial historic importance to the local area. Arnott's at the North Strathfield site was established in 1907 and was their main base from 1907 to 1996. Surviving signage and logos are still present at this site.
17*	Bakehouse Quarter (former Arnott's complex)	Local	20–22 George Street. See above description.

*Refer to **Appendix B**



Figure 4.12 **View looking west along Park Road showing dense vegetation along the M4 perimeter. (Source: AECOM)**

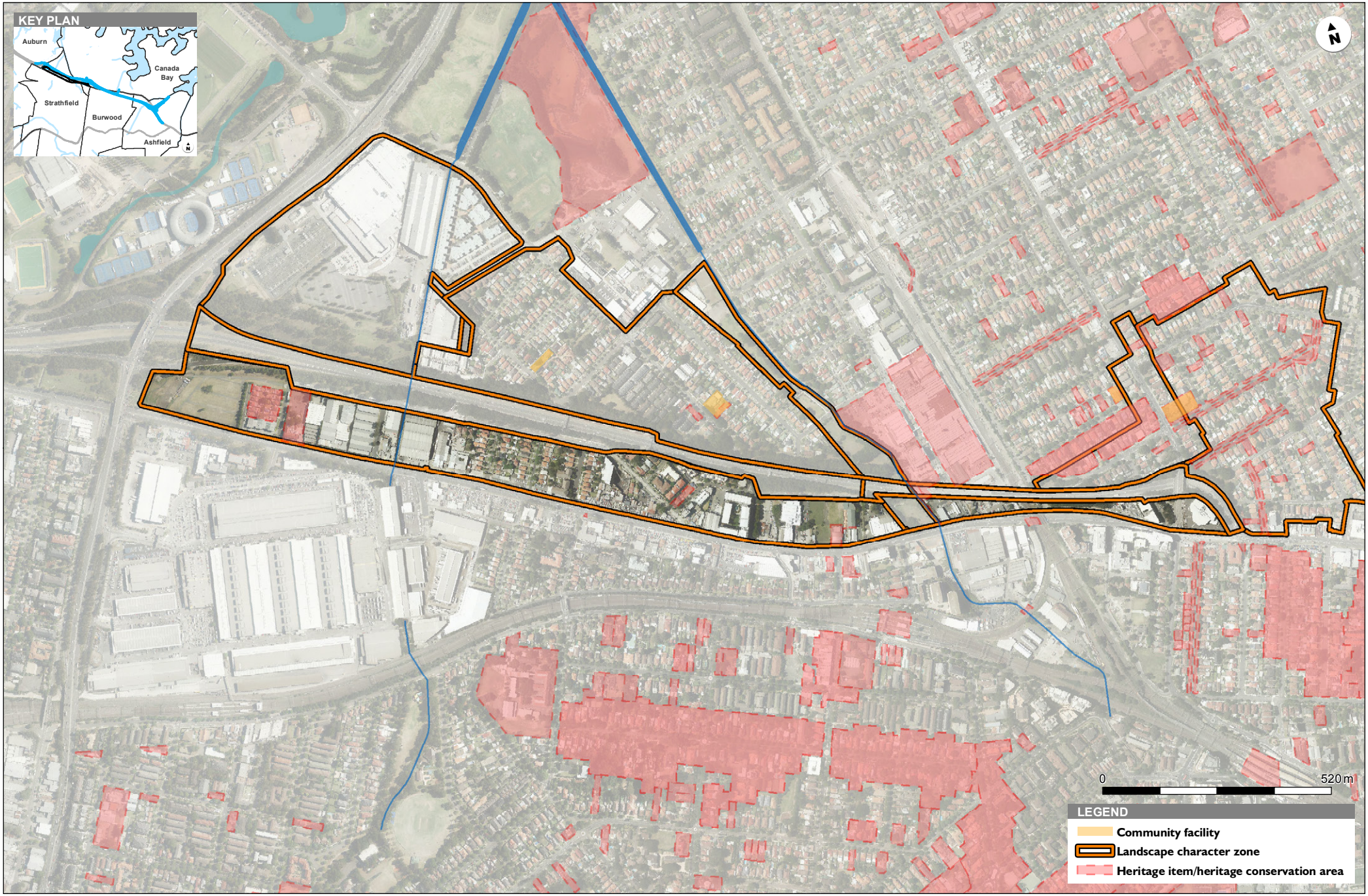


Figure 4.13 Aerial photograph of Parramatta Road (west) precinct



Figure 4.14 **View looking west along Park Street to open space and heritage listed residential development at the western end of the precinct. (Source: AECOM)**



Figure 4.15 **View looking west along Park Road showing overhead power lines in council verge restricting extent of screening along this boundary. (Source: AECOM)**

4.2.4 LCZ 4 – Underwood Road precinct

This precinct comprises predominantly low density free-standing residences from the early 1900s, with more recent medium density development accessed from Underwood Road and the end of Verley Drive. The quiet streets generally incorporate mature street tree plantings. A substantial open space reserve (Bill Boyce Reserve) adjoins the M4 (**Figure 4.40**).

The precinct exhibits a pleasant, quiet residential atmosphere with strong consistency of built form, well-tended gardens and mature streetscapes. The heavily planted and generally wide M4 corridor edge comprises a significant, visually soft and unusual feature within this landscape, ie it is unlikely that such an extent of continuous tree cover could be present in this heavily built-up area other than for the presence of the M4. This vegetated corridor creates a regular backdrop to the LCZ when viewed from the public domain, including from Verley Drive, Wentworth Road South, Bill Boyce Reserve, Short Street East, Underwood Road and Ismay Avenue.

Non-Aboriginal heritage

Non-Aboriginal heritage located within this LCZ is listed in **Table 4.2**.

Table 4.2 LCZ 4 non-Aboriginal heritage

Item reference	Name	Significance	Description
06*	Weatherboard cottage and garden	Local	1 Short Street East. Good example of a modest timber cottage and garden.
04*	1950s garden, carport and fence	Local	74 Underwood Road. 1950s front yard landscape, incorporating Neptune fantasia carport, fountain and front fence crafted by owner.

*Refer to Appendix B



Figure 4.16 **View looking south along Wentworth Road South towards the M4. (Source: AECOM)**



Figure 4.17 Aerial photograph of Underwood Avenue precinct.



Figure 4.18 **View looking east along Underwood Avenue towards the M4 bridge crossing. (Source: AECOM)**



Figure 4.19 **View looking south down Ismay Avenue towards the M4. (Source: AECOM)**

4.2.5 LCZ 5 – Powells Creek precinct

The Powells Creek precinct comprises an open corridor with a concrete lined drainage channel that flows from south to north under the M4, and adjoining electricity transmission easement. Refer to **Figure 4.21**. Strathfield Council is proposing a new park along the Powells Creek Corridor between Pomeroy Street and Parramatta Road (refer to https://www.strathfield.nsw.gov.au/home/parks-and-recreation/powells-creek-masterplan/). The area between Allen Street and the M4 has recently been developed and opened by Council as part of a new master plan (refer to **Figure 4.20**). Part of the corridor north of Allen Street has recently been subject to low-growing landscape upgrade works (refer to **Figure 4.22**).

From the Parramatta Road side, the corridor provides visual change from the hard and busy setting of Parramatta Road. The proposed park along the Powells Creek corridor can also be expected to provide a complementary open space element within the context of the adjoining Bakehouse Quarter (refer to **Figure 4.23**).

Table 4.3 LCZ 5 non-Aboriginal heritage

Item reference	Name	Significance	Description
16	Shops	Local	16–18 George Street
17*	Bakehouse Quarter (former Arnott's complex)	Local	11 George Street. The Bakehouse Quarter includes the former Arnott's biscuit factory and related buildings that are of substantial historic importance to the local area. Arnott's at the North Strathfield site was established in 1907 and was their main base from 1907 to 1996. Surviving signage and logos are still present at this site.
17*	Bakehouse Quarter (former Arnott's complex)	Local	20–22 George Street. See above description.

*Refer to **Appendix B**



Figure 4.20 View looking south along Powells Creek (upstream) towards the M4 from Allen Street. (Source: AECOM)

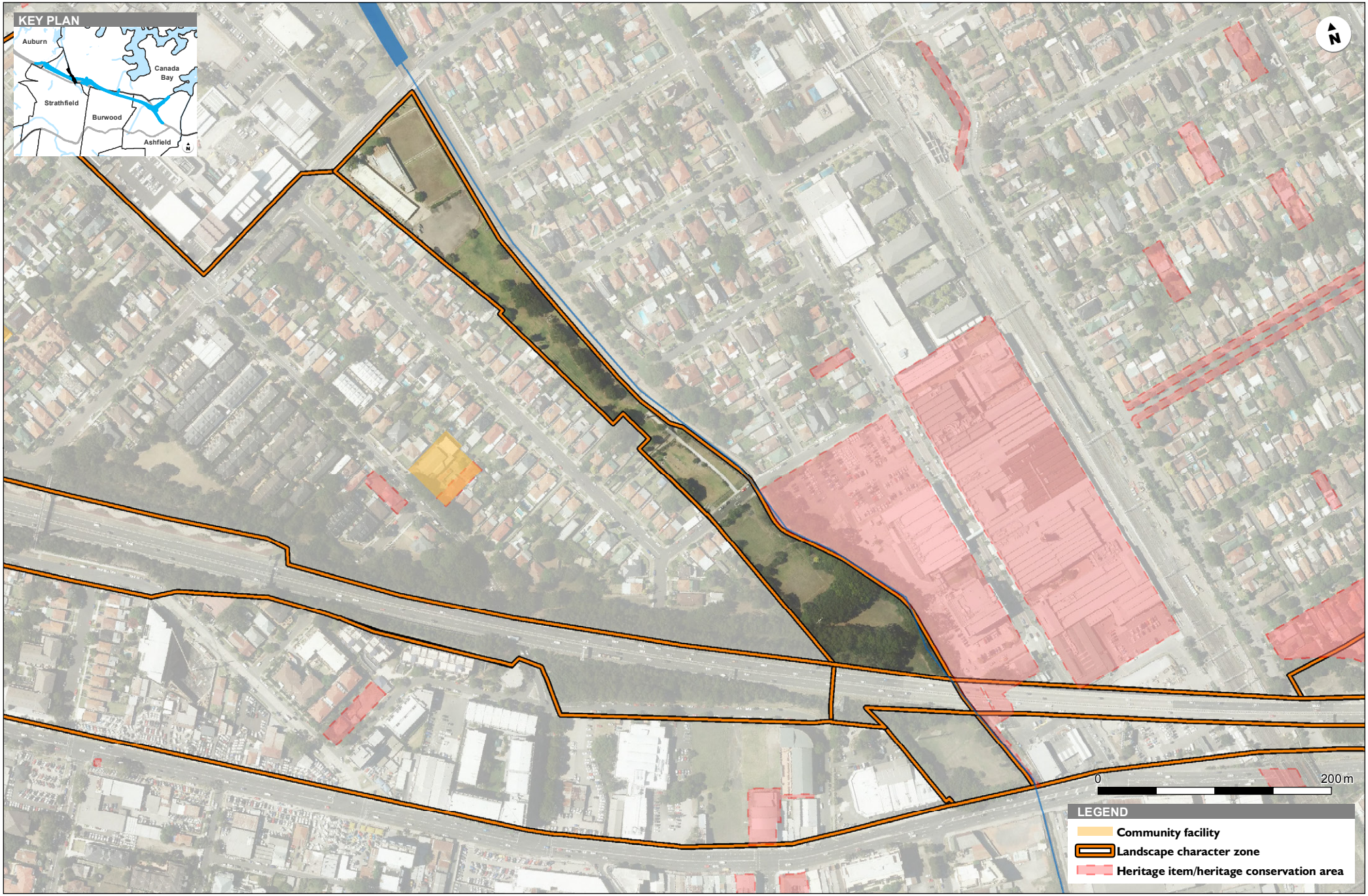


Figure 421 Aerial photograph of Powells Creek precinct



Figure 4.22 **View looking north along the Powells Creek corridor from Allen Street to the low planting amenity landscape within the electricity transmission and drainage corridor. (Source: AECOM)**



Figure 4.23 **View from Parramatta Road looking north along Powells Creek (downstream) towards the M4, east of Station Street. (Source: AECOM)**



Figure 4.24 **Detail view of proposed park area from Parramatta Road showing existing tall, wide span M4 bridge framing a view through to the main northern part of the park. (Source: AECOM)**

4.2.6 LCZ 6 – Concord Road precinct

This precinct encompasses Concord Road and Sydney Street west, which funnels traffic from the M4 to Concord Road. Both roads are predominantly lined by low density residential development. Housing fronting these two roads generally exhibits an entropy effect consistent with a lesser level of investment in maintenance and development than similar residences in adjacent quieter streets. This is particularly noticeable for Sydney Street. Additionally, these streets have substantially less street trees than the adjacent quieter residential streets (refer to **Figure 4.25**, **Figure 4.26**, **Figure 4.27** and **Figure 4.28**).

A place of worship (Sydney Cheil Church) is situated on the corner of Sydney Street east and Concord Road. The building is set back about 15 metres from the road frontage and includes a children's playground. The frontage also includes a row of pine trees and a hedge to provide privacy screening from Concord Road (refer to **Figure 4.29**).

Table 4.4 LCZ 6 non-Aboriginal heritage

Item reference	Name	Significance	Description
18*	Powell's Estate HCA	Local	Queen, Carrington and Sydney streets. Victorian period subdivision featuring a regular layout and uniform allotments. Houses from all periods from the 1880s to the 1940s represented.
28*	House	Local	15 Queen Street. Federation bungalow.
19*	House	Local	35 Sydney Street. One of a pair of well-preserved Victorian Gothic villas, each a mirror image of the other.
22*	House	Local	33 Sydney Street. See description above.
23*	House	Local	23 Sydney Street. Substantial Victorian house.
24*	House	Local	11 Sydney Street. Italianate Victorian villa.
51*	House	Local	64 Concord Road. Large Inter-War Bungalow.
61*	House	Local	2 Carrington Street. Federation Queen Anne bungalow.
59*	House	Local	4 Carrington Street. Timber Federation house.
56*	House	Local	14 Carrington Street. Federation brick cottage.
53*	Sydney Cheil Church (Wesley Uniting Church and hall)	Local	81 Concord Road. Place of worship from the interwar period with surviving gate and fence from the earlier development of Thornleigh House. A place of Methodist (now Uniting) worship since 1927.
20*	House “Glenora”	Local	11 Thornleigh Avenue. Interwar bungalow with unusual detailing.
52*	House	Local	99 Concord Road. A good example of a Federation Arts and Crafts style house.
31*	House	Local	123 Patterson Street. Single-gabled interwar bungalow.

*Refer to Appendix B

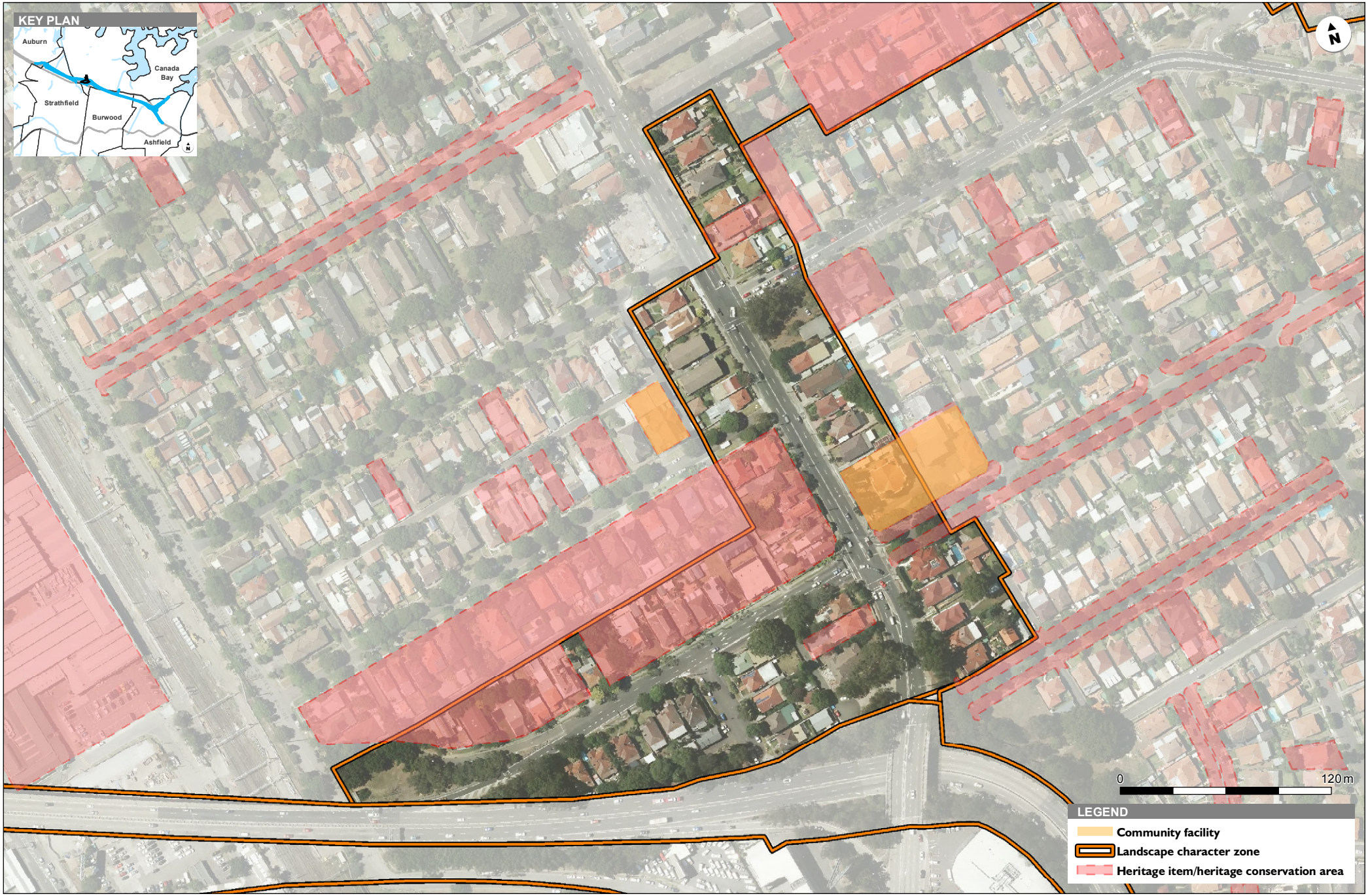


Figure 4.25 **Aerial photograph of the Concord Road precinct**



Figure 4.26 **View looking east along Sydney Street to the intersection with Concord Road. (Source: AECOM)**



Figure 4.27 **View looking north along Concord Road from the intersection with Sydney Street. (Source: AECOM)**



Figure 4.28 **View looking east along Sydney Street to the intersection with Concord Road. (Source: AECOM)**



Figure 4.29 **Detail view looking south along Concord Road to the Sydney Cheil Church. (Source: AECOM)**

4.2.7 LCZ 7 – Edward Street precinct

This precinct is characterised by a homogenous period character of free-standing residential bungalows from about the early 1900s, including elements such as dark brick, stained glass windows, tuck pointing and terracotta roofs. A moderate level of new low-density housing on existing blocks is also present within the precinct, and is generally architecturally sympathetic with the existing period character of the area. Edward Street is lined by a mature avenue of heritage listed brush box trees (refer to **Figure 4.32**) as is Sydney Street east. By contrast, streets within the southern part of this precinct generally have little in the way of consistent street tree planting, eg Franklyn Street (refer to **Figure 4.30**).

Table 4.5 LCZ 7 non-Aboriginal heritage

Item reference	Name	Significance	Description
48*	House	Local	16 Edward Street. Modest double gabled interwar bungalow,1920s leadlight and Art Nouveau wrought iron and brick fence.
44*	House “Wangi”	Local	21 Franklyn Street. Good interwar bungalow.
45*	House	State	6 Franklyn Street. Interwar bungalow.
434*	Street trees	Local	Franklyn Street, avenue of New England peppermint trees from circa 1940s.
47*	Street trees	Local	Edward Street, avenue of brush box circa 1940s.
25*	Street trees	Local	Sydney Street, avenue of brush box circa 1950s.

*Refer to Appendix B



Figure 4.30 View looking south down Franklyn Street from the corner of Alexandra Street showing the generally homogeneous nature of the housing within this precinct. (Source: AECOM)



Figure 4.31 Aerial photograph of the Edward Street Precinct



Figure 4.32 **View looking east along Edward Street showing the generally homogeneous nature of housing and attractive leafy streetscape within this precinct. (Source: AECOM)**

Both Ada Street and Alexandra Street have characteristics similar to that of a lane, being relatively narrow, and having one boundary of side fences. The southern side of Ada Street has housing fronting onto it. The northern side of Alexandra Street has garages and rear fences from a single loaded subdivision pattern, with the residences fronting onto Edward Street (refer to **Figure 4.33**).



Figure 4.33 **View looking west along Alexandra Street from the intersection with Franklyn Street showing side fencing to left of frame and rear fences and garages to right of frame. (Source: AECOM)**

A further feature of this precinct is the residual impacts from previous developments including the existing M4, as reported by local residents:

> *A left over parcel of land adjoining the M4 intersection with Parramatta Road contains a noise wall and screen tree planting along the M4 perimeter, and otherwise some stands of large trees including several camphor laurels. The area which is roughly slashed is partially closed off with chain wire fencing and exhibits a disused and potentially unsafe character* (Personal communication as noted by a local resident at an on-site community meeting) (refer to **Figure 4.34**).
>
> *A relatively recent medium density apartment building situated at the southern end of Franklyn Street is visually out of character for the precinct, with the laneway behind it generating regular ongoing illegal tipping of refuse (Personal communication as confirmed by a local resident at an on-site community meeting)* (refer to **Figure 4.35**).

Areas such as these provide opportunities for better integration with urban design outcomes associated with the project.



Figure 4.34 **View looking north to a residual land parcel from construction of the existing M4 which is reported to be a locale for anti-social behaviour at night. (Source: AECOM)**



Figure 4.35 **View looking south down Ada Lane to a site of reported regular substantial quantities of illegally tipped refuse (see bottom right of frame). (Source: AECOM)**

4.2.8 LCZ 8 – Concord Oval precinct

This precinct comprises a formal football field with substantial grandstand and club building in the west and the Cintra Park hockey facility in the eastern portion of the precinct. Concord Oval and associated colourful grandstand comprises a visually prominent feature of the driver experience along Parramatta Road. The northern part of the precinct comprises an informal open area for overflow car parking.

The precinct sits between Parramatta Road and the relatively busy Gipps Street. St Lukes Park sporting fields are located adjacent to the northern perimeter of the precinct. The precinct has low density residential development backing onto the eastern boundary from Taylor Street, and adjacent low density residential development on Loftus Street fronting the western precinct boundary (refer to **Figure 4.37**. The southern, eastern and northern precinct boundaries are generally well vegetated.

Table 4.6 LCZ 8 non-Aboriginal heritage

Item reference	Name	Significance	Description
72*	St Luke's Park entrance, gates and trees	Local	Former entrance to St Lukes Park (1913) and five mature Moreton bay Figs (c.1890s–1900)
133*	Sewage Pumping station No 22 (SP0022)	Local	Listing by Sydney Water

*Refer to Appendix B



Figure 4.36 View looking east along Parramatta Road towards Concord Oval grandstand. (Source: AECOM)



Figure 4.37 Aerial photograph of Concord Oval precinct



Figure 4.38 **View looking west towards the Cintra Park hockey facility from near the Gipps Street entry. (Source: AECOM)**

4.2.9 LCZ 9 – Dobroyd Parade precinct

This precinct comprises the commencement of a major change in landscape character from that of the Parramatta Road corridor and adjacent suburbs to views of open parkland followed by views to Iron Cove. Housing opposite Timbrell Park is typically screened to avoid views to the heavily trafficked Dobroyd Parade.

Table 4.7 **LCZ 9 non-Aboriginal heritage**

Item reference	Name	Significance	Description
116*	Haberfield HCA	Local (potentially State)	Haberfield is characterised by a uniform pattern of allotments, which only contain one house on a generously sized lot, unusual for the Victoria era. There is a fine ensemble of Federation houses and original tree plantings remaining in many of the verges.
134*	Iron Cove Creek	S170 item	

*Refer to Appendix B



Figure 4.39 **View from Reg Coady Reserve looking west along Dobroyd Parade towards Wattle Street from near the intersection with Waratah Street. (Source: AECOM)**

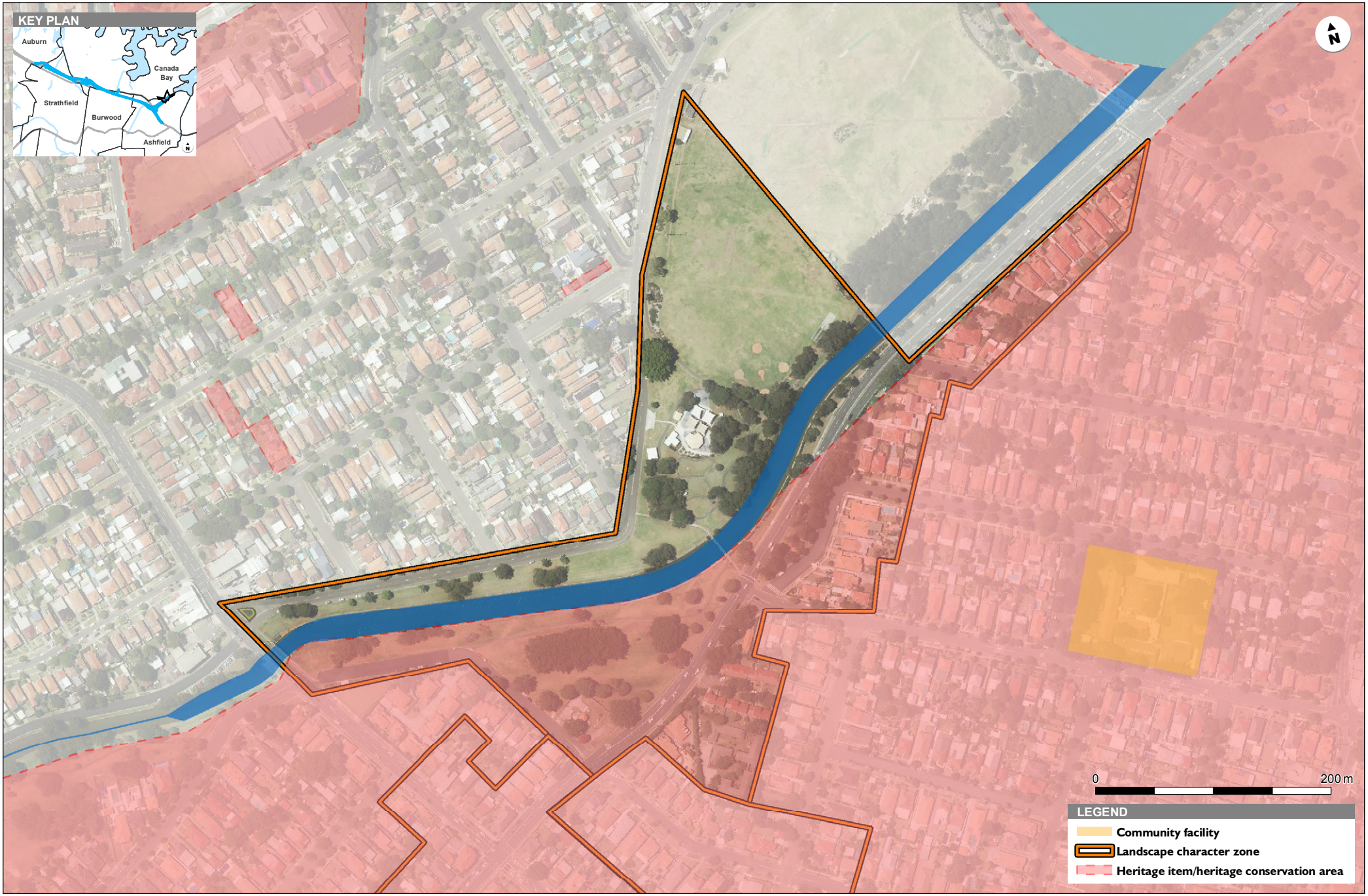


Figure 4.40 Aerial photograph of Dobroyd Parade precinct showing generally informal planting setting



Figure 4.41 View looking west along Dobroyd Parade from near the intersection with Waratah Street.

4.2.10 LCZ 10 – Wattle Street precinct

This precinct is typically characterised by Federation period, free-standing residences, with some contemporary infill dwellings and walk up units. A place of worship is located near the corner with Parramatta Road (Jehovah's Witnesses) (refer to **Figure 4.42**).

There is no formal tree planting to the street, but a moderate level of trees and landscape planting within front gardens provides garden amenity (refer to **Figure 4.43** and **Figure 4.44**).

The intersection with Parramatta Road is planted with a substantial grove of eucalypts and casuarinas which provides a green edge effect to the street entry from Parramatta Road.

Housing to the northern side of Wattle Street does not appear to be subject to the same extent of previously described entropy effect impacting housing within the Concord Road precinct (ie a lesser level of investment in maintenance and development than similar residences in adjacent quieter streets).

Table 4.8 LCZ 10 non-Aboriginal heritage

Item reference	Name	Significance	Description
116*	Haberfield HCA	Local	Haberfield is characterised by a uniform pattern of allotments, which only contain one house on a generously sized lot, unusual for the Victoria era. There is a fine ensemble of Federation houses and original tree plantings remaining in many of the verges.
113*	House	Local	9 Wattle Street. An example of John Spencer-Stansfield's Design No 1, which was used in many Haberfield houses for Richard Stanton.
112*	Houses	Local (Section 170)	19 Wattle Street. A Federation bungalow.
111*	House	Local (Section 170)	21 Wattle Street. An interwar bungalow.

Item reference	Name	Significance	Description
110*	Houses	Local (Section 170)	23–25 Wattle Street. A pair of Federation semi-detached bungalows.
109*	House	Local (Section 170)	35 Wattle Street. A Federation bungalow.
108*	House	Local (Section 170)	37–39 Wattle Street. A pair of Federation semi-detached cottages.
107*	House "Airley"	Local (Section 170)	41–43 Wattle Street. A pair of Federation semi-detached bungalows.
106*	House	Local (Section 170)	51 Wattle Street. A pair of Federation semi-detached bungalows.
105*	House "Bunnia"	Local (Section 170)	53 Wattle Street. Federation bungalow, a good representative example of the housing stock within the area.
104*	House	Local (Section 170)	164 Ramsay Street. 1916 intact Californian bungalow
114*	Houses "Cashman's Corner"	Local	150–152 Ramsay Street. Three shop-and-dwelling occupancies, despite having been altered, exhibit some of the character of John Spencer-Stansfield s work, designed in the Arts and Crafts style of architecture.
115*	Houses "Cashman's Corner"	Local	146–148 Ramsay Street. See above description.

*Refer to Appendix B

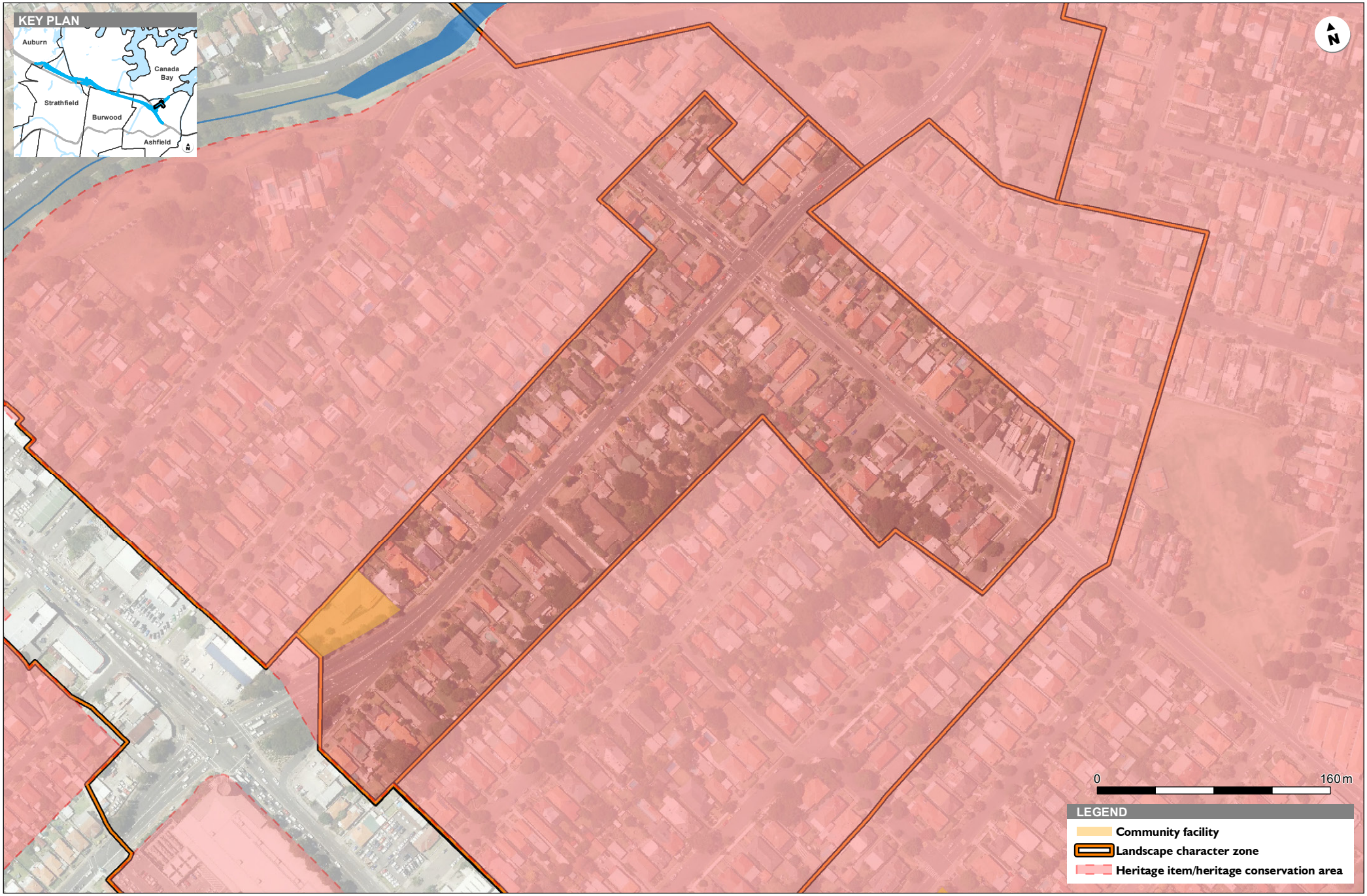


Figure 4.42 Aerial photograph of Wattle Street precinct



Figure 4.43 **View looking east along Wattle Street showing detached residential development with moderate level of trees and landscape amenity planting. (Source: AECOM)**



Figure 4.44 **View looking south along Ramsay Street near the intersection with Northcote Street. (Source: AECOM)**

4.2.11 LCZ 11 -– Parramatta Road (east) precinct

The character of this precinct is defined by the heavily trafficked Parramatta Road with a mix of car yards, fast food outlets, furniture and hardware stores and professional offices, interspersed with small pockets of low density residential lots (refer to **Figure 4.45**).

The road corridor exhibits a high level of visual clutter, comprising road and advertising signage, a concentrated variety and varying quality of low-rise building types and colours with varied setbacks from the road, in conjunction with road infrastructure and associated heavy traffic. This is combined with an almost complete lack of trees, with the exception of the gardens of the Yasmar Juvenile Training Facility and Ashfield Park, each of which are separately assessed in later sections. In conjunction with persistent levels of traffic noise and glare, the corridor comprises an inhospitable place for pedestrians, and often slow progress for motorists (refer to **Figure 4.46** and **Figure 4.47**).

Adjacent residential areas to the north tend to be relatively quiet with a generally homogeneous cover of early 1900s free-standing housing, typical of the Federation period. The streets are relatively wide and contain avenue plantings of street trees, some of which however are in poor condition due to issues such as pruning for power lines and placement of bitumen to the base of the trunks. Brush box and crepe myrtle are the predominant street tree species (refer to **Figure 4.48** and **Figure 4.49**).

In contrast, the adjacent residential areas to the south of Parramatta Road comprise relatively narrow streets, in some cases without street trees, and a mix of housing types including three-storey walk-up units, townhouses and free standing residential development generally dating from about the Federation period. These streets do however exhibit a substantial level of tree and general landscape amenity planting within front garden areas (refer to **Figure 4.50** and **Figure 4.51**).

Table 4.9 LCZ 11 non-Aboriginal heritage

Item reference	Name	Significance	Description
116*	Haberfield HCA	Local	Haberfield is characterised by a uniform pattern of allotments, which only contain one house on a generously sized lot, unusual for the Victoria era. There is a fine ensemble of Federation houses and original tree plantings remaining in many of the verges.
122*	Vita-Weet building, formerly Peek Freans Biscuit Factory	Local	476 Parramatta Road. A landmark industrial building with a dominant clock tower (the Bunnings building).
121*	Ilford Estate HCA	Local	Characterised by interwar bungalows and mature street trees.
119*	House ‘Bunyas’	State	1–5 Rogers Avenue. An Arts and Crafts bungalow with direct association with Richard Stanton, the progenitor of Haberfield, and as the major extant work of its architect, John Spencer-Stansfield.

*Refer to **Appendix B**

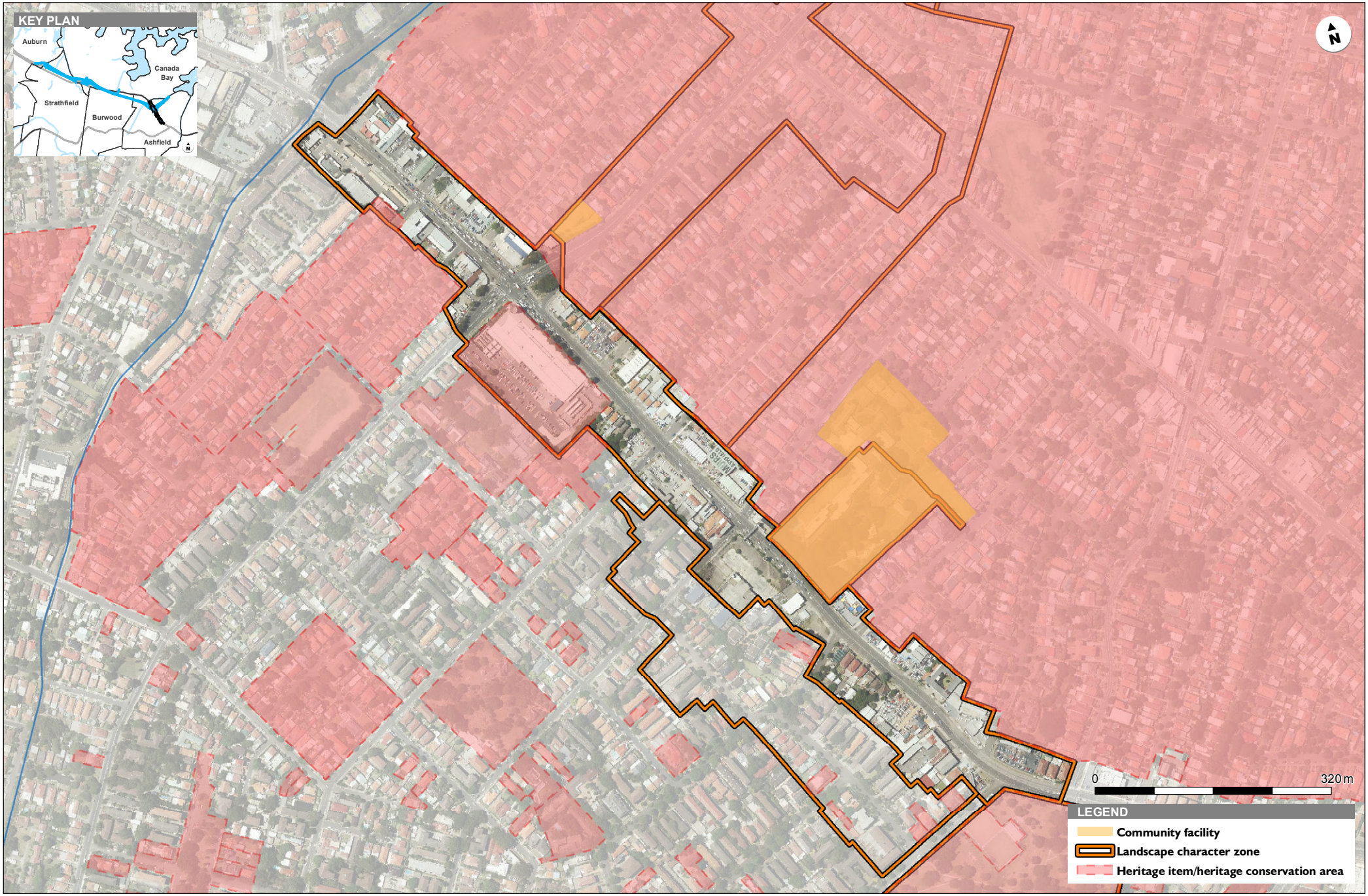


Figure 4.45 Aerial photograph of the Parramatta Road (east) precinct



Figure 4.46 **Typical view looking north along Parramatta Road from corner of Wattle Street. (Source: AECOM)**



Figure 4.47 **Typical view looking north along Parramatta Road from corner of Bland Street. (Source: AECOM)**



Figure 4.48 **Typical view of adjacent residential areas to the east of Parramatta Road, looking east along Alt Street. (Source: AECOM)**



Figure 4.49 **Typical view of adjacent residential areas to the east of Parramatta Road looking east along Bland Street. (Source: AECOM)**



Figure 4.50 **Typical view of adjacent residential areas to the west of Parramatta Road, looking west along Bland Street. (Source: AECOM)**



Figure 4.51 **View looking west along Bland Street showing a mix of housing types. (Source: AECOM)**

4.2.12 LCZ 12 – Haberfield precinct

This precinct comprises relatively quiet, local streets with a large component of Federation period housing, and street tree planting of variable condition. The character of this precinct is strongly defined by the relative lack of vehicle movements on often wide streets and the Federation period character reflected in much of the housing (refer to **Figure 4.52** and **Figure 4.54**).

Table 4.10 LCZ 12 non-Aboriginal heritage

Item reference	Name	Significance	Description
116*	Haberfield HCA	Local	Haberfield is characterised by a uniform pattern of allotments, which only contain one house on a generously sized lot, unusual for the Victoria era. There is a fine ensemble of Federation houses and original tree plantings remaining in many of the verges.
103*	House	Local	46 Martin Street. Weatherboard cottage with original features contributes to the local streetscape.

*Refer to *European Heritage Impact Assessment* report (GML 2015)



Figure 4.52 View looking east along Walker Avenue.

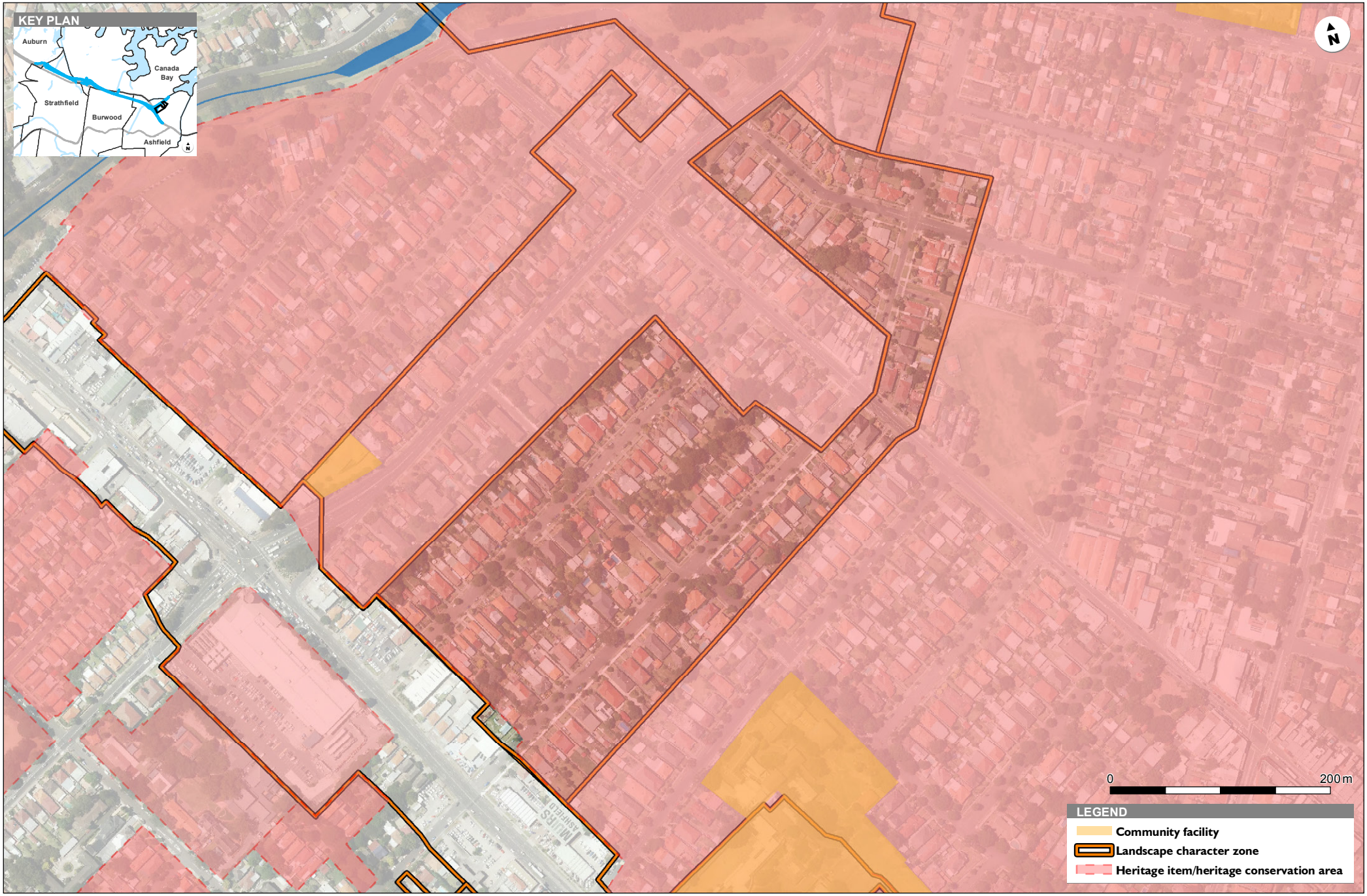


Figure 4.53 Aerial photograph of Haberfield precinct



Figure 4.54 View looking north along Alt Street at intersection with Martin Street.

4.2.13 LCZ 13 – Yasmar Juvenile Training Facility

This precinct is in sharp visual contrast to that of the adjoining Parramatta Road (east) precinct. The site is listed on the State Heritage Register (SHR), and contains a distinctive, densely wooded stand of trees to the Parramatta Road frontage including four large Morton Bay figs. Additionally, the frontage contains a heritage listed formal gate setting with ornate sandstone piers (refer to **Figure 4.56**).

An inner tall security wall set some 12–15 metres behind the Parramatta Road boundary precludes views into the site. The concentrated extent and density of the site vegetation substantially screens the inner security wall and comprises a landmark, visually contrasting 'forest' element to Parramatta Road (refer to **Figure 4.55** and **Figure 4.57**).

Table 4.11 LCZ 13 non-Aboriginal heritage

Item Reference	Name	Significance	Description
116*	Haberfield HCA	Local	Haberfield is characterised by a uniform pattern of allotments, which only contain one house on a generously sized lot, unusual for the Victoria era. There is a fine ensemble of Federation houses and original tree plantings remaining in many of the verges.

Item Reference	Name	Significance	Description
44*	Yasmar	State	185 Parramatta Road. A rare example of a suburban villa in its garden setting, that remains in a relatively intact condition. Yasmar is the only relatively intact villa house estate remaining on Parramatta Road, the oldest roadway in Australia, commenced in 1792. Yasmar's house is an example of John Bibb's residential work. The gateposts, gates and curved carriageway leading to the turning circle survive in near original condition. The property has strong associations with Simeon Lord, the Ramsay Family and GJN Grace. The garden is a rare example of the Gardenesque style.

*Refer to Appendix B



Figure 4.55 **View looking south along Parramatta Road to the Yasmar Juvenile Training Facility to middle of frame showing the height and extent of the landmark landscape, which is in strong visual contrast to the surrounding landscape. (Source: AECOM)**

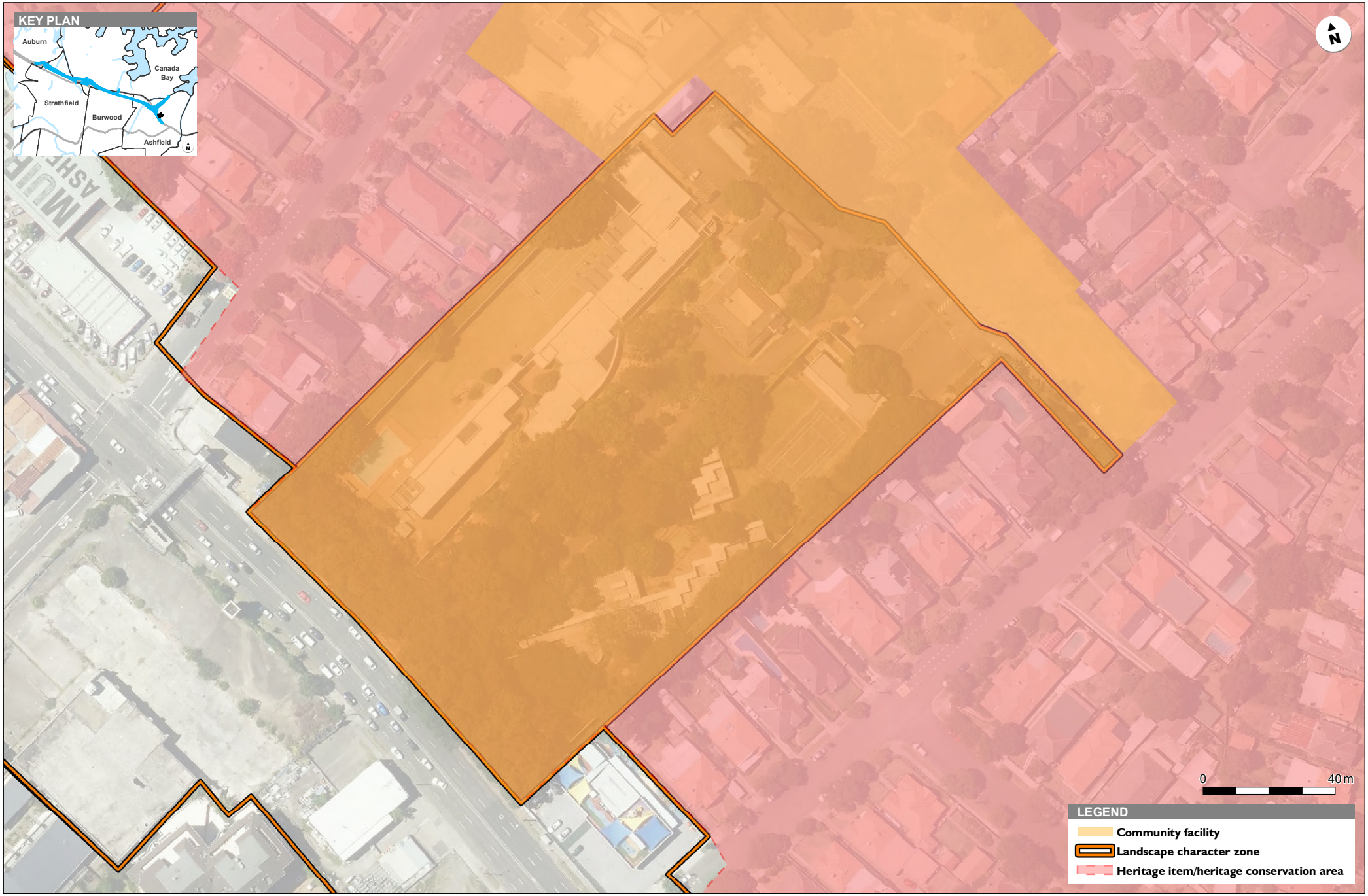


Figure 4.56 **Aerial photograph of the Yasmar Juvenile Training Facility**



Figure 4.57 **View looking east across Parramatta Road to the heritage listed formal gate setting of the Yasmar juvenile training facility. (Source: AECOM)**

4.2.14 LCZ 14 – Ashfield medium density precinct

The visual character of the precinct is defined by a mixture of medium density and single lot residential development with generous street tree plantings, a quiet setting with relatively low traffic volumes, and a pattern of angled streets (refer to **Figure 4.58**, **Figure 4.59**, **Figure 4.60** and **Figure 4.61**).

Table 4.12 **LCZ 13 non-Aboriginal heritage**

Item Reference	Name	Significance	Description
125*	House	Local	96 Chandos Street
126*	House	Local	94 Chandos Street
128*	House	Local	86 Orpington Street
129*	House	Local	82 Orpington Street
130*	Plats	Local	84 Gipps Street

*Refer to *European Heritage Impact Assessment* report (GML 2015)

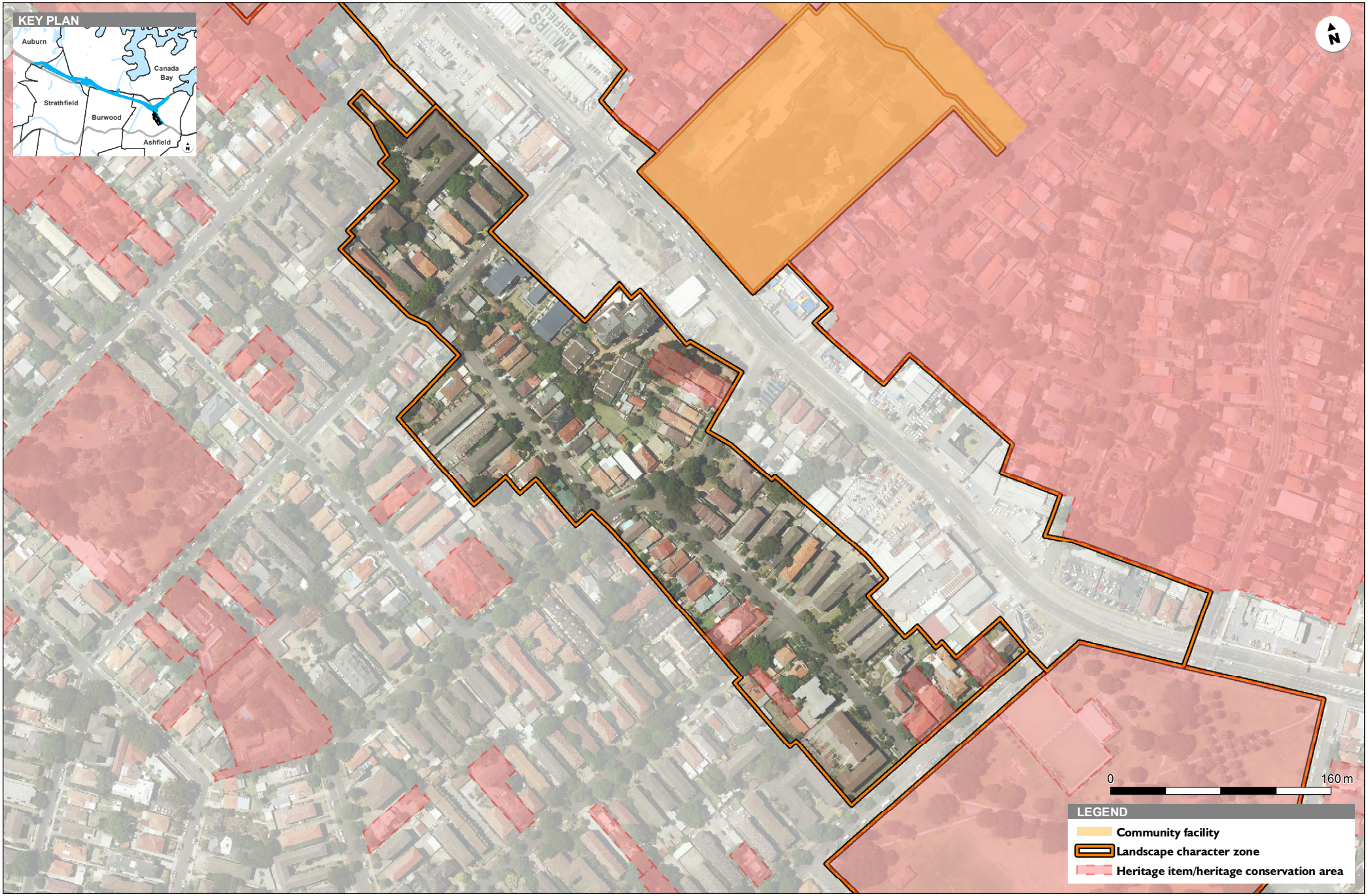


Figure 4.58 **Aerial photograph of Ashfield medium density precinct showing angled streets and a mixture of medium and low density residential development**



Figure 4.59 View looking east along Chandos Street.



Figure 4.60 View looking north along Loftus street near the corner of Orpington Street.



Figure 4.61 View looking south along Loftus street near the corner of Cecil Street.

4.2.15 LCZ 15 – Ashfield Park

As with the Yasmar Juvenile Training Facility, this precinct is in sharp visual contrast to that of the adjoining Parramatta Road precinct. Ashfield Park was proclaimed in 1885 and is a locally listed heritage item, with visually strong axial plantings of large trees, including a cruciform planting of tall palm trees that addresses Parramatta Road. These formal elements are complemented with informal groupings of trees and open areas (refer to **Figure 4.63**).

Facilities include a football field, a bowling club with two bowling greens and clubhouse, a playground, a picnic rotunda and BBQ area. A war memorial is situated at the centre of the park. A distinctive feature of the park is a flower bed with topiary planting that spells out the name of the park located on a sloping bank addressing the Parramatta Road frontage.

The park comprises a landmark open space element within the otherwise heavily built-up Parramatta Road corridor, and a rare element of visual respite and interest from the visually harsh built environment of Parramatta Road (refer to **Figure 4.64**).

Table 4.13 LCZ 15 non-Aboriginal heritage

Item reference	Name	Significance	Description
131*	Ashfield Park (public reserve)	Local	Parramatta Road, Orpington, Pembroke and Ormond streets. Ashfield's oldest and largest public park. The park has notable formal paths, and contains one of Sydney's finest avenues of Canary Island date palm. The park is located on a portion of James Underwood's estate and a number of significant structures.

*Refer to *European Heritage Impact Assessment* report (GML 2015)

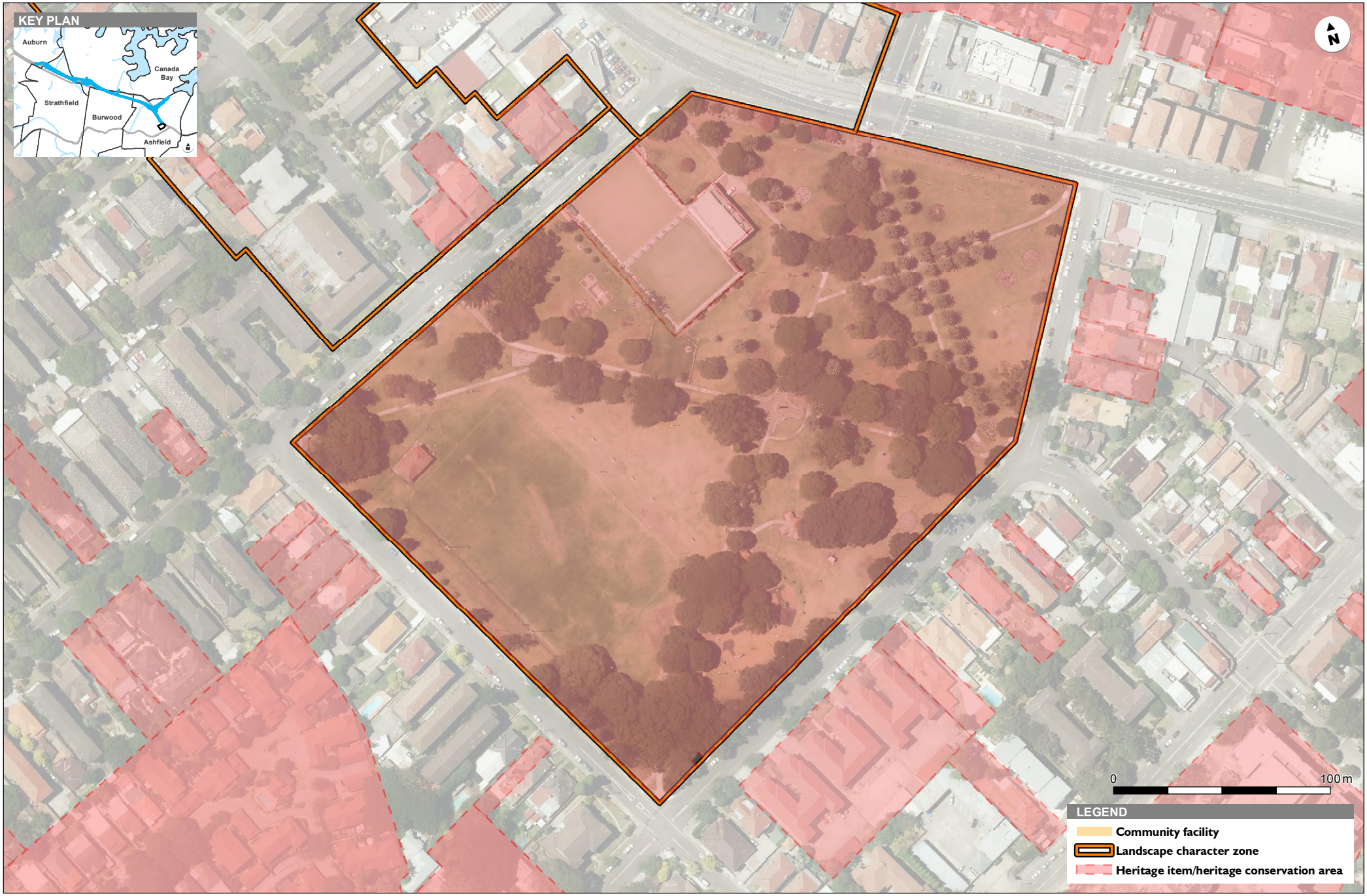


Figure 4.62 Aerial photograph of Ashfield Park showing the combination of axial plantings



Figure 4.63 **View looking west along Parramatta Road from the corner of Ormond Street. (Source: AECOM)**



Figure 4.64 **View from near the corner of Orpington Street looking east to the Ashfield Park frontage with Parramatta Road. (Source: AECOM)**

4.3 Policy and planning setting

The policy and planning setting for the landscape and visual aspects of the project has been established with regard to the following regional planning documents and relevant local environment plans:

- A Plan for Growing Sydney (NSW Government 2014)
- Draft Parramatta Road Urban Renewal Strategy (Urban Growth NSW 2015)
- Auburn Local Environmental Plan 2010 (Auburn LEP 2010)
- Strathfield Local Environmental Plan 2012 (Strathfield LEP 2012)
- Canada Bay Local Environmental Plan 2013 (Canada Bay LEP 2013)
- Burwood Local Environmental Plan 2012 (Burwood LEP 2012)
- Ashfield Local Environmental Plan 2013 (Ashfield LEP 2013).

The desired future character of the area has been determined, based on the strategic direction provided in these documents.

A Plan for Growing Sydney provides guidance on land use planning decisions in Sydney for the next 20 years. The plan describes where people are likely to live and work, and how they will move around the city and its subregions. The plan also guides subregional planning by identifying the metropolitan priorities for each of the subregions across Sydney. Subregional planning demonstrates how the growth of the city will be closely integrated with long-term transport and infrastructure planning, as major renewal and growth programs capitalise on existing and planned transport.

The project is located within the Auburn, Strathfield, Canada Bay, Burwood and Ashfield local government areas (LGAs), which are contained within the Central subregion under *A Plan for Growing Sydney*.

The priorities for the Central subregion that are relevant to the project (when considered as part of the project) are:

- Enable delivery of key transport projects to facilitate better connections to Global Sydney, including Sydney Rapid Transit, CBD and South East Light Rail, and WestConnex.
- Work with Councils to identify suitable locations for housing intensification and urban renewal, including employment agglomerations, particularly around Priority Precincts, established and new centres, and along key public transport corridors.
- Investigate a potential light rail corridor from Parramatta to Sydney CBD via Parramatta Road.

The strategy for the Central subregion implies that the desired future character of the broader region is to continue to grow the dominant role the subregion plays in the economic, social and cultural life of Sydney. Priorities for the subregion include encouraging housing intensification and urban renewal in suitable locations, particularly around established and new centres and along key public transport corridors, ensuring a competitive economy via the enablement of key transport projects including the M4 East, protecting Sydney Harbour's function as a working harbour, and identifying and protecting strategically important industrial zoned land.

The New Parramatta Road: Draft Parramatta Road Urban Renewal Strategy (UrbanGrowth NSW 2015) (Parramatta Road Strategy) identifies areas along the Parramatta Road corridor where there will be a focus on encouraging growth and changes in the long term (about 20 years). The aim of the strategy is to increase the number of people living and working in the corridor by 2031. It is envisaged that up to 40,000 new dwellings and 50,000 new jobs would be generated (UrbanGrowth NSW 2015).

The project is identified within the Parramatta Road strategy as a catalyst for the restoration of the Parramatta Road corridor, because it would contribute to the removal of through traffic from the corridor. ‘Through traffic’ in this context refers to traffic that travels more than five kilometres along Parramatta Road to destinations away from Parramatta Road. The reduction in traffic, particularly trucks, would assist in improving public transport and urban amenity, both of which would support future growth along the corridor, in particular residential development.

The desired future character of areas specific to key components of the project has been inferred from the land zoning provisions under the relevant environmental planning instruments. Existing land use zonings and the desired character of these zonings are summarised in **Table 4.14**. Details of potential landscape character impacts are provided in **section 6.1**.

Table 4.14 Land use zonings within LCZs

LCZ	Description of land use zoning and desired character
LCZ 1 – M4 Motorway	The M4 is zoned SP2 Infrastructure under the Strathfield LEP 2012. This zoning reflects the desire to maintain accessibility, supporting economic activity and efficient freight movement.
LCZ 2 – Homebush commercial precinct	The M4 in this area is zoned SP2 Infrastructure under the Strathfield LEP 2012. This zoning reflects the desire to maintain accessibility, supporting economic activity and efficient freight movement. Future development would be to a maximum height of 12 m. The land adjoining the M4 extending north to Sydney Olympic Park and east to residential development in the suburb of Homebush consists of land zoned IN1 General Industrial under the Strathfield LEP 2012. This zoning reflects the desire to encourage development which supports employment generation, to develop and protect designated industrial land and to provide sites for integrated and large floor plate activities. Future development would include buildings up to a height of 12 m This land use zoning reflects the objectives as defined for the Central subregion under *A Plan for Growing Sydney* for ongoing development of industrial land uses in appropriate locations.
LCZ	**Description of land use zoning and desired character**
LCZ 3 – Parramatta Road (west) precinct	The land adjoining the M4 and extending south to Parramatta Road, between Marlborough Road and Concord Road is comprised of a mix of zoning under the Strathfield LEP 2012 and the Canada Bay LEP 2013. Land at the western end of this precinct is zoned B6 Enterprise Corridor under the Strathfield LEP 2012. This zoning reflects the desire to maintain accessibility and efficient movement of commuter and freight traffic, and to encourage economic activity and provision of a range of employment uses. This zoning is consistent with the objectives for the Central subregion under *A Plan for Growing Sydney* and the objectives for the Homebush Area Precinct under the *Draft Parramatta Road Urban Renewal Strategy*. Council has also listed the Welfare Street Heritage Conservation Area, as well as individually listing the adjacent Wentworth Hotel, at the western end of the LCZ. As such, it can be inferred that Council desires the future character of this portion of the LCZ to

	conserve the identified heritage characteristics. Land in the centre of this precinct, from Kanoona Avenue to George Street, is comprised of land zoned B4 Mixed Use and R4 High-Density Residential under the Strathfield LEP 2012. This combination of land use zones establishes the desired future character of this area as consisting of a mix of compatible employment-generating and residential land uses, with strategic sites developed for urban intensification uses, complemented by provision of local and regional employment. Land at the eastern end of this precinct, extending to Concord Road, is comprised primarily of land zoned B6 – Enterprise Corridor under the Canada Bay LEP 2013 and establishes the desired future character of the area as being one that supports ongoing development of strategic road corridors to provide for a mix of economic uses, and includes buildings up to a maximum height of 12 metres.
LCZ	**Description of land use zoning and desired character**
LCZ 4 – Underwood Road precinct	This precinct consists of land zoned SP2 Infrastructure, R3 Medium Density Residential and RE1 Public Recreation under the Strathfield LEP 2012. The land zoned SP2 Infrastructure includes the M4 and reflects the desire to maintain accessibility, supporting economic activity and efficient freight movement. The surrounding zoning identifies the desired future character of the broader area being to support future growth via urban intensification along and near to important strategic road and public transport corridors. This land use zoning is consistent with the objectives for the Homebush and Burwood area precincts under the *Draft Parramatta Road Urban Renewal Strategy*. Building heights in new development within R3 Medium Density Residential zones in this region are 9 metres.
LCZ 5 – Powells Creek precinct	The land on which the M4 is sited is zoned SP2 Infrastructure and reflects the desire to maintain accessibility, supporting economic activity and efficient freight movement. The surrounding zoning consists of a finger of land zoned RE1 Public Recreation under the Strathfield LEP 2012 extending north west from the rail corridor south of Parramatta Road, under the M4, bound by land zoned R3 Medium Density Residential and B4 Mixed Use under the Strathfield LEP 2012 on the western boundary and land zoned B3 Commercial Core under the Canada Bay LEP 2013 on the eastern boundary. The RE1 Public Recreation zoning identifies that the future character of this area should provide

	for public open space or recreational activities. The abutting R2 Low Density Residential zoning identifies the future desired character as retaining the existing low density nature of development. Land zoned B3 Commercial Core establishes that the future character of this area should have regard to provision of economic and employment generating development and activities. This includes buildings up to a maximum height of 27 metres.
LCZ	**Description of land use zoning and desired character**
LCZ 6 – Concord Road precinct	The M4 is within an area zoned SP2 Infrastructure under the Canada Bay LEP 2013 and reflects the desire to maintain accessibility, supporting economic activity and efficient freight movement. Land zoned R3 Medium Density Residential under the Canada Bay LEP 2013 abuts the M4 and extends northwards, as far west as the railway and as far east as Concord Road. Land east of Concord Road consists of land zoned R2 Low Density Residential under the Canada Bay LEP 2013. The application of R3 and R2 zones in these areas identifies the desired future character of this area being to retain the existing low to medium density nature of development and to provide for development of facilities and services which support residential living. Council has listed the Powell's Estate Heritage Conservation Area, comprising the block between Sydney Street West and Carrington Street, as well as listing several individual houses beyond this heritage conservation area, including to the other side of Carrington Street, Concord Road, and the Sydney Cheil Church on Concord Road. As such, it can be inferred that Council desires the future character of this area to conserve the identified heritage characteristics.
LCZ 7 – Edward Street precinct	The land east of Concord Road and north of Parramatta Road is zoned R3 – Medium Density Residential and R2 Low Density Residential under the Canada Bay LEP 2013. The application of R3 and R2 zones in these areas identifies the desired future character of this area as one which should retain the existing low to medium density nature of development. Council has listed the street trees within Sydney Street East, Edward Street and Franklyn Street as heritage items, in addition to several houses within these streets. As such, it can be inferred that Council desires the future character of this area to conserve the identified heritage characteristics, particularly with regard to streetscape.
LCZ	**Description of land use zoning and desired character**

LCZ 8 – Concord Oval precinct	The hockey field is at the southern end of an extensive area of land zoned RE1 - Public Recreation under the Canada Bay LEP 2013. This reflects the desired future character of this area as being one that provides for recreational and open space uses and the protection of important recreational and/ or environmentally significant open space. Land adjacent to the hockey field consists of land zoned R2 Medium Density Residential and R3 High Density Residential under the Canada Bay LEP and indicates that the desired future character for these regions is to support the development of residential urban intensification. This corresponds with the objectives of *A Plan for Growing Sydney* and the principles of the *Draft Parramatta Road Urban Renewal Strategy*.
LCZ 9 – Dobroyd Parade precinct LCZ 10 – Wattle Street precinct LCZ 12 – Haberfield precinct	Wattle Street is located on land zoned SP2 Classified Road under the Ashfield LEP 2013 which reflects the desire to maintain accessibility, supporting economic activity and efficient commuter and freight movement. Land in the vicinity of the Wattle Street interchange is predominantly zoned R2 - Low Density Residential and R3 Medium Density Residential under the Ashfield LEP 2013. These land use zonings identify the desired future character of the area as one which retains the existing low to medium density nature of development. Building heights for future development in these zones are 9 m and 7 m respectively. Land north of Wattle Street, adjacent to and east of Martin Street is zoned RE1 Public Recreation under the Ashfield LEP 2013, which establishes a future character direction as one which supports the protection of important recreation and/ or environmentally sensitive land and the use of this land for recreational purposes. Council has listed effectively all of the area covered by these LCZ's as being within the Haberfield Conservation Area. Additionally, both Council and State government authorities (s.170 heritage items) have listed individual dwellings within LCZ 10 and LCZ 12 as heritage items. As such, it can be inferred that Council desires the future character of this area to conserve the identified heritage characteristics.

LCZ	Description of land use zoning and desired character
LCZ 11 – Parramatta Road (east) precinct	Parramatta Road between Henley Marine Drive in the north west and Ormond Street in the south-east is within an area zoned SP2 Infrastructure under the Ashfield LEP 2013 and reflects the desire to maintain accessibility, supporting economic activity and efficient freight and commuter movement. In this precinct, Parramatta Road is bound on both sides by land zoned B6 Enterprise Corridor under the Ashfield LEP 2013 and establishes the desired future character of the area as being one that supports ongoing development of strategic road corridors to provide for a mix of economic uses, and includes buildings up to a maximum height of 10 m. This land use zoning is consistent with the objectives of *A Plan for Growing Sydney*.
LCZ 12 – Parramatta Road / Wattle Street Precinct	Wattle Street and Parramatta Road are located on land zoned SP2 Infrastructure under the Ashfield LEP 2013 which reflects the desire to maintain accessibility, supporting economic activity and efficient freight and commuter movement. Land immediately adjacent to the Wattle Street/Parramatta Road intersection is zoned B6 Enterprise Corridor under the Ashfield LEP 2013 and establishes the desired future character of the area as being one that supports ongoing development of strategic road corridors to provide for a mix of economic uses. New development could consist of buildings to a maximum height of 15 metres. This land use zoning is consistent with the objectives of *A Plan for Growing Sydney* and the *Draft Parramatta Road Urban Renewal Strategy*.
LCZ 13 – Yasmar Juvenile Training Facility	The Yasmar Juvenile Training Facility is sited on land zoned R2 – Low Density Residential under the Ashfield LEP 2013 and sets the future landscape character of this site as being one that supports suitable development which gives regard to the existing low density residential environment and the development of facilities and services needed to meet residents daily requirements. This site is listed on both the State heritage Register and as a local heritage item. As such, it can be inferred that Council desires the future character of this area to conserve the identified heritage characteristics.

LCZ	Description of land use zoning and desired character
LCZ 14 – Ashfield medium density precinct	The predominant land use zonings consist of R3 Medium Density Residential and R2 Low Density Residential under the Ashfield LEP 2013, which establishes the desired future character of the area as protecting the medium to low density residential setting away from the Parramatta Road corridor. This corresponds with the objectives of the *Draft Parramatta Road Urban Renewal Strategy*. Land outside of these zones is predominantly zoned R2 Low Density Residential and R3 Medium Density Residential under the Ashfield LEP 2013. These land use zonings identify the desired future character of the area as one which retains the existing low to medium density nature of development. Building heights for future development in these zones consists of heights of 7 m and 9 m respectively.
LCZ 15 – Ashfield Park	Ashfield Park is sited on land zoned RE1 – Public Recreation under the Ashfield LEP 2013. The RE1 zoning sets the desired future landscape character of this precinct as being one that enables the use of the land by residents for recreational and/or public open space and ensures that adjacent development has regard to environmental and landscape impacts on land classified under the RE1 zone. This site is listed by Council as a local heritage item. As such, it can be inferred that Council desires the future character of this area to conserve the identified heritage characteristics of the site.

4.3.1 WestConnex Motorway Urban Design Framework

The objective of the urban and landscape design for the project is focused on achieving the objectives of the WUDF to deliver benefits to road users and the community. Therefore the WUDF is the appropriate benchmark for assessing the urban and landscape design proposal.

The following urban design vision, objectives and principles are derived from the WUDF.

Vision

> *The WestConnex motorway shall be a sustainable, high quality and transformational project for the people of Sydney and NSW. Exhibiting design excellence as a whole and in all constituent parts, it should be sensitively integrated into the natural and built environment, help build communities and contribute to the future liveability of the city (p.44 WUDF).*

The framework's vision statement then states that 'a "whole of corridor" design approach shall be adopted, to ensure the realisation of a memorable motorway experience that is legible, identifiable and integrated into the existing urban fabric'.

The successful project 'integration within the existing urban fabric' is critical to a well-managed response to potential visual impact and is of direct relevance to this assessment.

Urban design objectives

The WUDF adopts six objectives by which to implement the project vision and create a project that best benefits both the road users and the community. Each of these objectives will be used to guide the project design and to benchmark project outcomes. Each of the objectives is supported by design principles and guidelines.

Objective 1: Leading edge environmental responsiveness

Planning, design, construction and long term management shall be based upon a natural systems approach which is responsive to the environment and promotes the highest levels of sustainability.

Objective 2: Connectivity and legibility

Build connectivity across the city, beyond the boundaries of the motorway corridor and promote increased legibility of places, buildings, streets and landmarks.

Objective 3: Place making

Create beautiful places, streets, structures and landscapes that draw their form, character and materiality from local context, the intrinsic natural and cultural qualities of each locale.

Objective 4: Urban renewal and liveability

Enable opportunities for urban renewal and provide high levels of urban amenity and liveability.

Objective 5: Memorable identity and a safe, pleasant experience

Provide a memorable project identity and experiences for road users and adjacent stakeholders which are safe, convenient and enjoyable.

Objective 6: A new quality benchmark

Provide design and construction quality of world class standard. WestConnex shall establish a new benchmark for integrated sustainability, engineering, art, architecture and urban design.

Implementing the urban design principles

The WUDF provides design direction for the key urban design elements of the project. Urban design elements refer to both the built and landscape works associated with road infrastructure and their composition as a whole. They embody the project vision, objectives and principles in a built outcome.

The WUDF builds on the existing suite of Roads and Maritime urban design guidelines and policies and is to be read in conjunction with these technical design documents:

- Bridge Aesthetics: Design guidelines to improve the appearance of bridges in NSW, Roads and Maritime Services Centre for Urban Design, July 2012
- Shotcrete Design Guidelines: Design guidelines to avoid, minimise and improve the appearance of shotcrete, NSW Roads and Traffic Authority, February 2007
- Noise Wall Design Guideline: Design guidelines to improve the appearance of noise walls in New South Wales, NSW Roads and Traffic Authority, February 2007
- Landscape Guideline: Landscape design and maintenance guidelines to improve the quality, safety and cost effectiveness of road corridor planting and seeding, NSW Roads and Traffic Authority, June 2008
- Biodiversity Guideline: Protecting and managing biodiversity on RTA projects, NSW Roads and Traffic Authority, 2011
- Tunnel Urban Design Guideline: Design guideline to improve the customer and community experience of road tunnels in built up urban areas, Roads and Maritime Services Centre for Urban Design, Draft for discussion March 2014.

The WUDF provides design direction for each category of Urban Design Element. This includes definition of an urban design approach and precedent images that benchmark the design quality expected in order to achieve the project vision and objectives. The urban design elements physically embody the urban design objectives. The key urban elements are categorised as:

- Bridges, viaducts and underpasses
- Tunnel portals, vent stacks and control centres
- Tunnel interiors
- Landscape
- Walls
- Road furniture
- Lighting
- Art installations.

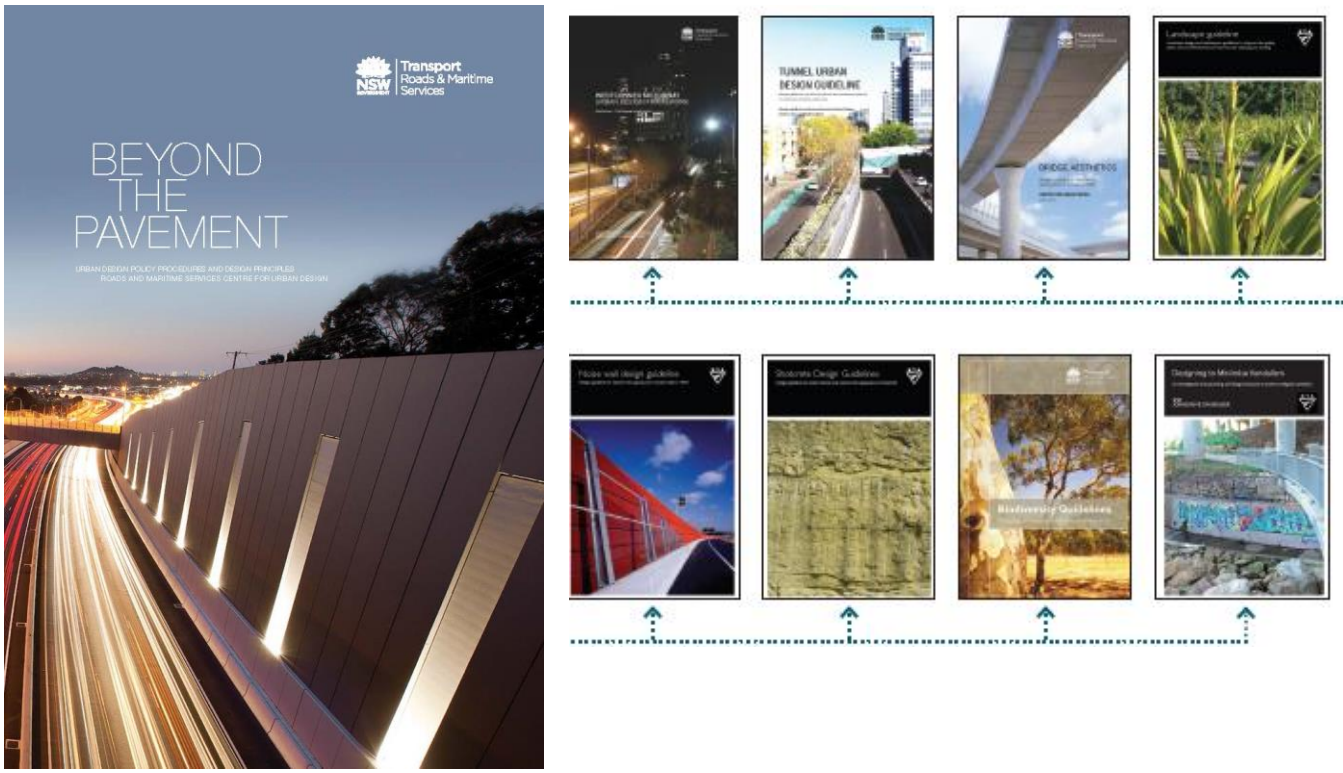


Figure 4.65 **The WUDF builds on and expressly refers to the existing suite of Roads and Maritime urban design guidelines and policies, including the principle *Beyond the Pavement* guiding document.**

A key consideration in the development of this proposal is its potential contribution to the WestConnex Revitalisation project and in particular the revitilisation of the Parramatta Road Corridor.

4.3.2 Parramatta Road Urban Transformation Program

The commitment to boost local economies, deliver jobs and improve amenity for existing and future residents is a key direction for the NSW Government along the Parramatta Road Corridor (PRC). Parramatta Road has been identified in the *Plan for Growing Sydney* (NSW Government 2014) as a key urban renewal corridor, critical to the growth of Sydney.

WestConnex is expected to remove up to 3,000 truck movements from Parramatta Road and significantly reduce current levels of traffic congestion along many parts of the corridor reducing travel times between Parramatta and Sydney Airport/Port Botany. This investment in the city's road network infrastructure would therefore facilitate a significant urban renewal opportunity on the surface of Parramatta Road which forms the focus of the Parramatta Road Urban Transformation Program.

The Parramatta Road Urban Transformation Program represents one of the most significant urban renewal projects in Sydney, with the potential to deliver improved amenity and productivity to the PRC. The renewal program aims to be ambitious but realistic in the vision presented for the future of the PRC and at all times recognise that the Corridor has an important role to play in the urban landscape of Sydney from a transport, economic, housing and public domain perspective.

The PRC Draft Concept Plan will provide direction on the staging, scale and nature of development within various precincts along the PRC and other related areas in line with transport and infrastructure improvements. The PRC Draft Concept Plan will provide a vision of how the Corridor might develop over the next 20 years. It identifies strategically important nodes or areas which could form the focus for revitalisation, being the 'precincts for further investigation'. These include,

- Camperdown.
- Leichhardt.
- Taverners Hill.
- Five Dock.
- Burwood.
- Homebush.
- Auburn.
- Granville.

Of the nodal precincts identified, only the Homebush precinct is directly, physically linked to the M4 East project. However, aspects of the project may influence the outcomes of the renewal program for all precincts, and these have been considered in **section 1.1.1**.

5 Assessment of construction impacts

This section assesses visual impacts on various receivers during construction. Site layouts are indicative and dimensions of structures and buildings mentioned in this section - including noise walls, hording, fences and acoustic sheds - are approximate at this stage and will be confirmed during detailed design.

5.1 Homebush Bay Drive civil site (C1)

The Homebush Bay Drive civil site compound would be located adjacent to the eastbound lanes of the M4, to the east of Homebush Bay Drive and to the south of the overflow car parking lot of the Direct Factory Outlets (DFO) at Homebush. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- Removal of vegetation
- A 2.5 metre (approximately) high hoarding and/or fencing surrounding the site
- Heavy and light vehicle access and egress from the M4 corridor. Vehicle movement may occur up to 24 hours per day, seven days per week where supporting tunnelling activities
- Staff amenities buildings
- A workshop
- A stockpile area and laydown areas
- Equipment such as excavators and cranes associated with the works
- Night time lighting of construction activities if supporting tunnelling or required for approved out-of-hours activities
- Construction of a maintenance facility and motorway control centre for the operation phase of the project.

The Homebush Bay Drive construction ancillary facility would be at grade with both the existing M4 and the DFO carpark. The site is currently medium to low density planted vegetation including grassland and mature trees. Vegetation currently in this area is expected to be removed and consequently views to the location of the construction compound would be opened up to motorists on the M4 and users of the DFO carpark.

As such, one representative receiver location has been identified for views from DFO carpark users (receiver location 1), one for motorists from the M4 (receiver location 2), and one for residents in the adjoining Verley Drive townhouse development (receiver location 3) as shown in **Figure 5.1**. **Figure 5.1** provides an indicative site layout which will be further developed during the detailed design and construction planning phases.



Figure 5.1 Homebush Bay Drive civil site (C1) receiver locations

Table 5.1 Homebush Bay Drive compound visual impact assessment

No.	Receiver location	Visual impact assessment
1	Motorists – M4	Provides a representative view for motorists using the M4, especially those travelling eastbound from the interchange with Homebush Bay Drive. The sensitivity of motorists is considered to be low due to the short period of time the compound would be visible, and also the driver's attention would be likely to be focused on the road. The magnitude of change is considered to be high due to the removal of vegetation, which would open views towards the construction compound and DFO beyond. This provides an overall visual impact assessment rating of moderate.
2	Carpark users – DFO Homebush carpark	Provides a representative view for motorists parking vehicles and walking to the DFO shopping complex. The sensitivity of this receptor group is considered to be low due to the short period of time users would be occupying the carpark and the utilitarian nature of the carpark environment. The magnitude of change is expected to be moderate because, although background vegetation is expected to be removed, it is likely that the narrow planting of trees along carpark boundary fence would be retained and would provide a partial screen to the works. This provides an overall visual impact assessment rating of moderate–low.
3	Residents – Verley Drive townhouses	Provides a representative view from upstairs windows for residents backing onto the compound (eight townhouses). The sensitivity of this receptor group is considered to be moderate due to the potential substantial visibility of the compound from upstairs windows, although these views are unlikely to be from living areas. The magnitude of change is expected to be high. This provides an overall visual impact assessment rating of high to moderate.

5.2 Pomeroy Street civil site compound (C2)

The Pomeroy Street civil site compound would be located in Bill Boyce Reserve, adjacent to Pomeroy Street and the M4. The site is currently an open, turfed area bordered with mature trees and the boundary fences of adjoining multistorey residences. The southern embankment from the edge of Bill Boyce Reserve down to the M4 is densely vegetated. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- Removal of vegetation
- A 4.5 metre (approximately) high temporary noise wall on all sides except the southern edge of the site
- Light vehicle access and egress from Pomeroy Street. Vehicle movement may occur up to 24 hours per day, seven days per week
- Site amenities buildings
- Storage containers
- Equipment such as excavators and cranes associated with the works

Representative receiver locations would include views from residential properties (receiver location 1), pedestrian users of the M4 overbridge and Pomeroy Street (receiver location 2) and motorists on the M4 (receiver location 3), as shown in **Figure 5.2**. **Figure 5.2** provides an indicative site layout which will be further developed during the detailed design and construction planning phases.



Figure 5.2 Pomeroy Street civil site (C2) receiver locations

Table 5.2 Pomeroy Street compound (C2) visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Pomeroy Street and Underwood Road	Provides a representative view for residences around the compound. Some residents may have views from upstairs windows over the boundary noise wall into the compound. The sensitivity of nearby residents to the compound is considered to be moderate, due to the views only being available from some upstairs windows of some residences, but with the potential for light spill into these rooms at night (potentially bedrooms), and viewing a 4.5 m wall along their boundary from both within the residences and from public and private outdoor spaces. The magnitude of the visual impact would be high given the extent of existing vegetation that would be removed and also taking into account the previously visual amenity provided by Bill Boyce Reserve and the duration over which the compound would be in place. This provides an overall visual impact assessment rating of high–moderate.
2	Pedestrians – Pomeroy Street and M4 overbridge	Provides a representative view for pedestrians walking past the compound. It is likely pedestrians would be walking for recreation in this area however the site would only be viewed for a short period of time. The sensitivity of this receptor group is considered to be low within the context of potentially relatively low receptor numbers. A large majority of the compound activities would be hidden from pedestrians by hoarding and or the noise wall. The magnitude of change is expected to be moderate due to the loss of vegetation in Bill Boyce Reserve and on the batter up from the M4. This provides an overall visual impact assessment rating of moderate–low.
3	Motorists – M4	Provides a representative view for motorists using M4. The sensitivity of motorists to change is considered to be low. The magnitude of change is considered to be moderate due to the removal of vegetation on the northern edge of the M4 next to the compound. Although the compound would be obscured by hoarding and the angle of view, the existing continuous wall of vegetation would be broken, opening views up to the northern edge of the motorway. This provides an overall visual impact assessment rating of moderate–low.

5.3 Underwood Road civil and tunnel site (C3)

Three separate sites make up the Underwood Road tunnel and civil site. All three sites would sit within a residential context and adjacent to the M4 corridor. The batter slope up to the M4 would provide a dense vegetative screen from vantage points at ground level. Vegetation adjoining the compound sites is expected to be removed during construction to accommodate future buildings required in the operation phase.

The west site is a civil site, situated between Short Street East, Underwood Road and the M4 corridor. The M4 runs over Underwood Road and sits about six metres higher than the site. On the embankment, dense vegetation provides a screen to the M4 above. It would be expected that the vegetation in this area would be removed to accommodate the future ventilation facility to be located here. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A 4.5 metre (approximately) temporary noise wall along the edges of the compound except the side facing the M4
- Heavy vehicle ingress from Short Street East and egress to Underwood Road.
- Temporary traffic light control on Underwood Road
- Equipment such as excavators and cranes associated with the works
- Construction of a distribution substation and a ventilation building for the operation phase of the project.

The east civil site occupies land between Underwood Road and Ismay Avenue, next to the M4 corridor and partially adjacent to a laneway connecting Underwood Road and Ismay Avenue. Residential properties would be acquired to accommodate the compound footprint. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A 4.5 metre (approximately) high temporary noise wall along the edges of the compound except the side facing the M4
- Water treatment plant
- Storage containers
- Double stacked site amenity buildings
- Equipment such as excavators and cranes associated with the works
- Heavy and light vehicle ingress and egress to and from Underwood Road. Vehicle movement may occur up to 24 hours per day and seven days per week to support the tunnelling activities within the tunnelling site compound, discussed below
- Temporary traffic light control on Underwood Road
- Night time lighting for heavy vehicle traffic coming through from the tunnelling activities within the adjacent tunnelling site compound, discussed below.

The third compound is a tunnelling location. This site, like the west and east civil sites, also sits adjacent to the M4 corridor, however it is bordered by Allen Street and the open space associated with Powells Creek. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A 4.5 metre (approximately) high temporary noise wall surrounding the site
- An acoustic shed, with approximate dimensions 60 meters long by 30 meters wide, and 15 metres high
- An electrical substation
- Storage, workshop and fuel buildings
- Double stacked site offices
- Equipment such as excavators and cranes associated with the works
- Night time lighting of construction activities
- Construction of a substation, fire water tanks a pump house for the operation phase of the project.

Representative receiver locations for all three sites would include views from residential properties (receiver location 1), pedestrians; including those within Powells Creek open space corridor (receiver location 2), motorists on Underwood Road, Ismay Avenue and Allen Street (receiver location 3) and motorists on the M4 (receiver location 4), as shown on **Figure 5.3**. **Figure 5.3** provides an indicative site layout which will be further developed during the detailed design and construction planning phases.



Figure 5.3 Underwood Road civil and tunnel site (C3) receiver locations

Table 5.3 Underwood Road civil and tunnel site (C3) visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Short Street East, Underwood Road, Ismay Avenue and Allen Street	Provides a representative view for residences around the compounds. The sensitivity of nearby residents to the compound is considered to be high due to the long viewing period of receptors and the proximity of the residences to the compounds. The magnitude of the visual impact would be moderate given the extent of existing vegetation that would be removed, opening views to the M4, and also the vantage of some residents who may look over noise walls into the compounds. Especially in the tunnelling site compound, plant and equipment would be expected to be visible above the noise wall hoarding. This provides an overall visual impact assessment rating of high–moderate.
2	Pedestrians – Short Street East, Underwood Road, Ismay Avenue, Allen Street and Powells Creek open space	Provides a representative view for pedestrians walking past the compounds. The sensitivity of this receptor group is considered to be high. Pedestrians are likely to be local residents walking for recreation in local streets or in the Powells Creek open space. The magnitude of change is expected to be moderate. The loss of vegetation would be a significant negative effect however the majority of the compound activities would be hidden by hoarding except the acoustic shed and the construction of the ventilation building. This provides an overall visual impact assessment rating of high–moderate.
3	Motorists – Underwood Road, Ismay Avenue and Allen Street	Provides a representative view for motorists driving on Underwood Road, Ismay Avenue and Allen Street. The sensitivity of this receptor group is considered to be low due to the relatively small extent of the view which would primarily comprise hoarding, within the context of a longer journey. The magnitude of change is expected to be moderate. The loss of vegetation would be a significant negative affect; however the majority of the compound activities would be hidden. This provides an overall visual impact assessment rating of moderate–low.
4	Motorists – M4	Provides a representative view for motorists using M4. The sensitivity of motorists to change is considered to be low. Vegetation on the northern edge of the motorway would be removed, breaking the continuous wall of vegetation; however the compounds and their activities and much of the vegetation would be obscured by the barriers alongside the motorway. The magnitude of change is considered to be low. This provides an overall visual impact assessment rating of low.

5.4 Powells Creek civil site (C4)

Powells Creek civil site would be located at the southern edge of the M4 between Underwood Road and Powells Creek. The site would occupy the vegetated area between Powell Street, Parramatta Road and the M4. The context of the area is a mix of commercial and multistorey residential buildings. The following structures, equipment and construction activities from all stages would be likely to be visible from surrounding receiver locations:

- Existing fencing and new fencing surrounding the site, typically three meters high
- Works associated with construction of the new M4 westbound on-ramp from Parramatta Road
- Heavy and light vehicle ingress and egress to and from Parramatta Road and Powell Street.
- Equipment such as excavators and cranes associated with the works
- Site amenities and storage buildings.

Representative receiver locations include views from: multistorey residential properties (receiver location 1), pedestrians on Powell Street (receiver location 2), recreational users of the Powells Creek open space (receiver location 3) and workers in commercial buildings (receiver location 4), as shown in **Figure 5.4**. Pedestrians on Parramatta Road and Underwood Road were considered but not assessed because only small sections of the compounds would be visible and also pedestrians would be unlikely to be walking for recreation.

Table 5.4 Powells Creek civil site visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Powell Street	Provides a representative view for residences on Powell Street. A multistorey residential building sits on the bend of Powell Street and would have views down into the site compound. The building has windows and balconies facing the vegetated batter up to the M4. The sensitivity of nearby residents is considered to be high. The loss of vegetation to the embankment would open views to the M4, resulting in a visual impact for these receptors and therefore the magnitude of change is considered to be high. This provides an overall visual impact assessment rating of high.
2	Pedestrians – Powell Street	Provides a representative view for pedestrians walking adjacent to the compound on Powell Street. The sensitivity of pedestrians would be low due to the existing context of multistorey residential and large commercial buildings. The magnitude of change would be high due to the loss of vegetation opening views to the M4. This provides an overall visual impact assessment rating of moderate.
3	Recreational users – Arnott's Reserve	Provides a representative view for recreational users of Arnott's Reserve open space. The sensitivity of the receiver would be low taking into account the existing context of large infrastructure eg the M4, the electricity easement. The magnitude of change is considered to be low as the majority of the site would be obscured by the M4 embankments and existing vegetation. This provides an overall visual impact assessment rating of low.
4	Workers – commercial premises, Powell Street	Provides a representative view for workers in the multistorey commercial buildings on the opposite side of Powell Street from the site compound. The sensitivity of the workers is considered to be low as their focus would be on internal activities. The magnitude of change is expected to be high due to the removal of vegetation on the M4 embankment. This provides an overall visual impact assessment rating of moderate.



Figure 5.4 Powells Creek civil site (C4) receiver locations

5.5 Concord Road civil and tunnel site (C5)

Two sites would make up the Concord Road civil and tunnel site compound. Both sites would sit within a residential context and multiple properties would be acquired to accommodate the construction sites. The sites would be located on both sides of Concord Road to the north of Parramatta Road. The southern edges of both compounds curve around the alignment of the M4 on- and off-ramps from Parramatta Road. Sydney Street creates the northern/western boundary. The westernmost site is the civil compound. The easternmost site is the tunnelling site, its eastern boundary runs along residential lots on Sydney Street, Edward Street, Alexandra Street and Ada Street. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations.

Eastern tunnelling site compound:

- A 4.5 metre (approximately) high temporary noise wall surrounding the northern section of the site
- In the southern section of the compound, a three meter high (approximately) temporary noise wall would sit along the eastern edge and a temporary concrete barrier and 1.2 metre (approximate) high hoarding would sit to the southern and western edges of the site
- An acoustic shed approximately 90 meters by 50 meters long and wide, and 15 meters high
- An electrical substation
- Single and double stacked site amenities buildings
- Storage and workshop buildings
- Temporary tunnel ventilation
- A water treatment plant
- Equipment such as excavators and cranes associated with the works
- Construction of the new above ground road, M4 westbound on ramp, cycle and pedestrian infrastructure for the operation phase of the project.
- Light vehicle ingress from Alexandra Street and ingress and egress from Ada Street. Vehicle movement may occur up to 24 hours per day and seven days per week
- Heavy vehicle ingress and egress from Concord Road, requiring reconfigured traffic light arrangement at the intersection of Sydney Street and Concord Road (receiver location 3). Vehicle movement may occur up to 24 hours per day and seven days per week
- Night time lighting of construction activities

Western civil site compound:

- A four metre (approximately) high temporary noise wall along the northern and western edges of the site
- A four metre (approximately) high hoarding along the southern and eastern edges of the site
- Site amenities buildings
- Equipment such as excavators and cranes associated with the works
- Heavy vehicle ingress and egress from Sydney Road
- Construction of the new dive structure for the operation phase of the project.

Representative receiver locations have been identified including residential properties (receiver location 1), pedestrians (receiver location 2) and motorists on Concord Road, as shown in **Figure 5.5**. Motorists on the M4 on- and off-ramps would be screened from the compound by existing noise walls and vegetation and therefore have not been assessed. **Figure 5.5** provides an indicative site layout which will be further developed during the detailed design and construction planning phases.

Table 5.5 Concord Road civil and tunnel site (C5) visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Concord Road, Concord Lane, Sydney Street, Edward Street, Alexandra Street, Ada Street, Daly Street, Franklyn Street	Provides a representative view for residences surrounding the compounds. The sensitivity of nearby residents to the compound is considered to be high, given the proximity to the compound. Some buildings and equipment would likely be visible above noise walls, fences and hoarding. The high noise walls would also be a significant change from the existing condition. Views from residential areas towards Concord Road currently consist of filtered views through street trees, which would be interrupted by the intervention of the high walls associated with the compounds. The magnitude of the visual impact would be high. This provides an overall visual impact assessment rating of high.
2	Pedestrians – Concord Road, Concord Lane, Sydney Street, Edward Street, Alexandra Street, Ada Street, Daly Street, Franklyn Street	Provides a representative view for pedestrians walking past the compounds. The sensitivity of this receptor group is considered to be high. Pedestrians on streets except Concord Road and Parramatta Road are likely to be local residents walking for recreation. The magnitude of change is high because of the loss of vegetation and the large area occupied by the compounds. This provides an overall visual impact assessment rating of high.
3	Motorists – Concord Road	Provides a representative view for motorists driving on Concord Road. The sensitivity of this receptor group is considered to be low due to the short viewing duration of motorists. The magnitude of change is expected to be high. The loss of vegetation would be a negative visual impact, however the majority of the compound activities would be hidden. Hoarding and noise walls would confine views to the road edge where currently the view is open to vegetation and residences set back from the road edge. This provides an overall visual impact assessment rating of moderate.



Figure 5.5 Concord Road civil and tunnel site (C5) receiver locations

5.6 Cintra Park tunnel site (C6)

The Cintra Park tunnel site would sit within the footprint of the existing Cintra Park hockey facility site. Stadium seating for Concord Oval lies to the west of the site, to the south is Parramatta Road, to the north sits Gipps Street and to the east are residential properties. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A 4.5 metre (approximately) high noise wall to the northern, eastern and southern sides of the compound
- A four metre (approximately) high hoarding and/or fencing on the western side of the compound
- An acoustic shed approximately 70 meters by 40 meters long and wide, and 15 meters high
- Electrical substations
- Storage and workshop buildings
- Ventilation fans
- Fresh air intake facility
- Double stacked site offices
- Equipment such as excavators and cranes associated with the works
- Light vehicle ingress and egress from Gipps Street
- Heavy vehicle ingress and egress from Parramatta Road. Egress to the south-western corner of the site would require reconfiguring of the intersection of Parramatta Road and Luke Avenue. Vehicle movement may occur up to 24 hours per day and seven days per week
- Night time lighting of construction activities.

One representative receiver location has been identified for views from residential properties in Taylor Street that back onto Cintra Park (receiver location 1), as shown in **Figure 5.6**, which provides an indicative site layout which will be further developed during the detailed design and construction planning phases. Users of Concord Oval have not been assessed because their focus would be within the oval, where the western edge of the site would border the back of the grandstand and vegetation. Pedestrians and motorists passing the compound have also been considered but not assessed. It is not expected that pedestrians would be walking for recreation purposes around the compound. Users of the St Lukes playing fields have been considered given that the fields are elevated in height above Cintra Park, but not assessed given the extent of intervening screening vegetation which is proposed to be retained.

Table 5.6 Cintra Park tunnel site (C6) visual impact assessment

No.	Receiver ocation	Visual impact assessment
1	Residents – Taylor Street	Provides a representative view for residences to the east of the compound. The sensitivity of nearby residents to the compound is considered to be high due to houses backing on to the compound site and the recreational utility in private open space. There is however a vegetative screen, that would be retained, between the properties and the compound. Some buildings within the compound would be visible above the noise wall and the noise wall itself would be visible above back fences, however the view would be filtered by vegetation. The magnitude of the visual impact would be moderate. This provides an overall visual impact assessment rating of high - moderate.



Figure 5.6 Cintra Park tunnel site (C6) receiver locations

5.7 Northcote Street tunnel site (C7)

The Northcote Street tunnel site compound would sit adjacent to Parramatta Road and span from Wolseley Street to Wattle Street in the footprint of commercial premises facing Parramatta Road and a number of residential properties sitting adjacent. The compound would temporarily dead-end Northcote Street at Parramatta Road for the period of construction. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- Removal of a number of trees, including two mature street trees on Northcote Street
- A temporary 4.5 metre (approximately) noise wall on three sides of the site and hoarding to Wattle Street
- Heavy vehicle ingress from Parramatta Road and egress to Wattle Street. Vehicle movement may occur up to 24 hours per day and seven days per week
- An acoustic shed approximately 90 meters by 50 meters long and wide, and 15 meters high
- A water treatment plant
- Storage, workshop and double stacked office buildings
- Equipment such as excavators and cranes associated with the works
- Night time lighting of construction activities

Representative receiver locations have been identified including residential properties (receiver location 1), pedestrians (receiver location 2) and motorists on Parramatta Road and Wattle Street (receiver location 3), as shown in **Figure 5.7,** which provides an indicative site layout which will be further developed during the detailed design and construction planning phases. Motorists on Wolseley Street were considered but not assessed. This is due to the short period of viewing time and the focus of Wolseley Street motorists being on the Parramatta Road intersection.

Table 5.5 Northcote Street tunnel site (C7) visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road	Provides a representative view for residences around the compound. The sensitivity of nearby residents to the compound is considered to be moderate, as their views would be predominantly side-on to the compound making the compound visible from side windows and back yards. The magnitude of the visual impact would be moderate given the existing land use in the construction compound area is predominantly commercial, consisting of large two-storey buildings, with a row of residential properties. Residential buildings directly adjacent to the compound are currently adjacent to other residences, however the existing commercial buildings would likely be visible currently and these residences therefore would not be as significantly impacted. This provides an overall visual impact assessment rating of moderate.
2	Pedestrians – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road, Page Avenue, Earle Avenue, Frederick Street	Provides a representative view for pedestrians walking past the compound. The sensitivity of this receptor group is considered to be low. It is unlikely pedestrians would be walking past the site for recreation purposes considering the visible sides of the compound face Parramatta Road and Wattle Street, which are main roads. Views the construction activities would be shielded via a hording structure which would be directly adjacent to the footpath on Parramatta Road, where buildings are currently set back. The dead-ending of Northcote Street would also obscure what is currently an open view out to Parramatta Road. Therefore the magnitude of change is expected to be moderate taking into account the predominantly commercial land use currently in this area. This provides an overall visual impact assessment rating of moderate–low.

No.	Receiver location	Visual impact assessment
3	Motorists – Wattle Street, Parramatta Road	Provides a representative view for motorists using the main roads of Parramatta and Wattle and Northcote Street. The sensitivity of motorists to change is considered to be low due to the short period of viewing time and the focus of the driver on the activity of driving. The magnitude of change is considered to be low due to the commercial land use in this area. Northcote Street would be dead-ended at Parramatta Road, however this would only affect a relatively small number of motorists on this street, those users would have a beneficial visual impact from fewer vehicles on their section of road. This provides an overall visual impact assessment rating of low.



Figure 5.7 Northcote Street tunnel site (C7) receiver locations

5.8 Eastern ventilation facility site (C8)

The eastern ventilation facility site would be located on the corner of Parramatta Road and Wattle Street. Commercial properties facing Parramatta Road and residential properties behind would be acquired to accommodate the compound. This site would support tunnel excavation work. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A six metre (approximately) high fence facing adjacent properties on Walker Avenue, four metre (approximately) high hoarding along Walker Avenue and a 2.4 metre (approximately) high fence facing Parramatta Road and Wattle Street
- Heavy and light vehicle ingress from Walker Avenue and egress on to Wattle Street. Vehicle movement may occur up to 24 hours per day and seven days per week if concrete deliveries are required to this site to support tunnelling activities
- Equipment such as excavators and cranes associated with the works
- Site amenities, storage, workshop and office buildings
- An electrical substation
- Construction of ventilation buildings, fire water tanks and pump buildings and electrical buildings for the operation phase of the project.
- Night time lighting of tunnelling support work

Representative receiver locations have been identified, including residential properties (receiver location 1), pedestrians (receiver location 2) and motorists (receiver location 3), as shown in **Figure 5.8,** which provides an indicative site layout which will be further developed during the detailed design and construction planning phases. The assessment does not take into account residences on the west side of Wattle Street as a separate compound would be located in that area and therefore the houses would not be occupied.

Table 5.7 Eastern ventilation facility site visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Wattle Street and Walker Avenue	Provides a representative view for residences around the compound site. Residents would have varying views to the compound from front yards, the back yards and the sides of properties. The sensitivity of residents is considered to be high. The magnitude of the visual impact would be high due to the change from a residential context to the likelihood of visible construction activities and the introduction of large noise walls. This provides an overall visual impact assessment rating of high.
2	Pedestrians – Wattle Street and Walker Avenue	Provides a representative view for pedestrians walking past the compound. The sensitivity of this receptor group is considered to be low. It is unlikely pedestrians would be walking past the site for recreation along Wattle Street or the affected end of Walker Avenue. The magnitude of change would be high, as discussed above. This provides an overall visual impact assessment rating of moderate.
3	Motorists – Wattle Street and Walker Avenue	Provides a representative view for motorists using Wattle Street and Walker Avenue. The sensitivity of motorists to change is considered to be low due to the short period of viewing time and the focus of the driver of the activity of driving. The magnitude of change is considered to be high as discussed above. This provides an overall visual impact assessment rating of moderate.

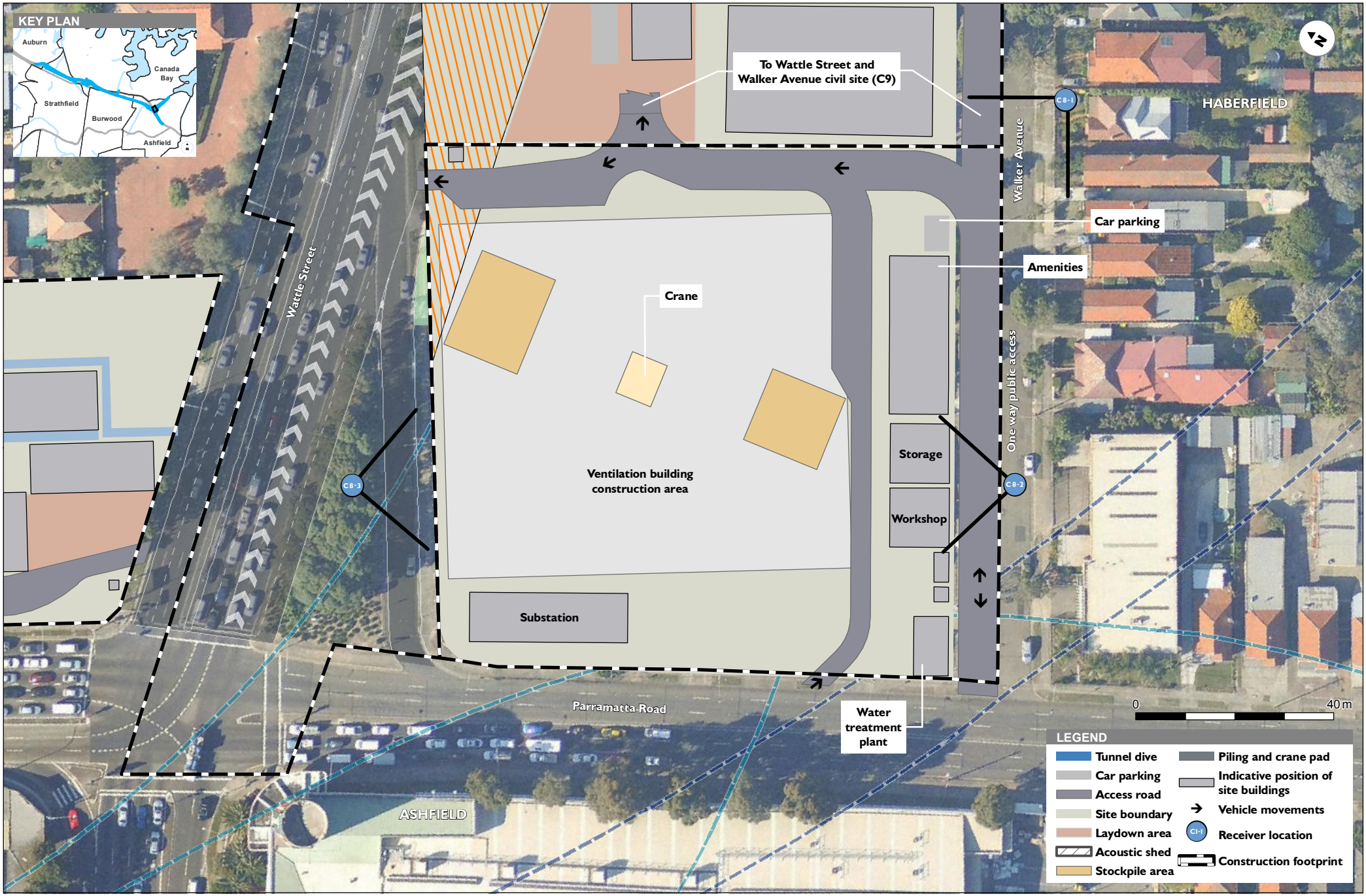


Figure 5.8 Eastern ventilation facility site (C8) receiver locations

5.9 Wattle Street and Walker Avenue civil site (C9)

The Wattle Street and Walker Avenue civil site would consist of three sections; two sites on the eastern edge of Wattle Street and one site on the western edge of Wattle Street. The southern edge sites would consist of a large and a small site. The large site runs from the eastern ventilation facility (C7) to Ramsay Street and then another section of the compound runs from Ramsay Street to just past Martin Street. The northern edge site compound would occupy a section of Reg Coady Reserve between Martin Street and Dobroyd Canal (Iron Cove Creek).

The large site on the southern edge of Wattle Street would occupy a row of properties facing Wattle Street. During the first and second stages of construction, an additional six properties fronting Walker Street and adjacent to the eastern ventilation facility (C7) would also be acquired for construction.

The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- A 2.1 metre or three metre (approximately) hoarding surrounding the site
- Heavy and light vehicle ingress and egress to and from Wattle Street and Ramsay Street. Light vehicle access will also occur on Walker Avenue.
- Temporary traffic light control on Wattle Street and Ramsay Street
- Equipment such as excavators and cranes associated with the works
- Site amenities and storage buildings
- Construction of the new Wattle Street road alignment for the operation phase of the project
- Representative receiver locations include views from: residential properties (receiver location 1); pedestrians, including those within Reg Coady Reserve open space (receiver location 2); and motorists (receiver location 3), as shown on **Figure 5.9,** which provides an indicative site layout which will be further developed during the detailed design and construction planning phases.

Table 5.8 Wattle Street and Walker Avenue civil site visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Wattle Street, Walker Avenue, Ramsay Street, Martin Street and Dobroyd Parade	Provides a representative view for residences around the compound sites. Residences would have varying views to the compound from front yards, back yards and the sides of properties. Due to long viewing periods from the likely location of living rooms, kitchens and back yards, the sensitivity of residents is considered to be high. Because there would be extensive work to reconfigure Wattle Street and given the existing context of residential land use, the magnitude of the visual impact would be high. This provides an overall visual impact assessment rating of high.
2	Pedestrians – Reg Coady Reserve, Wattle Street, Walker Avenue, Ramsay Street, Martin Street, Dobroyd Parade and Parramatta Road	Provides a representative view for pedestrians walking past the compound. The sensitivity of this receptor group is considered to be moderate. It is unlikely pedestrians would be walking past the site for recreation along Parramatta Road or Wattle Street, although locals would use Walker Avenue, Ramsay Street, Martin Street or Dobroyd Parade and Reg Coady Reserve for recreation. The magnitude of change would be greater on the main roads of Parramatta Road and Wattle Street and lower on local roads where retained houses would obscure views to the compounds. The overall magnitude of change would be moderate. This provides an overall visual impact assessment rating of moderate.
3	Motorists – Wattle Street, Walker Avenue, Ramsay Street, Martin Street, Dobroyd Parade and Parramatta Road	Provides a representative view for motorists using the main roads of Parramatta Road and Wattle Street, and the local roads of Walker Avenue, Ramsay Street, Martin Street, Dobroyd Parade. The sensitivity of motorists to change is considered to be low due to the short period of viewing time and the focus of the driver on the activity of driving. The magnitude of change is considered to be high due to the change in street layout to Wattle Street and Walker Avenue. This provides an overall visual impact assessment rating of moderate.



Figure 5.9 Wattle Street and Walker Avenue civil site (C9) receiver locations

5.10 Parramatta Road civil site (C10)

The Parramatta Road civil site compound would be located on the south-western side of Parramatta Road between Bland Street and Orpington Street. Chandos Street would be dead-ended at Parramatta Road. The following structures, equipment and construction activities would be likely to be visible from surrounding receiver locations:

- Removal of a number of trees, including two mature street trees on Chandos Street
- A 2.1 metre (approximately) hoarding addressing Parramatta Road and a temporary three metre (approximately) hoarding along the edge of the rest of the site
- Heavy vehicle ingress from Parramatta Road and egress to Bland Street. Light vehicle ingress and egress from Orpington Street.
- Water tanks and pump station
- Storage and site office buildings
- Equipment such as excavators and cranes associated with the works.

Representative receiver locations have been identified including; residential properties (receiver location 1), pedestrians (receiver location 2), users of the Ashfield Bowling Club (receiver location 3), viewers from commercial premises (receiver location 4), and motorists (receiver location 5), as shown in **Figure 5.10,** which provides an indicative site layout which will be further developed during the detailed design and construction planning phases. The residents of Presbyterian Aged Care Haberfield on Parramatta Road have been considered but not assessed due to the lack of windows that would face the site and the inward focus of the home to the internal courtyard. The residents of Willows Private Nursing Home have been assessed as part of the general rating for residents (receiver location 1).

Table 5.9 Parramatta Road civil site visual impact assessment

No.	Receiver location	Visual impact assessment
1	Residents – Bland Street, Chandos Street, Orpington Street, Loftus Street, Parramatta Road	Provides a representative view for residences around the compound. Only a small proportion of residences would have views over the hoarding and into the construction site; this is because some of the residences are only single-storey and the majority of others, although multistorey, do not have windows that would face the site. The exception is on Chandos Street, where a multistorey residential building that would have views into the site sits directly adjacent to the site compound. The sensitivity of nearby residents is considered to be moderate due to the relatively low number of residents with views. The properties currently addressing Parramatta Road are active commercial, derelict commercial, vacant land and a few residential properties. The existing visual condition is considered to be of predominantly low quality. It is not considered that the change to a construction site compound would be a significantly negative visual impact considering the current land uses along Parramatta Road. Therefore the magnitude of the visual impact would be low. This provides an overall visual impact assessment rating of moderate–low.

No.	Receiver location	Visual impact assessment
2	Pedestrians – Bland Street, Chandos Street, Orpington Street, Loftus Street, Parramatta Road	Provides a representative view for pedestrians walking past the compound. Pedestrians on Parramatta Road are unlikely to be walking for recreation and the Parramatta Road footpath, along the northern edge of the compound, would be closed during construction. On the smaller roads such as Bland Street, Chandos Street, Orpington Street and Loftus Street, pedestrians are more likely to be walking for recreation, however their exposure to the site would be minimal. For the most part, site activity would be obscured by the hoarding, except fleetingly where pedestrians use the Parramatta Road overbridge and would see into the site. Therefore the sensitivity of this receptor group is considered to be low. The properties currently addressing Parramatta Road are active commercial, derelict commercial, vacant land and a few residential properties. The existing visual condition is considered to be a predominantly low quality. The magnitude of change is therefore expected to be low. The overall rating would be low.
3	Users – Ashfield Bowling Club	Provides a representative view for recreational users of the Ashfield Bowling Club. Although users would tend to be at the club for extended periods of time, their focus would be directed towards their activity and therefore the sensitivity of the receptor is considered to be moderate. Only a small section of the site compound would be visible and the view would not be significantly diminished from the existing view of the car sales yard. Therefore the magnitude of change would be low. This provides an overall visual impact assessment rating of moderate–low.
4	Workers – Commercial premises, Parramatta Road	Provides a representative view for workers in the multistorey commercial buildings on the northern side of Parramatta Road, opposite to the site. The sensitivity of the workers is considered to be low as their focus would be on internal activities. The magnitude of change is expected to be moderate due to the extent of the site that would be visible from the higher vantage point. This provides an overall visual impact assessment rating of moderate–low.
5	Motorists – Bland Street, Chandos Street, Orpington Street, Loftus Street, Parramatta Road.	Provides a representative view for motorists. The sensitivity of motorists to change is considered to be low due to the short period of viewing time and the focus of the driver on the activity of driving. The magnitude of change is considered to be low due to the largely commercial land use existing in this area. This provides an overall visual impact assessment rating of low.

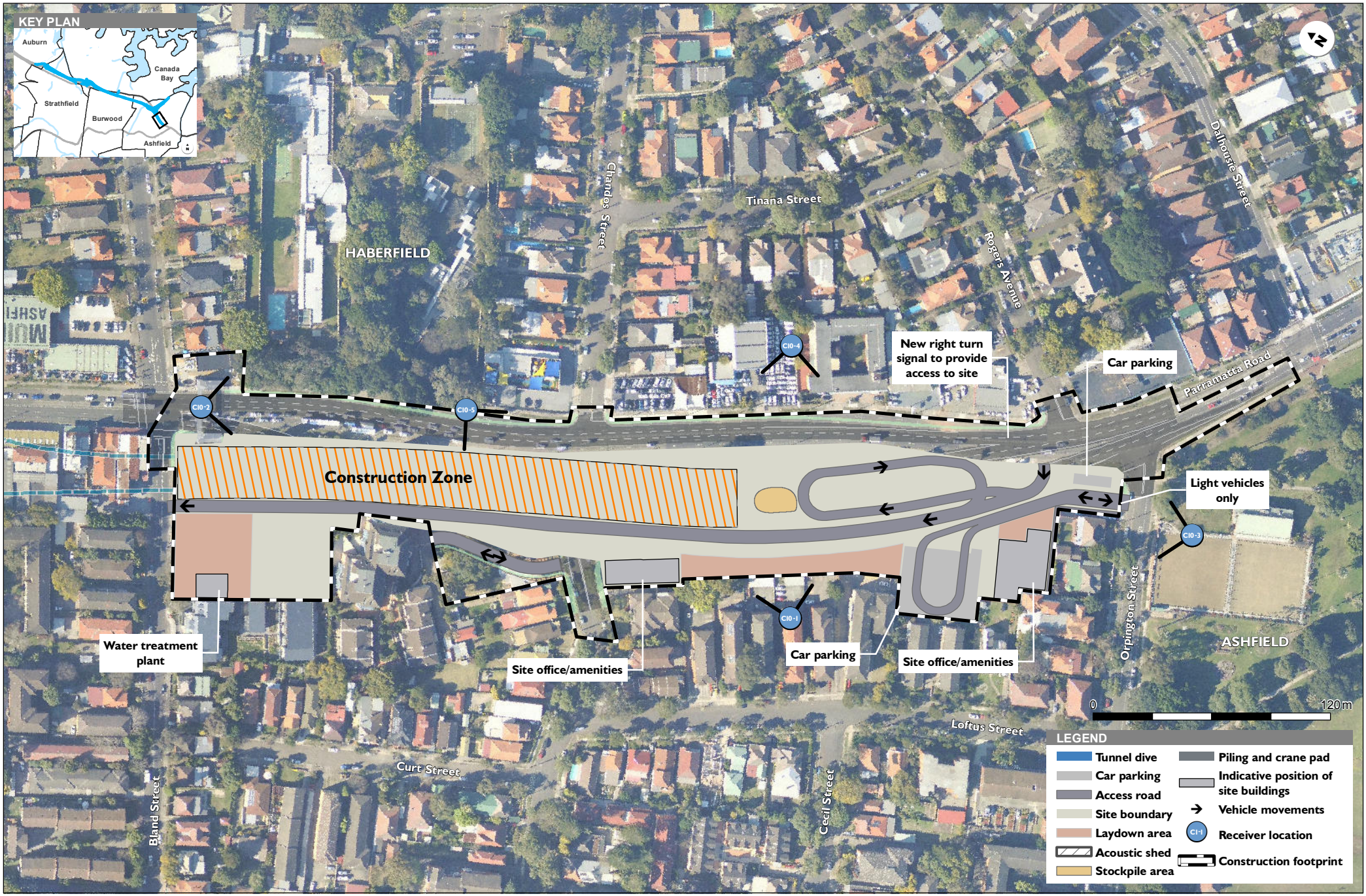


Figure 5.10 Parramatta Road civil site (C10) receiver locations

5.11 Summary of construction impacts

A summary of the construction site compounds assessments for the relevant receiver groups is provided below in **Table 5.10**.

Table 5.10 Summary of construction impacts

Receiver		Sensitivity to change	Magnitude of change	Overall rating
Homebush Bay Drive civil site (C1)				
1	Motorists – M4	Low	High	Moderate
2	Carpark users	Low	Moderate	Moderate–low
3	Residents	Moderate	High	Moderate–high
Pomeroy Street civil site (C2)				
1	Residents	Moderate	High	Moderate–high
2	Pedestrians	Low	Moderate	Moderate–low
3	Motorists – M4	Low	Moderate	Moderate–low
Underwood Road civil and tunnel site (C3)				
1	Residents	High	Moderate	High–moderate
2	Pedestrians	High	Moderate	High–moderate
3	Motorists – local roads	Low	Moderate	Moderate–low
4	Motorists – M4	Low	Low	Low
Powells Creek civil site (C4)				
1	Residents	High	High	High
2	Pedestrians	Low	High	Moderate
3	Recreational users – Powells Creek open space	Low	Low	Low
4	Office workers	Low	High	Moderate
Concord Road civil and tunnel site (C5)				
1	Residents	High	High	High
2	Pedestrians	High	High	High
3	Motorists – local roads	Low	High	Moderate
Cintra Park tunnel site (C6)				
1	Residents	High	Moderate	High-moderate
Northcote Street tunnel site (C7)				
1	Residents	Moderate	Moderate	Moderate
2	Pedestrians	Low	Moderate	Moderate–low
3	Motorists – local roads	Low	Low	Low
Eastern ventilation facility site (C8)				
1	Residents	High	High	High
2	Pedestrians	Low	High	Moderate
3	Motorists – local roads	Low	High	Moderate
Wattle Street and Walker Avenue civil site (C9)				
1	Residents	High	High	High
2	Pedestrians	Moderate	Moderate	Moderate
3	Motorists – local roads	Low	High	Moderate
Parramatta Road civil site (C10)				
1	Residents	Moderate	Low	Moderate–low
2	Pedestrians	Low	Low	Low
3	Users – Ashfield Bowling Club	Moderate	Low	Moderate–low
4	Office workers	Low	Moderate	Moderate–low
5	Motorists – local roads	Low	Low	Low

5.12 Construction lighting impacts

The potential night lighting impacts at the relevant construction sites are assessed in **Table 5.11**. Sites that contain tunnelling activities or sites that support tunnelling actives, which includes C3, C5, C6, C7 and C8, have been assessed. The impact on pedestrians has not been assessed due to the relatively low number of pedestrians walking at night for recreation.

Table 5.11 Night lighting construction impact assessment

Construction area	Night lighting impact assessment
Underwood Road tunnel and civil site compound (C3)	The visual setting of the construction compound includes lighting associated with Underwood Road, local streets; Ismay Avenue and Allen Street, and associated vehicular traffic, and illuminated windows of the residential properties. The M4 runs above a residential area, however lighting associated with the motorway is predominantly screened by a vegetated batter. Lighting during construction would be associated with activities within the two compounds and the access and egress points. Lighting would be designed to minimise light spill, which would reduce the amount of light trespass onto adjoining residential properties. Removal of vegetation adjacent to the M4 would make the existing motorway lighting more visible. The sensitivity of the residents is considered to be high, however given that very few residences are directly adjacent to the compound or are tall enough to see above walls and hording, the magnitude of lighting increase is considered to be low. Similarly, the M4 wall would provide some light screening and along with the proposed light spill reduction measures, the overall visual impact assessment rating is moderate. The sensitivity of local motorists is anticipated to be low, and the magnitude of lighting relative to the road lighting to be low, providing an overall visual impact assessment rating of low. The sensitivity of motorists on the M4 Motorway is anticipated to be low, and the magnitude of lighting relative to the road lighting to be low, providing an overall visual impact assessment rating of low.
Concord Road civil and tunnel site (C5)	The visual setting of the construction compound includes lighting associated with Concord Road and Sydney Road as large arterial roads, local streets and associated vehicular traffic, and illuminated windows of the residential properties. The M4 runs to the south of the compounds, however lighting associated with the motorway is predominantly screened by vegetation and noise walls. Lighting during construction would include the site offices, the car parking areas, access and egress points and lighting of associated compound works. Lighting would be designed to minimise light spill, which would reduce the amount of light trespass onto adjoining residential properties. The sensitivity of the residents is considered to be moderate, however the magnitude of lighting impacts is considered to be low given that very few residences are directly adjacent to compounds or tall enough to see above walls and hording, providing an overall visual impact assessment rating of moderate to low. The sensitivity of local motorists is anticipated to be low, and the magnitude of lighting relative to the road lighting to be moderate, providing an overall visual impact assessment rating of moderate to low.

Cintra Park tunnel site (C6)	The visual setting of the construction compound includes lighting associated with Parramatta Road, Concord Oval and Cintra Park hockey field training and match lighting. Lighting during construction would include the site offices, the car parking area, access and egress points and lighting associated with the acoustic shed. Lighting would be designed to minimise light spill, which would reduce the amount of light trespass onto adjoining residential properties. The sensitivity of the residents is considered to be moderate given the existing condition of the residences next to a well-lit sports field and the row of vegetation providing screening. The magnitude of lighting increase is considered to be low, due to the existing night time lighting associated with Cintra Park, however the hours the site will be illuminated would be increased, providing an overall visual impact assessment rating of moderate to low.
Northcote Street tunnel site (C7)	The visual setting of the construction compound includes lighting associated with Parramatta Road, local streets and associated vehicular traffic, and illuminated windows of the residential properties. Lighting during construction would include the site offices, and lighting associated with the acoustic shed. Lighting would be designed to minimise light spill, which would reduce the amount of light trespass onto adjoining residential properties. The sensitivity of the residents is considered to be moderate given the existing residences being located adjacent to commercial businesses and Parramatta Road, but also set back behind a row of residential properties. The magnitude of lighting increase is considered to be low, due to the existing lighting associated with commercial business and Parramatta Road and the a large area of works taking place within the containment of the acoustic shed. This provides an overall visual impact assessment rating of moderate to low. The sensitivity of local motorists is anticipated to be low, and the magnitude of lighting relative to the road and commercial lighting to be low due to the same reasons stated previously, providing an overall visual impact assessment rating of low.
Eastern ventilation facility site (C8)	The visual setting of the construction compound includes lighting associated with Parramatta Road, local streets and associated vehicular traffic, and illuminated windows of the residential properties and also the commercial buildings along Parramatta Road. Lighting during construction would occur when necessary to support tunnelling work, including delivery of concrete and include the site offices and car parking. Lighting would be designed to minimise light spill, which would reduce the amount of light trespass onto adjoining residential properties. The sensitivity of the residents is considered to be low due to the houses being single storey and distanced from the compound by Waker Avenue. Residences on the north side of Walker avenue and on Wattle Street

	have net been assessed as these locations will be occupied by site compounds C7 and C9. The magnitude of lighting increase is also considered to be low, due to the existing lighting associated with commercial business and Parramatta Road, however the hours the site will be illuminated would be increased, providing an overall visual impact assessment rating of low. The sensitivity of local motorists is anticipated to be low, and the magnitude of lighting change relative to roads and commercial lighting would be negligible. Providing an overall visual impact assessment rating of negligible.

5.13 Summary of construction lighting impacts

The potential night lighting impacts at each construction site are summarised in **Table 5.12**.

Table 5.12 Summary of night lighting construction impact assessment

Receiver		Sensitivity to change	Magnitude of change	Overall rating
Underwood Road tunnel and civil site compound (C3)				
1	Residents	Moderate	Low	Moderate to low
2	Motorists – local roads	Low	Low	Low
3	Motorists – M4	Low	Low	Low
Concord Road civil and tunnel site (C5)				
1	Residents	Moderate	Low	Moderate to low
2	Motorists – local roads	Low	Moderate	Moderate to low
Cintra Park tunnel site (C6)				
1	Residents	Low	Moderate	Moderate to low
Northcote Street tunnel site (C7)				
1	Residents	Moderate	Low	Moderate to low
2	Motorists – local roads	Low	Low	Low
Eastern ventilation facility site (C8)				
1	Residents	Low	Low	Low
2	Motorists – local roads	Low	Negligible	Negligible

6 Assessment of operational impacts

6.1 Landscape character impact assessment

This section assesses impacts of the project on the landscape character zones described in **section 4.2**. The project elements described within this section will be further developed through the detailed design and value engineering process.

6.1.1 Landscape character zone 1 – M4 Motorway

Project effects

The M4 Motorway LCZ would continue to be defined as a district transport corridor, though will change from that of a visually enclosed four lane motorway, with vegetated embankments, to a substantially wider corridor incorporating multiple lanes (increasing from six lanes to 14 lanes at the western end including the Homebush Bay Drive on- and off-ramps), elevated road sections with bridges and tunnel portals. Particularly, the character of the corridor would change from that of a landscape with a relatively narrow carriageway and a wide vegetated edge, to that of a predominantly hard surface corridor, including a much wider carriageway, retaining walls, flyovers and portals.

Key elements of the change would include:

- Retaining walls up to about six metres high along portions of the corridor boundary and the elevated roadways within the corridor, which will be finalised through the detailed design process
- Three flyover bridges
- Tunnel portals and associated dive structures
- Removal of existing vegetated batters, and replacement with retaining walls and noise walls, with limited opportunities for vegetative screening
- Removal of a vegetative screening edge within the road corridor along:
  - A section at the end of Verley Drive (off Wentworth Road South)
  - Sections of Park Road
  - Sections between Bill Boyce Reserve and Underwood Road
  - The southern edge of the Powells Creek on-ramp to the M4 towards Concord Road
- A reduced vegetative screening edge within the road corridor to:
  - Bill Boyce Reserve
  - The remaining sections of Park Road
  - The northern edge of the M4 from Bill Boyce Reserve to the Powells Creek Corridor
  - The eastern half of Powell Street that adjoins the M4
  - The western edge of Concord Road between Parramatta Road and the M4
  - The northern edge of the M4 travelling east between the Sydney Road exit and Parramatta Road.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.1 LCZ 1 – M4 motorway precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate given that: The LCZ is predominantly characterised by a visually strong and simple design, comprising an axial corridor, with a relatively narrow carriageway, set within screen tree planting, in conjunction with a remnant ornamental landscape edge treatment from the time of the Sydney Olympics This vegetative screen is less apparent in some areas east of Short Street West, in addition to being absent where the M4 crosses the Powells Creek corridor and Northern Rail Line. The magnitude of the change is considered to be high, within the context of the widening of the corridor, comprising a hard landscape characterised by carriageways, retaining walls, flyovers, dive structures/portals etc, and with an intermittent and reduced width of edge vegetation.	This provides a landscape character impact assessment rating of high–moderate.

6.1.2 Landscape character zone 2 – Homebush commercial precinct

Project effects

The width of the open space between the Homebush Bay Drive on-ramp and the adjacent car park and electrical substation would be reduced, however as the remaining open space contains moderate screen tree planting that has the opportunity for additional planting, it can be expected that the visual character of this zone would remain broadly intact as a result of the project. While it is likely that the proposed maintenance facility and motorway control centre buildings would be partially visible from this location, these are of well-considered design and are in context visually with the built form of the warehouse/commercial premises within this LCZ.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.2 LCZ 2 – Homebush commercial precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be low, given that the LCZ comprises a 'back-of-house' landscape setting including carparks and an electricity substation, and as such comprises a utilitarian landscape which inherently has the capacity to incorporate significant changes in the landscape. The magnitude of change is considered to be low given that the LCZ vegetated edge effect can be expected to be broadly retained and to some extent supplemented with new screen plantings, and the proposed maintenance facility and motorway control centre buildings would be visually in context with the built form of this LCZ.	This provides a landscape character impact assessment rating of low.

6.1.3 Landscape character zone 3 – Parramatta Road (west) precinct

Project effects

The Parramatta Road (west) precinct LCZ currently contains a substantial vegetated edge to the M4 along most of its length ranging between about 10 and 30 metres in width, with the exception of the

M4 bridge crossing of Powells Creek and the Northern Rail Line. Most of this screening vegetation falls within the M4 corridor. Key effects of the project on vegetation in this LCZ comprise:

- Removal of vegetation
  - To the southern edge of the existing M4 corridor to enable the construction of the proposed on-ramp from Parramatta Road
  - Along the Park Road M4 edge, the eastern end of which lies adjacent to a low density residential precinct, and the western end of which contains industrial development
  - To the eastern end of Powell Street which includes medium density residential development
  - Between the property on the eastern corner of Parramatta Road and Powell Street and the M4
  - To the western edge of Concord Road between Parramatta Road and the M4
  - At Queen Street for the Queen Street cycleway ramp.
- The western residential component (Welfare Street precinct group HCA) would potentially be impacted by moving the Homebush Bay exit ramp (surface works), closer to the western edge of this precinct
- With regard to the light industrial component of this LCZ, Park Road incorporates 90 degree parking bays along the M4, with intermittent landscape beds planted with trees and shrubs. This planting on the land of Strathfield Council would be retained along this edge.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.3 LCZ 3 – Parramatta Road (west) precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate, given that: The precinct contains residential development adjacent to the M4, comprising the Welfare Street precinct group HCA, and the low density residential precinct along the eastern end of Park Road. Also, two residential properties adjoin the M4 between Short Street West and Park Road An existing component of the LCZ is the vegetative planting within the M4 corridor, which would be removed or reduced in width. The magnitude of the change is considered to be moderate given that the LCZ would have a reduction in the extent of the existing dense screen tree planting along the M4, with the project extending to the edge of the M4 corridor along much of the western boundary. The proposed retaining walls and noise walls associated with the Homebush Bay Drive off-ramp would also be in close proximity to residential areas of the LCZ.	This provides a landscape character impact assessment rating of moderate.

6.1.4 Landscape character zone 4 – Underwood Avenue precinct

Project effects

Generally, the potential visual impacts of the project in this LCZ would be limited to the edge of adjoining residential land uses. In this LCZ, the M4 carriageway would be brought about 35–40 metres closer to existing residential development near the eastern end of Bill Boyce Reserve, subject to detailed design, with cut-and-cover treatment adjacent to residential development to the end of Ismay Avenue.

The project effects on the Underwood Avenue precinct would be:

- The acquisition of 10 residential properties east of Underwood Road and associated change in streetscape character to this road, and the ends of Ismay Avenue and Allen Street
- The introduction of new elements on the edge of the LCZ including the Western ventilation facility which would be visually connected with the M4
- The existing wide, dense and tall tree planting along the M4 edge with this LCZ would be:
  - Removed alongside a new medium density residential development at the end of Verley Drive
  - Removed adjacent to the single lot residential development at the end of Verley Drive
  - Removed adjacent to residential units at the eastern end of Bill Boyce Reserve, and some sections between Bill Boyce Reserve and Short Street East
  - Reduced to the residential edge of this LCZ from the end of Verley Drive to Arnotts Reserve
- The new medium density residential development at the end of Verley Drive would be adjacent to the proposed flyover, albeit behind a noise wall and not visible to residents
- The project would be subject to increased visibility from the public domain and community facilities including Underwood Road and the proposed the new park space between Underwood Road and Ismay Avenue
- The corridor would be generally without screening vegetation between Bill Boyce Reserve and Short Street East, with upper storey residential units at the rear of 73 Underwood Road and the end of Short Street potentially looking onto a substation, and through a transparent noise wall to the M4 carriageway
- Most of the proposed tree planting between Short Street East and Ismay Avenue would be above cut-and-cover structures, using around a one metre deep soil profile (subject to detailed design). The proposed park landscape between Underwood Road and Ismay Avenue currently comprises an informal design of turf, shrubs and trees, with the opportunity to include park embellishment, such as a path system, park furniture, play equipment, lighting, etc, during detailed design
- The works at the eastern end of the LCZ contain three parcels of residual land for which a future land use is yet to be determined. These would potentially be suitable for redevelopment such as medium density or single lot residential development. The design of future development of these land parcels would need to be visually complementary with the project and the character of this LCZ.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.4 LCZ 4 – Underwood Avenue precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate within the context of: The quiet and well established residential character of the LCZ, generally including vegetated streetscapes The visually strong element of the existing vegetated screen planting alongside the M4, which comprises a defining element of the LCZ The existing relationship of the LCZ with the M4 boundary. The magnitude of change is considered to be high within the context of: The extent of the project being limited to the edge of the LCZ The addition of the visually uncharacteristic elements of the ventilation outlet and substation within the LCZ Reliance on the success of planting on cut-and-cover structure to provide a substantial, long-term level of screening to: – The ventilation outlet and substation – The M4 from the proposed park between Underwood Road and Ismay Avenue and future development within the adjoining residual land parcel The loss of a vegetative screen to the M4 including: – The western end of the LCZ and associated visual prominence of the existing M4 noise walls at the end of Verley Drive – To sections of the eastern end of the LCZ between Bill Boyce Reserve and Short Street West.	This provides an overall landscape character impact assessment rating of high–moderate.

6.1.5 Landscape character zone 5 – Powells Creek precinct

Project effects

The project proposes the construction of an on-ramp from Parramatta Road in this LCZ, comprising a combination of single lane bridge and road along the existing M4 embankment. The bridge would be about 120 metres long (subject to detailed design) and commence from the Parramatta Road entry point over the Powells Creek stormwater channel, climbing to an alignment generally parallel with the M4, where it would land on the existing M4 embankment. The on-ramp would then comprise a single lane road constructed along a retaining wall and ascend along the batter to join the M4 carriageway.

The key project effects on the Powells Creek precinct LCZ would be:

- The bridge would sit below the level of the M4 deck, which provides a generous high, wide, framed opening through to the northern section of Arnotts Reserve. The new bridge would comprise a relatively low, contrasting diagonal form, and potentially visually bulky element that has the potential to reduce the sense of openness and accessibility currently available under the M4 deck
- The proposed on-ramp bridge, new intersection and associated traffic would comprise new and visually contrasting elements for the proposed park
- The placement of tall tree planting within the vicinity of the bridge may reduce the extent of views available beneath the M4 bridge to the landscape beyond.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.5 LCZ 5 – Powells Creek precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate within the context of the existing master plan proposed for the area. The magnitude of change is considered to be moderate within the context of the overall extent of the Arnott's Reserve and potential impact on this open space, but also taking into consideration the similarity of the proposed infrastructure to the existing M4 bridge in this LCZ.	This provides an overall landscape character impact assessment rating of moderate.

6.1.6 Landscape character zone 6 – Concord Road precinct

Project effects

The key project effects on the Concord Road precinct LCZ would be:

- The main impacts of the project within this LCZ would be contained to Sydney Street west and the ends of Sydney Street east, Edward Street, and Alexandra Street, creating a new interchange landscape character including two large informal parks. The ability of these two parks to be able to attract a high level of recreational usage would be reduced due to their visual and aural exposure to the interchange. As such further consideration will need to be given to design aspects which promote safety, amenity and visibility
- The area of housing removed on the north side of Sydney Street west adjoins the Powells Estate HCA
- Loss of frontage to Sydney Cheil Church on Concord Road and associated mature screen tree planting
- Removal of housing on Sydney Street east and on Concord Road within an area already suffering from an existing entropy effect (refer to section 4.2.6)
- Removal of the vegetative screen on the M4 boundary.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.6 LCZ 6 – Concord Road precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be low within the context of the existing busy road environment, existing entropy effects and proximity to the M4. The magnitude of change is high due the change in character from that of low density residential streets (albeit very busy ones), to that of a large motorway interchange with associated ramps, bridges and portals, flyover ramp, and freeway landscape incorporating large island areas of trees and grass.	This provides an overall landscape character impact assessment rating of moderate.

6.1.7 Landscape character zone 7 – Edward Street precinct

Project effects

The key project effects on the Edward Street LCZ would be:

- Walling off Sydney Street east and Edward Street with retaining and noise walls would be out of character with the LCZ. In this regard:
  - The Edward Street turning head is in close proximity to the M4 on-ramp and requires further design development to allow the incorporation of an area of landscaping at this point, so that the view through the heritage listed street tree planting to the proposed retaining wall is softened
  - The view along Sydney Street east terminates in a narrow area of trees and grass, potentially with a noise wall behind
- The proposed park settings between Edward Street and Alexandra Street, and between Sydney Street east and Edward Street, would be out of the landscape character of the precinct. The landscape proposed comprises an informal general tree planting of Cumberland Plain Woodland species in grass; however a cultural planting that responds to the Federation-era streetscape/residential garden character of the precinct, or appropriate residential precinct park elements such as park furniture, lighting and signage, etc would be more appropriate for this LCZ

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.7 LCZ 7 – Edward Street precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be high within the context of the characteristic Federation-era streetscape including the heritage listed avenue planting, though it is noted that the precinct currently displays elements of disuse and disconnectedness near to the existing M4. The magnitude of change is considered to be moderate within the context of the project being limited to the edge of the precinct including the east-west facing streets, but also taking into account the change in character to the streetscape by the introduction of retaining walls and noise walls that would substantially cut into the existing grid pattern of the street and housing and the termination of through streets.	This provides an overall landscape character impact assessment rating of high–moderate. Consideration of further design development of the turning heads and inclusion of cultural plantings could assist in mitigating the potential impacts in this LCZ.

6.1.8 Landscape character zone 8 - Concord Oval precinct

Project effects

The key project effects on the Concord Oval LCZ would be:

- Removal of trees to the Parramatta Road frontage. These trees currently comprise a visually prominent landscape element to the Parramatta Road frontage
- Removal of one large fig tree on the north-east corner of the Concord Oval land parcel
- Retention of existing buildings along the western boundary of the Cintra Park site, and two large stormwater tanks in the south-western corner
- Pruning of existing mature screening trees along the eastern boundary

- New infrastructure facilities comprising: a water treatment plant (about 30 x 17 x five metres high), a water treatment pond (about 28 x 12 metres), a distribution substation (about 32 x 17 x five metres high) and a fresh air supply facility (about 11 x 6 x five metres high), subject to detailed design
- Landscaping comprising: general tree planting, turf, areas of mass planting around the water treatment plant, the water treatment pond and distribution substation, and the maintenance vehicle access driveway
- Areas of potential future active recreation in the north of the site.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.8 LCZ 8 – Concord Oval precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be high, given the context of the very specific landscape character of the site, which is defined by the formal playing field land use, including: the Concord Oval grandstands; the Cintra Park hockey field and associated club facility; existing trees, particularly along the eastern and southern boundaries; and also including a recent addition of an existing substantial infrastructure development, comprising a stormwater treatment plant (within a large shed) and two large stormwater storage tanks. The magnitude of change is considered to be moderate, given that the project would add an additional group of infrastructure-related buildings into the existing setting, and given the removal of most of the substantial trees along the Parramatta Road frontage, though retaining some land for future active recreation activities within the site.	This provides an overall landscape character impact assessment rating of high to moderate.

6.1.9 Landscape character zone 9 – Dobroyd Parade precinct

Project effects

The key project effects on the Dobroyd Parade precinct LCZ would be:

- Widening of Dobroyd Parade from around 20 metres to between 30 and 40 metres wide (from four to up to seven lanes), subject to detailed design
- Maintaining or slightly increasing the existing carriageway setbacks and screening to housing on the southern side of Dobroyd Parade
- Removal of screen planting in front of two residences on the northern side of Dobroyd Parade, on the corner of Martin Street
- Decrease of parkland frontage to Reg Coady Reserve of around 20 metres in width, subject to detailed design, between Martin Street and Waratah Street, and then extending almost to the edge of Iron Cove Creek between Waratah Street and Loudon Avenue, resulting in the existing setback of Iron Cove Creek from the Dobroyd Parade kerb being reduced. However, the informal and open layout of Reg Coady Reserve has the potential to visually accommodate the proposed loss of land between Martin Street and Waratah Street
- Removal of two large trees (including a large fig), and additional small and medium sized trees in Reg Coady Reserve subject to detailed design and construction planning.
- Removal of the two metre setback of the footpath from the kerb to the south side of Dobroyd Parade, between Waratah Street and Martin Street
- Formal tree planting along the western edge of Reg Coady Reserve, contrasting with the existing informal planting layout of the reserve.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.9 LCZ 9 – Dobroyd Parade precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate, given that the informal and open layout of Reg Coady Reserve has the potential to visually accommodate the proposed reduction in the width of the reserve, and within the context that the reserve is already located on a busy road. The magnitude of change is considered to be moderate, given the doubling in the width of the road, but also taking account of the retention of existing privacy screening to the residential development facing onto Dobroyd Parade, and the relatively minor loss of parkland to Reg Coady Reserve within the context of the capacity of the reserve to visually absorb the change.	This provides an overall landscape character impact assessment rating of moderate.

6.1.10 Landscape character zone 10 – Wattle Street precinct

Project effects

The key project impacts on the Wattle Street precinct LCZ would be:

- A change in landscape character for Wattle Street, from a congested four lane road with fronting single lot residential development, to a motorway interchange landscape
- Introduction of a visual break in the residential character of Ramsay Street where it crosses Wattle Street (about 80 metres wide, subject to detailed design) with a motorway interchange landscape
- Construction of infrastructure on the corner of Wattle Street and Parramatta Road, comprising the Eastern ventilation facility and associated electrical substations, including the acquisition of ten residences on the western side of Walker Avenue. This infrastructure would be opposite a Jehovah's Witnesses place of worship on the western side of Wattle Street
- Widening of Wattle Street from around 20 metres wide up to around 80 metres wide, subject to detailed design, with the addition of two tunnel portals at Ramsay Street, and a further two portals midway between Ramsay Street and Parramatta Road, and acquisition of residences on the southern side of the road, including 10 heritage listed buildings within the Haberfield HCA
- Acquisition of eight residences on Ramsay Street and three residences on Martin Street, including one heritage residence on Martin Street
- Acquisition of commercial development on Parramatta Road between Wolseley Street and Wattle Street
- Potential for retained housing on the northern side of Wattle Street to succumb further to major road entropy effects as exists at Sydney Road and Concord Road
- A reduction in the extent of traffic immediately in front of residential housing between Ash Lane and Ramsay Street from four lanes to two lanes, with a similar but less pronounced increase in amenity between Ramsay Street and Martin Street
- Provision of a noise wall to the eastern side of Wattle Street, located between the ventilation facility at the western end of Wattle Street and Ramsay Street, which has the potential to create a poor quality space between the back of the noise wall and the back fences of the remaining residences on the north side of Walker Street.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.10 LCZ 10 – Wattle Street precinct landscape character assessment

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate within the existing context of both Wattle Street and Ramsay Street being busy roads. The magnitude of change is considered to be high given the quadrupling of the road corridor width, introduction of dive structure/tunnel portals and loss of housing.	This provides an overall landscape character impact assessment rating of high–moderate.

6.1.11 Landscape character zone 11 – Parramatta Road (east) precinct

Project effects

The key project effects on the Parramatta Road LCZ would be:

- The existing relatively narrow, straight road would take on a broadly curving alignment that is consistent with the frontage of Ashfield Park. The width of the road gradually increases from about 25 to 75 metres at its widest point (subject to detailed design) at the centre of the project footprint, before narrowing back into the existing carriageway
- The LCZ has no street trees. The project would introduce a wide boulevard design incorporating a substantial soft landscape component including a semi-formal planting of tall eucalypt street trees. The boulevard provides a complimentary linking element with the adjacent Ashfield Park and would be, in the main, complementary with the dense 'forest' planting within the Yasmar frontage
- The character of intersecting residential streets would be broadly maintained
- On balance, the project would change the character of this LCZ beneficially. Although a small group of mixed housing would be acquired south of Chandos Street, including attractive examples of an interwar Art Deco influenced flat building and a Federation-era free-standing residence, the positive changes would be due to the prominent urban design and landscape initiatives that are proposed as part of the road design. Also, the project proposes to remove much of the existing visual clutter of various commercial premises, associated signage, and vacant building blocks in this LCZ.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.11 LCZ 11 – Parramatta Road (east) precinct

Sensitivity and Magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be low. The magnitude of change is high, but that change is also considered on balance to comprise a beneficial effect on the landscape character of the zone.	This provides an overall landscape character impact assessment rating of moderate beneficial.

6.1.12 Landscape character zone 12 – Haberfield precinct

Project effects

The key project effects on the Haberfield precinct LCZ would be:

- Change in the visual character of Walker Avenue:
  - Created by the proposed boulevard planting of large eucalypts to Wattle Street visible from the Walker Avenue footpaths
  - The increased proximity of residences along the western side of Walker Street to the Wattle Street interchange (previously separated by a row of housing)
- Virtually all of this LCZ falls within the Haberfield HCA, with a significant change in character proposed to the Parramatta Road end of Walker Avenue including:
  - Visual prominence of an uncharacteristic infrastructure facility, including a tall ventilation outlet (around 25 metres high), set within a visually uncharacteristic landscape setting. This facility would be seen from some of the front rooms and front gardens of residences to the eastern side/southern end of Walker Avenue, and from the footpaths of Walker Avenue for pedestrians walking south along Walker Avenue towards Parramatta Road
  - Acquisition of 10 houses on the western side of the street, leaving a row of 10 houses on the eastern side, with reduced symmetry on the street
- Impact on the landscape character of Martin Street with the acquisition of three residences (including one heritage-listed residence) and introduction of a boulevard landscape with associated tall tree planting at the end of the street.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.12 LCZ 12 – Haberfield precinct landscape character assessment

Sensitivity and magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be high within the context of quality of Federation-era housing stock and quiet, wide streetscape character. The magnitude of change is considered to be high within the context of the concentrated impacts at the ends of Walker Avenue and Martin Street in conjunction with the broader landscape character impacts along the length of Walker Street.	This provides an overall landscape character impact assessment rating of high. These impacts could be reduced by investigating opportunities reduce the visibility of the infrastructure and through careful consideration of development proposed for the residual land on Walker Avenue (refer to **section 7.1**.

6.1.13 Landscape character zone 13 – Yasmar Juvenile Training Facility

Project effects

The key project effects on the Yasmar Juvenile Training Facility LCZ would be:

- A gradual widening of the road verge to the southern half of the frontage, and the addition of a row of large eucalypt street trees to the verge within this widened area

- The addition of large street trees to the widened verge area could result in an overly crowded canopy along the Yasmar road frontage and potentially affect three existing Morton Bay figs, considered to be of heritage significance. The southernmost specimen of these figs has its canopy spreading across about one-and-a-half lanes of southbound traffic. The canopies of the remaining trees within the Yasmar frontage generally extend to the existing Parramatta Road kerb
- The addition of street trees to the Yasmar frontage would be visually out of character with the existing distinctive 'forest' edge to this facility, which would be best left as a visually prominent element of the Parramatta Road landscape in its own right, and this could be achieved through appropriate landscaping design.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.13 LCZ 13 – Yasmar Juvenile Training Facility landscape character assessment

Sensitivity and magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be high within the context of the heritage significance of the site, and the distinctive existing dense 'forest' planting to the frontage, including the characteristic period planting of Morton Bay figs. The magnitude of change is considered to be high, within the context of the potential extent of change to the character of the Yasmar frontage component of this LCZ.	This provides an overall landscape character impact assessment rating of high. These impacts could largely be mitigated through implementing an appropriate landscaping design in this LCZ.

6.1.14 Landscape character zone 14 – Ashfield medium density precinct

Project effects

The key project effects on the Ashfield medium density LCZ would be:

- Opening up of views onto the Parramatta Road interchange from residential development, including:
  - A three-storey unit development on the eastern side of Loftus Street which is currently screened from Parramatta Road
  - A five-storey unit development accessed from Chandos Street which is currently setback from Parramatta Road
- Four-storey unit development on Bland Street will adjoin residual land for which a land use is yet be determined
- Two-storey unit development and a free standing residential development on Chandos Street will adjoin residual land for which a land use is yet be determined
- A nursing home and a heritage listed residence on Orpington Street will adjoin residual land for which a land use is yet be determined
- A change in the quiet, mixed residential landscape character of Loftus Street, and the eastern end of Chandos Street, to one that directly adjoins the Parramatta road frontage in many instances, and otherwise adjoins residual land for which land uses have yet to be determined.

Landscape character assessment

The sensitivity of the landscape to change is considered in the following table.

Table 6.14 LCZ 14 – Ashfield medium density precinct landscape character assessment

Sensitivity and magnitude	Landscape character assessment
The sensitivity of the landscape to change is considered to be moderate, given that the extent of the change is relatively limited within the context of the broader LCZ, and that a defining element of the landscape character is the mixed nature of the residential development, comprising both well maintained examples of the original Federation-era residential development, in conjunction with a more recent overlay of generally utilitarian unit development. This fabric of the LCZ is therefore generally amenable to a variety of changes. The magnitude of change is considered to be moderate, given that most of the existing development adjoining this LCZ directly impacted by the project exhibits low landscape character qualities. Also contributing to this rating is the proposed substantial boulevard tall tree planting along the new Parramatta Road corridor and the potential for a more considered architectural and urban design response to the development that will occur within the residual land parcels, for which land use is yet to be determined.	This provides an overall landscape character impact assessment rating of moderate.

6.1.15 Landscape character zone 15 – Ashfield Park

Project effects

The project would effect a minor change to the setting of the area surrounding Ashfield Park, with the widening of Parramatta Road to the west, and introduction of tall eucalypt street tree planting along both sides of Parramatta Road and within a median adjoining the off-ramp dive structure. As Parramatta Road crests about 50 metres north of the Ashfield Park corner, much of the project infrastructure would not be visible from the park. The proposed street tree planting would however be visible for quite some distance over the crest, though this change is considered to be beneficial to the character of the park.

Landscape character assessment

Table 6.15 LCZ 15 – Ashfield Park

Sensitivity and magnitude	Landscape character assessment
The sensitivity of the landscape to the proposed change is considered to be high. The magnitude of change is considered to be low (beneficial) within the context of the improved outcome from street tree planting.	This provides an overall landscape character impact assessment rating of low beneficial.

6.1.16 Summary of landscape character zone assessments

The table below provides a summary of LCZ assessments.

Table 6.16 Summary of LCZ assessments

Landscape character zone	Sensitivity to change	Magnitude of change	Overall rating
Landscape character zone 1 – M4 Motorway	Moderate	High	High–moderate
Landscape character zone 2 – Homebush commercial precinct	Low	Low	Low
Landscape character zone 3 – Parramatta Road (west) precinct	Moderate	Moderate	Moderate
Landscape character zone 4 – Underwood Avenue precinct	Moderate	High	High–moderate
Landscape character zone 5 – Powells Creek precinct	Moderate	Moderate	Moderate
Landscape character zone 6 – Concord Road precinct	Low	High	Moderate
Landscape character zone 7 – Edward Street precinct	High	Moderate	High–moderate
Landscape character zone 8 - Concord Oval precinct	High	Moderate	High-moderate
Landscape character zone 9 – Dobroyd Parade precinct	Moderate	Moderate	Moderate
Landscape character zone 10 – Wattle Street precinct	Moderate	High	High–moderate
Landscape character zone 11 – Parramatta Road (east) precinct	Low	High	Moderate beneficial
Landscape character zone 12 – Haberfield precinct	High	High	High
Landscape character zone 13 – Yasmar Juvenile Training Facility	High	High	High
Landscape character zone 14 – Ashfield medium density precinct	Moderate	Moderate	Moderate
Landscape character zone 15 – Ashfield Park precinct	High	Low	Low beneficial

6.2 Desired future character assessment

6.2.1 Landscape character zone 1 – M4 Motorway

The proposed character of this LCZ is in keeping with the SP2 Infrastructure desire to maintain accessibility, supporting economic activity and efficient freight movement.

6.2.2 Landscape character zone 2 – Homebush commercial precinct

The proposed maintenance facility and motorway control centre would be sited on land zoned SP2 Infrastructure, which identifies the desired future character of the area being to support the provision of infrastructure and ancillary elements to contribute to the growth of economic activity and efficient freight movement.

A proposed water quality basin would be sited predominantly on land zoned SP2 Infrastructure and partially on land zoned IN1 General Industrial. This zoning identifies the desired future character of the area as supporting the provision of infrastructure to support economic activity and efficient freight movement.

6.2.3 Landscape character zone 3 – Parramatta Road (west) precinct

The land at the western end of this precinct is zoned B6 Enterprise Corridor. As such the project reflects the desire to maintain accessibility and efficient movement of commuter and freight traffic, and to encourage economic activity and provision of a range of employment uses.

The land in the centre of the precinct is zoned B4 Mixed Use and R4 High Density Residential. As such the project is consistent with the desire within for a mix of compatible employment generating and residential land uses in this area, with strategic sites developed for urban intensification uses. Strathfield Council's verge on the northern side of Park Road has the potential to provide screening of the project for the lower floors of high density residential development, with higher floors looking over the project to obtain regional views, including across Sydney Olympic Park.

The land at the eastern end of this precinct is zoned for local and regional employment uses, primarily with land zoned B6 – Enterprise Corridor. As such, the project components reflect the desire for the future character of the area as being one that supports ongoing development of strategic road corridors to provide for a mix of economic uses, and includes buildings up to a maximum height of 12 metres.

6.2.4 Landscape character zone 4 – Underwood Road precinct

The Underwood Road precinct consists of land zoned SP2 Infrastructure, R3 Medium Density Residential and RE1 Public Recreation under the Strathfield LEP 2012. The project seeks to reinstate landscape screening and integration to the M4 and the associated infrastructure of the ventilation outlet and substation through the provision of parks, and street tree planting to Underwood Avenue.

The surrounding zoning identifies the desired future character of the broader area being to support future growth via urban intensification along and near to important strategic road and public transport corridors, with buildings heights of new development within R3 Medium Density Residential zones of nine metres. This desire for urban intensification with increased building heights, associated increased bulk and scale, and modern architectural forms, can be seen as visually contextual with the project elements.

6.2.5 Landscape character zone 5 – Powells Creek precinct

The Powells Creek precinct is zoned RE1, which identifies that this area should provide for public open space or recreational activities. This corridor intersects with the SP2 Infrastructure zoned land of the M4 corridor. The Parramatta Road on-ramp passes through this RE1 zoned precinct. However, the on-ramp has been located such that:

- It commences from Parramatta Road close to the eastern edge of the RE1 zone, thereby protecting existing mature fig trees within the RE1 zone along the Parramatta Road boundary
- Then swings east, climbing over the Powells Creek stormwater drainage channel, before swinging west close to the M4 viaduct
- Then entering the SP2 zone, continuing to climb along the M4 batter before entering the motorway.

In this way, the design of the ramp has been undertaken so as to minimise the land take and visual impact of the structure on the RE1 land. Additionally, the ramp structure would provide the capability for pedestrian connection beneath it, and then beneath the M4 viaduct through to the RE1 land north of the motorway.

Further, the ramp makes provision for access under it and through to the main part of the open space corridor.

As can be seen from the above, although the on-ramp is not envisaged within the RE1 zoning for this precinct, significant efforts have been made to minimise the impact of this necessary project element on the RE1 zone.

The on-ramp itself is compatible with the adjoining SP2 Infrastructure zoned land.

6.2.6 Landscape character zone 6 – Concord Road precinct

The Concord Road precinct is zoned SP2 Infrastructure comprising the M4 along its southern edge, R3 Medium Density Residential west of Concord Road, and R2 Low Density Residential east of and fronting onto Concord Road, for a width equal to the depth of the house blocks.

The R3 zoning identifies the desired future character of this zone to support future growth via urban intensification along and near to important strategic road and public transport corridors. This desire for urban intensification with increased building heights, associated increased bulk and scale, and modern architectural forms, can be seen as visually contextual and able to respond with the proposed project elements.

All 10 houses within the R2 zone fronting the east side of Concord Road, from Edward Street north to Patterson Street would be acquired for the project, with the remaining property on the corner of Patterson Street and Sydney Cheil Church on the corner of Sydney Street both subject to partial acquisition of the road frontage. Given the proposed R3 zoning for the west side of Concord Road in this area, and the reduced depth of all of the residential lots north of Sydney Street on the east side of the proposed wider Concord Road, an R2 zoning would appear to no longer be appropriate for this section of Concord Road.

6.2.7 Landscape character zone 7 – Edward Street precinct

The Edward Street precinct is predominantly zoned for R2 Low Density Residential development. The southern Parramatta Road boundary of the precinct is zoned B6 Enterprise Corridor, which is adjoined by a variable width, relatively narrow band of R3 Medium Density Residential development.

The project extends into the R2 zone, impacting on the ends of Sydney Street east, Edward Street and Alexandra Street with a flyover on-ramp to the M4 directly adjoining the precinct, tunnel dive structures, and a pedestrian overbridge. Residual land between the on-ramp and the R2 precinct would comprise green spaces with a linking pathway.

6.2.8 Landscape character zone 8 – Concord Oval precinct

The Concord Oval precinct is zoned RE1 Public Recreation. The hockey field area within which the project would take place primarily adjoins R2 Low Density Residential development to the east. Even though the proposed infrastructure is not in keeping with the desired future character for this area, ie as being one that provides for recreational and/or environmentally significant open space, the development has been sited such that it would allow for the reinstatement of active recreation playing fields if required. Additionally, the project infrastructure would be an addition to an existing substantial infrastructure development undertaken by Strathfield Council for stormwater treatment and storage within the same hockey field area. By making provision for reinstatement of active recreational playing fields, the project infrastructure minimises the impact on the recreational attributes of this area. The landscaping associated with the infrastructure further assists in visual integration of the project and landscape amenity within the recreational setting.

6.2.9 Landscape character zone 9 – Dobroyd Parade precinct

The Dobroyd Parade precinct comprises a mix of: SP2 Classified Road (Dobroyd Parade), SP2 Drainage (Iron Cove Creek), RE1 Public Recreation (Reg Coady Reserve, which encompasses both RE1 and SP2 land, and Timbrell Park), and both R2 Low Density Residential and R3 Medium Density Residential on adjacent streets.

The project would broadly maintain the desired future character of the R2 and R3 zones through retention of the existing frontages to these areas, with most of the frontage screening vegetation retained intact, and some increases in verge width. Very little RE1 land would be directly affected by the project, being limited to a small section adjoining Iron Cove Creek.

The project could be seen as broadly maintaining the desired future character for this precinct.

6.2.10 Landscape character zone 10 – Wattle Street precinct

Wattle Street and that part of Ramsay Street north of Wattle Street is zoned SP2 Classified Road. The existing residential development fronting the southern side of Wattle Street is zoned R3 Medium Density Residential. The remainder of this precinct is zoned R2 Low Density Residential with the exception of a small component of B1 Neighbourhood Centre on the corner of Ramsay Street and Alt Street.

The project has already or would acquire all of the R3 land, and a corridor or R2 land through Ramsay Street and the western side of Martin Street.

The project could be seen to be generally supportive of the desired for character of the R2 zoning for the eastern side of Wattle Street, with the provision of a wide median with tall tree planting, reducing the exposure of most of the residences facing onto the street from four lanes to two lanes.

The project would require the acquisition of nine dwellings in Ramsey Street and three dwellings in Martin Street. Much of this land would be reinstated to a formal boulevard street tree planting, providing a substantial setback from the carriageway for the residential blocks, all of which would adjoin the project on their long edge.

6.2.11 Landscape character zone 11 – Parramatta Road (east) precinct

The Parramatta Road corridor within this precinct is bound by a B6 Enterprise Corridor zoning. The project would be in keeping with the desired for character of this zone, in that it supports ongoing development of strategic road corridors to provide for a mix of economic uses, and is consistent with the *Draft Parramatta Road Urban Renewal Strategy*.

6.2.12 Landscape character zone 12 - Haberfield precinct

Virtually all of the land within the Haberfield precinct is zoned R2 Low Density Residential, with the desired future character comprising the retention of the existing low density housing, with an upper development height of seven metres.

The project would not meet the desired future character for this precinct, impacting upon the western end of Walker Avenue through the introduction of major infrastructure, and the loss of further housing within the street for which no redevelopment plans are yet in place, and to the northern end of Martin Street through the loss of housing.

The project would provide substantial landscaping where these impacts occur to assist visual integration with the R2 zone. Consideration of measures such as those proposed in section 8 of this report may further assist in the integration of the project within this precinct.

6.2.13 Landscape character zone 13 – Yasmar juvenile training facility

The project would provide an increased verge width to much of the road frontage, increasing the visual setback of the site from Parramatta Road. In addition, the provision of a substantial wide median, tall tree planting would effectively reduce the visual prominence of the road from the site, with three eastbound lanes adjoining the site, rather than the current six lanes. The proposed landscape treatment of tall tree boulevard planting between Orpington Street and Bland Street would provide a visual complement to the distinctive dense 'forest' planting within the Yasmar frontage. In this way, the project could be seen to complement the character of Yasmar.

6.2.14 Landscape character zone 14 – Ashfield medium density precinct

The project would retain most of the R2 Low Density Residential and R3 Medium Density Residential areas within this precinct, and reflects the desired future character for the area through the retention of a buffer zone along the southern Parramatta Road frontage between the carriageway and the adjacent R2 and R3 zones. The buffer, which comprises residual land suitable for redevelopment consistent with the *Draft Parramatta Road Urban Renewal Strategy*, and landscaped park and verge spaces, would assist in maintaining the character of the precinct, including its separation from Parramatta Road.

6.2.15 Landscape character zone 15 – Ashfield Park

The project would not be visually prominent from Ashfield Park, with the exception of the proposed street/median tree and massed planting between Orpington Street and Bland Street, which would be visually complementary with the park landscape. The project would demonstrate regard to environmental and landscape impacts on the RE1 land, and is considered to be consistent with the desired future character of this precinct.

6.3 Urban Design Assessment

6.3.1 Urban design concept

Urban context

The project would extend from Homebush Bay Drive in the west to Wattle Street (City West Link) at Haberfield, and Parramatta Road at Ashfield in the east, with a major new interchange at Concord Road and the City West Link. The existing adjacent land uses include light industrial, commercial and residential typologies and are described in detail in **section 4.2**.

Waterways cross the alignment at four points, including Saleyards Creek, Powells Creek, St Lukes Canal and Dobroyd Canal (Iron Cove Creek). Important road networks interface with the project at Homebush Bay Drive, Concord Road, Wattle Street, Bland Street, Chandos Street and Ramsay Street. The project corridor also crosses the North Shore, Northern and Western lines just south of the North Strathfield Station.



Figure 6.1 View along the Powells Creek corridor.

There are no existing dedicated shared paths or cycle opportunities along the section of the existing M4 between Homebush Bay Drive and Concord Road. There is a good shared path link across the M4 corridor from Pomeroy Street to Park Street linking North Strathfield with Homebush West, while Underwood Road passes beneath the M4 about 400 metres further to the east. Additional road crossings beneath the M4 exist at George Street, Railway Lane, Railway Street and Queen Street before the interchange with Concord Road. The Powells Creek corridor also passes beneath the M4 providing potential pedestrian access. This reserve is subject of a current council master plan which will upgrade the recreation and amenity function of the area.



Figure 6.2 View along the existing M4 just west of the Pomeroy Street pedestrian bridge, note the existing and well established screen planting along each side.

The proposed intersections and tunnel portals at Concord Road, Wattle Street and Parramatta Road each have an interface with existing street networks and pedestrian footpath systems on each side of existing streets. Traffic lights provide for pedestrian crossings at each of the existing intersections. These would be retained and modified within all of the proposed intersections. The existing pedestrian bridge over Parramatta Road at Bland Street would also be retained and modified to suit the proposed road alignment.



Figure 6.3 Typical existing view north along Concord Road, in the neighbourhood of the proposed Concord Road interchange.

Other sections of the project east of Concord Road include the Concord Oval, the intersection of Parramatta Road with Wattle Street, Wattle Street itself, and a section of Parramatta Road between Bland Street and Ashfield Park.



Figure 6.4 Existing views west along Parramatta Road, at the corner of Bland Street.

6.3.2 Urban design elements

The urban design elements of the project are intended to embody the project vision, design philosophy, objectives and principles in a built outcome. A series of urban design elements and specific concept design areas have been developed, including the Concord Road interchange, and City West Link interchange, as well as the various motorway facility precincts.

These various design areas are reviewed and assessed against the objectives of the WUDF in this section. All elements discussed as subject to further development during detailed design.

Principles for road architecture

This is an assessment of the proposed road architecture design principles against those of the WUDF.

Table 6.17 Principles for road architecture assessment table

Urban design elements: Principles for road architecture	Assessment	Recommendations
Consistency: The preferred design has considered the design and arrangements of all elements as part of a family of elements that relate to each other and the existing road network. This will provide consistency and variety to provide a memorable, safe and enjoyable experience.	This preferred design principle is consistent with WUDF Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'.	Nil
Simplicity: The design, form, materials and arrangement of all elements must be simple, elegant, refined and carefully integrated with adjoining elements.	This preferred design principle is consistent with the WUDF Principle 6.2 to 'provide a simple and elegant design beautifully integrating with built and landscape elements.' The preferred design does not yet fully address project integration within context, such as adjoining streetscapes and existing landscape character.	The transition from intersection precincts into existing streetscapes will be further developed during detailed design and consider pedestrian footpath improvements and street tree planting for improved amenity. Opportunities to maximise planting along the corridor boundary to optimise site integration will also be considered.
Context: The design of all elements must be relevant to the existing local context and road function.	This preferred design principle is consistent with the WUDF Principle 6.3 to 'use robust, high quality and durable materials appropriate to the urban setting.' This principle is applied throughout the preferred design which offers a simple, robust set of design elements that are neutral, non-site specific and fit for purpose.	Nil

The preferred design for the project includes narrow shards of landscaping within the active road corridor. The project footprint provides limited opportunities for new structure planting to be established along the corridor boundaries, especially the southern alignment. Within the M4 section the result is likely to be like that of the Lane Cove Tunnel approaches at Artarmon.



Figure 6.5 **Existing aerial view of the M4, the motorway is well screened by existing vegetation along the northern and southern corridor boundaries.**

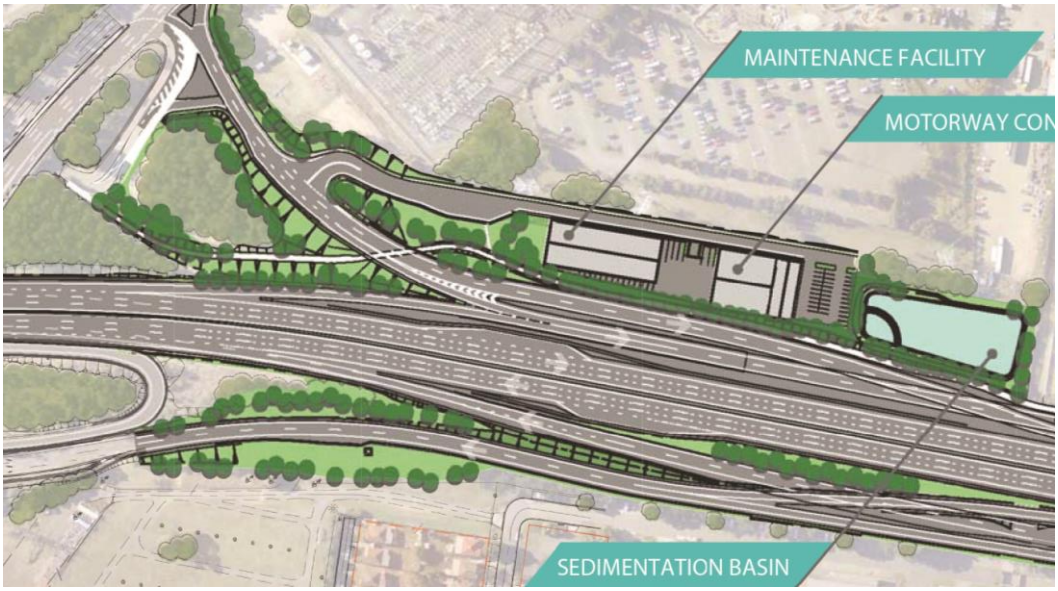


Figure 6.6 **Indicative landscape design elements at Homebush Bay Drive Interchange. This image is conceptual and is included for illustration purposes only.**

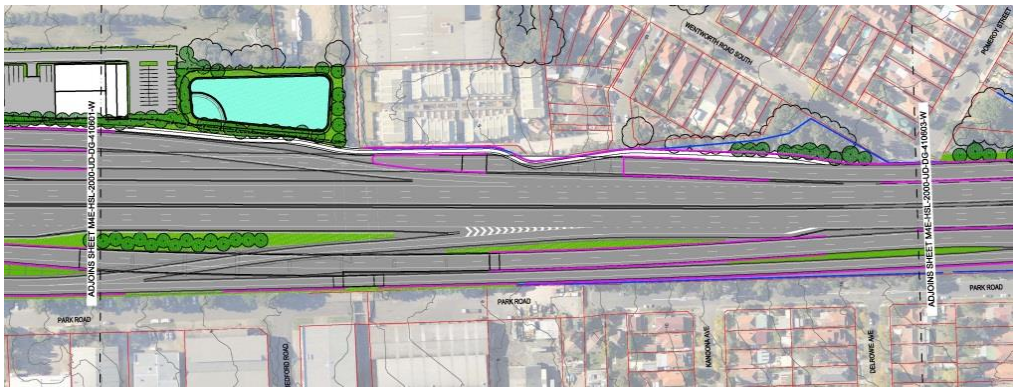


Figure 6.7 **Indicative landscape design elements in motorway corridor. This image is conceptual and is included for illustration purposes only.**

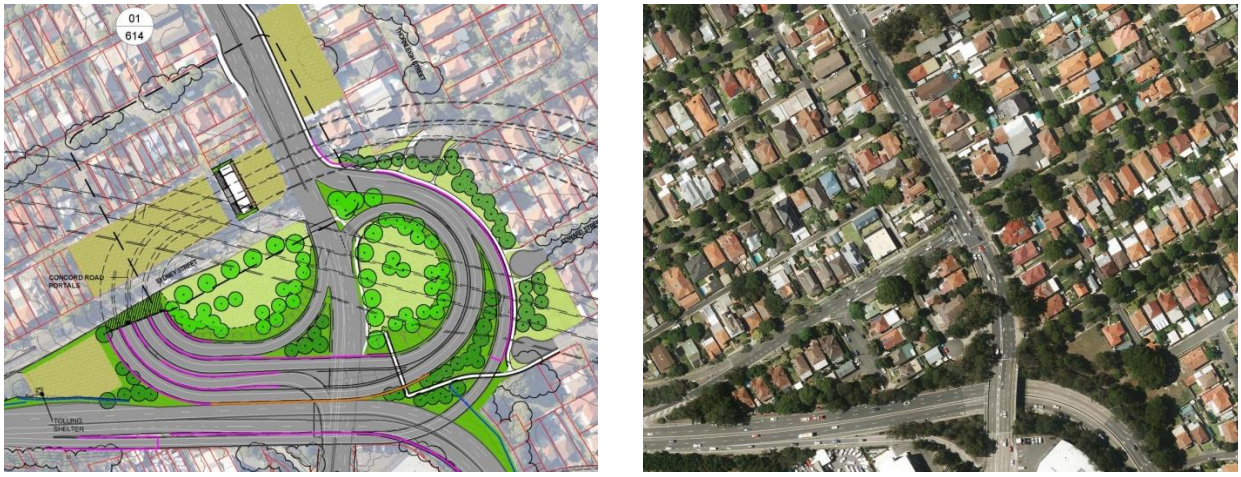


Figure 6.8 **Indicative landscape design elements at Concord Road interchange compared with the existing aerial view. This image is conceptual and is included for illustration purposes only. The proposal will require the loss of several existing residential blocks and street structure.**

The physical impact of the proposed intersections such as at Concord Road and Wattle Street is significant and results in the loss of existing residential blocks and their attendant infrastructure of street grids and street trees. The project seeks to minimise these impacts, to reinstate landscape infrastructure, and to knit the proposal within its urban setting. The transition from intersection precincts, such as from the Concord Road interchange into existing streetscapes includes shared footpath upgrades and street tree planting to mediate the scale of the infrastructure intervention and to provide improved pedestrian amenity.

Homebush Bay Drive interchange, tunnel approaches and portals

Design intent

The proposed design intent for tunnel portals is to create a refined design aesthetic that avoids clutter and poor finishing. The proposed portal design is proposed to be unobtrusive yet attractive.

The proposed dive structures and tunnel portal walls all adopt the same palette of materials. The portal walls are to be of select paint with anti-graffiti coating. The portal facade is to be of composite metal cladding (black) on a structural steel frame. The dive wall cladding is to be of composite metal cladding (silver grey) on structural steel frame. A feature lighting rebate is proposed to be offset within the composite metal cladding (white) and highlighted with up-lighting at base, concealed by the road barrier. This palette is applied to all dive and portal structures.

By adopting a consistent, uncomplicated palette of details and materials the proposal presents a replicable design suite that is well adapted to each locale. The project is fairly neutral and therefore elements fit well within their context, and should also stand the test of time.

Although the preferred design footprint results in the loss of existing vegetation, wherever possible the project intends to maximise retention of existing vegetation and introduce extensive areas of revegetation using massed plantings to verge and median areas of the motorway. Therefore the density, size and numbers of proposed re-planting will be critical to the successful integration of the proposal within its context.

As such, additional tree planting of selected eucalypts is proposed beyond required clear zone safety setbacks to build on the ‘green volume’ in this section of the Motorway.

The proposal also seeks to create a series of tall eucalypt tree-lined tunnel approaches, with an emphasis on providing an identity for each interchange by creating a series of 'green canopies' that help blend the proposed infrastructure elements within the local built and natural fabric.

With respect to the Parramatta Road Urban Renewal Program, the project retains the shared-path crossing at Pomeroy Street, and road crossings beneath the motorway at George Street, Railway Lane and Railway Street, and Queen Street. The proposed on-ramp at Powell's Creek may disrupt the potential for pedestrian activation north south beneath the M4 and this would be addressed in the ongoing design development.

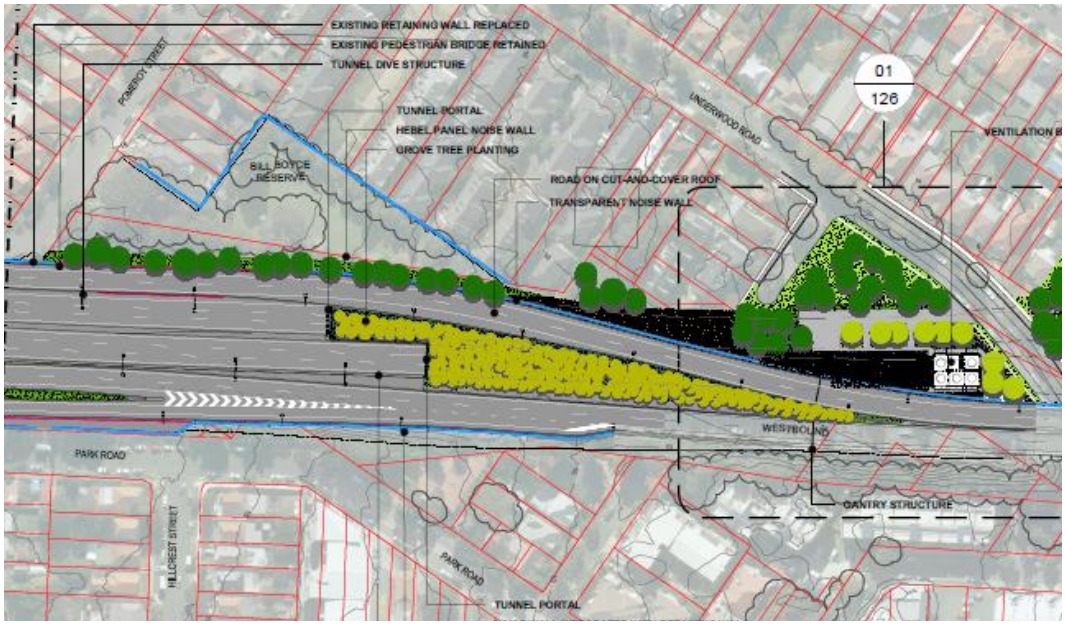


Figure 6.9 **Indicative landscape design elements and portal arrangement at the western tunnel entry. As much of the existing structure planting is removed the proposal relies heavily on the success of planting above the cut-and-cover structure to blend the portal into its setting. This image is conceptual and is included for illustration purposes only.**

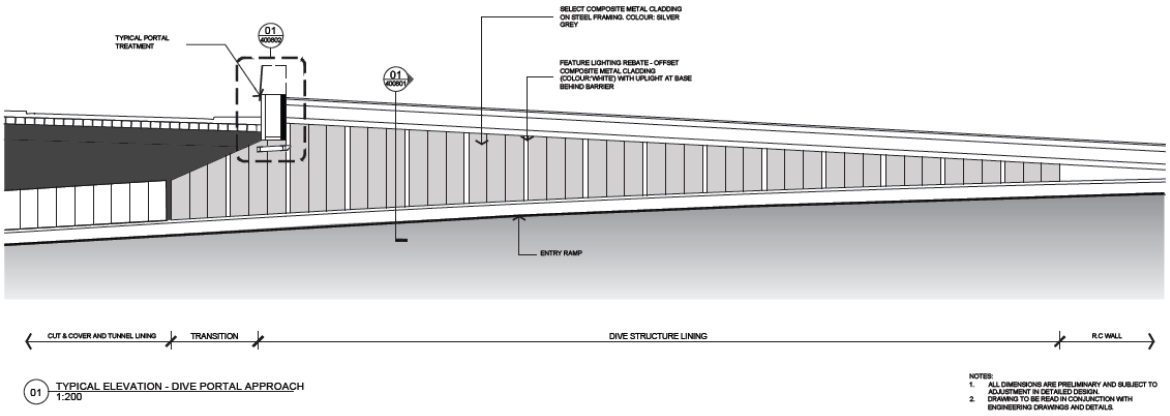


Figure 6.10 **Indicative typical long section through tunnel portal and approach ramp. This image is conceptual and is included for illustration purposes only.**

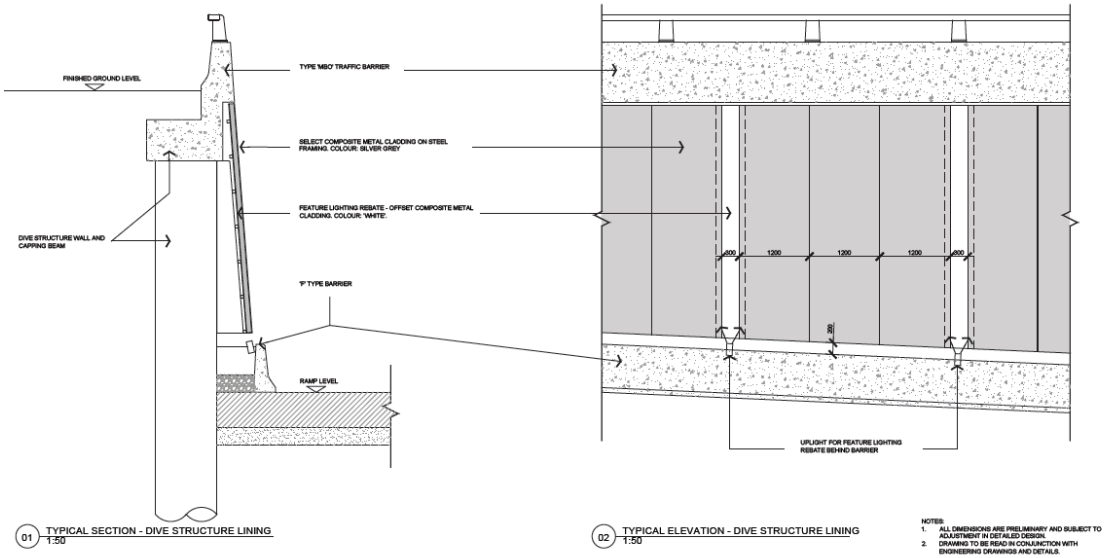


Figure 6.10 Indicative typical cross sections through tunnel portal fascia panels. This image is conceptual and is included for illustration purposes only.

Summary of proposal design principles

Table 6.18 Summary of proposal design principles – Homebush Bay Drive interchange tunnel approaches and portal

Urban design elements: Principles for tunnel approaches and portals	Assessment	Recommendations
Design portals and approaches as unobtrusive architectural elements that are simple and refined, avoiding clutter and poor finishing.	This preferred design principle is consistent with WUDF Principle 5.4 to 'create distinctive portal access points that reinforce the character of the local area'. The principle is applied throughout all tunnel approaches and portals.	The preferred design adopts a high quality design approach that provides consistency, and therefore optimal integration, throughout the proposal. This design approach has the potential to be readily applied to future stages of WestConnex.
Ensure precincts are beautiful, high quality, engaging and functional.	This design principle is consistent with WUDF Principle 6.2 to provide 'a simple and elegant design beautifully integrating with built and landscape elements'. It has been applied to the architectural elements of the preferred design.	The successful integration of the built and landscape components will be further demonstrated in detailed design.
Design should attempt to respond to biophysical factors and reflect local context.	This preferred design principle is consistent with WUDF Principle 1 to deliver 'leading edge environmental responsiveness' and Principle 5.6 to 'use landscape to define different character zones.' The impact of the construction footprint will result in the loss of existing vegetation and landscape context.	Detailed design will explore further opportunities to respond to local landscape and ecological context, particularly in the development of a well-considered planting palette.

Urban design elements: Principles for tunnel approaches and portals	Assessment	Recommendations
Provide attractive welcoming entrances that fit into the local built and natural fabric and provide a gradation of light on approach.	This design principle is consistent with WUDF Principle 5.4 to 'create distinctive portal access points that reinforce the character of the local area', 'gradation of light on approach'.	The principle is applied throughout all tunnel approaches and portals. In the next stage of detailed design the gradation of light on approach to tunnel portals will need to be carefully considered.
Design to consider the integration of lighting, signage and art to enhance travel experience.	This design principle is consistent with WUDF Principle 6.4 that 'fittings, fixtures and equipment shall be considered as a complete set of integrated urban design elements'. It is also consistent with WUDF Principle 6.5 to 'define and implement an urban art strategy for the entire WestConnex motorway…'	The preferred design does not yet include an arts strategy. Consideration of the integration of arts within the proposal will be considered in the future design stages.
Use central tunnel portals to achieve a regular street edge design, promoting connectivity and wayfinding for motorists.	This preferred design principle is consistent with WUDF Principle 2.4 to 'clearly articulate motorway transition zones…'. It has been consistently applied.	Nil
Use robust, durable materials.	This design principle is consistent with WUDF Principle 6.3 to 'use robust, high quality and durable materials', and it has been consistently applied.	Nil
Use the portal area to add value to the community through the provision of open space, connectivity and vegetation.	This preferred design principle is consistent with WUDF Principle 5.7 to 'to provide a well vegetated 'green' corridor by providing substantial accessible space.'	Areas of new open space are defined in the preferred design. The next stage of design will further consider issues of accessibility and activation, to optimise integration within the local context.

Concord Road interchange

The images below compare the existing site with the proposed landscape plan for Concord Road interchange.



Figure 6.11 Aerial photograph of the existing Concord Road interchange site.

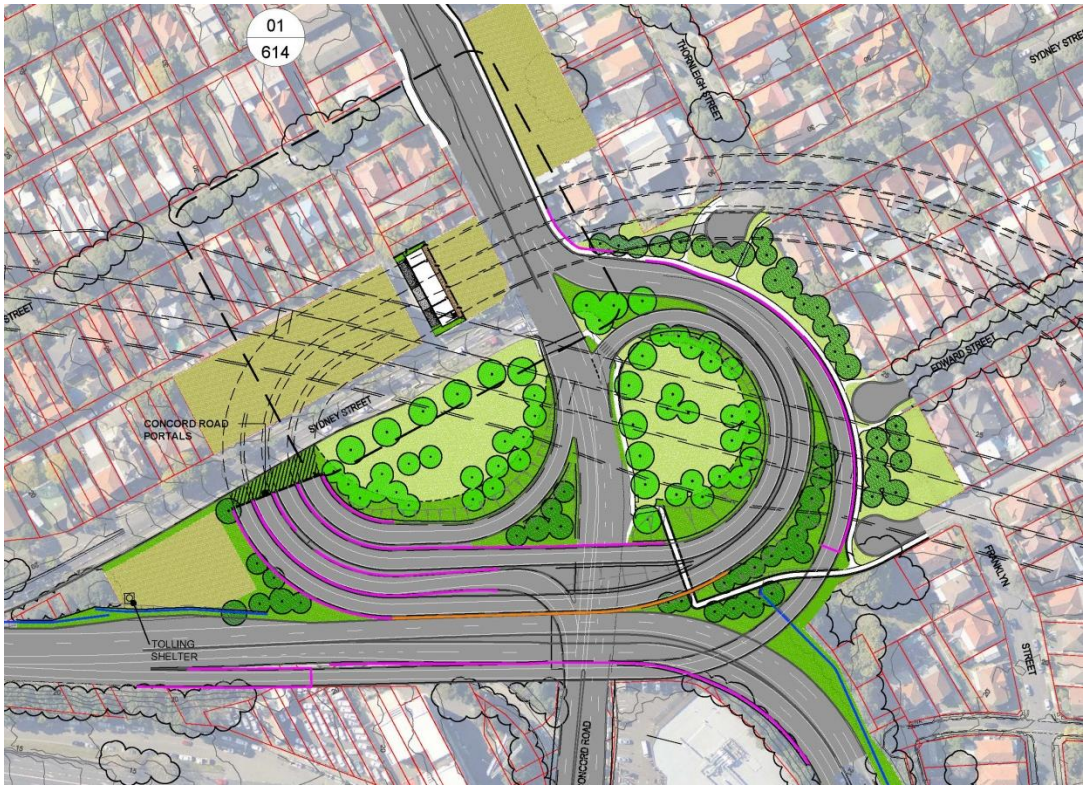


Figure 6.12 Indicative Concord Road interchange landscape plan. Note the mustard yellow areas are residual lands proposed for potential future re-development. Light green areas are lands proposed as future public realm. This image is conceptual and is included for illustration purposes only.

Design intent

The preferred design for the Concord Road interchange improves on the original reference design, with more efficient road geometry and a smaller project footprint. The design seeks to result in a compact solution that does not further divide existing residential areas and minimises impacts on residential areas east of Concord Road.

Existing pedestrian street level connectivity between Concord Road and Parramatta Road would be replaced by an off-road shared path and bridge. This is intended to connect Concord Road, north of the intersection, with Alexandra and Franklyn Streets, and from there to Parramatta Road. The landscape proposal includes new tree planting and two new pocket parks for local community use.

This intersection proposal includes a distribution substation above the cut-and-cover structure on Concord Lane, accessible from Sydney Street. A tolling gantry would be located at the south-west end of Sydney Street. Residual land areas above the cut-and-cover tunnel are intended for future development which would be subject to separate statutory approvals.



Figure 6.13 **Existing view of the proposed Concord Road interchange. The area in the foreground is the site of the main intersection works. This image is conceptual and is included for illustration purposes only.**

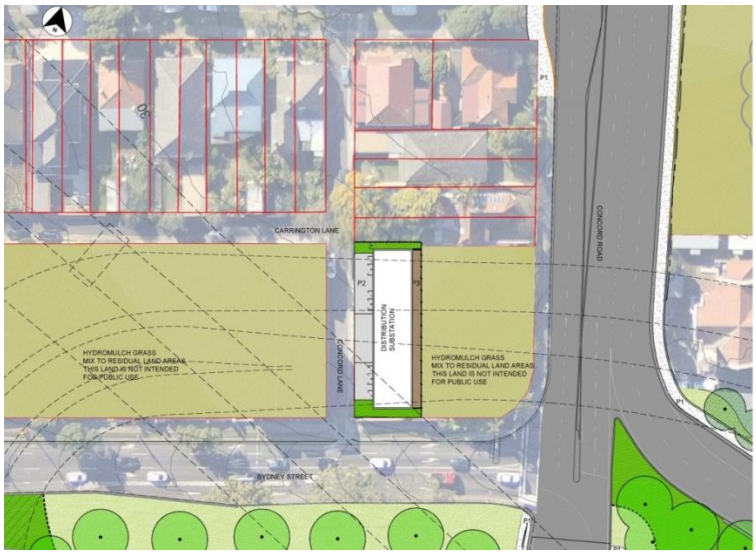


Figure 6.14 **Indicative Concord Road interchange landscape plan at the distribution substation. The mustard yellow areas are residual lands for possible future redevelopment. This image is conceptual and is included for illustration purposes only.**

Assessment

- The engineering and architectural aspects of the Concord Road intersection are well resolved. Opportunities to further integrate the project within its urban context, the public realm and landscape design aspects will be explored during detailed design.
- The proposed distribution substation design is intended to be unobtrusive with a scale and form consistent with the adjacent residential character, however the substation design is not yet fully integrated within its urban context (discussed in more detail in the sections below regarding distribution substation at Concord Road).
- The residual lands, with the exception of a narrow strip of mass planting on the perimeter of the tolling gantry, are to be hydromulched as a temporary landscape cover. Particular landscape finishes would be proposed as the future use of these lands is developed.
- The future uses of these residual lands is not yet known, however they should be considered with regard to the Parramatta Road urban renewal program with particular attention to their capacity to activate this and adjacent precincts.
- The two proposed pocket parks are presented as areas of amenity turf bordered by mass planting and highlighted with tree planting. The larger space south of Sydney Road is about 3500 square metres, subject to detailed design, a third of which is mass planting on embankments; the smaller space between Concord Road and the tunnel off-ramps is about 2600 square metres, subject to detailed design, and again a third of that area is mass planting on embankments. The larger space is accessible from the corner of Sydney Street and Concord Road, requiring crossings of both streets. The smaller space is accessible from the north by crossing Concord Road from the larger space, and then crossing the tunnel off-ramp. From here the space connects to the south with Alexandra and Franklyn Streets via a shared pedestrian bridge.
- The two pocket parks have the potential to present programing challenges because of their isolation, size, the surrounding high capacity/high speed roads, and their gradients down towards the tunnel ramps. This combination of factors will require redress in the design development phase, including consideration of noise walls, in order to optimise access, security and amenity.
- Pedestrian and bicycle access can be made from Concord Road to Parramatta Road via the more circuitous route from east of Concord Road.
- Existing public transport services and facilities are retained. These need to be considered in further detail with respect to their strategic contribution to the broader Parramatta Road urban renewal program.

Wattle Street interchange

Design intent

The preferred design for the City West Link/Haberfield interchange has efficient road geometry and a small project footprint. The majority of the project footprint is to be located between Wattle Street north, Parramatta Road to the west, Martin Street to the east; and to the south the boundary would be defined by the rear boundary of properties on the north side of Walker Avenue.

Two residual land lots would be located on the eastern side of Parramatta Road, either side of Northcote Street. These are currently retail frontage lots and future land uses are not yet known. A third area of residual land represents six residential properties being acquired for construction purposes on Walker Avenue. These lots currently support residential uses and it is assumed that this is the intended future use.

The project combines the on- and off-ramps together in one portal location centrally located in the road reserve. This allows the Wattle Street surface connections to run around the on- and off-ramps allowing a regular street edge condition to remain along both sides of Wattle Street, thereby retaining existing pedestrian movements and connectivity.

The western verge of Wattle Street is to remain unchanged and the eastern verge is to be increased to six metres wide, subject to detailed design, as part of the Wattle Street reconstruction. This is intended to allow sufficient space for proposed street tree plantings of Spotted Gum (*Corymbia maculata*).

The proposed landscape design approach references the character of the adjoining Reg Coady Reserve and the parklands that run alongside Iron Cove Creek that consist of large canopy trees and open grassed parkland. This landscape character is intended to be applied to the widened verges and central median area of the reconstructed Wattle Street. The resulting new areas of 'green volume' are to comprise new turfed median and verge areas, and expansive canopies of new Spotted Gum street tree plantings. These are intended to provide much needed shade and amenity in what is currently a relatively barren street environment.



Figure 6.15 Existing aerial view of the proposed Haberfield interchange.



Figure 6.16 Indicative Wattle Street (City Wst Link) interchange landscape plan. The proposed residual lands are coloured mustard yellow and are proposed for future redevelopment. This image is conceptual and is included for illustration purposes only.

Assessment

- The engineering and architectural aspects of the Wattle Street interchange are well resolved
- The preferred design requires the intended public realm and landscape design to be fully realised in order to be well integrated within its urban context. Therefore large, robust trees of reasonable girth are required to provide shade, make an early visual impact and to withstand deliberate vandalism
- The project requires successful tree planting on areas of cut-and-cover structure in order to achieve an integrated project outcome
- Current pedestrian footpaths and cycleways are retained or modified. However, these should be considered in further detail with respect to their strategic contribution to the broader WestConnex revitalisation program
- The Wattle Street interchange places the footpath against the back of kerb. The detail design phase should consider introducing a landscape buffer in order to separate pedestrians from high speed traffic, and thereby improve amenity outcomes. This may also require the consideration of barriers in order to achieve the proposed street tree planting.
- The future uses of the residual lands is not known, however they should be considered with regard to the Parramatta Road urban renewal program, with particular attention to their capacity to activate this and adjacent precincts. Future development of residual lands would be subject to separate statutory approvals
- Existing public transport services and facilities are retained. These need to be considered in further detail with respect to their strategic contribution to the broader Parramatta Road urban renewal program.

Parramatta Road interchange

Design intent

The design for the eastern connection to Parramatta Road combines the entry and exit portals in one location with a centrally located spatial provision for a future mass transit corridor. The eastern portal presents as a significant reconfiguration of Parramatta Road between Ashfield Park in the east and Bland Street to the west. This existing section of Parramatta Road, being devoid of street trees, presents as a barren and unfriendly environment for pedestrians and motorists. Both Ashfield Park and the grounds of the Yasmar educational facility provide valuable structural planting and visual relief within the otherwise sterile streetscape.

The proposal relies on extensive tree planting to compete with the scale of the infrastructure, to minimise the visual impact of the tunnel portal and to improve the amenity of the street. The design proposes to provide a six metre wide verge, subject to detailed design, with sufficient space to accommodate new street tree plantings of Sydney blue gum (*Eucalyptus saligna*). The northern and western areas of the central median are also proposed to be planted with avenues of Sydney blue gums to increase the ‘green volume’ and to provide shade and amenity.

The entry and exit portals present a similar design to the western, Wattle Street and future M4–M5 Link portals. The portal treatments are simple, attractive and respond to the functional requirements of the project. They are well resolved architecturally and will contribute to the motoring experience and be respectful to local context.

The existing pedestrian bridge over Parramatta Road at Bland Street would be retained, however the southern stair set would be modified to accommodate the reconstructed westbound section of Parramatta Road. The existing stair would be removed and replaced with a new stair connecting to Bland Street.



Figure 6.17 Existing aerial view of the proposed Parramatta Road interchange.



Figure 6.18 Indicative Parramatta Road interchange landscape plan. The proposed residual lands are coloured mustard yellow and are proposed for future redevelopment. This image is conceptual and is included for illustration purposes only.

Assessment

- The engineering and architectural aspects of the Parramatta Road interchange are well resolved
- The preferred design requires the intended public realm and landscape design to be fully realised in order to be well integrated within its urban context. Therefore large, robust trees of reasonable girth are required to provide shade, make an early visual impact and to withstand deliberate vandalism
- The project requires successful tree planting on areas of cut-and-cover structure in order to achieve an integrated project outcome, particularly at the corner of Parramatta Road and Bland Street
- The preferred design for Parramatta Road places the footpath against the back of kerb. Better amenity for pedestrians may be provided by setting the path back behind a landscape buffer. Similarly, street trees are proposed to be set back from kerb in order to comply with Roads and Maritime requirements regarding frangibility and design speed.

Tunnel interiors

Design intent

The proposed design approach to tunnel interiors refers to the WUDF*, RMS Tunnel Urban Design Guideline – Draft for discussion* as a key guiding document.

WUDF Objective 2 includes design principles of particular relevance to tunnel design. These are:

- Provide visual stimuli within the road corridor appropriate to the posted speed that creates a progressive sequence of visual events, within and without the corridor, and an enhanced view of the road
- Provide architectural articulation to the horizontal and vertical surfaces, materials and the lighting of motorway tunnels to visually and psychologically break up the extent of tunnel lengths
- Provide visual cues for drivers to understanding their vertical and horizontal location in relation to the urban setting through the form, materials, finishes, lighting of the motorway.

The WUDF requires the following design approach to be applied to the design of tunnel interiors:

- Provide architectural variation to vertical surfaces of motorway tunnels to visually and psychologically break up the extent of tunnel lengths
- Tunnel design should attempt to respond to biophysical factors and reflect local context
- Consider the integration of lighting, signage and art to enhance travel experience
- Integrate an overall vision for the entire project.

The project includes the following tunnel interior elements:

- Short sections providing architectural variation with black panel inserts at approximately one kilometre intervals
- Location identifiers with custom image panels at a mid-tunnel location
- Coloured feature lighting at selected locations and coloured lining panels within breakdown bays
- All safety and emergency exit signage requirements.

Materials and finishes

The key material elements of the proposed tunnel interiors are:

- Near side (left side) treatments
  - Standard white compressed fibre cement epoxy coated lining panels on steel framing to 3500 millimetres above pavement throughout tunnel interiors
  - Short sections with variable width black panel inserts at approximately one kilometre intervals (mainline only) that will introduce a textural effect with black panels in variable widths as a contrast to the standard white panel, providing a subtle variation in visual rhythm on the near side lining and reducing monotony
  - Custom image panels and variable width black and silver grey panels as location identifiers around mid-tunnel at Concord (occurs once in eastbound and westbound tunnels)
- Off side (right side) treatments:
  - Standard white compressed fibre cement epoxy coated lining panels on steel framing to 3500 millimetres above pavement between cross passages
  - Cross passages for emergency use occur at 120 metre intervals and will be marked by the use of jade green custom coloured panels incorporating a white running man symbol.

Location identifiers

The project proposes location identifiers on near side linings that inform motorists' orientation to above ground features. These location markers are also proposed to include a section of linear feature lighting in the roof providing an additional layer of interest.

These events are proposed to occur at a mid-tunnel point at Concord in both eastbound and westbound tunnels, about two minutes along the journey at 80 kilometres per hour.

The location identifiers will be coordinated with tunnel safety features to ensure that legibility of safety features will not be compromised.

Tunnel lighting

The project incorporates lighting strategies to reduce the potential impacts of driver monotony within tunnels. The proposal will feature coloured lighting used in conjunction with alternate coloured lining panels within breakdown bays, as well as potential strip feature lighting at tunnel location identifier sites to provide a subtle change in character within the tunnel that relates to a specific function or location.

The addition of feature strip lighting at location identifiers would be a positive response to the framework objectives and where feasible, should be investigated as part of detailed design.



Figure 6.19 **The proposal includes potential feature lighting at location identifiers. Where feasible, this feature will be confirmed as an integral component of the tunnel lighting strategy. This image is conceptual and is included for illustration purposes only.**

Table 6.19 **Summary of proposal design principles table**

Urban design elements: Principles for tunnel interiors	Assessment	Recommendations
Provide architectural variation to vertical surfaces of motorway tunnels to visually and psychologically break up the extent of tunnel lengths.	This preferred design principle is consistent with WUDF Principle 2.2 to 'provide architectural articulation to the horizontal and vertical surfaces, materials and the lighting of motorway tunnels to visually and psychologically break up the extent of tunnel lengths.'	Nil. This principle has been applied to the tunnel designs.

Urban design elements: Principles for tunnel interiors	Assessment	Recommendations
Interiors should respond to geographical location and assist in way finding and speed monitoring.	This preferred design principle is consistent with WUDF Principle 2.3 to 'provide visual cues for drivers to understanding their vertical and horizontal location in relation to the urban setting through the form, materials, finishes, lighting of the motorway.'	Nil. This principle has been applied to the tunnel designs.
Consider the integration of lighting and art to enhance the travel experience, improve patronage and make the tunnels more comfortable to use.	This preferred design principle is consistent with WUDF Principle 6.1, 2.2 and 2.3.	The appropriate integration of 'the arts' into the tunnel design will be considered detailed design.
Ensure neat, well aligned panelling and barriers and a good integration with portals.	This preferred design principle is consistent with WUDF Principle 6.4 above.	Nil. This principle has been applied to the tunnel designs.

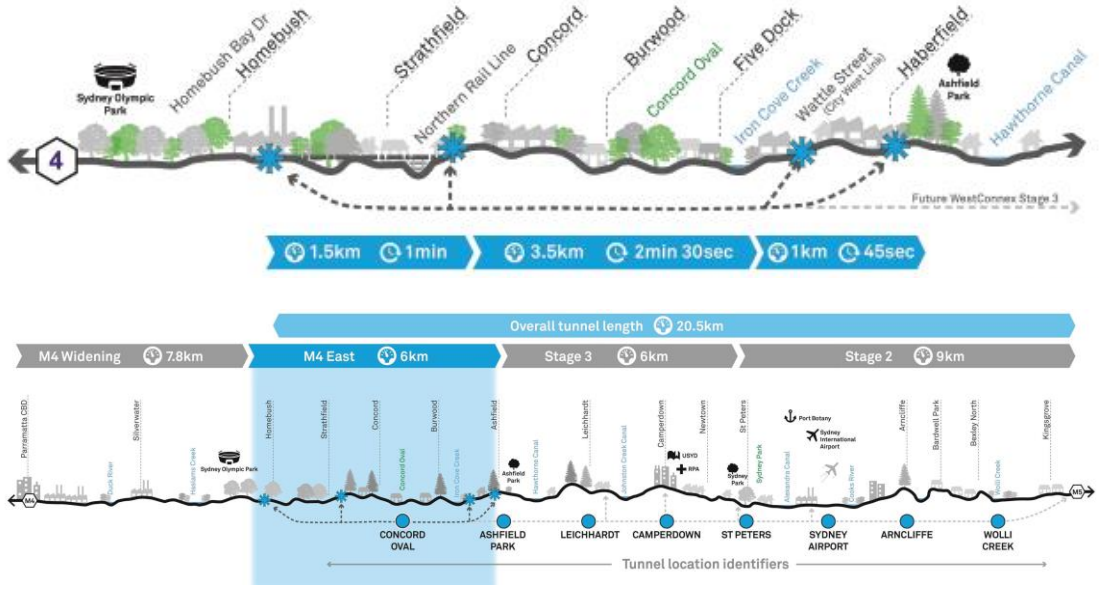


Figure 6.20 **The proposal has suggested a location identifier strategy that can also be adopted by future tunnel stages. This image is conceptual and is included for illustration purposes only.**

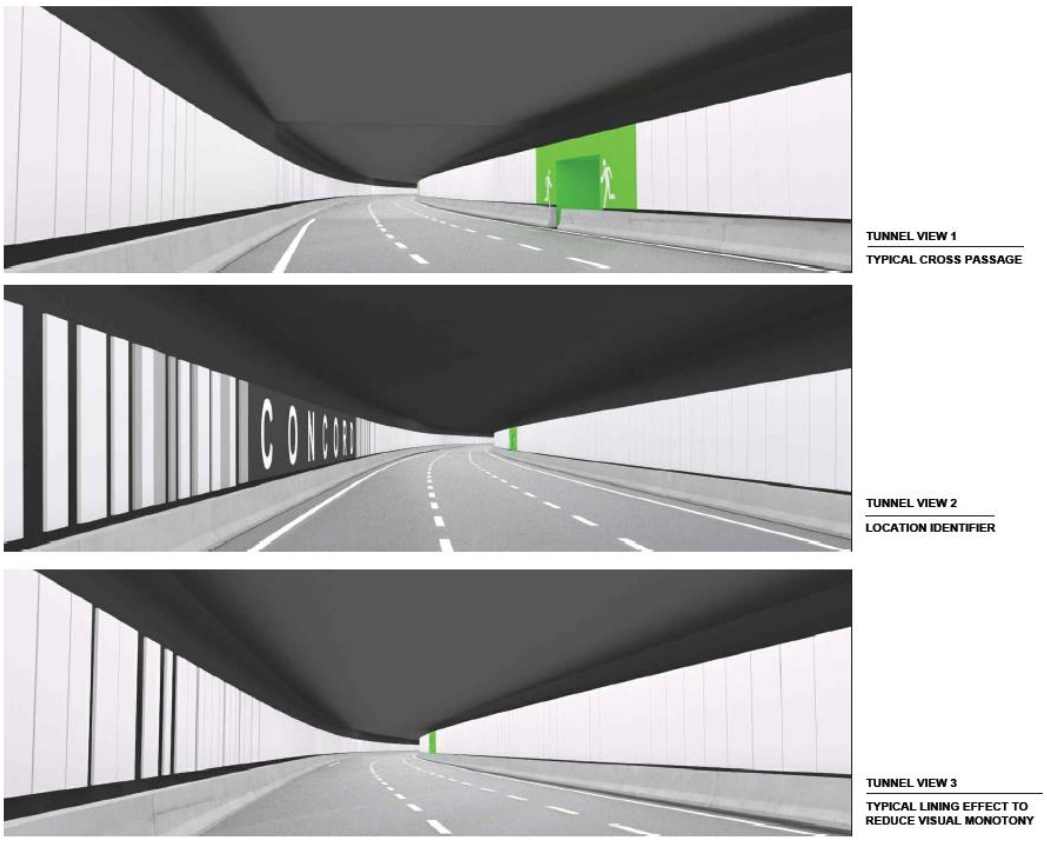


Figure 6.21 **The proposal includes a strategy for identifying cross passages, location identifiers and typical lining effects to reduce visual monotony for drivers. This image is conceptual and is included for illustration purposes only.**

Tunnel services buildings

Design intent

There are several buildings that would form part of the essential operational 'road furniture' of the project, including:

- Homebush Bay Drive interchange:
  - Maintenance facility near Homebush Bay Drive
  - Motorway control centre at Homebush Bay Drive
  - Western ventilation facility near Underwood Road
  - Distribution substation at Underwood Road
  - 33 kV substation at Ismay Avenue
  - Fire pump room and tanks at Ismay Avenue
- Concord Road interchange:
  - Distribution substation at Concord Road
  - Operational fresh air intake facility at the Cintra Park tunnel site
  - Water treatment plant at the Cintra Park tunnel site
- Parramatta Road interchange:
  - Eastern ventilation facility at Parramatta Road
  - Distribution substation at Parramatta Road
  - Fire tanks and pump building at Bland Street.

The form and composition of the buildings aligns with their overall function and urban setting, in conjunction with a restrained approach to the material palette and well-crafted architectural detailing. The building design philosophy is for understated elegance. These various buildings are discussed in greater detail in the following sections.

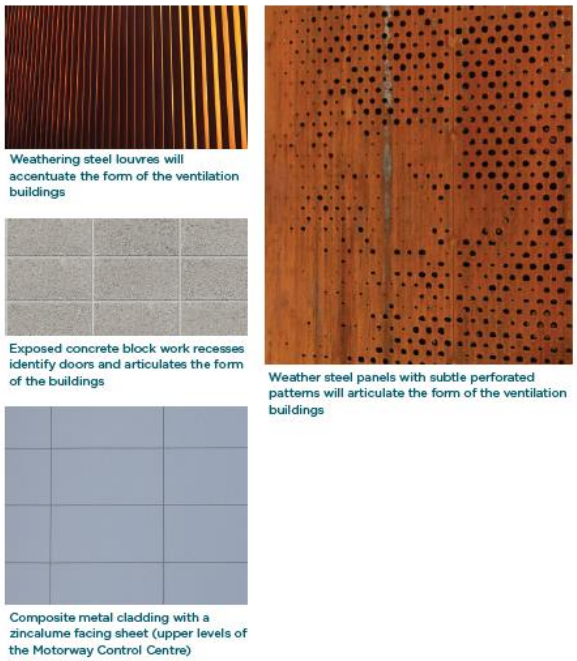


Figure 6.22 Indicative tunnel services buildings materiality. This image is conceptual and is included for illustration purposes only.

Motorway control centre and maintenance facility near Homebush Bay Drive

Design intent

Three structures are proposed at the motorway control centre and maintenance facility near Homebush Bay Drive – a large covered store to the west, a workshop facility to the east, and the control centre above the workshop facility. Efficient vehicle access to and from the facilities is proposed without disrupting local traffic.

An access road is proposed from the Homebush Bay Drive on-ramp to the M4 located to the north of the complex, with access to the secure maintenance area between the two built structures, and staff and visitor parking to the east of the workshop and office building.

A large workshop space is proposed to provide storage and maintenance facilities, with a smaller insertion to the eastern facade that accommodates the staff offices and amenities.

A second structure accessible across a common hardstand courtyard is proposed to provide a large covered external storage area. Water would be collected from the roofed area, stored and treated for re-use on site.

A proposed control centre is to be located to the eastern end of the building group, above the office spaces associated with the workshop. The building would be slightly elevated, and is framed on the northern and southern ends by deep reveals. The control centre would be located on the middle floor, with open plan office space on the top floor.

Materials, colours and finishes

Precast concrete panels are proposed to form a hardwearing and secure dado to the workshop facility. Vertical profiled metal Zincalume cladding would be applied to the upper section of wall, and the roof the workshop. The roof of the covered external storage area would also be a concealed, fixed Zincalume-finish profiled metal roof.

The control centre would be defined by a deep reveal on the northern and southern facades. Composite metal panels with a Zincalume facing sheet to the exterior would accentuate the overall form and define the opening to the upper part of the building.

Table 6.20 Summary of proposal design principles table

Urban design elements: Principles for motorway control centre and maintenance facility	Assessment	Recommendations
Buildings form part of the broader family of the essential operational 'road furniture' that would exist along the motorway, shaping its identity and character.	This preferred design principle is consistent with WUDF Principle 6.4 and Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'.	Nil. The principle has been applied to the design of the control centre and facilities.
Design facilities with a holistic approach to maintain consistency in quality and expression over the course of construction and life of the motorway.	This preferred design principle is consistent with WUDF Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'.	Nil. The principle has been applied to the design of the control centre and facilities.

Urban design elements: Principles for motorway control centre and maintenance facility	Assessment	Recommendations
Design as integrated architectural elements that are refined and elegant.	This preferred design principle is consistent with WUDF Principle 6.2 to provide 'a simple and elegant design beautifully integrating with built and landscape elements'.	Nil. The principle has been applied to the design of the control centre and facilities.



Figure 6.23 **Aerial view of the proposed location of the proposed motorway control centre and maintenance facility, north of the western portion of the M4.**



Figure 6.24 **Indicative landscape plan for the motorway control centre and maintenance facility. This image is conceptual and is included for illustration purposes only.**

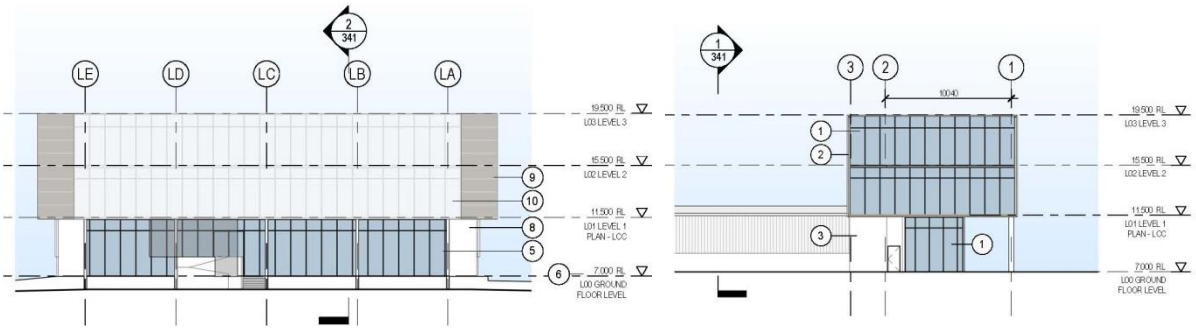


Figure 6.25 **Indicative east and south elevations of the control centre and maintenance facility workshop.**



Figure 6.26 **Visualisation of the proposed landscape plan for the control centre and maintenance facility. This image is conceptual and is included for illustration purposes only.**

Assessment

- The architectural proposal is well considered, building heights are generally single story except for the workshop, and can be easily screened in sufficient tree regrowth is established. Building material selection is appropriate to context
- The proposal involves major earthworks and level benching to accommodate the proposed buildings, resulting in the clearance of the existing mature tree structure. The proposal requires the successful re-establishment of similar tree structure in order to be well integrated within the landscape setting.

Ventilation and electricity facilities

Design intent

The project includes two ventilation facilities. The western ventilation facility and distribution substation would be located on the cut-and-cover structure immediately adjacent to the M4 bridge over Underwood Road. Associated with this ventilation facility is a 33 kV substation between Underwood Road and Ismay Avenue. This facility would also include a fire pump room and water tank enclosure.

The eastern ventilation facility is proposed to be located at the corner of Wattle Street and Parramatta Road. The facility would include supply inlets and exhaust outlets together with a fire tank and pump building, and two smaller electrical distribution buildings.

An electricity distribution substation is proposed to be located above the cut-and-cover structure at the corner of Sydney Street and Concord Road, adjacent to the proposed Concord Road intersection.

An operation fresh air supply facility is proposed to be located at the Cintra Park tunnel site. This site includes air intake infrastructure, an electrical distribution substation building, a water treatment plant building and a water treatment pond.

Table 6.21 Summary of proposal design principles table – ventilation facilities

Urban design elements: Principles for ventilation facilities	Assessment	Recommendations
Design as an integrated architectural element that is refined and elegant.	This preferred design principle is consistent with WUDF Principle 6.4 that 'All visible motorway operations fittings, fixtures and equipment shall be considered as a complete set of integrated urban design elements'. This has been consistently applied in that all building facilities are designed with an integrated and common set of finishes, a 'kit-of-parts'.	Nil. The principle has been applied to the preferred design of the ventilation building.
Consider the ventilation outlet ground interface and its vertical integration both directly adjacent to existing built form and landscape and from a distance.	This preferred design principle is consistent with WUDF Principle 3.6 and Principle 6.4 regarding integration of the proposal within context and/or future development opportunities. The proposed facilities are essentially isolated within their specific project areas.	Nil. The principle has been applied to the preferred design of the ventilation building and assessed against ground level photomontage viewpoints elsewhere in the report.
Explore a unified design expression for ventilation outlets located near tunnel portals.	This preferred design principle is consistent with WUDF Principle 6.4. The two ventilation buildings are located directly above tunnel cut-and-cover structures. The facilities do exhibit a unified design expression of themselves.	Nil. The principle has been applied to the preferred design of the ventilation building.
Form and character of ventilation outlets should respect local character and context.	This preferred design principle is consistent with WUDF Principle 6.4. The form and character of each of the ventilation buildings is a logical response to setting.	Nil. The principle has been applied to the preferred design of the ventilation building.
Utilise robust, high quality and durable materials, appropriate to context and to deter vandalism.	This preferred design principle is consistent with WUDF Principle 6.3 to 'use robust, high quality and durable materials'.	Nil. The principle has been applied to the ventilation building design.

Integration with other structures

The project does not propose to utilise key structures, such as 'outlets', for multiple uses, however the western ventilation facility has been integrated within the embankments associated with the adjacent existing M4 and the adjacent proposed cut and fill structures of the tunnel. This will effectively reduce the overall scale, height and massing of the various structures within a single integrated composition.

The design of the eastern ventilation facility will consider the opportunity to integrate the facility structures within their current and future urban setting, with regard to the Parramatta Road and the adjacent Bunning building.

Western ventilation facility and 33kV substation at Ismay Avenue

Design intent

The proposed western ventilation facility is conceived as two discrete objects. The distribution substation would be a long, low horizontal structure to be concealed within the civil structure above

the westbound carriageway. The proposed ventilation outlet is intended to be ‘an understated sculptural marker’; a concrete shaft wrapped in ‘a lightweight perforated veil’.

A planted courtyard and vehicle circulation to the north is intended to ensure that the building is recessed from the Underwood Road and Short Street East as far as possible, in an attempt to reduce its street level presence in the local urban environment.

Within the ventilation outlet, an internal stair would be provided to access the fan assemblies, attenuators and dampers, in addition to access for regular air quality monitoring. The fans would be located directly above the westbound exit carriageway in order to improve operational efficiency. External removable access panels would be located at fan-floor level, concealing doors within the precast concrete structure, for horizontal slide-out fan replacement.

The ventilation outlet is intended to be visually separate from the horizontal building. The outlet’s cladding is intended as ‘an honest representation of the function of the building’. The vertical joints of the cladding system are intended to accentuate the vertical slenderness of the tower and reduce its apparent width. Two discrete bands of darker steel fins (louvres), perpendicular to the main cladding, are also intended to accentuate the verticality of the outlet.

A 33kV substation, a fire pump room and water tank enclosure are proposed to be located adjacent to the existing M4, east of the ventilation facility at Underwood Road. Maintenance access would be provided from Ismay Avenue.

Materials, colours and finishes

The horizontal portion of the building group is proposed to be clad in lightweight light grey extruded terracotta tiles. This is intended to acknowledge the traditional material of the Californian bungalows and Federation-era houses in the adjacent precinct.

Openings providing service access to the plant rooms are proposed to be grouped into common recesses, exposing the structure of smooth-faced charcoal concrete block (stack bond pattern). Access doors within the block work would be painted a light grey to match.

A similar approach is proposed for the cladding to the street facades of the 33kV substation, the fire pump room and the water tank enclosure.

The proposed weathering steel finish to the veil of the ventilation outlet would be deliberately detailed to sculpt and accentuate the vertical form, with strongly articulated vertical shadow gaps and more subtle horizontal joins decreasing in frequency toward the top of the tower.

Two typologies are proposed to define the specific choice of building materials and detailing – the first comprising the occupied buildings (for example the maintenance facility and the motorway control centre) the second comprising the buildings and facilities that support the operation of the tunnels and portals.



Weathering steel louvres will accentuate the form of the ventilation buildings



Exposed concrete block work recesses identify doors and articulates the form of the buildings



Composite metal cladding with a zincalume facing sheet (upper levels of the Motorway Control Centre)



Weather steel panels with subtle perforated patterns will articulate the form of the ventilation buildings



Prefinished terracotta panels clad the electrical and mechanical buildings. The consistent use of the material provides a cohesive brand for each of the buildings

Figure 6.27 **The materials proposed for the ventilation outlets and other facilities are to be drawn from a consistent project-wide palette. This image is conceptual and is included for illustration purposes only.**



Figure 6.28 **Indicative arrangement of the ventilation outlet and other facilities at Underwood Road. This image is conceptual and is included for illustration purposes only.**

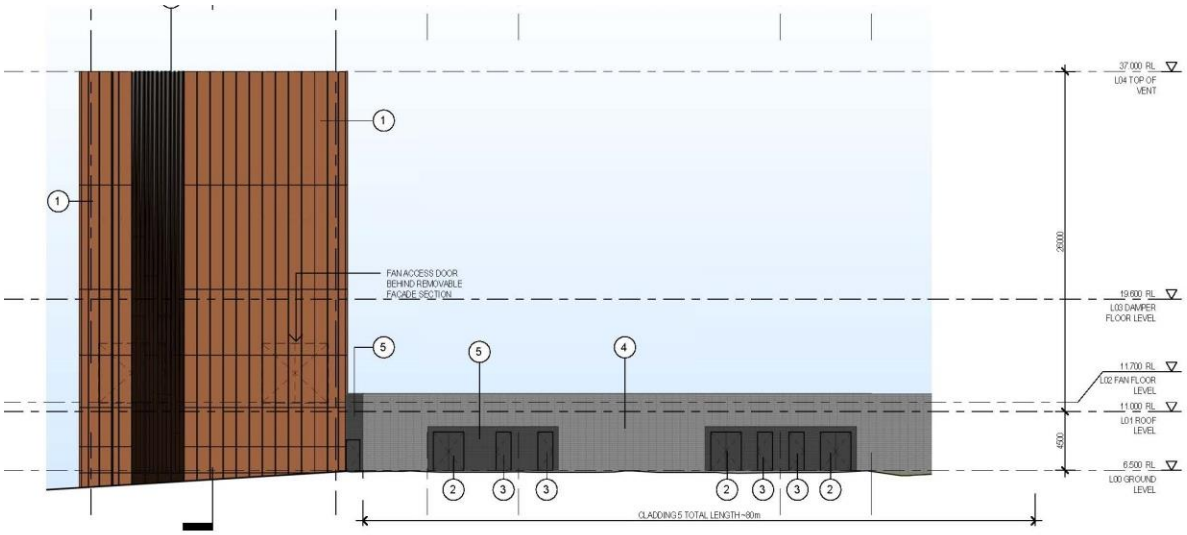


Figure 6.29 **Indicative north elevation of the western ventilation outlet and adjacent substation building. This image is conceptual and is included for illustration purposes only.**



Figure 6.30 **Indicative perspective of the western ventilation outlet and adjacent substation building from the east. This image is conceptual and is included for illustration purposes only.**



Figure 6.31 **Indicative arrangement of the 33kV substation at Ismay Avenue. This image is conceptual and is included for illustration purposes only.**

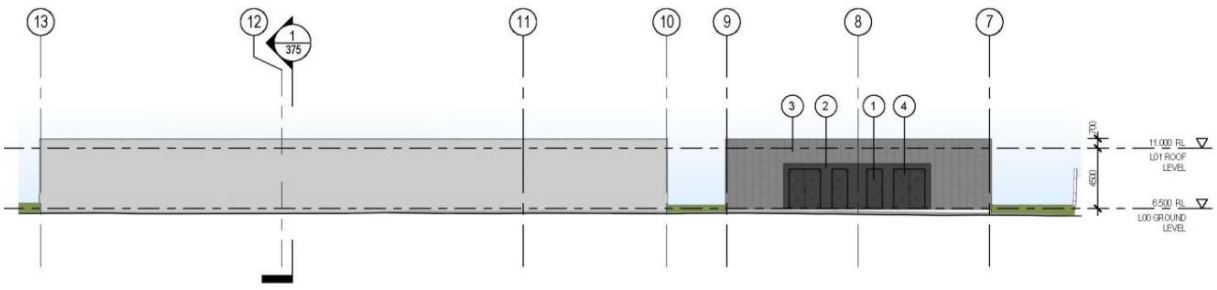


Figure 6.32 **Indicative arrangement of the 33kV substation at Ismay Avenue. This image is conceptual and is included for illustration purposes only.**

Assessment

- The proposed ventilation outlet for the western ventilation facility would be located adjacent to the existing elevated section of the M4, making good use of the cut-and-fill structure to create an efficient footprint. However, the proposed north elevation of the outlet facing the adjacent residential buildings is about 10 storeys high and 20 metres wide, subject to detailed design. Most houses in the area are single-storey, and some are two-storeys high with an eight metre frontage. The preferred design therefore requires the landscape proposition to effectively integrate the project within its setting
- The project proposes residual lands for future redevelopment and amenity functions, presenting further opportunities to reconcile the scale of the ventilation structures within their settings
- The residual land to the north of the proposed ventilation buildings is intended as public realm. These lots are of sufficient size to support trees of appropriate stature and density to effectively mediate between the scale of the proposal and that of the residential neighbours
- The architectural treatment of the ventilation outlet is a logical response to the need to influence the apparent mass of the structure, particularly the northern elevation. The use of vertical jointing, shadow lines and vertical louvres all assist in this regard.

Distribution substation at Concord Road

Design intent

The preferred design of the distribution substation at Concord Road is intended to be unobtrusive with a scale and form consistent with the adjacent residential character. It includes provision for maintenance vehicle access and parking from Concord Lane, and returns a parcel of land toward Concord Road for future development.

Materials, colours and finishes

The proposed materials and finishes of the distribution substation would be similar cladding to the distribution substation within the western ventilation facility. Openings providing service access to the plant rooms would be grouped into common recesses, exposing the structure – a smooth-faced charcoal concrete block (stack bond pattern). Access doors within the blockwork would be painted a light grey to match.

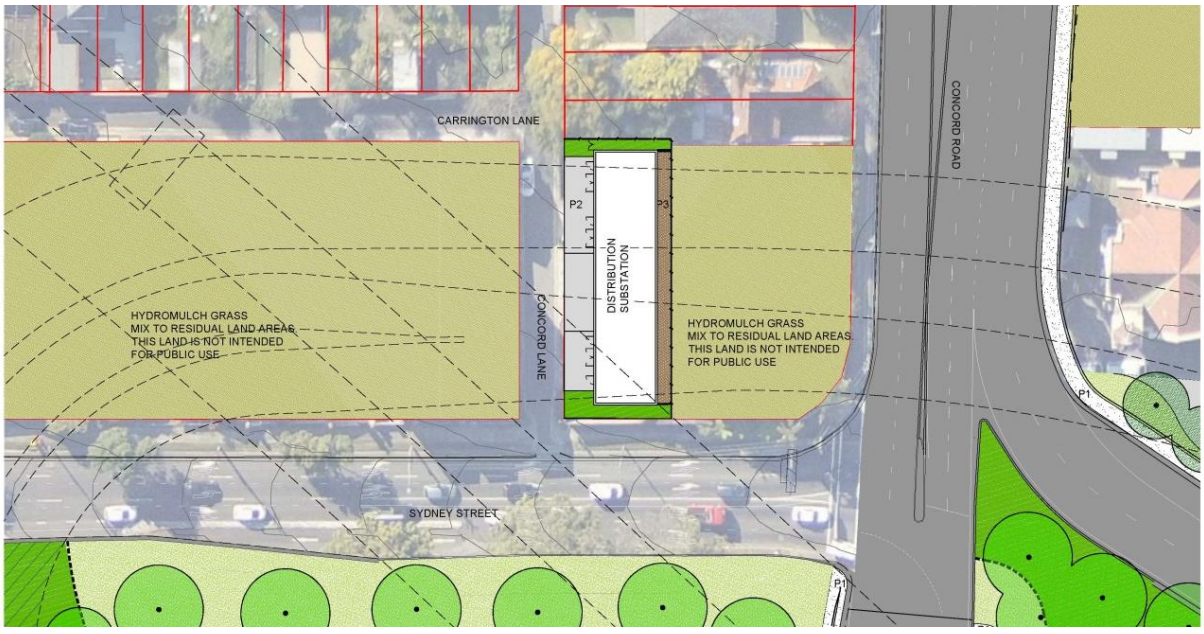


Figure 6.33 **Indicative landscape plan for the Concord Road distribution substation. This image is conceptual and is included for illustration purposes only.**

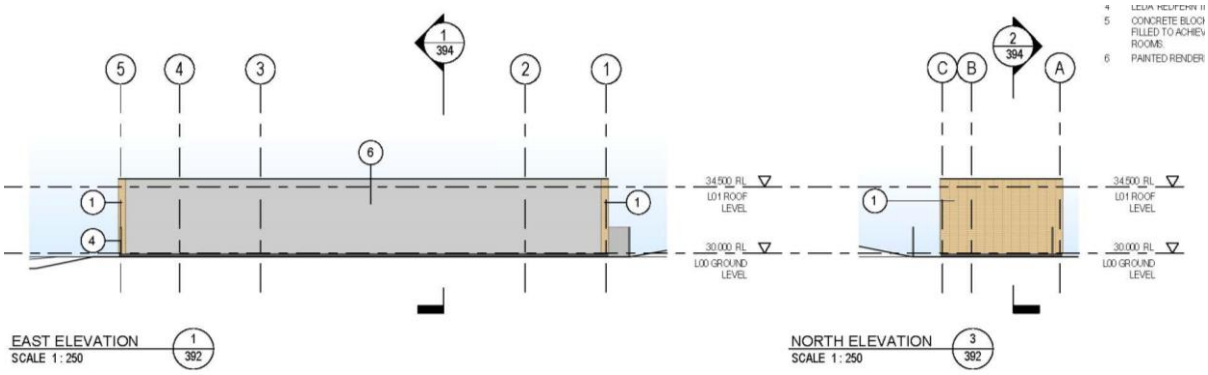


Figure 6.34 **Indicative east and north elevation treatments for the Concord Road distribution substation. This image is conceptual and is included for illustration purposes only.**



Figure 6.35 **Indicative axonometric view from the south west of the Concord Road distribution substation. This image is conceptual and is included for illustration purposes only.**

Assessment

- The preferred design assumes that the residual land between the distribution substation and Concord Road would be fully developed in the future, and that therefore the east elevation of the building can be treated as a blank wall. But it would be fully exposed until this happens
- The proposed substation building height and material finishes (other than the elevation to Concord Road) would be consistent with existing residential buildings, but in other respects such as shape (plan and section) and mass, the building would not read as an integral component of the residential neighbourhood

- The residual land to the west of the substation would be intended for future development, and as with all proposed residual lands it would be hydromulched as a temporary landscape cover. Identification of other landscape finishes would be undertaken in tandem with the design for the residual land
- The proposed substation would therefore stand alone, with no landscape mitigation other than hydromulch as a surface finish, until the future redevelopment.

Fresh air intake facility at Cintra Park tunnel site

Design intent

The operational functions at the Cintra Park tunnel site are intended to be distributed among a number of smaller built forms to reduce their overall scale, consistent with the park setting and the adjacent residential properties.

An effort has been made to locate the buildings and sedimentation basin such that the established trees within the facility are retained.

A small fresh air supply facility is proposed to be located in the south of the site, a distribution substation to the southeast, and a water treatment plant to the east. A suite of rooms for disaster recovery are also attached eastern side of the distribution substation building.

The building forms are proposed to enclose two sides of a landscaped sedimentation pond.

Operational vehicle access is to be provided from Gipps Street toward the north of the site.

Materials, colours and finishes

The distribution substation and water treatment plant buildings are proposed as rendered and painted concrete block work. Openings providing service access to the plant rooms would be grouped in a similar manner to the other distribution substations with common recesses exposing bands of the structure – a smooth-faced charcoal concrete block (stack bond pattern). Access doors within the block work would be painted a light grey to match.

The fresh air supply facility, comprising grey polished precast concrete panels would form the northern and southern facades with recessed walls to the east and west painted black, in order to reduce visual scale and a contrast in form.

Assessment

The use of residential scale buildings would be suitably domestic, and should integrate well with the adjacent residential neighbourhoods, characterised by Californian bungalow and Federation-era style houses. There are contemporary houses within the neighbourhood (for example 7 and 7A Taylor Street), with rendered and painted finishes in grey tones similar to the proposed fresh air supply facility.

All of the proposed elevations (with the exception of the east elevation of the water treatment plant) would include vertical bandings around door features etc that express modularity reflective of the local residential scale.

Eastern ventilation facility

Design intent

The eastern ventilation facility would be located between Wattle Street to the west, Walker Avenue to the east, and Parramatta Road to the south. The built form of the main ventilation outlet is a gridded, square tower, the upper portion clad with reflective feature panels. The lower air supply inlet has similar square proportions on plan but is about half of the height of the ventilation outlet, and features horizontal weathering louvres on all elevations. The shape and proportions of both buildings reflects their function. They are proposed to be located toward the centre of the site in order to permit extensive planting to the boundary.

The two electrical distribution buildings to the east of the site, and water tank and pump building to the north of the site would be all, rectangular single-storey buildings.

The ventilation outlet would be the tallest structure of the facility and located away from the residential precinct of Walker Avenue. Located on the corner of the site it would be well placed to engage visually with the existing Bunnings clock tower on the opposite corner of Parramatta Road, the towers are of similar height. Like the Bunnings building, the ventilation facility has the opportunity to engage directly with Parramatta Road, if the setback and angle to the street grid is lessened, along with the proposed landscape zone and security fencing.

Materials, colours and finishes

The ventilation outlet is proposed to be clad with composite metal panelised cladding. The upper half of the ventilation outlet would be expressed with reflective feature panels of a smaller modular than its lower half. This expressed modularity breaks down the visual mass of the outlet, whilst presenting a lively, well balanced elevation.

The upper portion of the air supply building would be clad with horizontal, weathered aluminium louvres, broken into vertical groups on each face, to give rhythm and scale. The modular cladding system of the supply building would adopt the same proportions as that of the main ventilation outlet cladding, such that the finishes of both buildings, although separate, would be clearly seen to be variations of the same theme.

A similar approach would be used on the lower electrical buildings. Although these would be clad with a terracotta facade system, it would adopt a smaller, finer variation of the modular. Therefore all of the buildings, although separated and of various scales and functions, would read as part of a well ordered composition.



Figure 6.36 Indicative landscape plan for the eastern ventilation facility. This image is conceptual and is included for illustration purposes only.

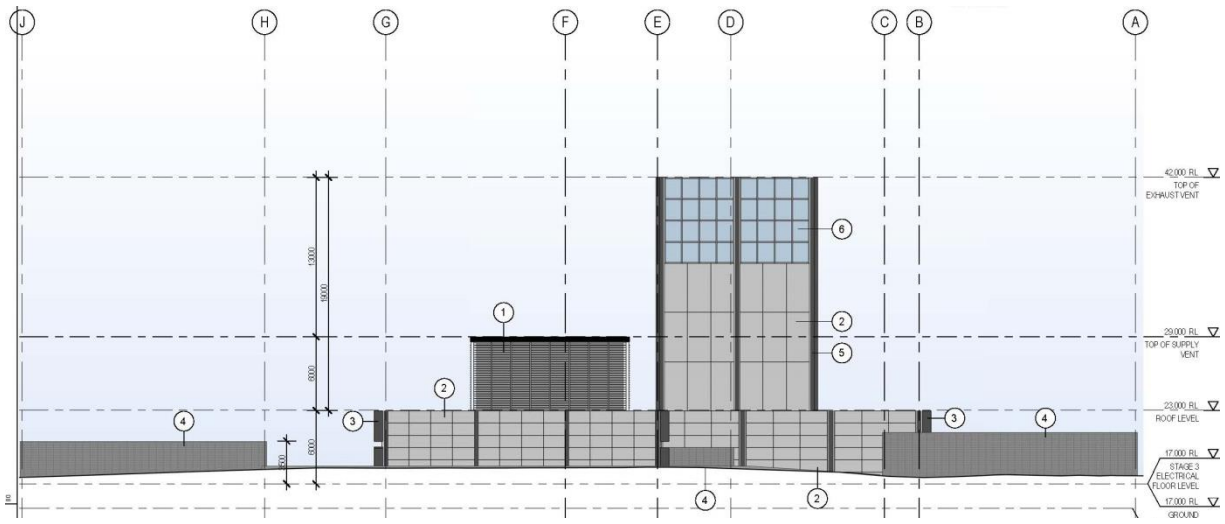


Figure 6.37 South west elevation of the eastern ventilation facility. This image is conceptual and is included for illustration purposes only.

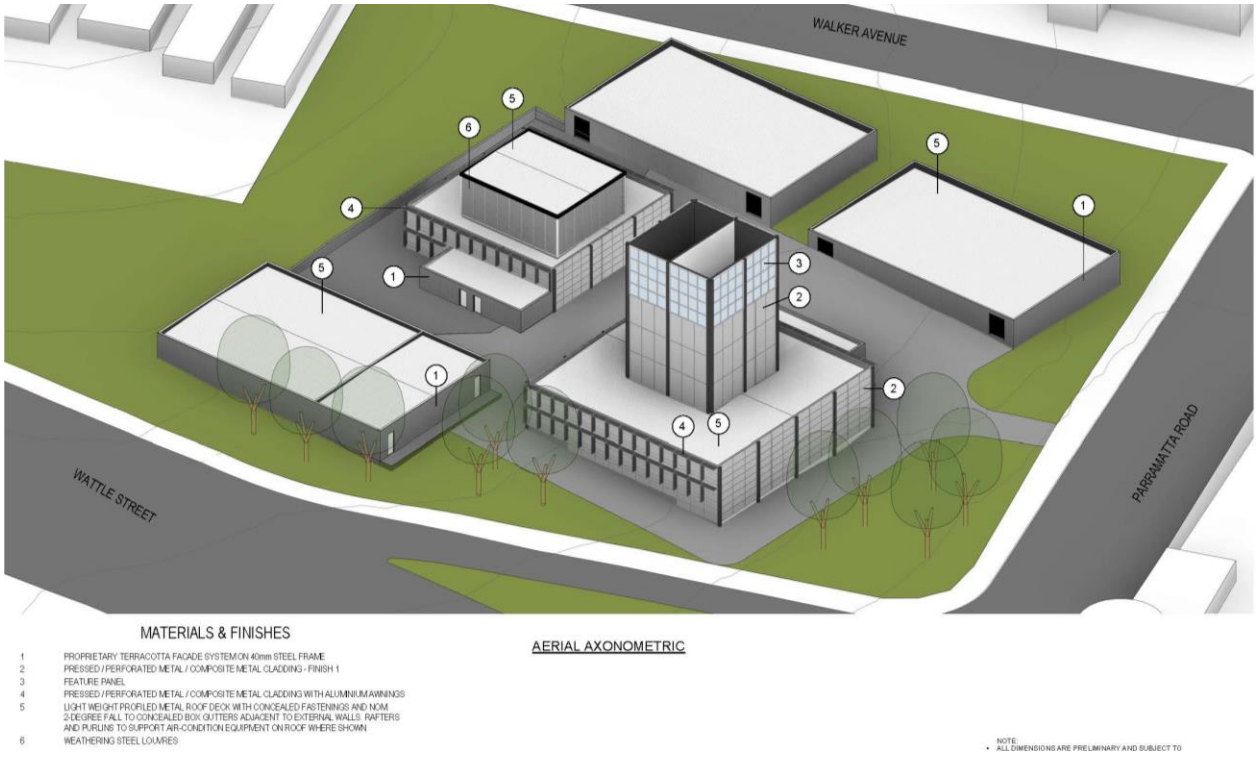


Figure 6.38 Axonometric view from the west of the eastern ventilation facility. This image is conceptual and is included for illustration purposes only.

Assessment

- The two distinct architectural expressions applied to this proposed facility are appropriate. The ventilation outlets and air supply inlets respond to the scale and form of the Bunnings buildings on the opposite side of Parramatta Road. The lower electrical buildings would respond in height and scale to the adjacent residential typologies. The application of the modular cladding systems would provide a unifying expression to what would otherwise be a confusion of very different functions and building types

- The Bunnings building opposite is rendered primarily with off-white and blue-grey tones, with a strong linear, horizontal rhythm along the street elevation, and highlighted with a strong vertical pattern on the clock tower. The ventilation facilities would be read primarily in relation to the Bunnings building. It is logical that the new building should acknowledge the primacy of the existing building typology. The visual relationship between the proposal and the residential buildings on Walker Avenue would be likely to be mediated by the retained and newly planted mature street trees. The choice of facade modularity, materiality and colour would therefore be very appropriate
- This assessment underlines the importance of, and the need for, street trees of stature to mediate between the scale of urban intervention and the site context. The numbers, density and size of the proposed tree planting intended to screen the ventilation facility must be adequate to the task
- The proposal to locate the ventilation outlet on the Wattle Street and Parramatta Road corner of the facility would be very appropriate from an urban design perspective, in so much as the ventilation outlet is of similar height to the Bunnings clock tower – together the two structures would be likely to imply a 'portal' feature to this section of Parramatta Road
- Similar to the Bunnings building, the proposed ventilation outlet and the rest of the facility has the opportunity to engage directly with Parramatta Road and fits comfortably visually within the street grid and Bunnings 'street wall' opposite.

Noise walls

Existing noise walls

Existing noise walls along the M4 are generally of two types. The first is the plain, aerated concrete panel or plank systems painted grey-green. The second type is a coloured masonry noise wall of concrete bricks along sections of the northern motorway boundary.

The first section of masonry wall is at the interface to the residential zone on the north of the motorway as it approaches the bridge abutment at Underwood Road. It reverts to the plain concrete noise wall on the bridge itself, reverting to the masonry style on the eastern side of the bridge. This noise wall continues up to within one kilometre of the eastern end of the motorway. There is a section of the masonry wall type (about 25 metres long) just east of the off-ramp to Sydney Street. This reverts to the plain concrete style for a short section (about 60 metres) and then back to the masonry style noise wall to the eastern end of the motorway.

On the southern boundary of the motorway noise walls are all of the plain concrete type.



Figure 6.39 **Two styles of noise wall characterise the existing M4: the concrete masonry style wall (above left) dominates along northern motorway boundary and the plain concrete modular noise wall style is predominant along the southern motorway boundary (above right).**

Table 6.22 Summary of proposal design principles table

Urban design elements: Principles for noise walls	Assessment	Recommendations
Simple, uncomplicated and consistent treatments applied to a variety of distinct events.	This preferred design principle is consistent with WUDF Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'.	Nil. The principle has been applied to the typical design details for noise walls.
Well resolved detailing that integrates the various road elements; rail, noise barrier, wall, topography, etc.	This preferred design principle is consistent with WUDF Principle 5.1.	The principle will be developed further detailed design.
Calm and gradual transitions.	This preferred design principle is consistent with WUDF Principle 5.1 and Principle 6.2 to provide 'a simple and elegant design beautifully integrating with built and landscape elements'. The principle has been applied to the noise walls evident in the available photomontages.	The principle will be developed further during detailed design. In particular the termination of the walls at each end, including overlapping sections and maintenance access openings where required.
Consistent alignment with tops generally running parallel with the road alignment, without stepping.	This preferred design principle is consistent with WUDF Principles 5.1 and Principle 6.2. The principle has been applied to the noise walls evident in the photomontages and typical elevations provided.	The principle will be developed further during detailed design, in particular to confirm how these details are coordinated with associated retaining walls.
Providing sufficient space for screen planting to both sides where possible.	This preferred design principle is consistent with WUDF Principle 1.8 to 'where possible, preserve wide margins and space along the road corridor to safely create an 'urban forest' along the motorway'. The current designs suggest that there is not sufficient room to achieve this outcome throughout the project alignment.	The principle will be developed further during detailed design.
Applying fine detail that is integral to the screen rather than explicit.		The principle will be developed further during detailed design.
Durable and easy to maintain.	This preferred design principle is consistent with WUDF Principle 6.3. However, the proposal to use aerated concrete panel noise walls is not consistent with that principle.	Aerated concrete panel noise walls can be susceptible to damage by adjacent vegetation and vandalism. An alternative design strategy could be considered during detailed design.
Ease of construction.	This preferred design principle is consistent with WUDF Principle 5.1.	Nil. The principle has been applied to the design of noise walls.

Urban design elements: Principles for noise walls	Assessment	Recommendations
Ensuring the design compliments existing noise barriers and road elements.	This preferred design principle is consistent with WUDF Principle 5.1.	Nil. The principle has been applied to the design of noise walls.
Applying a consistent design approach to other road elements including materials and colour palettes.	This preferred design principle is consistent with WUDF Principle 5.1.	Nil. The principle has been applied to the design of noise walls.

Proposed noise walls and headlight screens

Three types of noise walls are proposed as follows.

Coloured Acrylic Transparent Walls

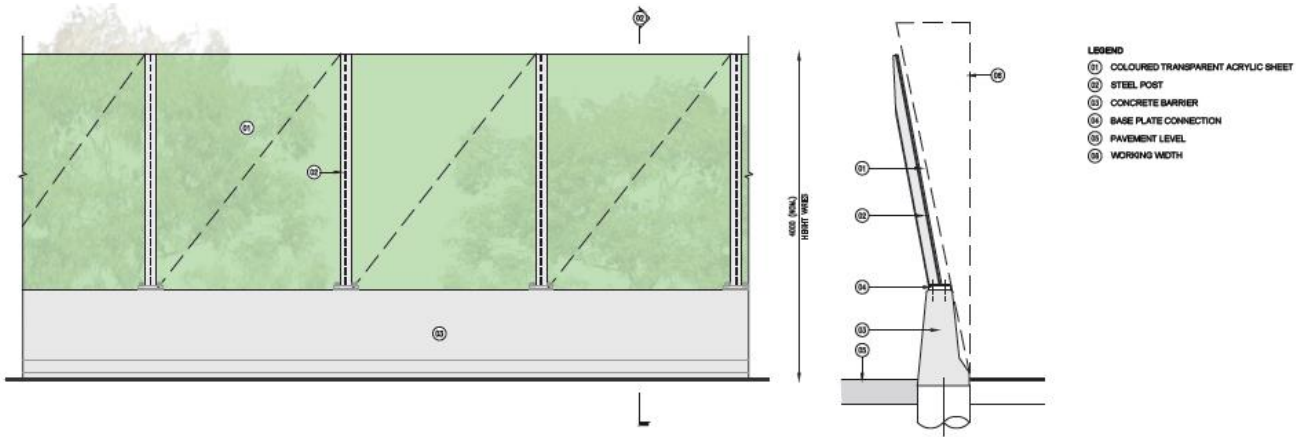


Figure 6.40 Indicative typical transparent noise wall, elevation and section. This image is conceptual and is included for illustration purposes only.

All transparent noise walls would be coloured green and are designed to allow views out over the adjoining landscape settings. These walls would be located generally in the following locations:

- Between Homebush Bay Drive and the Concord Road interchange:
  - On the northern edge of the tunnel portals, running east over the cut-and-cover roof, on Underwood Road overbridge as a replacement to the existing wall, and as a replacement to the existing blockwork wall
  - Wall height would vary from about three to six metres subject to detailed design
- Concord Road interchange:
  - Between the Concord Road interchange tunnel on and off-ramps and Sydney, Edward and Alexandra Street residential properties
  - Wall height would be between around one and three metres
- Wattle Street between Parramatta Road and Loudon Avenue and Parramatta Road between Wattle Street and Wolseley Street:
  - Wall heights would vary between around two and five metres in height subject to detailed design

These noise walls would be consistent with the requirements of the WUDF and appropriate to the alignment context.

Vertical concrete panel walls

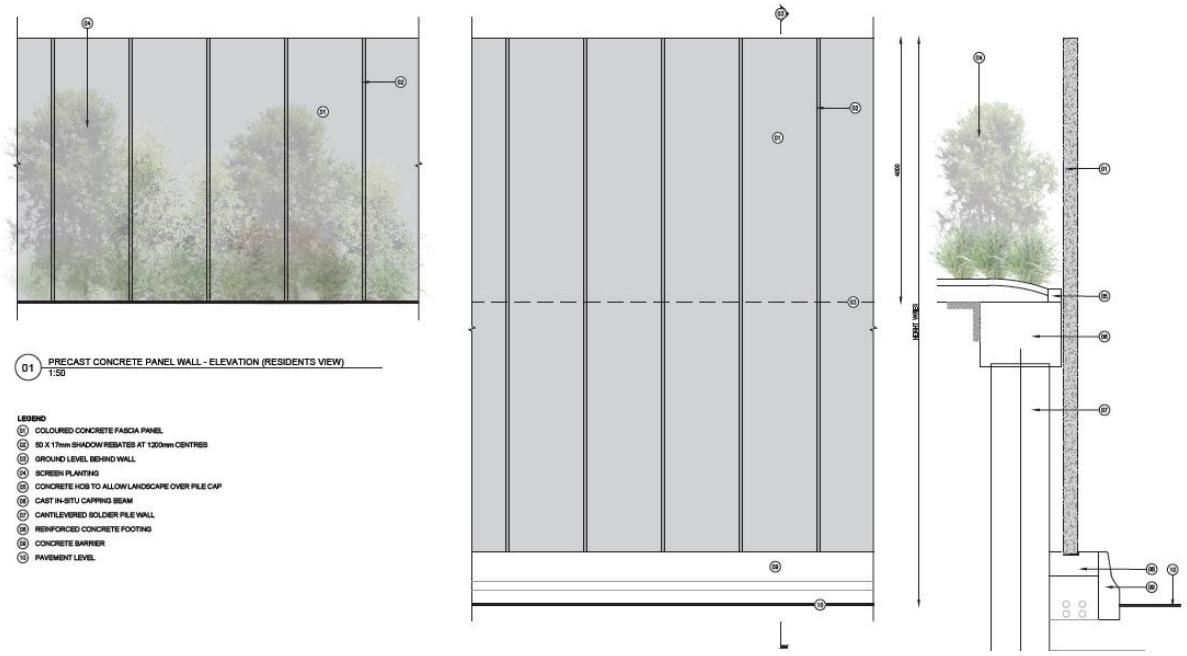


Figure 6.41 Indicative typical precast panel retaining wall (cantilevered soldier pile wall) extended to form noise wall, elevation and section. This image is conceptual and is included for illustration purposes only.

The overall design of the concrete panel noise walls would present a coherent, integrated and consistent feel and appearance throughout the project. The walls would be of precast concrete panels to match retaining wall cladding panels, where the noise wall would simply be an extension of the retaining wall detail below to achieve required noise wall height. These walls are generally proposed in the following locations:

- M4 East between Homebush Bay Drive and the Concord Road interchange:
  - Wall heights would vary between around three and six metres in height subject to detailed design
- Wattle Street between Parramatta Road and Mortley Avenue and Parramatta Road between Wattle Street and Wolseley Street:
  - Wall heights would vary between around two and five metres in height subject to detailed design

These noise walls would be consistent with the requirements of the WUDF and appropriate to the alignment context.

Aerated concrete panel walls



Figure 6.42 Indicative typical aerated concrete panel noise wall; elevation and section. This image is conceptual and is included for illustration purposes only.

These walls are generally proposed in the following locations:

- M4 East between Homebush Bay Drive and the Concord Road interchange:
  - Wall heights would vary between around three and six metres in height subject to detailed design

Headlight screens

Where they are required, the proposed design approach is to minimise the visual impact of headlight screens through:

- Simple, uncomplicated and consistent treatments
- Well resolved detailing
- Consistent alignment with tops generally running parallel with the road alignment, without stepping.

A headlight screen would be required at the Concord Road interchange, between the realigned M4 eastbound and eastbound tunnel on-ramp from Concord Road. The wall would run for about 140 metres between CH220–CH360, subject to detailed design.

The headlight screen panel is proposed to be a compressed fibre cement panel on a steel support frame with a select paint finish. No details are provided but based on this description the headlight screens would be likely to be consistent with the requirements of the WUDF and appropriate to the alignment context.

(Refer to the *Roads and Maritime Noise Wall Guidelines: Design guidelines to avoid, minimise and improve the appearance of noise walls in NSW* (2007).)

Retaining walls

Existing retaining walls

Existing retaining walls within the existing M4 are limited to the mass concrete buttress walls of the bridge and viaduct abutments, and interlocking (crib-lock style) precast concrete systems. These systems have not been designed to present a consistent suite of wall typologies, but to respond to different ground conditions as they arise.




Figure 6.43 View to the south under the existing M4 bridge over Underwood Road.

WestConnex urban design guidelines: Walls

- The WUDF includes the following requirements for wall systems:
- Design all wall types as a family of elements to reinforce motorway identity
- Design high quality, robust walls of architectural merit and detail (use class 2 concrete as a minimum). Balance wall heights with planting opportunities
- Consider vandalism when designing walls and its long term management strategy
- Integrate transparent noise walls where there are opportunities to view the broader landscape setting and buffer from residents and road users
- Consider the visual appearance of noise walls from either side
- Consider the design of handrails, balustrades and jointing patterns in unison with the design of walls
- Do not use shotcrete that is visible to road users or residents, cover with panelling or avoid the need for it (Refer to the Roads and Traffic Authority of NSW: '*Shotcrete Design Guidelines: Design guidelines to avoid, minimise and improve the appearance of Shotcrete'*, June 2005).

Table 6.23 Summary of proposal design principles table – retaining walls

Proposal urban design elements: Principles for retaining walls	Assessment	Commitments
All retaining walls must be designed to be a suite of elements.	This preferred design principle is consistent with WUDF Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'. The principle will be applied to the design of retaining walls finishes.	Retaining wall finishes have not yet been detailed in the preferred design.
Neutral in colour with non-reflective finishes.	This preferred design principle is consistent with WUDF Principle 5.1.	Nil. This approach is adopted in the preferred design.
Wall tops are to form continuous smooth flowing lines with no stepping.	This preferred design principle is consistent with WUDF principles 5.1 and 6.2. The principle has been applied to the retaining walls evident in the photomontages. .	The next stage of detailed design will demonstrate that this level of detail is consistent throughout all elements of the project.
Wall plan layouts are simple, with straight or large radius curved alignments, without sharp changes of direction.	This preferred design principle is consistent with WUDF principles 5.1 and 6.2. The principle has been applied to the retaining walls evident in the photomontages.	Further design development will seek full coordination between the various design disciplines, to deliver a fully integrated and coordinated project outcome. The termination of retaining walls requires careful consideration.

Proposed retaining walls

Design intent

To date, the design for the project has focused on the walls that line the tunnel portal dive structures and will address details of retaining wall types during detailed design. It is assumed, however, that other walls may vary in size and therefore the treatment will also vary to ensure they are appropriate to the scale.

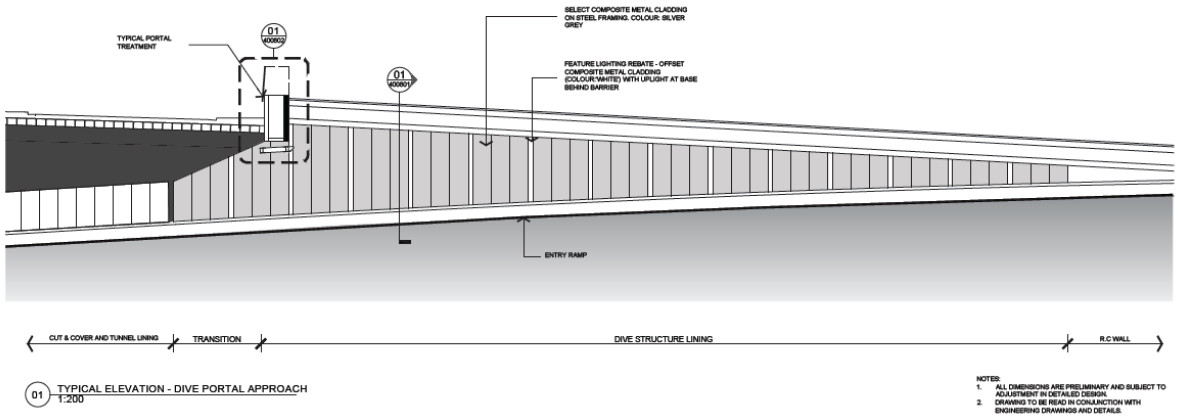


Figure 6.44 **Indicative typical elevation to dive structure at tunnel portal. A modular fascia panel system is proposed with a strong vertical jointing pattern, highlighted by steel framing and a lighting rebate. This image is conceptual and is included for illustration purposes only.**

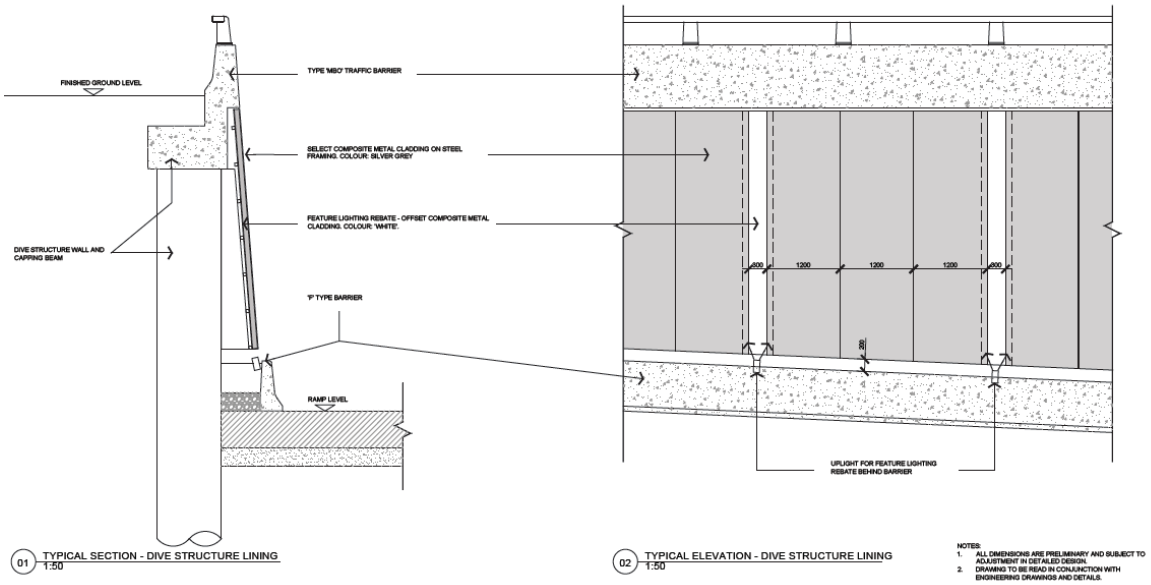


Figure 6.45 **Indicative detail of proposed typical elevation to dive structure at tunnel portal. The detail highlights the steel framing and a lighting rebate. This image is conceptual and is included for illustration purposes only.**

Lighting

Existing Lighting

Existing highway and street lighting is generally based on high pressure sodium induction lighting systems.

WestConnex urban design guidelines: Feature lighting

The WUDF includes the following requirements for feature lighting:

- Dynamic and creative feature lighting should also be energy efficient, avoid light spill and be easy to maintain

- Feature lighting to create an artistic effect, articulate urban forms of walls and bridges and amplify the night time experience
- Feature lighting to be located in select locations in line with the strategy so as not to dilute the power of each intervention
- Implement where appropriate to extend the aesthetic of the motorway architectural elements into the night
- Balance feature lighting with the constraints of cost, safety, context and environment.

Table 6.24 Summary of proposal design principles table – lighting

Proposal urban design elements: Principles for lighting	Assessment	Recommendations
Dynamic and creative feature lighting should be energy efficient, avoid light spill and be easy to maintain.	This preferred design principle is consistent with the WUDF feature lightning guidelines.	Other than special tunnel lighting the preferred design includes only schematic lighting. The achievement of this principle will be demonstrated during detailed design development.
Feature lighting to create an artistic effect, articulate urban forms of walls and bridges and amplify the night time experience.	This preferred design principle is consistent with the WUDF feature lightning guidelines.	The next stage of design development will demonstrate the achievement of this principle.
Feature lighting to be located in select locations in line with the strategy so as not to dilute the power of each intervention.	This preferred design principle is consistent with the WUDF feature lightning guidelines.	The project is selective in the use of feature lighting. The next stage of design development will demonstrate the achievement of this principle.
Balance feature lighting with the constraints of cost, safety, context and environment.	This Preferred design principle is consistent with the WUDF guidelines.	The next stage of design development will demonstrate the achievement of this principle.

Bridges

Existing bridges are located at Underwood Road and Concord Road; there is also a long viaduct structure over Powells Creek Reserve and the adjacent rail/road corridor including George, Railway and Queen Streets – a total length of about 350 metres. Each of these structures is quite different in character.

WestConnex urban design guidelines: Bridges, viaducts and underpasses

The WUDF requires the following approach to be taken to the design of bridges and viaducts:

- Each bridge should be an exemplary work that enriches the city fabric of Australia's international city
- Structures should be simple, refined and elegant with minimal piers and abutments to maximise usability, permeability and visual transparency beneath
- Accentuate horizontal forms to complement the urban landscape / context and enliven the journey
- Good proportions between deck overhang
- Open spill through of abutments preferred
- Bridge widening – Remain sensitive to the existing character

- Consider the vertical alignment of the viaduct and how it will be viewed in relation to adjacent built form and landscape
- Consider the experience from underneath by considering the opportunity for well-scaled, useable, appealing and safe spaces beneath structures
- Unified and integrated design
- Maximise opportunities along viaducts for greater appreciation of context
- Pedestrian underpasses to be generous in scale, well lit, provide clear sight lines and feel safe. Portal and underpass interiors to be welcoming and have architectural merit, appropriate to the context and setting. (Refer to *Roads and Traffic Authority of NSW: Bridge Aesthetics: Design guidelines to improve the appearance of bridges in NSW'*, July 2012)

Existing Underwood Road motorway bridge



Figure 6.46 View to the south under the existing M4 bridge over Underwood Road.

Assessment

The motorway bridge over Underwood Road is a concrete deck structure supported by Super-T girders launched from a laid-back abutment on each side, and set on two perpendicular rectangular headstocks on rectangular piers. The headstock arrangement is unrefined and, together with the solid noise walls above, adds to the overall effect of a heavy, deep deck with a poor slenderness ratio. The embankments below the bridge approaches and around the abutments support tree planting.

No modifications to this bridge are proposed however much of the planted vegetation will be removed as a result of the project.

Existing Pomeroy Street pedestrian bridge

Assessment

The existing bowed, asymmetric cable-stay pedestrian/shared path bridge spans the M4 from Pomeroy Street in the north to Park Road to the south, about three by 75 metres long. The launch zones at each end of the bridge are characterised by mature tree and shrub plantings that book-end the bridge deck, visually framing and grounding it.

This bridge is to be retained with no proposed modifications. However the existing vegetation adjacent to each existing abutment will be removed as a result of the project.



Figure 6.47 View to the east under the existing M4 pedestrian bridge at Pomeroy Street.

Existing M4 viaduct between Powells Creek corridor and Queen Street





Figure 6.48 **Two views under the existing M4 viaduct at Railway Lane. Note the simple deck and pier structure, with no Super-T girders or headstock elements.**

Assessment

This long section of viaduct is a simple deck structure directly supported on rectangular, blade piers. The deck presents as a simple, horizontal structure and appears to be of minimal depth in elevation. This is further emphasised by its slenderness ratio, minimal parapet edge condition and double-rail steel crash barrier. The viaduct is well aligned with the Roads and Maritime guidelines for bridge design.

No modifications to this viaduct are proposed, however the project includes a westbound on-ramp from Parramatta Road at Powells Creek Reserve. This ramp is intended to run south to north along Powells Creek, curving to the west, grading up to connect with the M4 just west of the viaduct structure. This ramp structure is discussed in more detail in the following Powells Creek on-ramp section.

Table 6.25 Summary of proposal design principles table – bridges

Urban design intent for bridges	Assessment	Commitments
The design approach to bridge modifications is in accordance with the Roads and Maritime *Bridge Aesthetics – Design guidelines to improve the appearance of bridges in NSW* and the *SWTC Appendix B.4 – Bridges and Other Structures, Section 1.2 Modifications to Existing Structures*.	This preferred design principle is consistent with WUDF Principle 5.1 to 'deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements'.	The approach has been commenced in the design of bridges.
Structures should be simple, refined and elegant with minimal piers and abutments to maximise usability, permeability and visual transparency.	This preferred design principle is consistent with WUDF Principle 6.2 to provide 'a simple and elegant design…which clearly express materials, refined simplicity of form and function'.	Further design development during detailed design will seek to achieve this approach. In particular, the fully realised three-dimensional coordination of all bridge, substructure and abutment elements as a 'whole of corridor' design outcome.
The design, form, materials and arrangement of all elements must be simple, elegant, refined and carefully integrated with adjoining elements.	This preferred design principle is consistent with WUDF principles 5.1 and 6.2.	In the next design stage further design development will ensure the achievement of this approach.
Bridge widening should remain sensitive to the existing character of the structure and surrounds, designed to 'fit' with the existing structure.	This preferred design principle is consistent with WUDF principles 5.1 and 6.2.	Further design development during detailed design will seek to achieve this approach. In particular to confirm how these details are coordinated with existing and proposed structures and existing and proposed footpath systems.
Pedestrian bridges need to be generous in scale, well lit, provide clear sightlines and feel safe with their design welcoming and have architectural merit, appropriate to the context and setting.	This preferred design principle is consistent with WUDF Principle 5.2 to 'ensure that all design solutions safeguard the safety and convenience of the road users and adjacent stakeholders.'	Further design development during detailed design will seek to achieve this approach. In particular, CPTED reviews will be integral to future design development stages.

Proposed M4 eastbound pedestrian/cycleway bridge

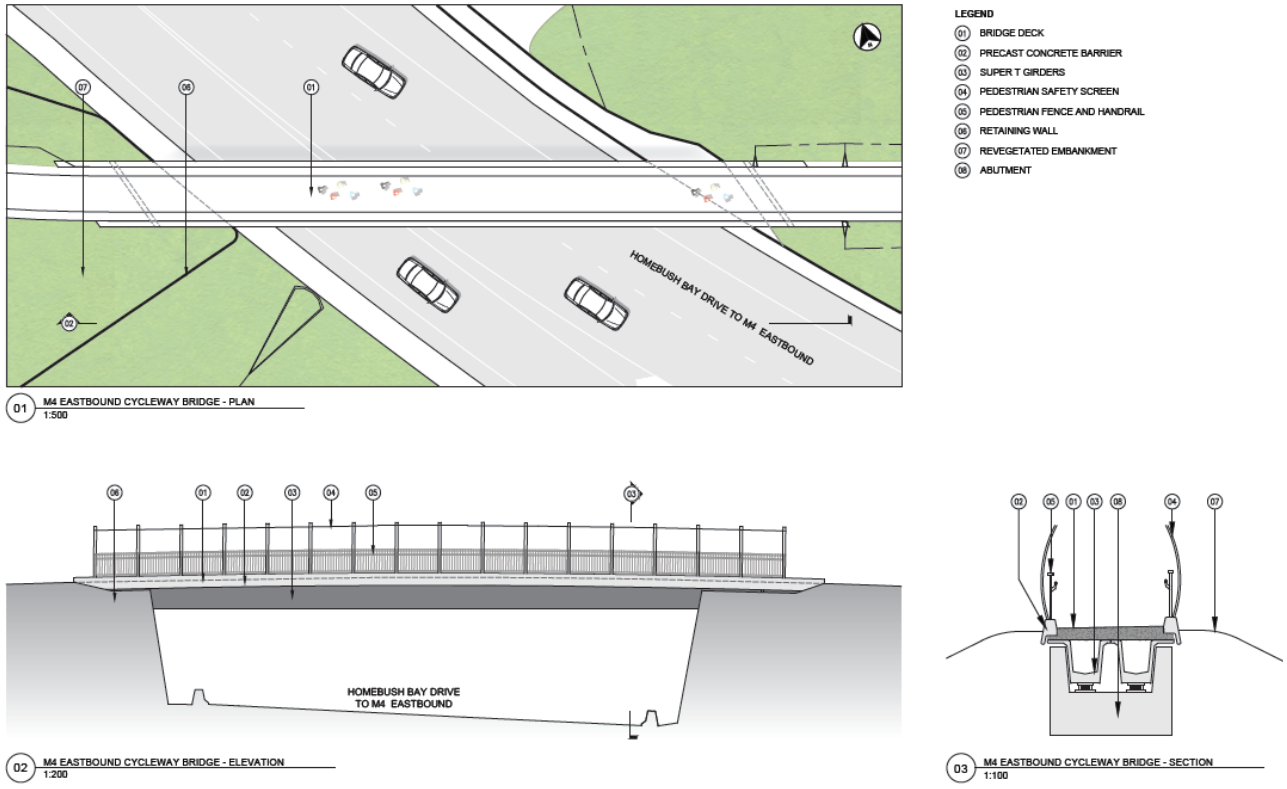


Figure 6.49 Indicative details of proposed M4 eastbound pedestrian/cycleway bridge. This image is conceptual and is included for illustration purposes only.

Assessment

Steel shuttering and precast factory-made elements should be utilised for highly visible bridge parts such as piers, girders and parapets to ensure a controlled, high quality finish.

Concrete surfaces close to traffic and accessible to the public should have a class 1 finish, elsewhere all concrete components should not be of less than a class 2 finish.

Bridge over Saleyards Creek

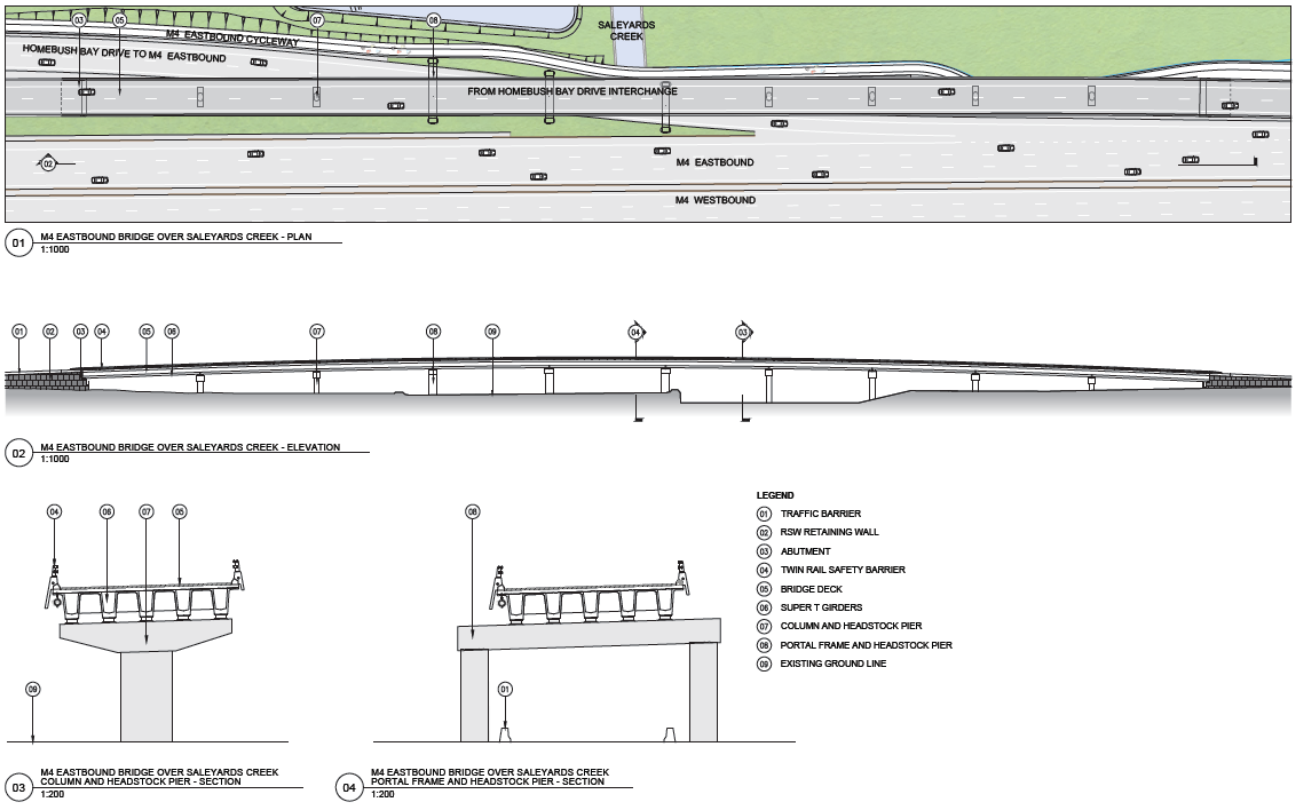


Figure 6.50 **Indicative plan of proposed M4 eastbound bridge over Saleyards Creek. This image is conceptual and is included for illustration purposes only.**

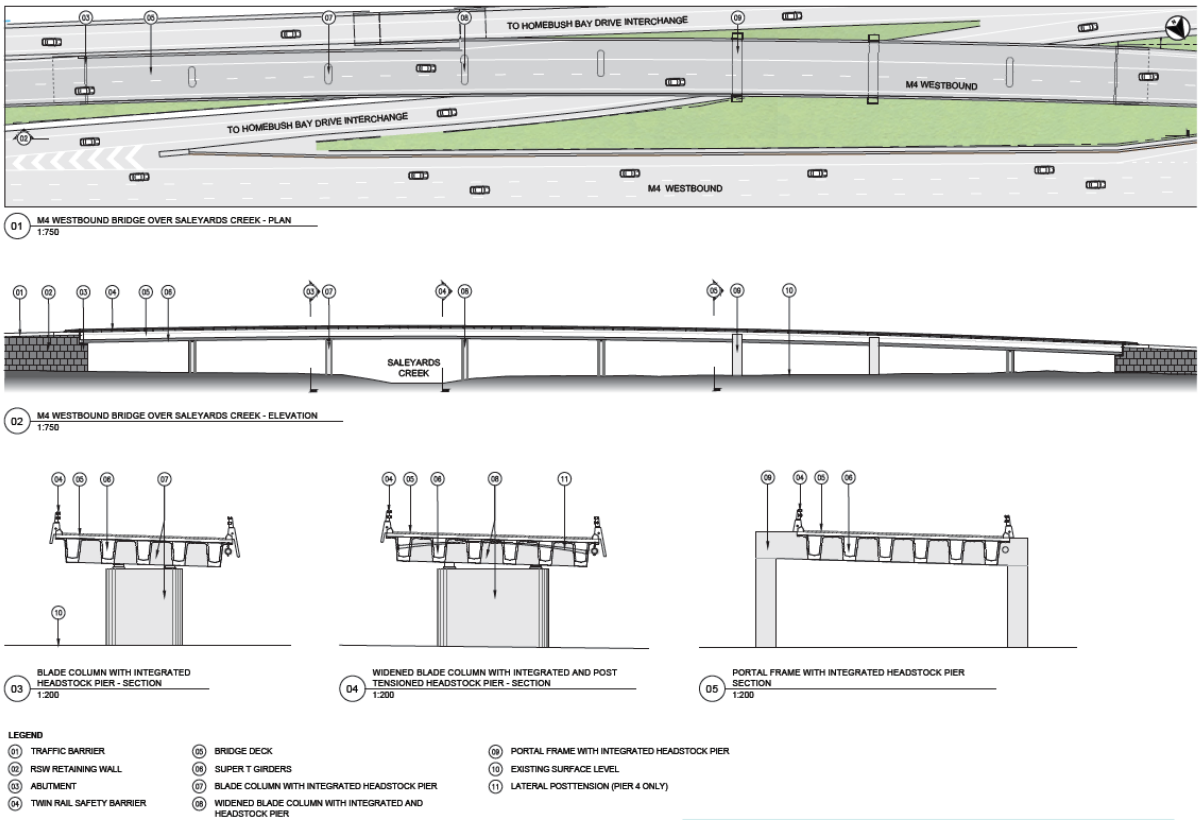


Figure 6.51 **Indicative concept drawing of M4 westbound bridge over Saleyards Creek. This image is conceptual and is included for illustration purposes only.**

Assessment

There are two low-level, low-visibility bridges proposed to be built over the existing Saleyards Creek culverts to the north and south of the existing culvert crossings. These structures should primarily be visible at the carriageway level of the motorway and only through crash barriers and associated guardrails, movement joints and the like. The concept general arrangement plans and sections would be developed further during detailed design.

Proposed on-ramp at Powells Creek

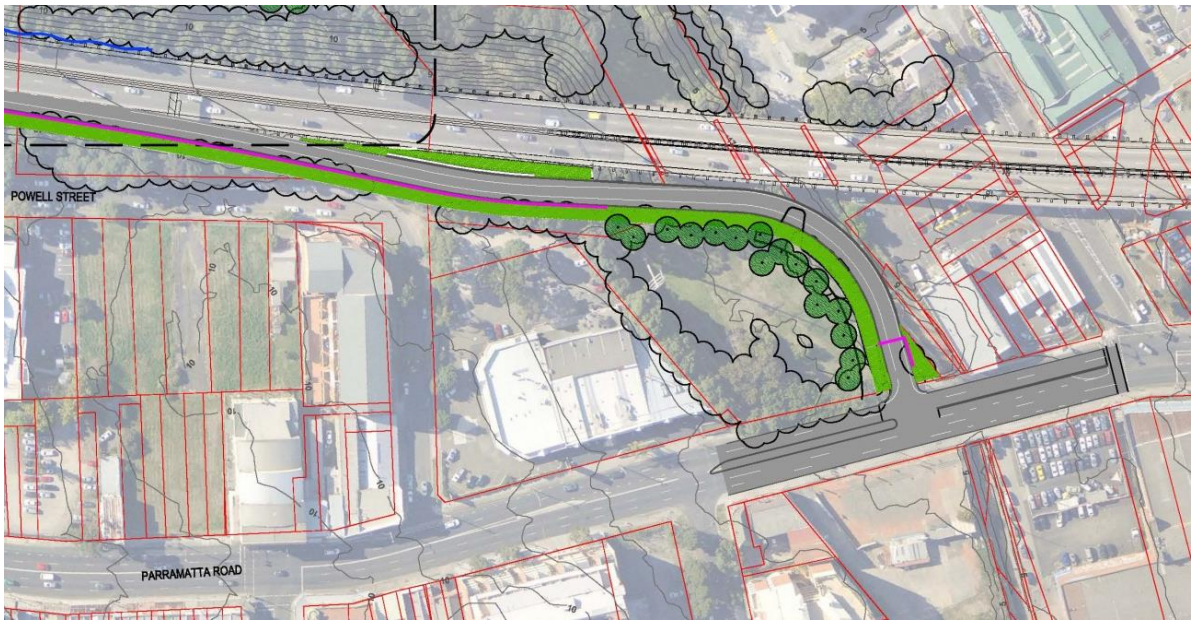


Figure 6.52 **Indicative plan of Powells Creek on-ramp. This image is conceptual and is included for illustration purposes only.**



Figure 6.53 Existing view north along Powels Creek, beneath existing M4 East viaduct; the proposed on-ramp would grade up directly in front of this structure towards the west (left of picture)

Assessment

This ramp is intended to run south to north along Powells Creek, turning to the west, grading up to connect with the M4 just west of the existing viaduct structure.

The on-ramp would comprise a single lane bridge and road section along the M4 embankment. The bridge section would be about 120 metres long (subject to detailed design). The bridge would sit below the level of the existing M4 deck and would comprise a new, contrasting diagonal form and potentially visually bulky element that would reduce the sense of openness and accessibility currently available under the M4 deck. The close proximity of the on-ramp to the existing viaduct means that the two structures will be read together as a composite. It is therefore essential that the proposed structure be evolved and considered as part of a total three-dimensional composition with the existing structure.

The project includes the provision of screen planting, shrubs and groundcover to the Parramatta Road edge of the bridge. This has the potential to remove access and the framed view to the main northern section of the park, and detailed design should consider the master plan area to the north (discussed in **section 6.4.2** Receiver Location 3).

Detailed designs of the proposed on-ramp structure are not yet available but will not be evolved in isolation. Critical considerations for design development include the materiality, depth of bridge deck and parapet, superstructure, pier spacing and type, and attendant structures such as retaining walls, abutments, noise walls and lighting. All of these considerations will be developed with reference to the context, character and form of the existing viaduct. In addition, the on-ramp structure design will consider the intent and detail of the Powells Creek park master plan.

Proposed westbound cycleway on-ramp from Queen Street

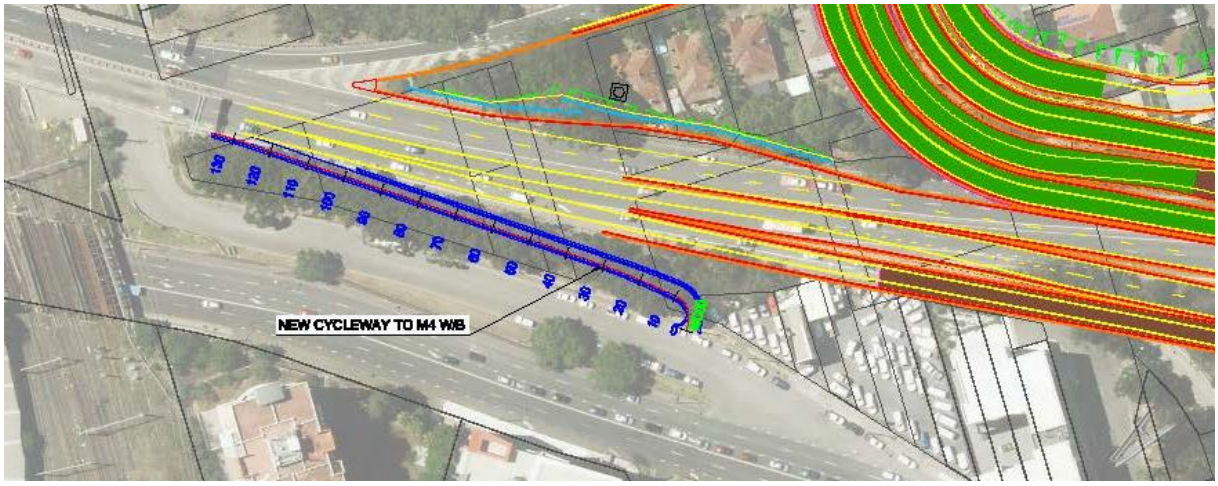


Figure 6.54 **Proposed cycleway on-ramp from Queens Street to the M4 westbound. This image is conceptual and is included for illustration purposes only.**

Assessment

The proposed Queen Street cycleway on-ramp would be approximately 130 metres long and constructed on the existing fill embankment on the south side of the M4. It is likely to require earthworks which may result in the loss of the existing trees on the embankment.

The details of this proposal are not yet defined, but should be evolved in the detailed design phase with the intent to minimise the potential loss of existing trees and maximise opportunities for the revegetation of the embankment. The evolving design should also address the requirements of the *RMS NSW Bicycle Guidelines* (July 2005), adequate provision of lighting and the installation of appropriate guardrails along the southern side of the cycleway.

Proposed modification of Concord Road bridge

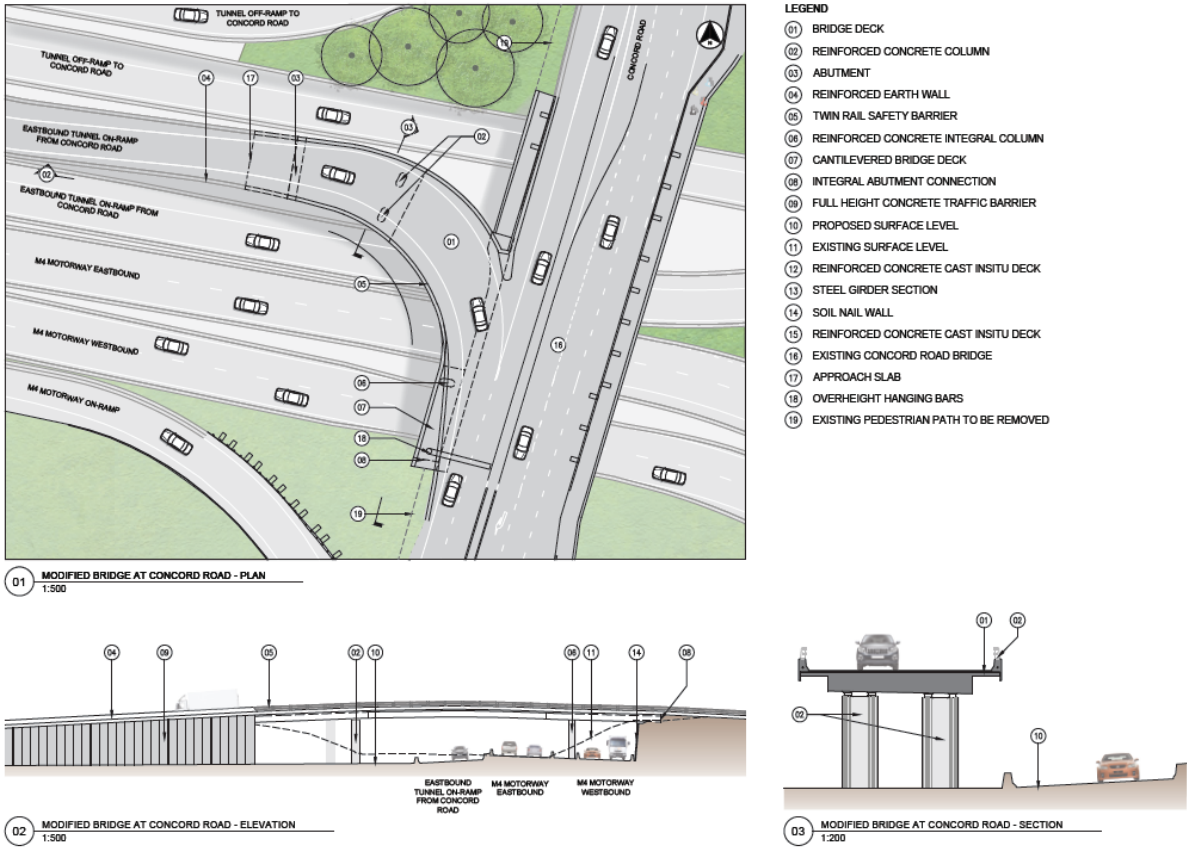


Figure 6.55 Indicative detail of proposed modification to the existing Concord Road bridge over the M4. This image is conceptual and is included for illustration purposes only.

Assessment

- The existing bridge over the M4 at Concord Road is intended to be widened to accommodate the eastbound on-ramp from Concord Road northbound towards the tunnel entrance. The existing Concord Road bridge over the M4 appears to have been designed to present a minimal depth of deck in elevation, in keeping with the Roads and Maritime guidelines for bridge design
- The bridge is proposed to be modified by the addition of an eastbound on-ramp attached to its western side. The modification includes a cantilevered bridge deck as an extension of the existing deck. This then connects with a series of steel box girders that support the proposed deck that grade down to meet the proposed abutment. The abutment is proposed as a reinforced earth wall structure
- The proposed on-ramp would require the removal of the existing pedestrian path on the western side of the bridge
- The detail design phase should consider the composition of the modified bridge in particular to address the elevation treatments in order to optimise its slenderness ratio, as recommended in the RMS guidelines for bridge design.

Modification to the existing pedestrian bridge over Parramatta Road at Bland Street

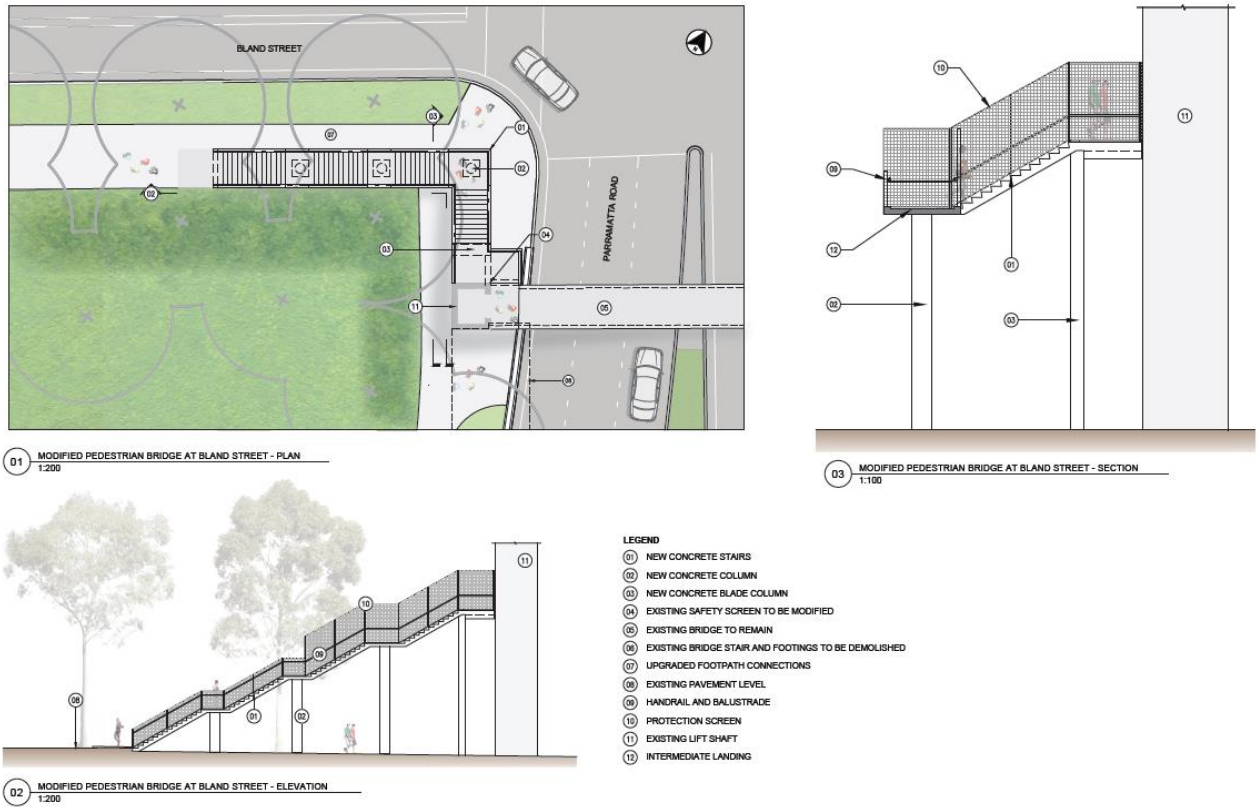


Figure 6.56 Indicative detail of proposed modification to the existing pedestrian bridge over Parramatta Road at Bland Street. This image is conceptual and is included for illustration purposes only.

Assessment

- The existing pedestrian bridge over Parramatta Road at Bland Street is proposed to be modified by replacing the western stairs with a new stair that connects with Bland Street
- The new stairs are proposed to be a reinforced concrete construction with detailing to match the existing stairs on the eastern side of the bridge, with the footpath re-aligned around the existing lift shaft to maintain pedestrian access. The new ground level landing would join the footpath at Bland Street with the stair columns located outside of any clear zones
- The proposed modifications are minimal – with the exception of the modified western stair set there would be little impact on the structure.

Landscape finishes

Assessment

The design of landscape finishes is intended to respond to the adjacent landscape, existing built and roadside environment. The proposal refers to finishes in the descriptions of the urban design elements (discussed in previous sections), such as dive structures, noise walls etc. In addition it also includes specific reference to slope stabilisation, medians and verges, and strategies for the use of shotcrete.



Figure 6.57 View to the east along the existing M4 showing the well vegetated, stabilised slopes along the north and south alignments.

Existing engineered earthworks

The western portion of the existing motorway is generally in cut compared with adjacent levels to the north and south. This section is characterised by generous, well vegetated batters on average gradients of 1H:3V. As the adjacent land becomes more elevated, especially on the southern boundary of the corridor, space is limited and these embankments are replaced by retained wall systems.

As the motorway approaches the Underwood Road overbridge, it becomes elevated on embankments along both northern and southern boundaries. These embankments vary between 1H:2V and 1H:3V gradients, and are well vegetated with trees and understorey planting (well-evidenced at Powell Street for example on the southern boundary).

To the east of Underwood Road the existing motorway continues as an elevated road and long viaduct (about 350 metres). At the Sydney Street off-ramp the motorway remains slightly higher relative to adjacent grades until it passes under the Concord Road bridge, then grading upwards to the south to intersect with Parramatta Road. In this eastern zone the difference in levels is generally via vegetated embankments of between 1H:2V and 1H:3V gradients.

WestConnex urban design guidelines: Landscape, landform and water sensitive design (WSUD)

- The WUDF requires the following design approach to landscape elements:
- Reflect and respond to diverse community values and encourage positive interaction
- Respond to specific local landscape topography and hydrology
- Reinstate local vegetation communities along riparian zones and green corridors
- Support and engage communities, connecting nearby facilities, incorporating shops, art and recreation spaces
- Recognise and enhance local identity
- Utilise green corridor opportunities for habitat creation and acoustic buffer zones
- Respond to history, memory and understanding of and continuity with the past
- Implement best-practice Water Sensitive Urban Design (WSUD) measures to increase the environmental performance of the WestConnex project
- Plants should be substantial in size and planted in dense arrangements.

Proposed finishes for slope stabilisation

Generally, all soft landscape areas across the project are proposed to be stabilised by containerised massed planting in prepared planting areas, or turf over a prepared turf underlay.

At the western end of the project, new earthworks are proposed to be integrated with existing cut and fill embankment formations in order to merge with existing landform profiles.

Typically, embankment slopes are proposed to vary from 4H:1V to 2H:1V. All tops and toes of embankments are to be rounded and feathered to blend into adjoining landforms. The WUDF recommends no landscape gradients greater than 3H:1V.

All cut and fill embankments are proposed to be revegetated using containerised plant stock in prepared planting areas comprising 200 millimetres of topsoil with a 100 millimetre layer of select mulch. The majority of new plantings are to be of frangible native grass and shrub species, supplemented with select tree species beyond clear zone safety setbacks.

Medians and verge areas

Unless otherwise paved, medians and verge areas are proposed be topsoiled and revegetated with grasses and shrubs within the limitations of clear zone safety requirements. The preferred design proposes 300 millimetre topsoil is to be applied to landscape areas.

Strategies and methodologies for shotcrete

Shotcrete is not proposed to be used in any visible part of the surface works throughout the project. It would, however, be used within the tunnel as part of the tunnel profile and also in combination with piled concrete retaining walls within the cut-and-cover sections of the tunnel portals.

Typically these areas are unlikely to be noticeable to drivers as they are concealed by the tunnel lining panels and painted black.

Planting

Design approach

The project incorporates the following objectives for road environments:

Safe

All required clear zone and safe sight distance setbacks to avoid the creation of hidden public places while maximising passive surveillance opportunities.

Integration with local setting

The design ‘maintains and enhances existing landscape character and vegetation patterns’.

Ecologically sound

The design proposes to use local species from existing and adjoining plant communities and assists in protecting and recovering local biodiversity.

Add character and value

The design intends to draw upon the existing landscape patterns of the area.

Low maintenance and cost effective

The design intends to utilise existing site soils and local and robust plant species in a bold and simple way.

Revegetation across the project footprint is intended to be achieved through direct planting of containerised plant stock into prepared planting areas in order to facilitate rapid establishment of new landscape installations.

Assessment

The design approach is consistent with the objectives of the WUDF and Roads and Maritime design guidelines. The application of a planting palette derived from Cumberland Plan Woodland species would be appropriate for those areas of natural plantings where it may be possible to re-establish endemic plant communities, but may not be appropriate in all areas, for example existing residential areas characterised by 'cultural plantings' in and around residential neighbourhoods. The suitability of the species mix would be further considered as part of detailed design.

Soil preparation

Design approach

The soil preparation treatments for the project would rely on investigation of existing site soils. The approach to planting on structures (e.g. above cut and cover sections) will require particular attention in the detailed design phase in terms of appropriate depth, drainage and composition, and may require the manufacture of mineral soils. The advice of a soil scientist and arborist should be sought for this purpose.

The project proposes a planting zone of 900 millimetres between the proposed drainage and mulch layers for massed planting areas on structure, subject to detailed design.

Assessment

- This approach would result in a planting zone of 900 millimetres between the proposed drainage and mulch layers, subject to detailed design. This may be adequate for native grasses and low shrubs, however it may not be appropriate for the establishment and long term support of tree species which may require an approach based on manufactured mineral soils rather than organic soil types.

6.3.3 Parramatta Road Urban Transformation Program

The Parramatta Road Urban Transformation Program proposes focused urban renewal at existing urban precincts or nodes. The objectives of the Program include:

- The creation of new connections between communities along Parramatta Road
- Improve public transport connections
- Enhance the existing road network
- Creation of a healthier and more visually attractive urban environment

These aspects are considered below in the assessment of the project, including at key intersection precincts such as Concord Road interchange and Wattle Street interchange, together with their attendant residual lands.

Assessment

An important component of this program is connectivity across the Parramatta Road corridor and the desire to improve movement between suburbs, seen to be divided by Parramatta Road, and thereby contribute to increased activation of the corridor.

The Homebush Precinct of the program crosses the project footprint between Parramatta Road and the residential area of Homebush north of the M4. The southern portion of the proposed Homebush Bay precinct would interface with the project, between Homebush Bay Drive interchange and Concord Road interchange.

Aspects of the project which may influence the outcomes of the objectives of the renewal program, for example, include:

- Opportunities to utilise surplus or residual land may contribute to revitalisation and in particular the activation of the precincts in which they are located

- Opportunities to create, promote and enhance connectivity across Parramatta Road, where impacts to connectivity are associated with the project, may also contribute to precinct activation and improved connectivity across Parramatta Road, and thus contribute to the revitalisation program
- The Wattle Street interchange would have a direct interface with Parramatta Road, and although this does not have a direct link to any of the PRC nodes, it does include residual lands with the potential to contribute to Parramatta Road corridor activation
- Within the precincts, the preferred design connects with existing footpaths and shared paths, and/or replaces those disrupted by the project. Connectivity across the Parramatta Road corridor, residual land redevelopment typology, pedestrian and cycle activation and public transport connectivity, would be developed further during detailed design and specifically addressed in the context of the Program
- Enhancements to the existing road network through the traffic and transport objectives of the project, including the provision of a corridor for potential future development of mass transit light rail within the project footprint and Parramatta Road corridor
- Improvements to pedestrian and shared path amenity will be considered. For example, in the context of the health and attractiveness of the local environment, it would be appropriate to optimise amenity along connecting pathway systems by considering introducing shade trees of appropriate scale and by separating users from busy traffic lanes where possible behind a landscape amenity strip.

6.4 Visibility of project

6.4.1 Visual envelope mapping

The visibility of the project is illustrated in visual envelope mapping (VEM) and outlined in this section. Refer to **Figure 6.58** to **Figure 6.62**.

Homebush Bay Drive section of project

As can be seen from the VEM:

- Homebush commercial, Parramatta Road (west) and Underwood Road LCZs: The existing M4 corridor buffer planting, and in some cases noise walls, will continue to provide screening to much of the western and eastern ends of the motorway, including screening to residential development at the western end and midway along Park Road. However, the retained vegetation adjacent to the light industrial development within the Parramatta Road (west) LCZ is likely to be insufficient to effectively screen this area. Additionally, much of the existing screening vegetation to part of the Homebush commercial LCZ, and virtually all of the vegetative screening to the Underwood Road LCZ is lost to the project, exposing some adjacent residential development to direct or filtered views of the project.



Figure 6.58 Visual envelope map of the Homebush Bay Drive section of the project.

Underwood Road section of project

As can be seen from the VEM in this section of the project:

- Parramatta Road (west), Underwood Road and Powells Creek LCZs: Virtually all of the Underwood Road LCZ vegetation along the M4 is lost to the project, exposing adjacent residential development and Bill Boyce Reserve to direct or filtered views of the project. The ventilation outlet at Underwood Road would likely be visible for a significant distance. The loss of vegetation along the M4 adjacent to Allen Street and the addition of the proposed buildings would be visible within the Powells Creek Reserve.



Figure 6.59 Visual envelope map of the Underwood Road section of the project.

Concord Road section of project

As can be seen from the Concord Road section VEM:

- Concord Road and Edward Street LCZs: The extent of views to the project within these LCZs is generally limited to adjacent residential development along the boundary of the project and views along adjoining residential streets, in addition to views from the M4 and the eastern end of the Parramatta Road (west) LCZ.



Figure 6.60 Visual envelope map of the Concord Road section of the project.

Wattle Street section of project

As can be seen from the Wattle Street VEM:

- Dobroyd Parade, Wattle Street and Haberfield LCZs: Views to the project would be mostly from residences directly adjacent to the project boundary and views along adjoining residential streets. The height of the eastern ventilation facility on Parramatta road would see the project visible above residential properties. Users of Reg Coady Reserve would have views towards the new road infrastructure
- Parramatta Road (east) LCZ: Views to the project would mostly be from adjacent residential development including medium density residential development, the northern corner of Ashfield Park and by motorists on Parramatta Road.



Figure 6.61 Visual envelope map of the Wattle Street section of the project.



Figure 6.62 Visual envelope map of the easternmost section of the project.

6.4.2 Key viewpoints

Receiver location 1 – M4 east of Homebush Bay Drive

Existing situation

This receiver location is situated about 300 metres east of Homebush Bay Drive (refer to **Figure 6.63**). This view comprises a relatively narrow and strongly visually enclosed corridor (refer to **Figure 6.64**). Screening to this area is provided by steep batters along much of the southern edge (right of frame) with dense plantings, comprising a full suite of canopy and mid-stratum trees with shrub and grassy understorey. The northern edge is distinguished by a formal, sinuous landscape setting that was undertaken for the Sydney Olympics but has since fallen into a state of disrepair.

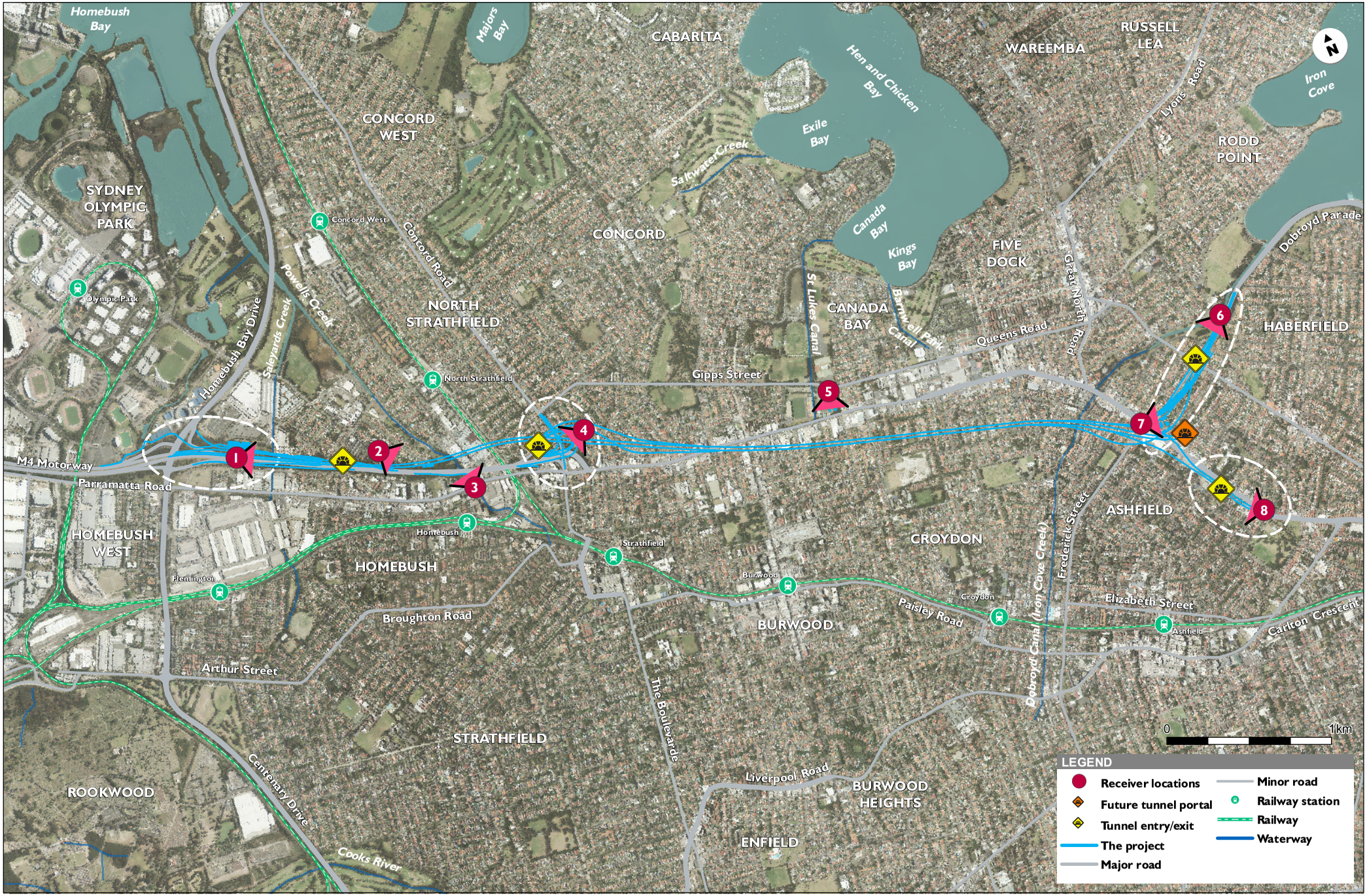


Figure 6.63 Operational receiver locations

Project effects

The view from this location would encompass six M4 eastbound and westbound lanes, two lanes either side of these comprising entry and exit points from flyovers and associated retaining walls/bridge abutments, and a further two lanes either side of these comprising on- and off-ramps to/from Homebush Bay Drive which would have inward-facing retaining walls at the corridor edge of about seven metres in height. The width of the road carriageway corridor would increase from about 25–95 metres wide, subject to detailed design, and comprise predominantly that of a hard landscape, which would be subject to a well-considered urban design and architectural design process that seeks to provide a well presented and refined hard landscape outcome. Refer to **Figure 6.65** and **Figure 6.66**.

Noise walls are proposed east of this location, ranging between about three metres to six metres high along the northern M4 boundary.

The extent of landscape screening along the M4 would be reduced, with no opportunity to provide tree planting between the carriageway and the motorway control centre, workshop and bulk equipment store to the north. A landscape strip of about five metres wide, subject to detailed design, will be planted to the tall trees between the westbound lanes exiting the M4 tunnel and the flyover from the project's surface works (refer to **Figure 6.66**). A narrow, discontinuous band of tall tree planting would be visible atop the retaining wall along the southern edge of the corridor, from an adjoining council roadway. The character of the corridor will change from that of a relatively narrow, densely vegetated corridor to that of a wide, predominantly hard landscape including flyovers and limited planting within and adjoining the corridor.

Lighting

The project would result in additional lighting sources being introduced to this area, associated with tunnel portals, on- and off-ramps, and new eastbound and westbound elevated surface flyovers. Additionally, the toll gantries would require specific illumination. The motorway control centre and maintenance facility would have safety and security lighting, including around the car park and access paths to buildings. Lighting would include cut-off fittings and would be directed to reduce light trespass.

The extent of glare emanating from the new lighting towards adjacent residential development is likely to be moderate given the inability to provide vegetative screening to areas within the project boundary, i.e. residential development on: Park Road; at the end of Verley Drive and Wentworth Road South either side Verley Drive where the westbound flyover would run alongside this development units at 65-71 and 73 Underwood Road; Short Street East. However, despite removal of vegetation, existing and new noise walls will have a similar, if not greater impact in most areas. This assessment also makes allowance for the design of the lighting which would include cut-off fittings and would be directed to reduce light trespass.

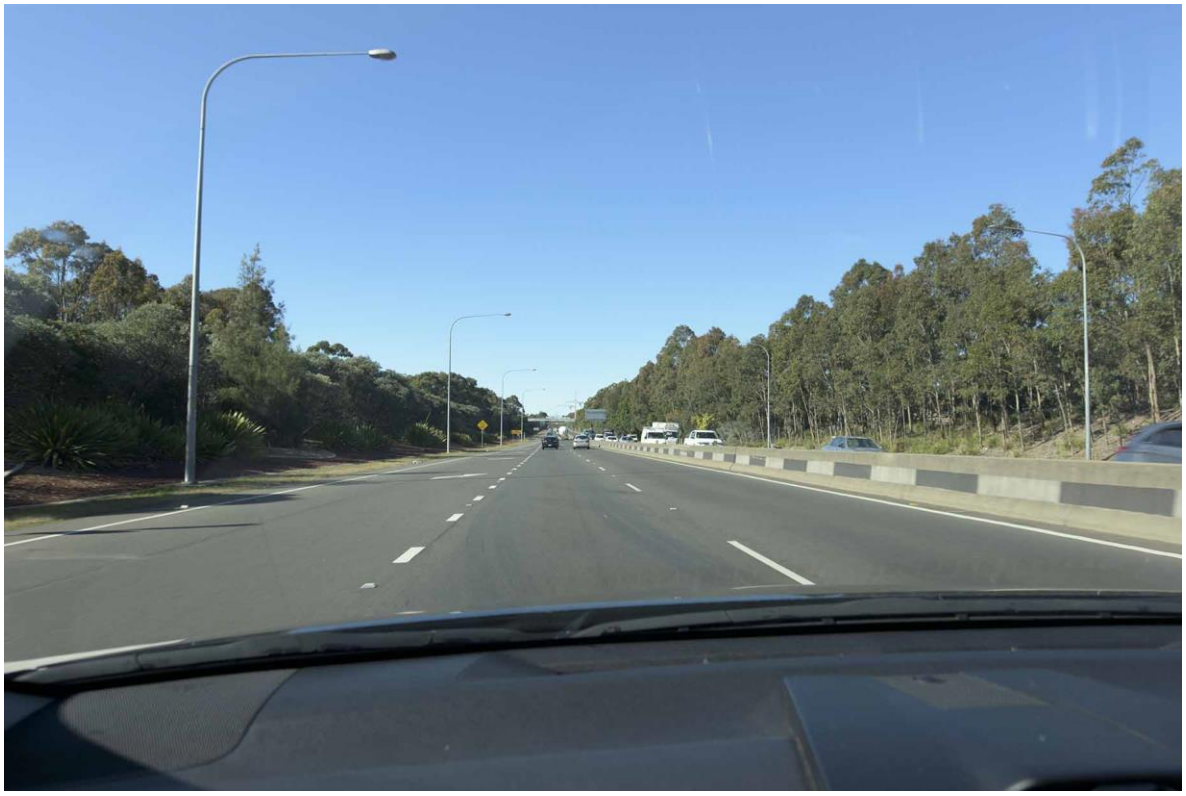


Figure 6.64 Current view from the M4 east of Homebush Bay Drive looking east.



Figure 6.65 Artist's impression at 12–18 months of operation from the M4 east of Homebush Bay Drive looking east.



Figure 6.66 **Artist's impression at 10 years of operation from M4 east of Homebush Bay Drive looking east.**

Visual impact assessment

Table 6.26 Receiver location 1 visual impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Motorists	The sensitivity of motorists to change is considered to be low, within the context that: Most users of this major transport route will be engaged in commuting associated with their work, or other travel where the travel experience is associated with that of a necessary functional means of quickly getting to their destination Notwithstanding the change in the character of the motorway from that of a visually homogeneous, well vegetated corridor to that of a predominantly hard landscape, this will be subject to a well-considered architectural and urban design process during the design development phase The duration of the view will be relatively fleeting, with the receiver either having been passing through a well vegetated corridor for much of their journey when travelling from the west, with this section of hard landscape comprising a relatively fleeting transition zone to that of the M4 tunnel. The magnitude of change is considered to be moderate within the context that the project is broadly an upgrading of an existing motorway, but that the form of that motorway will change from a relatively narrow (four lanes plus entry and exist lanes), simple one that is predominantly tightly visually enclosed by cut batters and dense vegetation, to one that is up to 14 lanes wide with bridging structures and other changes in level, tunnel portals and limited soft landscape integration.	This provides an overall visual impact assessment rating of moderate–low.

Table 6.27 Receiver location 1 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents	The sensitivity of residential receivers is considered to be high given the relatively large number of affected receivers and the proximity of the roadway. The magnitude of change is considered to be low, as residents will be shielded by new noise walls.	This provides an overall lighting impact assessment rating of moderate. This could be reduced through the application of mitigation measures such as planting to edges beyond the M4 boundary, and with at-receiver planting, as discussed in **sections 7.1.1** and **7.1.3**.
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be moderate within the context of a motorway setting.	This provides an overall visual impact assessment rating of moderate–low.

Receiver location 2 – Underwood Road looking south towards M4

Existing situation

The view from this location is situated about 40 metres south of the intersection with Short Street East and is representative of views from the Underwood Road streetscape looking south towards the M4 (refer to **Figure 6.63** and **Figure 6.67**). This includes:

- Nearby residents from the front rooms of their homes, and when entering and leaving their homes
- The congregation of the Our Lady of the Assumption Catholic Church
- Local residents walking along Underwood Road
- Motorists driving along the road.
- A small glimpse of the M4 bridge over Underwood Road is visible to centre of frame. Even though the M4 runs across the centre of frame, it is currently substantially screened by a dense tree planting along the motorway's edge that predominantly causes it to be either not seen or visually recessive.

The view includes:

- Our Lady of the Assumption Catholic Church (located just beyond left of frame in **Figure 6.67**)
- A well-vegetated streetscape comprising a mix of exotic street tree predominantly comprising plane trees (Platanus spp.) along the left-hand side of the road, and heavily lopped Chinese Tallowwood trees (Sapium sebiferum) under power lines to the right hand side of the road. The tall eucalypts in the background are part of the M4 landscape buffer planting
- Single-storey residential development to the right hand side of the road, including a heritage-listed weatherboard house (right of frame).

This part of the street comprises predominantly single-storey free-standing residences from the Federation era, and exhibits a relatively quiet, suburban, well-vegetated street character.

Project effects

The key project effect that would be visible from this receiver location would be a significant change in visual character to the centre-right of frame including (refer **Figure 6.68** and **Figure 6.69**):

- The removal of the housing and all vegetation to the southern corner of Short Street West
- The construction of:
  - A ventilation facility about 30 metres high, and 15 metres by 20 metres wide, subject to detailed design, with a cladding of weather steel perforated panels with discrete vertical panels of darker steel fins, and terracotta extruded tiles
  - A distribution substation about 5.5 metres high, and 40 metres by 15 metres wide, subject to detailed design, clad with light grey extruded terracotta tiles and smooth-faced charcoal concrete block, with access doors painted a light grey to match
- A triangular open park space with turf and informal tree plantings of eucalypts located on the southern corner of Short Street Westin front of the ventilation facility and substation. A view to the existing M4 transparent noise wall behind the substation with moving vehicles visible through this
- A mass-planted batter to the eastern (left side) of the road linking with the existing M4 bridge abutment.

The current relatively quiet, leafy suburban character of the view will be subject to the introduction of visually uncharacteristic infrastructure development and a substantial view of the M4, in conjunction with a tall eucalypt and turf landscape setting.

Lighting

The distribution substation and ventilation facility would have safety and security lighting, but this would be at a relatively low level. Lighting would include cut-off fittings and would be directed to reduce light trespass.

Lights from vehicles using the M4 would be visible from the street through the proposed transparent noise wall, however the visibility of this effect would reduce as proposed landscaping matured.

The closest housing to the M4 on the eastern side of Underwood Road is about 50 metres, while 65-71 and 73 Underwood Road rear units are about 10-20 metres from the elevated carriageway. The units at the end of Short Street East are about 20 metres and the Catholic Church is about 70 metres from the M4.



Figure 6.67 **Existing view from Underwood Road looking south towards M4.**



Figure 6.68 **Artist's impression at 12–18 months of operation from Underwood Road looking south towards M4**



Figure 6.69 **Artist's impression at 10 years of operation from Underwood Road looking south towards M4**

Visual impact assessment

Table 6.28 **Receiver location 2 impact assessment**

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents/church congregation	The sensitivity of nearby residents and the congregation of the local place of worship is considered to be high, given their sense of proprietary interest in the view from their homes and place of worship, and within the context of their knowledge of the function of the ventilation building. The magnitude of change is considered to be high, particularly with regard to the introduction of a large, visually prominent infrastructure environment, including a substantial view of the M4, notwithstanding the architecturally well-considered design of the ventilation building in particular.	This provides an overall visual impact assessment rating of high. This impact could be reduced through exploring opportunities to provide avenue planting to reduce the visual prominence of the ventilation facility from these receivers (**section 7.1**).

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Pedestrians	The sensitivity of pedestrians is considered to be moderate within the context that these receivers can be expected to be nearby residents either strolling recreationally/walking the dog, etc in the mornings, evenings, on weekends, or local residents on their way to or from work (eg walking to Parramatta Road to catch a bus). These receivers can generally be expected to be walking at a slow or moderate pace with an interest in their surroundings, although the view experienced would just be a small part of a longer walk. The magnitude of change is considered to be high, particularly with regard to the introduction of a large, visually prominent infrastructure environment, including a substantial view of the M4.	This provides an overall visual impact assessment rating of high–moderate.
Motorists	The sensitivity of motorists travelling south on Underwood Road is considered to be low given: That this viewpoint is likely to comprise only a small proportion of a larger vehicle journey, which includes other nearby highly urbanised and infrastructure landscape settings The context of the well-considered architectural outcome which provides a landmark/point visual interest along the journey Reinstatement of a substantial tall tree landscape within the middle ground. The magnitude of change is considered to be moderate, particularly with regard to the introduction of a substantial, visually prominent infrastructure environment, including a substantial view of the M4, but taking into account the relatively short duration within which this view will be available, and the fact that the view is likely to comprise a small part of a longer journey.	This provides an overall visual impact assessment rating of moderate–low.

Table 6.29 Receiver location 2 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents/ church congregation	The sensitivity of residents/church congregation to additional lighting is considered to be moderate given the relatively small number of receivers and their proximity to the project, and the sense of proprietary interest that these receivers could be expected to take in their local environment. The magnitude of change is considered to be moderate given that existing M4 lighting is not likely to be highly visible from these receivers, but can be expected to be highly visible from some receivers as a result of the project.	This provides an overall lighting impact assessment rating of moderate. This could be reduced through the application of mitigation measures such as the provision of street tree planting and at-receiver planting, as discussed in **section 7.1.4**.
Pedestrians	The sensitivity of pedestrians to additional lighting is considered to be low. The magnitude of change is considered to be low	This provides an overall visual impact assessment rating of low.
Motorists	The sensitivity of motorists to additional lighting is considered to be low The magnitude of change is considered to be low within the context of the short duration of view	This provides an overall visual impact assessment rating of low.

Receiver location 3 – Parramatta Road looking north to Powells Creek corridor

Existing situation

This view from this location is situated on Parramatta Road looking north towards the Powells Creek corridor (refer to **Figure 6.63** and **Figure 6.70**). This area is proposed to become the southern entry to a park that would stretch from Parramatta Road, north under the existing M4 viaduct to Pomeroy Street, a distance of some 800 metres (Strathfield Council 2008). A master plan has been prepared for the park by Strathfield Council, with two precincts within the master plan already implemented comprising Allen Street Reserve north of Allen Street (refer **Figure 4.22**), and the new Arnotts Reserve to the south of Allen Street (refer **Figure 4.21**). The master plan includes the provision of a pedestrian bridge with access from midway between Parramatta Road and Allen Street direct to the cafe/restaurant/hotel centre of the development on George Street, within the Bakehouse Quarter. Signage at this location states ‘proposed park coming soon’ (refer to **Figure 4.21**). The master plan provides for both informal and active (eg basketball courts) recreation within this area.

The site currently comprises an open rough-grassed area flanked to the east by Powells Creek, and to the west and south by a line of large trees including Moreton Bay fig trees (*Ficus macrophylla*) and brush box (*Lophestemon confertus*). The existing M4 travels over the Powells Creek corridor. The viaduct has a vertical separation between the underside of the deck and ground of about 8–10 metres, with a span between piers of about 35–40 metres. This provides a visually generous opening for future park users to the main northern part of the park, and visual frame to the well-vegetated corridor beyond.

Development immediately adjacent to the area east of Powells Creek comprises a warehouse/commercial building that currently operates as a cafe/food outlet. The site adjoining the area to the west had at the time of inspection been cleared, and was in the early stages of earthworks for development.

Where the proposed Powells Creek on-ramp to the M4 runs up along the existing motorway embankment, it is viewed from a multi-storey apartment block at the eastern end of Powell Street, facing east. The lower floors of this development is currently moderately well screened from the M4 by existing trees on the M4 embankment, however residents in higher units currently look over the screen planting to see the M4. In addition, a large advertising billboard behind the screen planting is brightly lit at night and would currently be visible to residents.

Project effects

The effects of the project would be as follows (refer to **Figure 6.71** and **Figure 6.72**):

- The construction of an on-ramp from Parramatta Road would comprise a combination of a single lane bridge and road along the existing M4 embankment. As previously described, the bridge would be about 120 metres long subject to detailed design, and intersect with Parramatta Road, rise over the Powells Creek stormwater channel and climb to an alignment broadly parallel with the M4, where it would land on the existing M4 embankment.
- The provision of a gross pollutant trap (GPT) and spill containment tank, both of which are likely to be buried.

Key elements and issues associated with the works would be as follows:

- The ramp would sit below the level of the existing viaduct and comprise a new, relatively low, visually contrasting diagonal form and potentially visually bulky element that would reduce the generous sense of openness and accessibility currently available under the M4 deck
- The proposed final landscape response for the park includes the provision of a mass planting of screening trees, shrubs and groundcover to the Parramatta Road edge of the bridge, which would remove both access and the framed view to the main northern section of the park. This approach would create a separate park from the rest of the proposed master plan area, the character of which would be fundamentally influenced by the busy Parramatta Road environment, without the visual and accessible relief of quieter areas north of the M4
- The proposed on-ramp bridge and associated new intersection with queueing traffic on Parramatta Road would create new and visually incongruous elements for the proposed park, causing it to look in on itself, as well as being looked into by motorists using the on-ramp.
- Where the on-ramp climbs along the M4 embankment, it is likely that there will be a gap in screening of the M4 of around 30-40 metres opposite the apartment block on the eastern end of Powell Street.

Lighting

Additional light would be introduced to this area during operation associated with the on-ramp and the new signalised intersection on Parramatta Road. Lighting would include cut-off fittings and would be directed to reduce light trespass.

The extent of glare emanating from the new lighting towards the proposed new park and park users to is likely to be beneficial, although this would be expected to reduce as landscaping matured. The extent of glare emanating from new lighting on the ramp where it runs from near the western edge of the Powells Creek corridor to the M4, and existing lighting from the M4, for residents within units on the eastern end of Powell Street is likely to be high. This is due to both new lighting on the ramp, and

the loss of existing tall screening alongside the M4, and the inability to reinstate screening vegetation within the project boundary between the western edge of the Powells Creek corridor and the eastern end of Powell Street, ie much of the lighting for the on-ramp, and existing M4 will be visible from these higher units (where it currently not likely to be visually prominent). This assessment makes allowance for the design of the lighting which would include cut-off fittings and would be directed to reduce light trespass.



Figure 6.70 Existing view from Parramatta Road looking north to the Powells Creek corridor.



Figure 6.71 Artist's impression at 12–18 months of operation from Parramatta Road looking north to the Powells Creek corridor.



Figure 6.72 Artist's impression at 10 years of operation from Parramatta Road looking north to the Powells Creek corridor.

Visual impact assessment

Table 6.30 Receiver location 3 visual impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Future park users	Given that a master plan has been publically exhibited, the visual impact of the project on future park users is assessed. The sensitivity of future park users is considered to be high, given that this would be a place of both informal/passive and active recreation within the otherwise busy environment of Parramatta Road, and strongly connected both visually and physically to the main northern, quiet part of the park, and also to the centre of the Bakehouse Quarter cafe strip. The magnitude of change is considered to be moderate, particularly with regard to the introduction of a large, infrastructure element, but also regarding the proposed landscape treatment (ie the visual and physical disconnect of this area of the park from the main northern end of the park).	This provides an overall visual impact assessment rating of high-moderate. This impact could be reduced through the application of mitigation measures such as maximising the vertical separation between the underside of the ramp and the ground, and developing the design in conjunction with Council's park master planning landscape architects, as discussed in Section 7.1.5.
Motorists	Notwithstanding that this receiver location comprises only a potentially fleeting component of a larger vehicle journey, the sensitivity of motorists travelling on Parramatta Road is considered to be moderate given the rarity of seeing a well-planned, corridor park/green space along this section of Parramatta Road, including the framed view under the M4 through to the park beyond. The magnitude of change from the proposed master plan is considered to be moderate within the context of the proposed open, highly accessible corridor park having a motorway on-ramp encircle it on two sides, but also taking into account the design of the ramp which would minimise both the bulk and scale of the structure, and loss of open space through detailed design.	This provides an overall visual impact assessment rating of – moderate.
Residents	The sensitivity of residents to the likely new views to existing M4 is considered to be high, given that: • A relatively large number of residents are affected • The M4 will be seen in relatively close detail. • This effect will be visible from balconies/elevated locations that look across the motorway, and potentially also living spaces within the units The magnitude of change is considered to be high given: Much of the new view may not be able to be screened from within the project boundary.	This provides an overall visual impact assessment rating of high. The impacts could be reduced through the application of mitigation measures such as collaboratively working with Council to provide screening vegetation, as discussed in **section 7.1.16**.

Table 6.31 Receiver location 3 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Future park users	The sensitivity of future park users to additional lighting is considered to be low within the context that this area will comprise a small component of a substantially larger park. The magnitude of change is considered to be beneficial for night-time park users, within the context of existing light levels on Parramatta Road and lighting on the M4 viaduct.	This provides an overall lighting impact assessment rating of moderate to low (beneficial).
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be low within the context of the short duration of view and motorway environment.	This provides an overall visual impact assessment rating of low.
Residents	The sensitivity of residents to the proposed new lighting and new views to existing M4 lighting is considered to be high, given that: This effect will be visible from balconies/elevated locations that look across the motorway, and potentially also living spaces within the units he lighting will be seen in close detail. The magnitude of change is considered to be moderate given: Lighting currently associated with the M4 is unlikely to be visually prominent from the residences with the exception of the large advertising bill board which is lit at night The fact that much of the new view appears unlikely to be able to be screened from within the project boundary	This provides an overall visual impact assessment rating of high to moderate. This impact could be reduced through the application of mitigation measures during the detailed design phase and addition of screening vegetation, as discussed **section 7.1.5**.

Receiver location 4 – Edward Street looking west towards Concord Road

Existing situation

Edward Street contains a substantially consistent period character of free-standing residential bungalows from the Federation era, including elements such as dark brick, stained glass windows, tuck pointing, picket fences and terracotta rooves. A relatively small amount of new, low density housing on existing blocks is also present within the street, and is generally architecturally sympathetic with the existing period character of the area. The street is lined by a mature avenue of heritage listed brush box trees (refer to **Figure 6.73**).

The view is representative of:

- Nearby residents from the front rooms of their homes in a few cases, and otherwise from their front gardens and when driving home west along Edward Street (the only option)
- Local residents who walk recreationally along the street.

Project effects

The key effects of the project would be as follows:

- Acquisition of eight residences at the western end of Edward Street
- Acquisition of the green park space as part of the road closure at the western end of the street, which would be replaced with a small street end turning circle that finishes hard against a footpath, and that finishes hard against the bridge abutment/noise wall of the proposed flyover access to the M4 from Concord Road, leading to:
  - Change in the character of the street when looking to the western end, with the green open space termination view point through the avenue planting replaced by a view to a retaining wall and noise wall about three metres high
  - The changed termination point view would become a new, uncharacteristic visual element within the streetscape from many residences that are currently unaffected by visual character impacts associated with the existing road closure, given that the road closure will move about 60 metres east of the current street end turning circle, ie five house blocks closer, subject to detailed design.

Lighting

Additional light would be introduced to this area during operation associated with the Concord Road interchange, including the on-ramp flyover to the M4 which comprises a new elevated edge boundary to this precinct, and is located close to housing at the end of the street. Lighting would include cut-off fittings and would be directed to reduce light trespass.

The extent of glare emanating from the new lighting towards the precinct is anticipated to be high due to the overall extent of lighting associated with the interchange, in addition to direct (line of sight to lighting) impacts from the interchange and the on-ramp flyover. This high rating would be expected to reduce by a minor to moderate extent as the proposed landscaping matured.



Figure 6.73 Existing view from Edward Street looking west towards Concord Road.



Figure 6.74 **Artist's impression at 12–18 months of operation from Edward Street looking west towards Concord Road.**



Figure 6.75 **Artist's impression at 10 years of operation from Edward Street looking west towards Concord Road.**

Visual impact assessment

Table 6.32 Receiver location 4 impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents	The sensitivity of residents living in Edward Street and other local residents who recreationally walk along the street is considered to be high, within the context of the substantially consistent Federation-era character of free-standing residences within the street, and in conjunction with the heritage listed avenue planting. This provides an attractive, high quality streetscape experience for receivers. Additionally, the change will visually affect a substantial portion of the street. The magnitude of change is considered to be high, notwithstanding that the change will only occupy a small portion of the street view. The impact will occur at the visual termination point of the street and will be experienced by most people in the street given that the street crests near the eastern end of the street. Similarly, recreational pedestrians will view at a high level of detail. The change in the view is out of character with the very specific character of the street.	This provides an overall visual impact assessment rating of high. This impact could be reduced through consideration of the modification of the location of the turning head as discussed in section 7.1.5, and collaboratively working with Council as discussed in **section 7.1.16.**

Table 6.33 Receiver location 4 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents	The sensitivity of residents to additional lighting is considered to be high The magnitude of change is considered to be high given that it may be difficult to achieve a high level of screening for direct lighting effects, eg on-ramp lighting seen from Edward Street, in addition to a general lighting glow associated with the overall extent of lighting required for the interchange.	This provides an overall lighting impact assessment rating of high.
Pedestrians	The sensitivity of pedestrians walking through the residential streets is considered to be moderate within the context that this area would be likely to comprise a relatively small component of a substantially larger walk The magnitude of change is considered to be high given that the street would currently be quite dark at night, and the project can be expected to substantially increase lighting levels towards the shortened end of the street.	This provides an overall visual impact assessment rating of high–moderate.

A reduction in these impacts could be expected through the application of mitigation measures discussed **section 7.1.5**, and collaboratively working with council, as discussed in **section 7.1.16**.

Receiver location 5 – Entry road to Cintra Park hockey facility looking south

Existing situation

This view is located on the entry road into the existing hockey facility off Gipps Street, looking south towards Parramatta Road. Key elements of the view comprise:

- The lines of mature trees which enclose the Cintra Park precinct to varying degrees, including:
  - The mature, large trees with connected canopies lining the eastern boundary of the hockey field and the Parramatta Road frontage
  - The line of trees along the Parramatta frontage including large mature specimens of fig trees and brush box trees, which in conjunction with the less mature boundary trees provide visual screening from the busy Parramatta Road
  - The intermittent lines of trees running along the back of the adjoining Concord Oval to the north-west
- The enclosed flat field nature of the site with the hockey field which is brightly lit until 10 o'clock each night, and associated club building
- The dull green stormwater tanks and large infrastructure shed that wraps around the south-west corner of the precinct, which comprises visually uncharacteristic elements within the context of the sporting precinct, and detracts from the visual amenity of the space.

The view is representative of:

- Active recreation users of the space, ie for hockey
- Local residents potentially using the space for both active and passive uses, eg running/exercise, and more contemplative strolling/walking the dog, or walking along Gipps Street and looking into the space
- Motorists driving along Gipps Street looking into the space.

Project effects

The key effects of the project would be as follows:

- Relocation of existing sporting infrastructure comprising existing synthetic surface hockey field with associated lighting
- The lines of trees along the eastern boundary of the hockey field would be retained though may be impacted by pruning and:
  - The proposed proximity of construction materials and concrete slabs for temporary buildings
  - The location of the proposed operational infrastructure elements along this boundary, comprising a water treatment plant, a water quality basin and a distribution substation and a fresh air intake facility.
- Removal of trees to the precinct along the Parramatta Road frontage
- The potential removal of other mature trees within the north-west of the site
- The introduction of new project elements comprising a water treatment plant, a water quality basin, a distribution substation and a fresh air intake facility
- Provision of sufficient space at completion of the project for the reinstatement of an active recreation field, if desired by Canada Bay Council.

Lighting

The project infrastructure would have safety and security lighting, but this would be at a relatively low level. In addition to the effects of the project on the above described receivers, the safety and security lighting may also be visible at night from the rear gardens of housing in Taylor Street backing onto the project. Lighting would include cut-off fittings and would be directed to reduce light trespass.



Figure 6.76 Existing view from entry road to Cintra Park hockey facility looking south.



Figure 6.77 Artist's impression at 12–18 months of operation from entry road to Cintra Park hockey facility looking south.



Figure 6.78 Artist's impression at 10 years of operation from entry road to Cintra Park hockey facility looking south.

Visual impact assessment

Table 6.34 Receiver location 5 impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Active recreation users	The sensitivity of active recreation users is considered to be low, given that the primary focus of this user group will be playing their particular sport, eg hockey, notwithstanding that this user group could also be expected to have a secondary interest in the landscape amenity of the setting within which the fields/courts are located. Assuming that some form of active recreation would be reinstated to the site, the magnitude of change is considered to be moderate, given the introduction of three new infrastructure buildings flanking the field along its southern and eastern perimeter, plus water quality basin with associated security fencing and maintenance vehicle access driveway, in addition to the existing stormwater treatment and storage facilities, and the retained utilitarian club amenities block. The field risks looking 'surrounded' on three sides by infrastructure rather than a more spacious landscape setting.	This provides an overall visual impact assessment rating of moderate–low.
Local residents – walking	The sensitivity of local residents is considered to be moderate given: That this is a recreational space The level of detail with which the new infrastructure would be viewed, eg due to walking along the facilities maintenance vehicle access driveway. The magnitude of change is considered to be low, given that the area already contains a substantial amount of infrastructure related development. The project would increase the coverage of infrastructure-related development across the site, though would retain areas for active recreation.	This provides an overall visual impact assessment rating of moderate-low.
Local residents – Taylor Street	The sensitivity of local residents backing onto the reserve is considered to be high given that the reserve is a recreational space, and both the water treatment plant and distribution substation buildings may be partially visible from back gardens above back fences. The magnitude of change is considered to be low, given the: Existing line of mature trees within the reserve/along the back boundary are proposed to be retained, and these comprise a major element of the view from these residences Extent of building seen area is likely to be low (notwithstanding that there would currently be no view of buildings from these back gardens).	This provides an overall visual impact assessment rating of moderate.

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Motorists	The sensitivity of motorists is considered to be low given the generally fleeting views that will be available from a moving vehicle. The magnitude of change is considered to be low, given the extent of existing screening along the Gipps Street frontage and potential for future infill of open/failed planting areas.	This provides an overall visual impact assessment rating of low.

Table 6.35 Receiver location 5 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Active recreation users	The sensitivity of active recreation users to additional lighting is considered to be low given their focus on active recreation activities and associated lighting The magnitude of change is considered to be low given that the project facilities would be subject to reduced levels of lighting compared to existing.	This provides an overall lighting impact assessment rating of low.
Residents – walking	The sensitivity of residents walking past or through the site to the proposed lighting is considered to be low given that the existing hockey field is brightly lit until 10 o'clock each night, and the proposed facilities will have relatively low levels of lighting The magnitude of change is considered to be low.	This provides an overall visual impact assessment rating of low.
Residents – Taylor Street	The sensitivity of residents living next to the project is considered to be moderate given the facilities will be subject to relatively low levels of lighting sufficient to meet safety and security levels which, notwithstanding that they will be on all night and will be in relatively close proximity to the properties, this lighting levels will be substantially lower than existing lighting levels. The magnitude of change is considered to be low.	This provides an overall visual impact assessment rating of low.
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be low within the context of the short duration of view.	This provides an overall visual impact assessment rating of low.

Receiver location 6 – Reg Coady Reserve near Iron Cove Creek looking west

Existing situation

This view is located within Reg Coady Reserve near the Iron Cove Creek pedestrian bridge looking west towards Martin Street. Key elements of the view comprise:

- Dobroyd Parade, with adjoining residential development generally well screened from the road
- A predominantly informal planting of large and medium sized trees within an open grassed setting, including occasional table and bench seating/shelters, a low skateboard ramp, and a winding bitumen path with lighting
- The open, tidal channel of Iron Cove Creek with fencing which comprises a broadly sinuous boundary with Timbrell Park on the other side of the creek, including a large children's play area and large expanse of playing fields. The channel has no water within it at lower tide levels
- Most of the reserve falls within the Haberfield HCA.

The view is representative of:

- Active recreation users of the space, eg jogging, exercise
- Passive recreation users of the space, eg contemplative strolling, walking the dog, sitting on park benches or under picnic shelters with views across to Timbrell Park, etc.
- Small numbers of residents, predominantly located at the end of Martin Street (west side), and the end Waratah Street (both sides). There would also be filtered views from the front rooms and gardens of those houses on the old Dobroyd Parade between Louden Avenue and Waratah Street, which would be situated behind a moderately dense roadside screen planting
- Motorists driving along Dobroyd Parade.

Project effects

The key effects of the project on this receiver location would be as follows:

- Widening of Dobroyd Parade from about 20 metres to between 30 and 40 metres wide (from four up to seven lanes)
- Noise wall along the southern edge of Dobroyd Parade, between Waratah Street and Crane Avenue, about five metres high
- Current screening to housing on the south side of Dobroyd Parade and carriageway setbacks is essentially maintained or slightly increased
- Removal of screen planting in front of two residences on the north side of Dobroyd Parade at the corner with Martin Street
- Reduction of parkland frontage to Reg Coady Reserve of up to about 20 metres in width, subject to detailed design, between Martin Street and Waratah Street. Loss of one large tree and also the likely loss of a large fig tree, and about seven small and medium sized trees to Reg Coady Reserve, subject to detailed design
- Removal of a two metre footpath set back from the kerb to the south side of Dobroyd Parade between Waratah Street and Martin Street, with the footpath proposed to abut the kerb
- Visually uncharacteristic formal tree planting along the western edge of Reg Coady Reserve, contrasting with the existing informal planting layout of the reserve
- The informal and open layout of Reg Coady Reserve has the potential to visually accommodate the proposed loss of land between Martin Street and Waratah Street.

Lighting

Additional light would be introduced to this area during operation associated with the road upgrade, in addition to the road being 10–20 metres closer to the park, subject to detailed design. The precinct will also be further affected by headlight glare due to the project being closer. Project lighting would include cut-off fittings and would be directed to reduce light trespass.

The extent of glare emanating from the new lighting towards the precinct is anticipated to be high due to the increased extent of lighting associated with the tunnel entry and exit ramps and tolling gantries, in addition to the road being closer to the park, and the relatively small area of the reserve. This high rating would be expected to reduce by a minor extent as the proposed landscaping matured.



Figure 6.79 Existing view from Reg Coady Reserve near Iron Cove Creek looking west.



Figure 6.80 Artist's impression at 12–18 months of operation from Reg Coady Reserve near Iron Cove Creek looking west.



Figure 6.81 **Artist's impression at 10 years of operation from Reg Coady Reserve near Iron Cove Creek looking west.**

Visual impact assessment

Table 6.36 **Receiver location 6 impact assessment**

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Active recreation users	The sensitivity of active recreation users is considered to be low, given that the primary focus of this user group would for instance be jogging, with a secondary element of the experience expected to be an appreciation of the landscape settings through which these receptors pass, and as this area has the potential to substantially retain its informal character. The magnitude of change is considered to be low, given the relatively small area removed and the capacity of Reg Coady Reserve to substantially retain its open, informally planted character, and that the part of the activity undertaken at the reserve is likely to be only a small component of a longer journey.	This provides an overall visual impact assessment rating of low.
Passive recreation users	The sensitivity of passive recreation users is considered to be low, given that the area is already highly exposed to traffic (both visually and perceived via levels of traffic noise), and the number of receivers who would spend extended periods of time here is anticipated to be low. This is notwithstanding that the existing seating facilities provide the opportunity to face away from Dobroyd Parade, looking north across Iron Cove Creek to Haberfield and Timbrell Park. The magnitude of change is considered to be low, given the capacity of the reserve to substantially retain its open, informally planted character.	This provides an overall visual impact assessment rating of low.

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Residents	The sensitivity of local residents is considered to be moderate given the: The relatively small number of receptors likely to experience increased, visually prominent views of road infrastructure and traffic The level of detail with which the new infrastructure would be viewed, eg from front gardens and windows. The magnitude of change is considered to be moderate, given that the area already contains a busy road, and where the noise wall is proposed between Waratah Street and Crane Avenue, this area is already moderately well screened from residences on the old Dobroyd Parade.	This provides an overall visual impact assessment rating of moderate.
Motorists	The sensitivity of motorists is considered to be low given that vehicles will generally be moving past the site at moderate speed, notwithstanding that vehicles travelling east and queuing on Dobroyd Parade at the Waratah Street lights, will obtain relatively long views through the reserve. The magnitude of change is considered to be moderate, given the capacity of the reserve to substantially retain its open, informally planted character.	This provides an overall visual impact assessment rating of moderate–low.

Table 6.37 Receiver location 6 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Active recreation users	The sensitivity of active recreation receivers is considered to be low given that the primary focus of this user group would be the recreation activity. The magnitude of change is considered to be moderate due to the proposed increase in levels of lighting.	This provides an overall lighting impact assessment rating of moderate to low.
Passive recreation users	The sensitivity of passive recreation users receivers is considered to be low given the number of receivers who would spend extended periods of time here is anticipated to be low. The magnitude of change is considered to be moderate due to the proposed increase in levels of lighting.	This provides an overall lighting impact assessment rating of moderate to low.
Residents	The sensitivity of residential receivers is considered to be high. The magnitude of change is considered to be moderate as existing high levels of screening to Dobroyd Parade will generally be retained.	This provides an overall lighting impact assessment rating of high to moderate.
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be moderate within the context of a motorway setting.	This provides an overall visual impact assessment rating of moderate to low.

Receiver location 7 – Parramatta Road at corner of Frederick Street looking east through south

Existing situation

This view is located on Parramatta Road at the corner of Frederick Street looking east along Wattle Street through to south along Parramatta Road. Key elements of the view comprise:

- The wide view along Wattle Street which crests about 80 metres from the corner
- The dense island planting of trees on the corner of Wattle Street
- The brightly coloured Bunnings building, formerly Peek Freans Biscuit Factory on the corner of Frederick Street and Parramatta Road, with its distinctive corner tower.
- The view is representative of pedestrians and motorists.

Project effects

The key effects of the project on this receiver location would be as follows:

- The introduction of the following new elements, comprising the:
  - Infrastructure group of buildings on the corner of Wattle Street comprising: ventilation facility building (podium about 30 by 30 metres and between 7–8.5 metres high, with an exhaust vent about 12 by 12 metres with a height of about 25 metres above finished ground level), air supply inlet building (podium about 22 by 22 metres and six metres high, with raised section about 12 x 15 metres and a total height including the podium of about 12 metres), fire pump and water tanks building (22.5 by 34.5 metres and up to about 4.5 metres high), and two electrical substation buildings (about 30 by 20 metres and between about six to seven metres high), subject to detailed design
  - Noise walls comprising: a curving wall along the southern edge of Wattle Street from about 100 metres north of Parramatta Road to Martin Street, about five metres high. This could result in an unconnected space between the back fences of the Walker Street residences and the noise wall, with potential safety and security related issues requiring consideration
  - Associated informal tall screen tree planting around the infrastructure group of buildings and formal boulevard style planting along the southern side and centre median of Wattle Street
  - Major widening of Wattle Street from seven lanes wide at the Parramatta Road intersection plus a slip lane to turn south onto Parramatta Road, to eight lanes wide plus provision for a further four lanes for dive structures provided for future M4 South tunnel entry and exit points
- The loss of all housing fronting the southern side of Wattle Street
- The loss of housing and commercial development on the eastern side of Parramatta Road between Wattle Street and Walker Avenue.

Notwithstanding the size of the proposed building infrastructure elements, these comprise an architecturally well-considered family of elements, which would replace the more haphazard, mixed development currently in place along this section of Parramatta Road. The road widening of Wattle Street would not be very visually different from what is currently in place.

The building elements would be sited within a landscaped setting that would help to reduce their visual prominence, while still revealing them as large urban building elements which are not uncommon along Parramatta Road streetscape. The landscape setting of the infrastructure group when seen from this receiver location would be integrated with a roadside avenue planting that would extend along the full length of the southern side of Wattle Street.

The loss of the residential streetscape along Wattle Street would be a change to the character of the view from this location; from that of a busy residential street, to that of a large, more formalised road corridor. However, given the fact that Wattle Street crests within about 80 metres of Parramatta Road, the possible future Stage 3 entry and exit portals would not be visible from this location. Gantries for tolling and VMS signage may be visible, depending on their final location.



Figure 6.82 **Existing view from Parramatta Road at the corner of Frederick Street looking east through south.**



Figure 6.83 **Artist's impression at 12–18 months of operation from Parramatta Road at the corner of Frederick Street looking east through south.**



Figure 6.84 **Artist's impression at 10 years of operation from Parramatta Road at the corner of Frederick Street looking east through south.**

Visual impact assessment

Table 6.38 Receiver location 7 impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Pedestrians	It is unlikely that pedestrians would walk along Parramatta Road by choice, if they could otherwise travel along quiet side streets. However, they would also be travelling slowly through the landscape and have time to view elements at close range, in high levels of detail. Further, pedestrians may cross Parramatta Road at this point as part of a recreational walk, eg walking from Ashfield along Frederick Street to access the open spaces of Reg Coady Reserve and Timbrell Park, and walk through some of the quiet, attractive Federation-era streets of Haberfield. Within this context, the view from this receiver location would be seen at a relatively high level of detail, but for a short period of time as part of a longer walk. However, within the context of the existing environment,, the sensitivity of pedestrians is considered to be low. The magnitude of change is considered to be high within the context of the substantial change in character that will occur to the view from this location, and particularly to the change in visual character of Wattle Street as described above.	This provides an overall visual impact assessment rating of moderate for pedestrians.
Motorists	The sensitivity of motorists is considered to be low given that this receiver group can be expected to be focussed on driving, which in most cases will be work related or some other necessary travel requirement, eg to shopping or visiting family/friends, etc. Additionally, the landscape character of the Parramatta Road corridor in particular generally has very low levels of visual amenity, and this view would be seen briefly as a small part of a larger journey. The magnitude of change for motorists is considered to be low within the context of the: Already busy major road intersection Proposed architecturally well-considered ventilation facility on the corner of Wattle Street, the scale of which is visually compatible with a major road Proposed substantial landscape integration of the works	This provides an overall visual impact assessment rating of– low for motorists.

Table 6.39 Receiver location 7 lighting impact assessment

Receiver	Sensitivity and Magnitude	Overall visual impact assessment
Pedestrians	The sensitivity of pedestrians to additional lighting is considered to be low given existing busy road, highly lit environment of Parramatta Road. The magnitude of change is considered to be low within the context given the existing high lighting levels along Parramatta Road.	This provides an overall visual impact assessment rating of low.
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be low within the context of the short duration of view and motorway environment.	This provides an overall visual impact assessment rating of low.

Receiver location 8 – Parramatta Road at corner of Rogers Avenue looking north

Existing situation

This view is located on Parramatta Road at the corner of Rogers Avenue looking west along Parramatta Road. The view comprises a substantially hard landscape dominated by the road and lined with a visually disparate mix of low-rise, predominantly commercial development, all with limited separation from Parramatta Road. There are very few street trees, and limited tree cover within fronting properties, with the exception of the extensive large tree planting within the Yasmar site, which extends out above eastbound traffic lanes.

The receiver is located at a local high point in the landscape, providing a long view down Parramatta Road, with a glimpse background district view of a highly urbanised ridgeline seen over development within the road corridor.

The view is representative for pedestrians and motorists.

Project effects

The key effects of the project on this receiver location would be as follows:

- All development on the southern side of Parramatta Road between Orpington Street and Bland Street would be lost, with the road widening to contain a further two lanes each for tunnel entry and exit portals, plus a centre median reserved for a future public transport transit link. The widening would incorporate a widened verge for much of the eastern side of the road, facilitating a footpath set back from the road edge behind the street tree planting
- The project would provide tall avenue planting down the majority of both sides of Parramatta Road, in conjunction with a median planting of shrubs and tall trees
- Initially, the view would potentially open up more extensive district views to the north-west above the road corridor development, but this would be lost should redevelopment of the four residual land parcels located along the southern edge of Parramatta Road take place. At the time of writing, the nature of the type of development that might be built within these land parcels is unknown
- The upper floors of the two- to three-storey residential unit development on Loftus Street that would adjoin the project along the southern edge of Parramatta Road would be likely to have views to the carriageway until the development of the above described residual land, with the exception of 7–9 to 17 Loftus Street which would adjoin a narrow park, and be likely to have long-term views through street tree planting to the project.

Lighting

Additional light would be introduced to this area during operation associated with the increased extent of lighting associated with the tunnel entry and exit ramps and tolling gantries and increased headlight glare from vehicles exiting the Parramatta Road portal. Project lighting would include cut-off fittings and would be directed to reduce light trespass.

The extent of glare emanating from the new lighting towards adjoining medium density residential development south of Parramatta Road is anticipated to be high due to the loss of shielding buildings on Parramatta Road and the road being closer to the residences. This level of glare may be locally reduced in some instances where relatively tall new buildings are located on residual land parcels. However, the above described units at 7–9 to 17 Loftus Street which would adjoin a narrow park, are likely to have long-term views through street tree planting to the project, as potentially would also residences adjoining residual land parcels that were not developed with relatively tall buildings. This high rating would be expected to reduce by a minor extent as the proposed landscaping matured.



Figure 6.85 Existing view from Parramatta Road at the corner of Rogers Avenue looking north.



Figure 6.86 **Artist's impression at 12–18 months of operation from Parramatta Road at the corner of Rogers Avenue looking north.**



Figure 6.87 **Artist's impression at 10 years of operation from Parramatta Road at the corner of Rogers Avenue looking north.**

Visual impact assessment

Table 6.40 Receiver location 8 impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Pedestrians	It is unlikely that pedestrians would walk along the busy Parramatta Road by choice, if they could otherwise walk along quiet side streets. However, where they did choose to walk along Parramatta Road, they would also be travelling slowly through the landscape and have time to view elements at close range, in high levels of detail. Further, local residents located north of Ashfield Park may walk along/cross Parramatta Road near this location to access the park. The view from this receiver location would be seen at a relatively high level of detail, but for a relatively short period of time as part of a longer walk. The number of receivers would be anticipated to range low to moderate levels if receivers waiting for and alighting from public transport (buses) was taken in account. Within this context, the sensitivity of pedestrians is considered to be low. The magnitude of change is considered to be high within the context of the substantial widening and change in character that will occur to the view from this location, including the increased street tree planting, and potentially increased volumes of traffic at peak periods. As discussed above, the nature of future development within the project residual land is not known at this time, but can be expected to comprise architecturally well-considered designs set with an appropriately designed landscape, in accordance with Ashfield Council planning requirements.	This provides an overall visual impact assessment rating for pedestrians of moderate.
Motorists	The sensitivity of motorists is considered to be low given that this receiver group can be expected to be focussed on driving, which in most cases will be work related or some other necessary travel requirement, eg to shopping or visiting family/friends, etc. Additionally, the landscape character of the Parramatta Road corridor in particular generally has very low levels of visual amenity, and this view would be seen briefly as a small part of a larger journey. Within the context of the above discussion of magnitude for pedestrians, the magnitude of change for motorists is considered to be high.	This provides an overall visual impact assessment rating of moderate for motorists.

Table 6.41 Receiver location 8 lighting impact assessment

Receiver	Sensitivity and magnitude	Overall visual impact assessment
Pedestrians	The sensitivity of pedestrians to additional lighting is considered to be low given the existing low amenity character of this area, and the motorway setting. The magnitude of change is considered to be high.	This provides an overall lighting impact assessment rating of moderate.
Motorists	The sensitivity of motorists to additional lighting is considered to be low. The magnitude of change is considered to be low within the context of the short duration of view and motorway environment.	This provides an overall visual impact assessment rating of low.
Residents	The sensitivity of residents to additional lighting is considered to be high within the context of their not currently being subject to views of Parramatta Road. The magnitude of change is considered to be high.	This provides an overall visual impact assessment rating of high.

6.4.3 Summary of key viewpoint visual impact assessments

The below provides a summary of key viewpoint impact assessments.

Table 6.42 Summary of key viewpoint assessments

Receiver		Sensitivity to change	Magnitude of change	Overall rating
Receiver location 1 – M4 east of Homebush Bay Drive				
1	Motorists	Low	Moderate	Moderate–low
Receiver location 2 – Underwood Road looking south towards M4				
1	Residents/church congregation	High	High	High
2	Pedestrians	Moderate	High	High–moderate
3	Motorists	Low	Moderate	Moderate–low
Receiver location 3 – Parramatta Road looking north to Powells Creek corridor				
1	Future park users	High	High	High
2	Motorists	Moderate	Moderate	moderate
3	Residents	High	High	High
Receiver location 4 – Edward Street looking west towards Concord Road				
1	Residents	High	High	High
Receiver location 5 – Entry road to Cintra Park hockey complex looking south				
1	Active recreational users	Low	Moderate	Moderate–Low
2	Residents – walking	Moderate	Low	Moderate-low
3	Residents – Taylor Street	High	Low	Moderate
4	Motorists	Low	Low	Low
Receiver location 6 – Reg Coady Reserve near Iron Cove Creek looking west				
1	Active recreational users	Low	Low	Low
2	Passive recreational users	Low	Low	Low
3	Residents	Moderate	Moderate	Moderate
4	Motorists	Low	Moderate	Moderate–Low
Receiver location 7 – Parramatta Road at corner of Frederick Street looking east				
1	Pedestrians	Low	High	Moderate
2	Motorists	Low	Low	Low

	Receiver	Sensitivity to change	Magnitude of change	Overall rating
Receiver location 8 – Parramatta Road at corner of Rogers Avenue looking north				
1	Pedestrians	Low	High	Moderate
2	Motorists	Low	High	Moderate

6.4.4 Summary of Lighting Impact Assessments

Table 6.43 Summary of lighting impact assessment

	Receiver	Sensitivity to change	Magnitude of change	Overall lighting impact rating
Receiver location 1 - M4 Motorway east of Homebush Bay Drive looking east				
1	Residents	High	High	High
2	Motorists	Low	Moderate	Moderate to low
Receiver Location 2 - Underwood Road looking south towards M4 Motorway				
1	Residents / church congregation	Moderate	Moderate	Moderate
2	Pedestrians	Low	Low	Low
3	Motorists	Low	Low	Low
Receiver Location 3 - Parramatta Road looking north to Powells Creek corridor				
1	Future Park Users	Low	Moderate	Moderate to low (beneficial)
2	Motorists	Low	Low	Low
3	Residents	High	Moderate	High to moderate
Receiver Location 4 - Edward Street looking west towards Concord Road				
1	Residents	High	High	High
	Pedestrians	Moderate	High	High to moderate
Receiver Location 5 - Entry road to Cintra Park hockey complex looking south				
1	Active Recreational Users	Low	Low	Low
2	Residents - walking	Low	Low	Low
3	Residents – Taylor Street	Low	Low	Low
4	Motorists	Low	Low	Low
Receiver Location 6 - Reg Coady Reserve near Iron Cove Creek looking west				
1	Active Recreational Users	Low	Moderate	Moderate to low
2	Passive Recreational Users	Low	Moderate	Moderate to low
3	Residents	High	Moderate	High to moderate
4	Motorists	Low	Low	Low
Receiver Location 7 - Parramatta Road at corner of Frederick Street looking east				
1	Pedestrians	Low	Low	Low
2	Motorists	Low	Low	Low
Receiver Location 8 - Parramatta Road at corner of Rogers Avenue looking north				
1	Pedestrians	Low	High	Moderate
2	Motorists	Low	Low	Low
3	Residents	High	High	High

7 Management of impacts

7.1 Landscape character and visual impact mitigation strategy

LCZ 1 – M4 Motorway

- Maximise opportunities for tree planting to those areas within the road corridor, where this is feasible and appropriate, to seek to:
  - Screen the carriageways from adjoining development
  - Break up the hard landscape of the carriageways and associated infrastructure of retaining walls, bridges, noise walls, etc between the carriageways
  - Provide a visually appealing urban design overlay for the corridor (WUDF) that includes, for example, vegetation as one component
- Minimise tall tree planting between Powells Creek and the Northern Line to maintain district views from the M4
- Consider at-receiver planting to reduce visual and lighting impacts on residential receivers.

LCZ 2 – Homebush commercial precinct

- Where practicable, incorporate substantial avenue planting along the northern edge of the motorway control centre access road to:
  - Provide landscape structure and shade along this edge
  - Supplement the proposed avenue of trees along the southern boundary of the bulk equipment store/workshop/motorway control centre in order to visually compartmentalise the extensive hard elements within the landscape, eg the M4, the electricity substation and the DFO warehouse development
- Where possible, provide trees within the equipment store/workshop/motorway control centre carparks to provide shade and visually break up the hard landscape
- Consider the incorporation of WSUD measures to provide passive irrigation of trees, particularly within carparks and other areas where stormwater run-on is limited.

LCZ 3 – Parramatta Road (west) precinct

Park Road

- Explore opportunities with Strathfield Council to provide landscape screening and tree planting between this precinct and the project corridor, for example through:
  - The incorporation of car parking tree planting bays on council land along the Park Road/M4 edge
  - Investigating opportunities to facilitate tree and shrub screen planting within the Park Road verge adjoining the M4, augmenting the existing low street tree planting on the residential side of Park Road west to the turning head beyond Kanoona Avenue. This is a relatively low budget option that would provide a streetscape amenity improvement for this section of Park Road and assist with screening of views to the project.

Powell Street

- Explore opportunities with Strathfield Council to provide landscape screening and tree planting between this precinct and the project corridor
- Investigate with Strathfield Council the feasibility of providing a pedestrian/cycleway link along the northern edge of Powell Street where it adjoins the M4 to link directly to the Powells Creek corridor between the M4 and the property on the eastern corner of Powell Street and Parramatta Road (3/DP1002876 and 81/DP870786). This approach has the potential to provide a greater level of public accessibility to the proposed park within LCZ 5 – Powells Creek precinct.

LCZ 4 – Underwood Road precinct

- During detailed design, consider a formal park design that incorporates measures (eg mounding/deeper soils areas) to facilitate a successful large tree planting program between Underwood Road and Ismay Avenue
- Explore opportunities with the local council to provide avenue planting down both sides of the street, and a linking canopy across the road, thereby reducing the visual prominence of the ventilation facility from the street, the front rooms/gardens of nearby residences, and the Our Lady of the Assumption Catholic Church
- During detailed design, consider the use of a planting mix for the proposed park on the corner of Short Street East and Underwood Road that draws upon the suburban setting of cultural plantings, and which may include elements such as park seating, other park furniture, paving, signage and lighting.
- Consider at-receiver planting to reduce visual and lighting impacts on residential receivers at 65-71 and 73 Underwood Road and the end of Short Street East
- Consider the use of street trees along both sides of Short Street East with a habit that will provide screening of views to the project, including for lighting from the carriageways.

LCZ 5 – Powells Creek precinct

- During detailed design of the M4 on-ramp at Powells Creek, consider incorporating design features which, where feasible:
  - Maximise the height of the opening underneath the ramp to facilitate views and pedestrian/cycle access under the structure to the northern end of the park eg designs which allow the bridge to climb as quickly as practicable
  - Use a refined, 'light' bridge structure eg with piers that align with the existing bridge piers of the M4 bridge
- Consider using design motifs from the bridge for other built form elements within the park, that have been derived in consultation with council's park master planning landscape architects.
- Consider the provision of active recreation facilities within the park area, e.g. basketball or skateboarding, which are compatible with traffic noise, relatively high background light levels at night and adjacent development.
- During detailed design, consider ways to increase the level of screening between the apartment block at the eastern end of Powell Street and the project.

LCZ 6 – Concord Road precinct

- Design the two large 'island' parks to meet CPTED requirements including, where feasible, spaces that will actively encourage a significant level of park use, eg active recreational facilities such as basketball courts or a skateboard facility
- Where residual land is utilised for housing, provide an architectural outcome that is responsive to the adjoining/adjacent Powell's Estate HCA
- Consider the design of the replacement boundary wall on Concord Road fronting Sydney Cheil Church, to seek to match the design and materials of the existing wall, which is in keeping with the design of the church.

LCZ 7 – Edward Street precinct

- Refine the design to the end of Edward Street to minimise the visual prominence of the on-ramp wall and noise wall eg facilitate a planting edge between the on-ramp wall and the footpath, and between the footpath and the Edward Street turning head, which reflects the federation era character of the streetscape. This could be achieved eg by moving the street end turning circle east so that it ends in line with the western side boundary of No. 20. This would retain existing driveway access while providing around five metres between the Concord Road/M4 on-ramp and the kerb of the turning circle for landscape integration of the wall

- Consider reducing the extent of landscaping required between the carriageway and noise wall (between Parramatta Road and the pedestrian bridge over the tunnel on- and off-ramps), which could be difficult to maintain, and instead retain sufficient room to provide screen planting along the M4 edge eg by providing a new noise wall to the edge of the M4 and increasing the extent of open space available to the Edward Street precinct
- Consider ways to better integrate the existing disused residual land between the end of Alexandra Street and Parramatta Road eg a pocket park responding to the Federation-era residential setting of the Edward Street precinct.

LCZ 8 – Concord Oval precinct

- Configure the construction and operational layout of the Cintra Park site so as to retain the mature line of trees running along the boundary and screening to adjoining receivers eg avoid soil compaction or the laying of materials over the root zone and establish tree protection zones in consultation with an arborist
- If practicable, during detailed design investigate opportunities to minimise the removal of established trees at Cintra Park to maintain screening to the site and visual amenity within the recreational spaces.

LCZ 9 – Dobroyd Parade precinct

- Consider the provision of a landscape design response to Reg Coady Reserve that re-integrates the new road edge with the landscape character of the park
- Consider a landscape response along the edge of Reg Coady Reserve edge which more closely reflects the existing generally informal planting character of the reserve
- Where feasible, consider moving the footpath away from the busy road edge on both sides of Dobroyd Parade. In conjunction with this approach, consider the provision of formal tree planting to the eastern side of Dobroyd Parade between the footpath and kerb to match the treatment between Martin Street and Ramsey Street.
- Regarding the proposed noise wall to the eastern edge of Dobroyd Parade:
  - consider augmentation of the existing screen planting to the area between Waratah Street and Crane Avenue on the residential side to maximise screening of the noise wall from this location
  - Consider setting the wall far enough back from Dobroyd Parade to provide an avenue of tall planting continuing up to Martin Street, as currently proposed north of Martin Street.

LCZ 10 – Wattle Street precinct

- Consider an opportunity to extend the street tree planting along the western side of Wattle Street and Dobroyd Parade
- During detailed design investigate opportunities to locate the footpath away from the busy kerb and provide the proposed tall tree planting between the kerb and the footpath, to match that proposed between Ramsey Street and Martin Street
- Consider an integrated artwork approach to the noise walls along Wattle Street and Dobroyd Parade.
- During the detail design process, consider ways to:
  - provide pedestrian and streetscape amenity between the noise walls and the street
  - to integrate the area between the back fences of the Walker Street residences and the curving noise wall

LCZ 11 – Parramatta Road (east) precinct

- Consider increasing the extent of street tree planting along the frontage between Chandos Street and Rogers Avenue eg through minor alterations to vehicle crossing points
- Consider refining the verge design to the southern edge of the Parramatta Road such that a planted verge and avenue tree planting is created between the footpath and the carriageway

- Consider providing a planted verge and avenue tree planting between the footpath and the carriageway to the Parramatta Road frontage to the residual land on the corner of Bland Street.

LCZ 12 – Haberfield precinct

- Investigate opportunities to increase the proposed street tree planting to Walker Avenue and seek to reinstate the original Brush Box street tree avenue character, in order to reduce the visibility of the infrastructure from pedestrians and residential receivers at the western end the street and reduce the landscape character impacts of the project in this precinct
- Careful consideration of development proposed for the residual land on Walker Avenue is needed to allow the development to visually complement the remaining row of low density housing on the other side/end of the street, and to reinforce the federation era landscape/heritage qualities and character of the street.

LCZ 13 – Yasmar Juvenile Training Facility

- Ensure that street trees are not planted in front of and immediately adjoining Yasmar, to retain the distinctive 'forest' edge character of this facility as seen from Parramatta Road.

LCZ 14 – Ashfield medium density precinct

- Consider the provision of substantial street tree planting within the parking lanes along Loftus Street to provide an increased level of street amenity, and to mitigate the landscape character impact of the Parramatta Road edge effect on the street.

LCZ 15 – Ashfield Park

- Consider establishing a stand of brush box trees to the northern corner of Orpington Street and Parramatta Road to tie in with the brush box tree planting in the opposite northern corner of Ashfield Park.

7.1.1 General recommendations

Tree planting on structure

- Consider engaging the services of an appropriately qualified and experienced arborist and/or soil scientist to assess the feasibility of proposed tree planting on structure (such as above the cut-and-cover sections). They would then make recommendations with regard to ensuring a long-term successful outcome that is sustainable within the context of potential extended periods of drought (no access to groundwater table), and prolonged or intense rainfall events (potential root anchorage limitations)
- Consider the use of WSUD measures in conjunction with on structure planting to reduce water stress effects, eg water harvesting off roads, incorporation of bi-oretention planting areas/planted swale treatment for stormwater polishing.

Collaboration with councils

- In consultation with the relevant council, provide urban design and landscape plan for park/residual area landscape treatments throughout the project boundary (eg between Sydney Road east and Edward Avenue adjoining the Concord Road interchange) that reflect the cultural setting of the adjoining residential precincts. Consider cultural plantings for these areas which draw upon the character of local streetscapes. Where feasible, consider the use of elements such as park furniture, play equipment, paving, lighting, art work, and signage. A more expansive planting palette should be developed during detailed design
- Consider undertaking the design, development and implementation of proposed pocket park spaces adjacent to residential areas land in consultation with the relevant council, such that upon completion of approved projects and an agreed plant establishment period, the ongoing care, control and management of these areas could be taken on by council.
- Where it is not possible to provide screen planting to visually sensitive areas within the project corridor, consider undertaking screen planting in consultation with the relevant council to council verge areas.

7.2 Urban design

The preferred design is generally consistent with the objectives and design principles set by the WestConnex urban design guidelines and RMS design guidelines. Where exceptions exist it is due to the lack of detailed design resolution at this early stage, rather than inappropriate design.

The nature of the design process is iterative, its direction is not always fixed or linear, but rather must evolve as various elements become more realised in detail and better coordinated as part of the project.

With this in mind the following recommendations are made to guide the detailed design of the project.

7.2.1 General recommendations

- During detailed design, continue to explore opportunities to minimise the project footprint and removal of vegetation; to maximise screen and structure planting; to further integrate landscape elements along the project boundaries into their urban setting; and to rationalise road alignments
- Where possible, seek to establish engineered slopes with gradients no steeper than 3H:1V eg through retaining walls
- During detailed design, explore ways to optimise project integration, and transition intersection precincts into existing streetscapes to improve connectivity, amenity and community value eg through footpath improvements and street tree planting
- During detailed design, optimise the integration of proposed open spaces within the local context and consider issues of accessibility and activation, to integrate noise walls and other features to improve amenity and attract users
- Consider coordinating the design of retaining wall and major structures across the project, regardless of structural typology, to present as a coordinated ‘suite of elements’ eg consistently finished to class 2 concrete minimum
- Consider lighting strategies that include alternatives to high-pressure sodium induction lighting systems eg LED saves energy, costs less to maintain and provides better, safer light quality for roads
- Consider ways to maximise opportunities for tree planting while satisfying road design requirements at spatially constrained street cross sections eg through the incorporation of crash barriers
- Consider ways to include an arts strategy across the project, developed during detailed design
- Where practicable, areas of residual land should be made good with appropriately sized street planting, especially those areas where mature street trees have been removed to provide construction access
- During detailed design, guidance should be developed to provide indications of the appropriate scale and typology of the future development of residual land, including ways to promote project integration and activation
- Consider having the detailed design regularly reviewed by an independent design and sustainability review panel to ensure design quality throughout each stage of works, in accordance with the WUDF Principle 6.6.

7.2.2 Tunnel interiors

- Consider the ‘integration of lighting and art to enhance the travel experience’ subject to detailed design, and user and safety audits. This includes, for example, ‘potential feature lighting’ at ‘location identifiers’
- Consider the gradation of light on approach to tunnel portals, subject to detailed design, and user and safety audits
- Consider 3D animation testing of the tunnel interior designs from the driver’s perspective. Also consider the regular review of these designs by an independent design and sustainability review panel.

7.2.3 Ventilation and substation facilities

During detailed design, refinements to the ventilation facilities designs should be considered to further moderate their visual impact.

Similarly, the distribution substation designs should be further refined during detailed design to be integrated as far as possible within each landscape and urban context eg by developing exposed elevations to a similar level of detail and through the addition of appropriate streetscape interventions.

During detailed design, (if feasible and having regard to the required subsurface arrangement with respect to the tunnel geometry), consideration should be given to the way that the eastern ventilation facility addresses Walker Avenue. This consideration would explore whether a public domain and redevelopment arrangement can be created. For example, further exploration as to whether the orientation of the exterior of the ventilation facility can be undertaken to mirror the Bunnings 'street-wall', with street trees providing scale mitigation and shade amenity.

7.2.4 Bridges

The following urban design aspects should be developed further during the detailed design of the proposed bridges:

- The interface between the project pedestrian bridge fencing, throw-screens and guard rails and the existing fence and guard rails of the connecting shared paths and tops of retaining walls
- The lighting of bridges, in particular pedestrian bridges and connecting shared path systems
- The highly visible bridge parts such as piers, girders and parapets, so as to ensure a controlled, integrated and high quality finish taking into account the *RMS Bridge Aesthetics: Design guidelines to improve the appearance of bridges in NSW*
- The refinement of composite sub-structures such as Super T girders, headstocks and piers requires, having regard to the bridge aesthetics guidelines
- The lighting of bridges and bridge undercrofts to enhance safety and add character to these spaces
- Opportunities for the enhancement of accessible public areas beneath viaduct and bridge structures to create inviting, safe and interesting environments with good solar access
- The design development of the Powells Creek on-ramp to consider access, amenity and safety
- Illustration of the integral abutment connection with the proposed cantilevered Concord Bridge deck
- Making-good and tying the project elements and realigned pedestrian access into existing footpaths
- The fascia wall panels and/or reinforced earth wall details for the proposed soil nail walls and reinforced earth walls.

7.2.5 Landscaping

The following aspects should be developed further during the detailed design of the landscaping for the project:

- The size of proposed trees, details of planting numbers and densities, to foster robust, rapid growth and canopy closure for shade and screening
- Soil preparation requirements, including a sound understanding of existing site soils and their chemistry, which vary from location to location. This is best achieved by appropriate soil analysis and the adoption of a soil management strategy. A soil management strategy should be developed during detailed design

- For areas of mass planting on grade along the project boundaries, and for sedimentation basin plantings, the integrated design team should seek the advice of an ecologist with experience in restoration planting. An ecologist would assist in the selection of appropriate species as a response to site soils, and also identify the potential to extend the benefit of ecological plantings beyond the site boundaries (eg habitat benefits within adjacent areas such as Powells Creek).
- The earthworks and existing embankment modifications required to support the proposed cycleway on-ramp at Queens Street should minimise loss of existing trees through minimising the extent of earthworks.

7.2.6 Parramatta Road urban renewal program

In the detailed design phase, the following should be considered in the context of the Parramatta Road urban renewal program:

- Maintaining and or enhancing pedestrian and cycle connectivity across the Parramatta Road corridor, including for example, appropriate crossing distances and times at controlled intersections for all users, safe median refuges, adequate lighting
- Residual land redevelopment typology, land use and design controls developed to provide certainty as to the quality of future street amenity and activation
- Maintaining and or enhancing public transport connectivity across the Parramatta Road corridor and to adjacent suburbs, including for example, appropriate location of bus stops, provision of shelters and attendant furniture
- Consider the opportunity to improve pedestrian and shared path amenity, for example by:
  - Introducing shade trees of appropriate scale
  - Separating users from busy traffic lanes wherever possible behind a landscape amenity strip
  - Providing appropriate lighting for pedestrian functions.

8 Conclusion

8.1 Urban design

This assessment has addressed the SEARs and:

- Assessed the proposed urban and landscape design to enhance the interchanges, tunnels, cut-and-cover and slot arrangements against the objectives and principles of the WUDF
- Considered the resulting residual land and treatments proposed
- Assessed how the proposed hard and soft urban design elements of the project would be consistent with the existing and desired future character of the area.

This assessment has considered the proposed urban and landscape elements of the project, including key structures (such as ventilation facilities) with reference to the WUDF and with consideration of the visual amenity implications of the proposal upon the surrounding areas; in terms of both impacts and potential impact mitigation.

Each of these considerations has been mindful of the guiding vision of the WUDF that:

> *The WestConnex motorway shall be a sustainable, high quality and transformational project for the people of Sydney and NSW. Exhibiting design excellence as a whole and in all constituent parts, it should be sensitively integrated into the natural and built environment, help build communities and contribute to the future liveability of the city (WUDF p.44).*

While the transformational potential of the project is likely to depend upon the delivery of the entirety of WestConnex, that success would be founded on the quality of its constituent parts. This assessment has therefore been particularly mindful of the design objectives, the need for sensitive integration within the project setting, and the impact of that upon communities and liveability.

This assessment has found that the preferred design is generally consistent with the objectives and design principles set by the WUDF and Roads and Maritime design guidelines. However, it is difficult at this early stage of the design resolution to be conclusive with regard to all of the required elements. Where exceptions exist it is generally due to the lack of detailed design resolution rather than inappropriate design.

This assessment has considered the potential for the project to enhance connectivity across Parramatta Road. To this end, the recommended design commitments include continued and careful consideration of future public transport, pedestrian and cycle links with Parramatta Road, with reference to the objectives of the Parramatta urban renewal program.

This assessment has considered the residual land proposed by the project. However, there is no detail at this stage as to the potential future uses of those lands, other than defined areas of public amenity. The recommended design commitments therefore include further investigation of potential land uses supported by outline development guidelines, such as future building heights, setbacks and densities, to better define the future character of these sites. The future desired character of these lands is indicated in **section 7.2** based on existing relevant LGA planning strategies.

The nature of the design process is iterative, its direction is not always fixed or linear, but rather must evolve as various elements become realised in detail and better coordinated as part of the whole project. With this in mind, a number of project design commitments are recommended to guide the continued development of the proposal in line with the recommended mitigation measures (**Chapter 7**).

The design development will be assessed by an urban design review panel.

8.2 Landscape character and visual impacts

Key landscape character and visual amenity issues arising from the assessment include a loss of a substantial corridor of vegetative screening to the existing M4, and change in character of the motorway to a much wider hardscape development that provides limited opportunities for landscape integration between the carriageways and along parts of the boundary.

Within the context of limited opportunities for substantial landscape integration between the carriageways, the design and execution of the urban design associated with the project works will be critical to the visual outcomes of the project, including:

- Limiting impacts to residential streetscapes, primarily comprising Edward Street in North Strathfield and Walker Avenue in Haberfield, where the existing Federation-era streetscapes are adversely impacted by the project
- These issues would benefit from consideration of the mitigation measures proposed in **Chapter 7**.
- Utilising a planting palette which is more responsive to the particular landscape character of different precincts eg Federation-era precincts that use brush box avenue plantings, have detailed garden settings and extensive examples of well-presented Federation-era architecture, such as Edward Street in North Strathfield, and Walker Avenue and Martin Street in Haberfield. The design development process should consider these cultural integration issues within these types of areas
- Design of park spaces that:
  - Relate to the landscape character of the locale
  - Provide park settings that are contextually and functionally suited to the residential environment
  - Provide a detailed design response to each space, or provide elements such as park furniture, lighting and a culturally responsive planting palette
- Future development for the residual land in Sydney Street west and Concord Road provides an opportunity for a form of development better suited to the high traffic environment than exists currently, and to provide a well-considered streetscape including street trees
- At the two ventilation facilities:
  - The western ventilation facility, which comprises a large, visually prominent and uncharacteristic element within the suburban setting, particularly when viewed from the low and medium density residential precinct to the north. This element can be expected to create a high level of visual impact from both the environs of the Our Lady of the Assumption Catholic Church and nearby residences in the short term, which would be expected to reduce as the proposed landscape treatment matures
  - The eastern ventilation facility, which is visually well placed with regard to its bulk and scale in the way that it addresses this major intersection, and comprises part of an architecturally integrated ensemble. Initially it would be visually prominent from the adjoining Walker Avenue residential precinct, particularly from those residences on the opposite side of the street. However, over time the visual prominence of these structures would be expected to diminish
- Both of the ventilation facilities would benefit from careful consideration of the placement of street trees as discussed within the mitigation measures
- Residual pocket of land adjoining the project from previous M4 works have in some instances fallen into disrepair. If feasible, consideration could be given to including these residential edge areas within a project design, which comprehensively addresses these edge/residential precinct issues, providing a legacy open space outcome for the project
- Some of the above considerations regarding space within the project for vegetative screening, and landscape character and functional integration issues with adjoining residential precincts may benefit from a collaborative design approach with the relevant councils.

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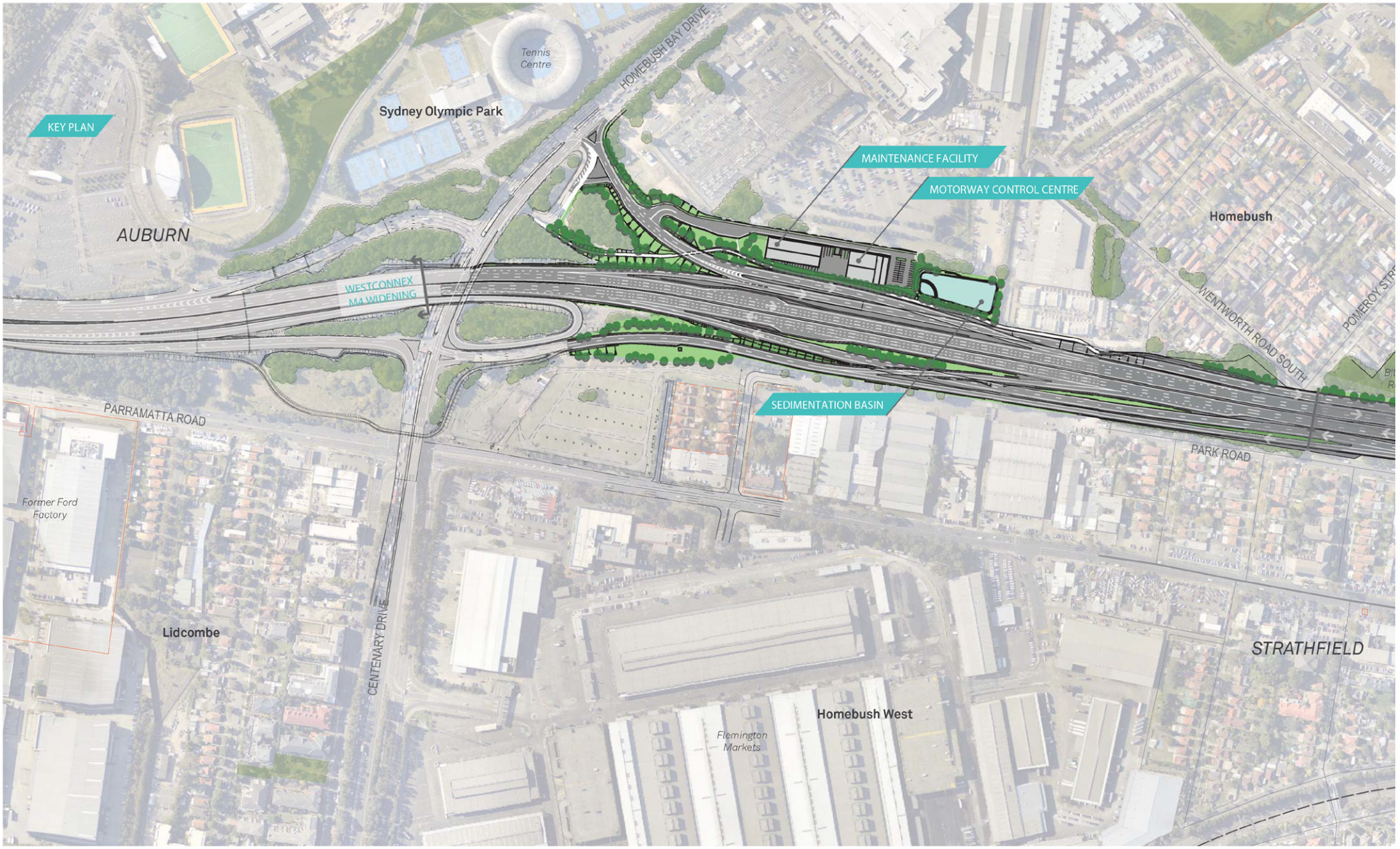
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Appendix A Urban design concept plans



LEIGHTON
SAMSUNG
SAMSUNG C&T
John Holland
WestConnex


CANADA BAY
CANADA BAY
North Strathfield
Strathfield
CONCORD ROAD
QUEEN STREET
NORTHERN LINE
PRINCESS AVENUE
CARRINGTON STREET
SYDNEY STREET
ALLEN STREET
GEORGE STREET
POMEROY STREET
UNDERWOOD ROAD
ISMAY AVENUE
Ismay Reserve
Bill Boyce Reserve
Catholic Church
Bakehouse Quarter (Former Arnott's Complex)
Concord Baptist Church
Concord Uniting Church
Powells Creek
Allen Street Reserve
ELECTRICAL SUBSTATION
VENTILATION OUTLET
POWELL STREET
ELECTRICAL SUBSTATION
FIRE PUMP & WATER TANKS
PARRAMATTA ROAD
Western Line
Homebush Station
LEICESTER AVENUE
WOODSTOCK AVENUE


Queen Elizabeth Park
Goddard Park
Stormwater Canal
St Lukes Park
Bowling Greens
Tennis Courts
Concord Oval
GIPPS STREET
Concord
ALEXANDRA STREET
LLOYD GEORGE AVENUE
COLES STREET
MELBOURNE STREET
JOHN STREET
BROUGHTON STREET
LANSDOWNE STREET
BURWOOD ROAD
LOFTUS STREET
BURTON STREET
Retirement Village
St Mary's Church and School
FRANKLIN STREET
DALY AVENUE
ADA STREET
Bath Arms Hotel
PARRAMATTA ROAD
ESHER STREET
SHAFTESBURY ROAD
LUKE AVENUE
MILTON STREET
SWAN AVENUE
MOSELY STREET
ROBERTS STREET
PHILLIP STREET
WENTWORTH ROAD
GRANT HAY STREET
NEICH PARADE
Burwood
ARCHER STREET
NEW STREET
BURWOOD
Philip Street Conservation Area
Mosely Roberts Streets Conservation Area
01
02
03
04
05


CANADA BAY
Canada Bay
Tennis Courts
Five Dock
Rosebank College
QUEENS ROAD
GIPPS STREET
SPENCER STREET
PARRAMATTA ROAD
WILLIAM STREET
REGATTA ROAD
HARRIS ROAD
COURLAND STREET
LAVENDER STREET
YORK AVE
ARLINGTON STREET
TAYLOR STREET
WALKER STREET
Canada Bay SES
WYCHBURY LN
WYCHBURY AVENUE
ALFRED STREET
SHORT STREET
LANG STREET
DALMAR STREET
BYRON STREET
SCOTT STREET
SOPHIA LN
CROYDON ROAD
WEST STREET
LUCAS ROAD
CHELTENHAM ROAD
ACTON STREET
BROGAN STREET
KINGSWOOD STREET
ALEXANDRA AVENUE
HAMMAND AVENUE
BURNS STREET
SUNBEAM AVENUE
Croydon
ASHFIELD
ROYCE AVE
Cheltenham Road Park
Ironcove Creek
01 WATER TREATMENT PLANT
02 SEDIMENTATION POND
03 ELECTRICAL SUBSTATION
04 FRESH AIR SUPPLY FACILITY
05 RELOCATED HOCKEY FIELD


CANADA BAY
Ironcove Creek
Reg Coady Reserve
WARATAH STREET
MARTIN STREET
FUTURE M4-M5 LINK TUNNEL
RAMSAY STREET
YORK AVE
ARLINGTON STREET
GREAT NORTH ROAD
Five Dock
HARBARBROOK AVENUE
Croker Park
HENLEY MARINE DRIVE
Jegorow Reserve
NORTHCOTE STREET
WOLSELEY STREET
CROYDON ROAD
WEST STREET
SUNBEAM AVENUE
Haberfield
ASHFIELD
ALT STREET
Algie Park
Haberfield Conservation Area
WALKER AVENUE
PAGE AVENUE
EARLE AVENUE
Ashfield
JOINS FOLLOWING IMAGE
PARRAMATTA ROAD
Haberfield Primary School
01
02
03
04
01 VENTILATION OUTLET
02 AIR SUPPLY INLET
03 FIRE PUMP & WATER TANKS
04 ELECTRICAL SUBSTATIONS
*INCLUDES ALL FACILITIES FOR FUTURE STAGES OF WESTCONNEX



LEGEND

- CUT / FILL EMBANKMENT
- TUNNEL ALIGNMENT
- TUNNEL ENTRY & EXIT POINT
- RETAINING WALL
- EXISTING MINOR / MAJOR ROAD
- RAIL LINE / TRAIN STATION
- AUBURN — LOCAL GOVERNMENT AREA
- Concord — SUBURB
- Ashfield Park — LOCALITY
- CREEK LINE / CANAL
- HERITAGE ITEM
- HERITAGE CONSERVATION AREA
- COMMUNITY LOCALITY
- FUTURE LAND USE TO BE DETERMINED
- EXISTING GREEN OPEN SPACE
- EXISTING VEGETATION
- VENTILATION OUTLET

INDICATIVE & PRELIMINARY LANDSCAPE CONCEPT

- GENERAL TREE PLANTING
- STREET TREE PLANTING
- GROVE TREE PLANTING
- BULKY SCREEN PLANTING
- MASSED PLANTING
- MASSED PLANTING ON STRUCTURE
- TURF
- TURF ON STRUCTURE
- SEDIMENTATION BASIN

JUNE 2015

0 20 40 60 80 100 200m

Aerial imagery: Sep-Oct 2014

LEIGHTON SAMSUNG SAMSUNG C&T John Holland

WestConnex

Appendix B Non-Aboriginal heritage mapping

Annotated non-Aboriginal heritage mapping with numbered relevant heritage items



Figure 6.1 Non-Aboriginal heritage items and heritage conservation areas - Homebush

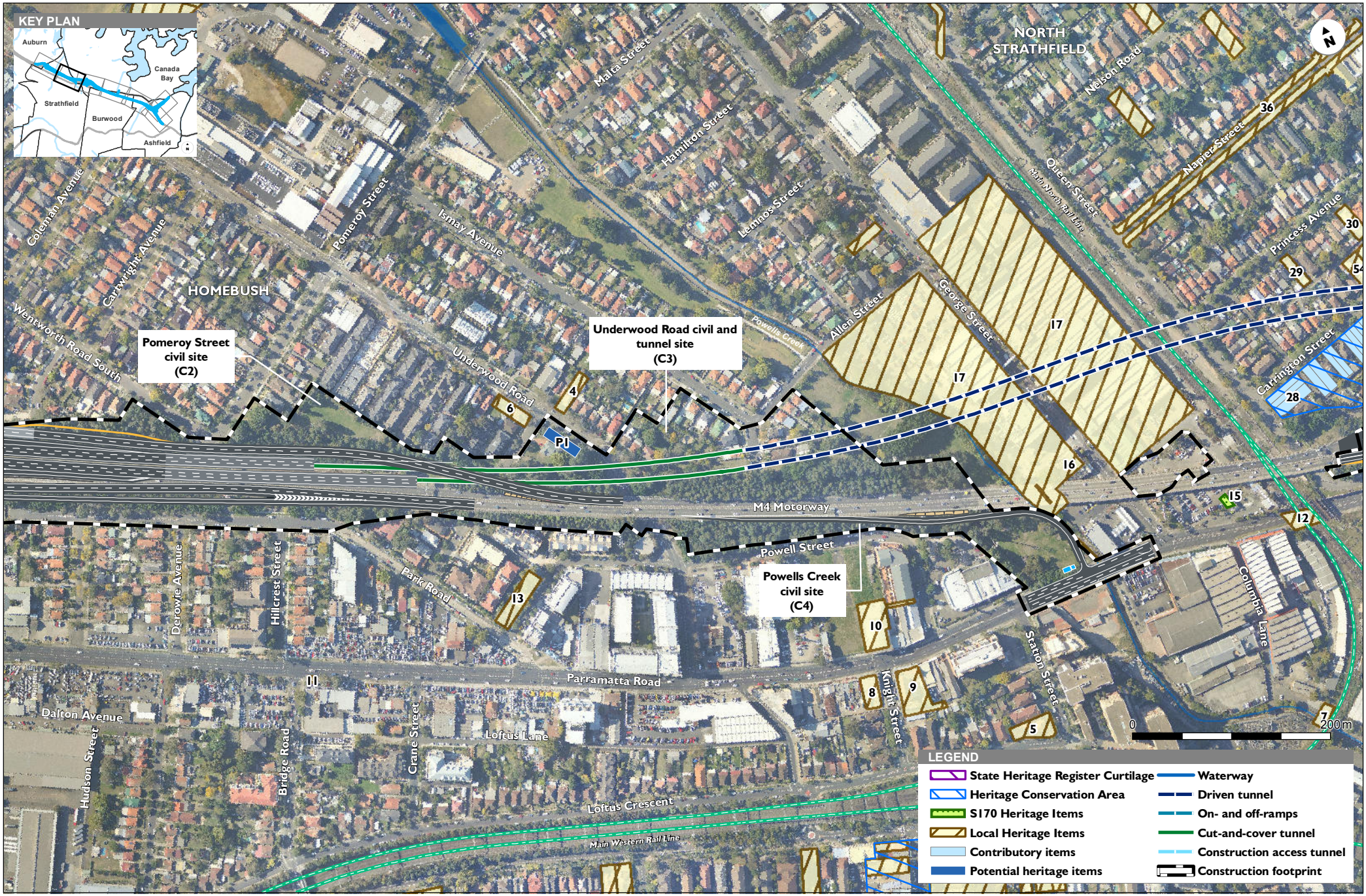


Figure 6.2 Non-Aboriginal heritage items and heritage conservation areas - North Strathfield



Figure 6.3 Non-Aboriginal heritage items and heritage conservation areas - Concord



Figure 6.4 Non-Aboriginal heritage items and heritage conservation areas - Cintra Park



Figure 6.5 Non-Aboriginal heritage items and heritage conservation areas - Five Dock and Croydon

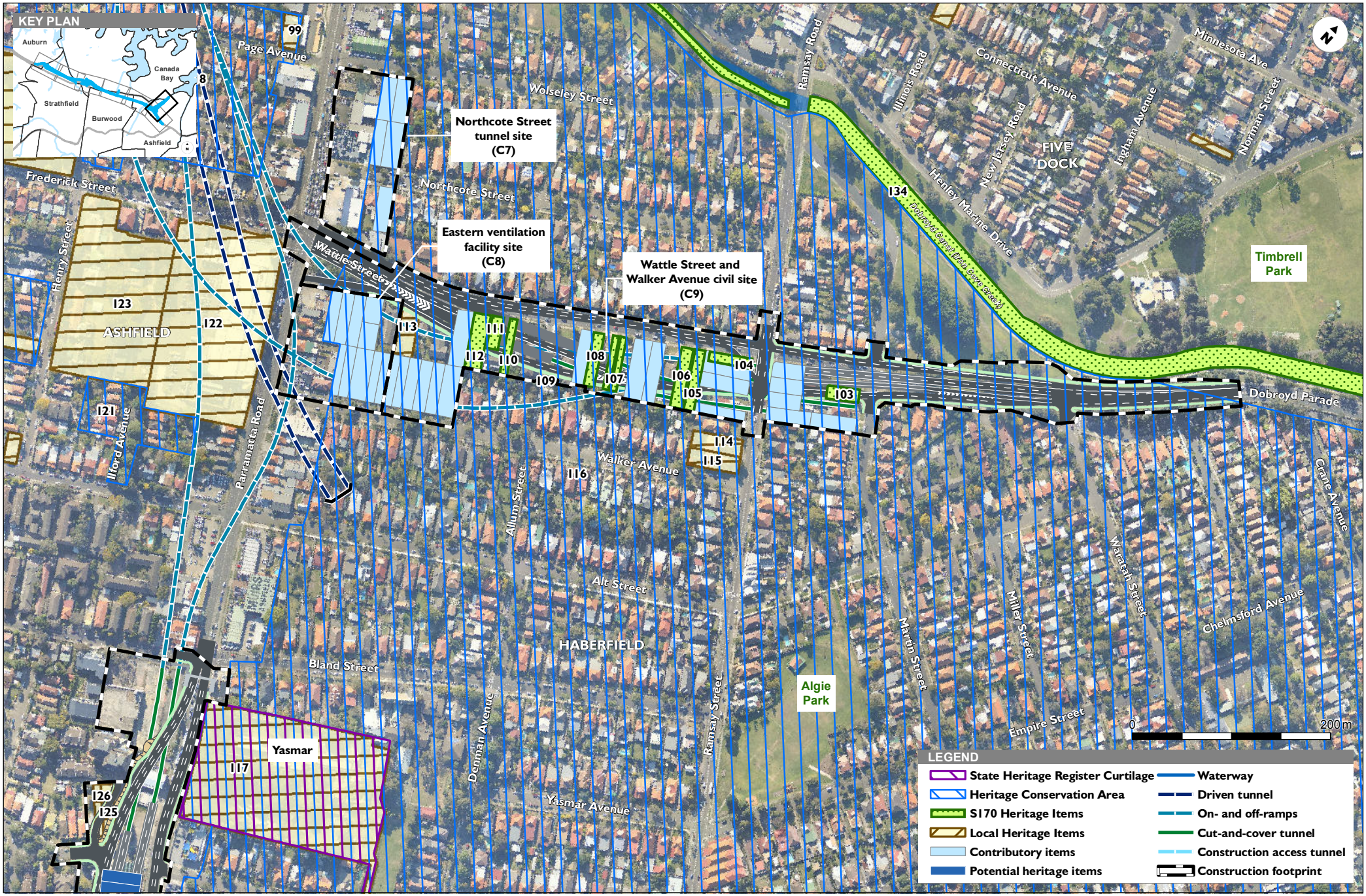


Figure 6.6 Non-Aboriginal heritage items and heritage conservation areas - Haberfield and Ashfield

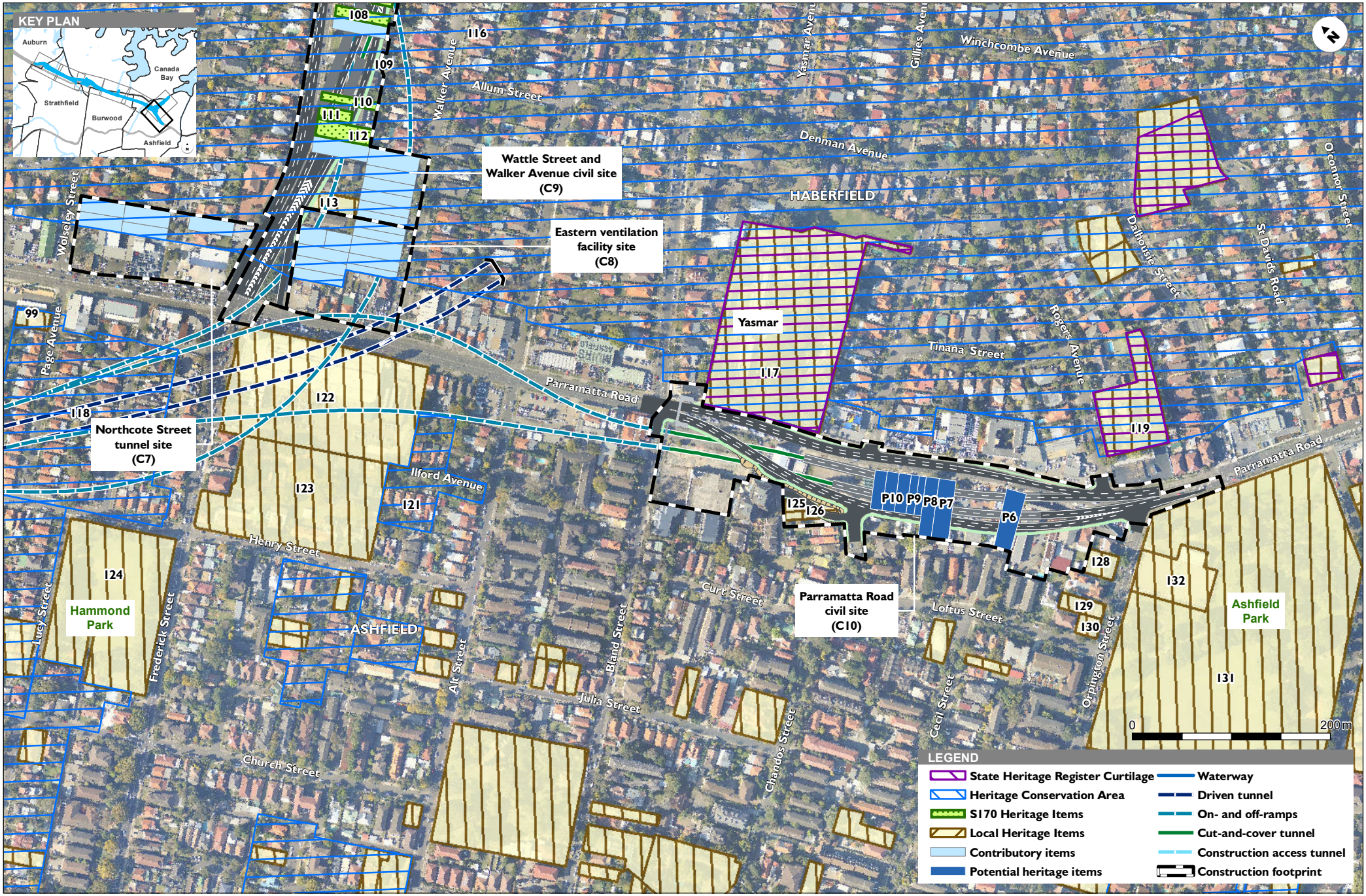


Figure 6.7 Non-Aboriginal heritage items and heritage conservation areas - Haberfield and Ashfield

Appendix C WUDF assessment

The tables below provide a legible comparison of the urban design objectives and principles of both the proposal and the WUDF.

Table B.1 Framework Objective 1 assessment table

Framework Objective 1: Leading edge environmental responsiveness		Preferred design urban design objective	Assessment
Planning, design, construction and long-term management shall be based upon a natural systems approach which is responsive to the environment and promotes the highest levels of sustainability.		The preferred design has prioritised minimising land acquisitions and optimising land use to reconnect communities and maximise opportunities for urban revitalisation along the alignment.	This preferred design objective is consistent with the WUDF. The proposal has improved on the geometry of the reference design to reduce the project footprint. In the next design phase further spatial efficiencies will be explored. A 'natural systems' approach will be an ongoing feature of the design as it evolves.
1.1	Consider the concept of 'green infrastructure' and its possible application to the project.	Protect and retain as much existing vegetation as possible to minimise the footprint, maximise vegetated screening and reduce community concerns over loss of green space and green links.	The preferred design seeks to maximise opportunities for vegetated screening as part of its approach to 'green infrastructure'. As the project evolves further aspects of a 'natural systems' approach will be explored.
1.2	Where possible, restore or re-establish fragmented vegetation and ecologically endangered plant communities. Where possible create additional public open space and enhance existing open space in and around the motorway corridor communities (ie Cumberland Plain Woodland).	Using only containerised planting stock to facilitate rapid establishment of new landscape installations. Feature plant species that reinforce local Cumberland Plain indigenous plant communities.	The use of Cumberland Plain Woodland species is an appropriate response to re-establish fragmented and endangered eco-systems. Notwithstanding the benefit of re-establishing endemic species, where appropriate, the use of domestic and cultural landscape species will also be developed in the next phase of design.
1.3	Protect and enhance waterways, re-establishing green corridors along existing creek lines where possible.	Use appropriate vegetation treatments appropriate to reinforce key landscape patterns.	This preferred design principle is supportive of the WUDF.
		Key elements such as retaining walls and noise walls would have a textured surface with an anti-graffiti paint to discourage vandalism.	This preferred design principle relates to WUDF Objective 1 'Leading edge environmental responsiveness'.

Framework Objective 1: Leading edge environmental responsiveness		Preferred design urban design objective	Assessment
1.4	Balance the composition of built form and landscape to maximize planting opportunities by ensuring appropriate slope gradients (1V:3H maximum) that allow successful plant establishment and ability to access and maintain long term.	Balance the composition of built form and landscape by maximising planting opportunities that visually compete with the scale of the proposed infrastructure elements.	This preferred design principle is consistent with the WUDF. The proposal seeks to adopt slopes in a range from 4H:1V to 2H:1V. Maximum grades of 3H:1V are preferred for plant establishment. Where these grades cannot be achieved because of spatial constraints a combination of retaining walls and 3H:1V grades will be considered.
1.5	Maximise opportunities for carbon sequestration, through planting trees on residual lands non critical to motorway operations.		Initiatives for carbon sequestration will be considered as the detailed design evolves.
1.6	Integrate (embed) sustainability principles and technologies into design thinking, detailing and delivery to help offset environmental footprint of the motorway. Explore the potential to incorporate the latest advances in material sciences, solar energy and water sensitive urban design initiatives (WSUD).		Opportunities for sustainable design and WSUD will be further explored in the detailed design stage of the proposal.
1.7	Ensure a robust, durable, long life, low cost, minimal maintenance outcome that deters vandalism.		The preferred design demonstrates the application of this principle, which will be carried through into the detailed design phase.
1.8	Where possible, preserve wide margins and space along the road corridor to safely create an ‘urban forest’ along the motorway. This will improve the environmental performance and physical aesthetic of the motorway by controlling the micro-climate, creating habitat and biodiversity, allowing for water infiltration to recharge aquifers and reducing the heat island affect.	Where possible, preserve wide margins and space along the road corridor to safely create an ‘urban forest’ along Parramatta Road.	This design principle is aligned with the WUDF. In the next design phase further opportunities for structure planting along the road corridor will be explored.

Table B.2 Framework Objective 2 assessment table

Framework Objective 2: Connectivity and legibility		Preferred design urban design objective	Assessment
Build connectivity across the city, beyond the boundaries of the motorway corridor and promote increased legibility of places, buildings, streets and landmarks.		The project will create a simple, legible and inviting design solution that will build connectivity across the city, within and beyond the boundaries of the motorway, enhancing journeys for motorists, pedestrian and cyclists alike.	The preferred design provides opportunities to enhance connectivity for all users, including cycle and pedestrian connections. In the next stage the design will be developed to include further details, including connections with bus stops.
2.1	Provide visual stimuli within the road corridor appropriate to the posted speed that creates a progressive sequence of visual events, within and without the corridor, and an enhanced view of the road.	Reinforce the legibility of landmarks such as Sydney Olympic Park, Concord Road interchange and the Parramatta Road interchange.	This design principle is consistent with the WUDF. The proposed intersections will be highly legible due to the scale and sequence of the interventions. The detailed design approach is simple and appropriate to that scale. Details of motorway navigation will be further refined in the next stage of design.
2.2	Provide architectural articulation to the horizontal and vertical surfaces, materials and the lighting of motorway tunnels to visually and psychologically break up the extent of tunnel lengths.	Provide visual stimuli within the tunnel that creates a progressive sequence of visual events for the motorist.	This preferred design principle is consistent with the WUDF. The detailed design approach is simple and appropriate to the scale and speed of movement through the tunnels.
		Provide architectural articulation to horizontal and vertical surfaces, materials and the lighting of tunnels to visually and psychologically break up the extent of tunnel lengths.	This preferred design principle is consistent with the WUDF. Further design details, such as 'location identifiers' and tunnel lighting, will be confirmed and refined in the next stage of design.
2.3	Provide visual cues for drivers to understanding their vertical and horizontal location in relation to the urban setting through the form, materials, finishes, lighting of the motorway.		This WUDF design principle is also covered in 2.2 above, and subject to further design development in the next stage of design.

Framework Objective 2: Connectivity and legibility		Preferred design urban design objective	Assessment
2.4	Clearly articulate motorway transition zones (eg above/below ground, on/off ramps, intersections) and the early warning of decision making points.		The preferred design adopts a road geometry that is self-explanatory and navigation intuitive. Areas of sensitivity such as tunnel portals (the transition from full sunlight to dark tunnel with no light transition) and wayfinding in complex zones such the M4 (approaches to viaducts and portals), will be further refined in the next stage of design.
2.5	Where possible, promote opportunities to `read the landscape' by providing visual access to/over water bodies and broader views.		The preferred design proposes the use of transparent noise walls where appropriate.
2.6	Reinforce road user safety by designing for movement within the corridor through landscape and built form to promote appropriate driver behaviour (ie to travel at appropriate speeds, slow down or merge).	Enhance shared paths to provide safe and seamless journeys for pedestrians and cyclists around tunnel entry and exit points.	This preferred design principle is consistent with the WUDF. Details of cycle and pedestrian connectivity with existing networks beyond the project boundary will be confirmed in the next stage of design.
2.7	Provide a simple and effective wayfinding and signage strategy that is appropriately located and designed in unison with all regulatory and operational signage requirements.	Provide self-explanatory roads and ease of wayfinding through simple and refined treatments of tunnel entry and exits, tunnel portals and facilities to make an enjoyable and legible journey for motorists.	Road systems within the preferred design are as simple and as 'self-explanatory' as possible. Motorway wayfinding in complex zones such the M4 and Concord Rd interchange will adopt an efficient and well-considered signage strategy.

Table B.3 Framework Objective 3 assessment table

Framework Objective 3: Place making		Preferred design urban design objective	Assessment
Create beautiful places, streets, structures and landscapes that draw their form, character and materiality from local context, the intrinsic natural and cultural qualities of each locale.		The project will add to local places, streets, structures and landscape and minimise impacts on the local community through the below design treatments:	This preferred design principle is consistent with the WUDF.
3.1	Ensure public places are beautiful, high quality, engaging and functional.	Using high quality and functional materials.	The preferred design applies this principle to all urban design elements.
		Activating the edges of public spaces through the design and by considering pedestrians and cyclists and adjacent land uses. Visually recede existing retained and new elements through using mid to dark tones whenever appropriate to minimise visual impacts.	The preferred design has considered adjacent land uses. Opportunities for pedestrian activation will be further explored in alignment with future residual land development.
3.2	Respond to the intrinsic natural and cultural qualities of each locale through form, colour, character and materiality.		The preferred design adopts a respectful architectural language, using materials of high quality, for the major urban design features such as vent stacks and tunnel portals.
3.3	Retain and protect valuable natural and cultural features.		The preferred design is respectful of natural and cultural features.
3.4	Optimise access to sunlight, daylight, breezes and views.		The preferred design is sensitive to issues of microclimate and adopts optimum solar access wherever possible.
3.5	Activate the edges of public places with complimentary activities and land uses.		There are no details provided as to how this principle is to be applied.
3.6	Integrate the interfaces (eg levels, utilities, servicing, entry and access points) with adjacent urban renewal opportunities to benefit the community.		Urban renewal opportunities are provided for in the preferred design by identifying residual land for that purpose. Opportunities for pedestrian activation will be further explored in alignment with future residual land development. The programing of public realm components will be further explored in the next phase of design.
3.7	Engage with communities, artists and local precinct groups in the design of the motorway, its places and precincts.		Opportunities to engage with communities, artists and local precinct groups will be considered in the next phase of design.

Framework Objective 3: Place making		Preferred design urban design objective	Assessment
3.8	Investigate opportunities for the redevelopment and renewal of surplus land holdings along the corridor.	Offering opportunities for the redevelopment and renewal of surplus land holdings along the corridor	Urban renewal opportunities are provided for in the preferred design by identifying residual land for that purpose. Details of future development, land uses, heights densities etc will be explored in the next stage of design.

Table B.4 Framework Objective 4 assessment table

Framework Objective 4: Urban renewal and liveability		Preferred design urban design objective	Assessment
Enable opportunities for urban renewal and provide high levels of urban amenity and liveability.		The preferred design has considered and integrated design with the local movement networks, places and land uses to enable opportunities for urban renewal and to create a more attractive place to live, work and socialise.	Urban renewal opportunities are provided for in the preferred design by identifying residual land for that purpose. Areas of proposed public realm have also been identified, for example at the Concord Road portal. Further details of land use and activation will be provided in the next stage of design.
		The design has prioritised minimising land acquisitions and optimising land use – to reconnect communities and maximise opportunities for urban revitalisation along the alignment.	The design intent is to minimise land acquisition. The next stage of design will demonstrate how communities will be reconnected and/or urban revitalisation maximised.
4.1	Examine strategies to achieve long-term reduction of local traffic volume, congestion, pollution, vibration and noise.	The preferred design aims to avoid ‘isolated land’ and remove through traffic by removing surface traffic which will achieve long term improvement in air quality and noise on surface roads and streets which support pedestrian activity.	This preferred design principle is aligned with the WUDF objectives.
4.2	Develop strategies to eliminate visual clutter and encourage the removal of extraneous and unnecessary signage and advertising from local buildings, streets and places.	Consolidating and simplifying structures and alignments to enhance surrounding areas.	This preferred design principle is aligned with the WUDF objectives. The minimalist architectural expression of major urban design elements further reinforces these design principles.

Framework Objective 4: Urban renewal and liveability		Preferred design urban design objective	Assessment
		Improving access to public and active transport. Restoring local street, pedestrian and bus connectivity (a regular street edge).	The next stage of design will demonstrate how pedestrian and bus connectivity can be improved by the project.
4.3	Wherever possible undertake footpath widening and the installation of a high quality suite of urban elements (eg street furniture, lighting, signage and pavements).	Widening footpaths to improve amenity for pedestrians and cyclists	This preferred design principle is aligned with the WUDF objectives. The full extent of footpath widening will be confirmed in the next stage of design.
		Featuring coloured built elements to add interest and identity.	This preferred design principle is aligned with the WUDF objectives and expressed in the architectural language of the project.
4.4	Encourage the development of active land uses (commercial, community, retail and recreational) at ground level and the passive surveillance of public spaces.	Considering the future land use of existing commercial areas that could potentially be rejuvenated – to be developed during detailed design.	Urban renewal opportunities are provided in the preferred design by identifying residual land for that purpose. Further details of land use and activation will be provided in the next stage of design.
4.5	Provide extensive tree planting of endemic species to achieve continuous tree canopy cover for shade, shelter and habitat creation.	Providing extensive tree planting of endemic species to achieve tree canopy cover for shade, shelter and habitat. Maintaining vegetated screening by reducing existing vegetation loss and enhancing existing vegetation screening by utilising similar plant species where possible.	The preferred design principle of providing endemic tree species is appropriate to those areas of the project adjacent to sensitive ecological zones. In areas that interface with the cultural plantings of existing residential zones it is appropriate to enhance that existing planting with like species. The next stage of design development will provide further detail of the range of appropriate plant species to be provided.
4.6	Provide sufficient space at intersections (on- and off-ramps) and overpasses to promote connectivity between modes and to improve the amenity and liveability of adjacent communities.		The preferred design provides sufficient space to achieve this principle. Further details will be developed in the next design stage.
4.7	Consider the needs of aging populations, young families and the physically impaired to ensure equitable access and easy movement for all.		The preferred design addresses the requirements and appropriate design standards for universal access.

Framework Objective 4: Urban renewal and liveability		Preferred design urban design objective	Assessment
4.8	Where possible create additional public open space and enhance existing open space in and around the motorway corridor.	Creating additional public open space and enhances existing open space in and around the project corridor, especially at Concord Road interchange.	Areas of proposed public realm have been proposed in the preferred design, for example at the Concord Road portal. Further details of activation and programing, including the enhancement of existing adjoining open spaces, will be provided in the next stage of design.
4.9	Consider the impact of the motorway on urban renewal opportunities by ensuring no dead zones are created or the sterilisation of development opportunities.		The preferred design identifies redevelopment opportunities as residual lands. No sterile or dead zones are created that may compromise these opportunities.
4.10	Investigate urban renewal on surplus lands and the selective initiation of land development on identified catalyst sites.		Urban renewal opportunities are provided for in the preferred design by identifying residual land for that purpose. The next stage of design will identify future land uses and opportunities for development activation.

Table B.5 Framework Objective 5 assessment table

Framework Objective 5: Memorable identity and a safe, pleasant experience		Preferred design urban design objective	Assessment
Provide a memorable project identity and experiences for road users and adjacent stakeholders which are safe, convenient and enjoyable.		The preferred design will provide a memorable identity and provide a high quality user experience for road users and adjacent stakeholders through.	This preferred design objective is aligned with the WUDF.
5.1	Develop a whole of project design philosophy and response that will deliver a consistent product using a unified approach to the form, detailing, fabrication and construction of all motorway and urban design elements but which also affords opportunities for local modulation to reflect the particular character of each locale.	Keeping a simple and consistent language of built elements and components to minimise visual clutter.	This design principle is consistent with the WUDF and has been demonstrated in the preferred design of all urban design elements.
5.2	Ensure that all design solutions safeguard the safety and convenience of the road users and adjacent stakeholders.		A safety in design and CPTED review of the preferred design will included in the next stage of design.

Framework Objective 5: Memorable identity and a safe, pleasant experience		Preferred design urban design objective	Assessment
5.3	Amplify design at key locations such as portals, junctions, bridges and river crossings.		The preferred design of key locations will be further developed in subsequent design stages. In particular, the application of integrated street improvements at the interface with existing neighbourhoods will be carefully considered.
5.4	Create distinctive portal access points that reinforce the character of the local area.	Creating distinctive portal access points that reinforce the character of the local area, but also being respectful to each individual setting.	This preferred design proposed for tunnel portals is simple, elegant and appropriate to the various settings.
5.5	Explore the differentiation of character zones within the tunnel zone between portals to vary driver experience and heighten awareness.	Differentiating character zones and breaking up tunnel lengths to vary the driver experience and heighten awareness of geographical location through lighting, signage and art.	This preferred design principle is consistent with the WUDF and is well demonstrated in the tunnel design.
5.6	Use landscape to define different character zones from broad landscape regeneration through to impact landscape design (ie airport and Sydney Olympic Park).		Detailed planting palettes, including non-endemic species, that respond to existing landscape character will be further developed in the next design stage.
5.7	Maximise opportunities to provide a well vegetated 'green' corridor by providing substantial accessible space, protecting existing vegetation and avoiding small unmaintainable spaces.	Maximising opportunities to provide a well vegetated 'green' corridor by providing substantial accessible space at Concord Road, protecting existing vegetation and avoiding small unmaintainable spaces.	This preferred design principle is consistent with the WUDF. The next stage of design will further consider issues of accessibility and activation within the proposed areas of public realm and explore opportunities for additional road corridor screen planting.

Table B.6 Framework Objective 6 assessment table

Framework Objective 6: A new quality benchmark		Preferred design urban design objective	Assessment
Provide design and construction quality of world class standard. The project shall establish a new benchmark for integrated sustainability, engineering, art, architecture and urban design.		The preferred design will deliver a world-class solution for the project that sets a new benchmark in the travel experience. The design will establish an identity for the existing M4 and future stages.	By adopting a consistent, high quality, design approach to tunnel portals and other urban design elements the preferred design achieves an urban design identity for the motorway that could also be adopted by future stages.
6.1	The project shall establish a new benchmark in urban transport and renewal in Australia and embrace world's best engineering, architecture and urban design practice.		The preferred design provides for building architecture, portal elements, tunnel linings, noise walls and retaining walls of high quality, and as such makes a positive contribution to the quality benchmark for the whole project.
6.2	Provide a simple and elegant design beautifully integrating with built and landscape elements which clearly express materials, refined simplicity of form and function.	Integrating the various existing and proposed new built form elements such as the dive structures, portals, noise walls and retaining walls to reinforce an integrated design solution that enhances visual unity and clarity.	This design principle has been demonstrated in the preferred design proposal for building architecture, portal elements, tunnel linings, noise walls and retaining walls. Similar quality benchmarks for remaining elements such as the motorway bridges and viaducts will be explored in the next stage of design.
6.3	Use robust, high quality and durable materials appropriate to the urban setting and avoid opportunities for vandalism.	Utilising durable and high quality materials to ensure the motorway maintains its identity for years to come.	This design principle has been demonstrated in the preferred design for portal elements, tunnel linings, transparent noise walls and retaining walls. In the next detailed design stage the principle will be applied to the design of bridges, viaducts, concrete noise wall panels and the materiality of components in general.
6.4	All visible motorway operation fittings, fixtures and equipment shall be considered as a complete set of integrated urban design elements.		The preferred design has set the framework to enable the application of this principle in the detailed design stage.

Framework Objective 6: A new quality benchmark		Preferred design urban design objective	Assessment
6.5	Define and implement an urban art strategy for the entire project, providing a clear vision and set of controls for an integrated artist response that is contextually relevant, resists an ad-hoc, fussy, plastering approach and ensures road safety.		An urban art strategy has not yet been included in the preferred design.
6.6	Adopt a design verification procedure using an eminent design and sustainability review panel to ensure design quality throughout each stage of works, from briefing to handover.		A design verification procedure will be included in all future stages of design.
6.7	Validate design and documentation using full-scale prototypes.		A design and documentation validation procedure will be included in all future stages of design.