Prepared for
Transport for NSW
ABN: 18 804 239 602

Elizabeth Drive - East Upgrade

Air Quality Impact Assessment

08-Sep-20232
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Client: Transport for NSW

ABN: 18 804 239 602

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Glossary and abbreviations

Term	Description
Construction ancillary facilities	Dedicated areas of land required for construction amenities, parking, materials/equipment storage, mobile asphalt batch plants and stockpiling.
Proposal	The upgrade of about 7.8 km of Elizabeth Drive between Badgerys Creek Road near the future M12 Motorway and about 600 m east of Duff Road at Cecil Hills.

Acronym	Definition
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ADR	Australia design rule
AEI	NSW EPA Air Emissions Inventory
ART	Articulated truck
ASS	Acid Sulfate Soils
AWS	Automated weather station
BoM	Bureau of Meteorology
BUSD	Diesel bus
CASANZ	Clean Air Society of Australia and New Zealand
CALMET	The CALMET meteorological model
CEMP	Construction Environmental Management Plan
CO	Carbon monoxide
CORINE	Coordination on Information for the Environment land cover codes
DEM	Digital elevation model
DLCV	Diesel light commercial vehicle
DPE	NSW Department of Planning and Environment
DPV	Diesel passenger vehicle
EF	Emission factor
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPA	NSW Environment Protection Authority
EPL	Environment protection licence
GIS	Graphical Information System
GMR	Greater metropolitan region (Sydney)
GPG	Good Practice Guide
GRAL	Graz Lagrangian Model
GRAMM	Graz Mesoscale Model
HDV	Heavy duty vehicles

Acronym	Definition
IAQM	Institute of Air Quality Management (United Kingdom)
ICSM	Intergovernmental Committee on Surveying and Mapping
km	kilometres
LCV	Light commercial vehicle
LDV	Light duty vehicles
LEP	Local Environmental Plan
LGA	Local Government Area
m	metres
m^3	Cubic metre
MTO	Match To Observations
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
NPI	National Pollutant Inventory
O_3	Ozone
OEH	NSW Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment
OLM	Ozone limiting method
PEF	Potency equivalency factors
PEP	Protection of the Environment Policy
PLCV	Petrol light commercial vehicle
$PM_{2.5}$	Particulate matter equal to or less than 2.5 microns in diameter
PM_{10}	Particulate matter equal to or less than 10 microns in diameter
POEO	Protection of the Environment Operations (Act)
PPV	Petrol passenger vehicle
PV	Passenger vehicle
RBF	Radial basis function
RIG	Rigid truck
SA1	Statical Area Level 1
SA2	Statical Area Level 2
SCF	Speed correction factor
SO_2	Sulphur dioxide
SYD	Sydney
TRAQ	Tool for Roadside Air Quality
TSIG	Transport Special Interest Group
TVOC	Total volatile organic compounds

Acronym	Definition
VOCs	Volatile organic compounds
WSA	Western Sydney Airport
$\Delta PM_{2.5}$	Incremental increase in annual ground level $PM_{2.5}$ concentration
µg	micrograms

Executive Summary

Elizabeth Drive is the main east-west corridor between Liverpool and surrounding suburbs. Future proposed and planned growth in this region of Western Sydney is expected with the planned development of the Western Sydney Airport (WSA) precinct, as well as related planned land releases for residential precincts and employment zones in the area.

This proposed growth would require the upgrade of Elizabeth Drive to provide increased capacity between the existing and planned road corridors in the surrounding area, and to support the proposed and planned development of the Western Sydney Aerotropolis. Transport for NSW proposes to upgrade about 7.8 kilometres of Elizabeth Drive between Badgerys Creek Road near the future M12 Motorway and about 600 metres east of Duff Road at Cecil Hills (the proposal).

Currently, the 7.8 kilometres of the proposal is predominantly a two-lane undivided road with no footpath and no median.

Subject to detailed design and construction planning, construction of the proposal is anticipated to take about 48 months to complete.

This air quality impact assessment report (this report) has been prepared as part of the Review of Environmental Factors (REF) prepared for the proposal. This report assesses the potential impacts to air quality due to the construction and operation of the proposal. The findings of this report are summarised below.

Construction impact assessment:

- An assessment of potential construction phase air quality impacts for the proposal was carried out in accordance with UK Institute of Air Quality Management's *Guidance on the assessment of dust from demolition and construction* (IAQM 2014). Construction activities for the proposal were quantified in terms of dust emission magnitude for construction, demolition, earthworks, construction and trackout.
- Risk of dust soiling, human health effects, and ecological effects were examined for the proposal and are summarised as follows:
  - The sensitivity of the area was determined to be 'high' for human receptors and 'high' for ecological receptors.
  - The overall risk for construction, demolition, earthworks, construction and trackout components are predicted to be 'medium' to 'high' for dust soiling, human health effects and ecological effects.
  - Mitigation strategies were identified and, with these in place, residual impacts due to construction dust are expected to be minimal.
- A quantitative assessment of combustion emissions from construction vehicle engines was carried out. Overall, potential air quality impacts are not expected to be significant.
- A qualitative assessment of potential odour emissions from the construction of the proposal was carried out. There is an extremely low probability for intercepting acid sulfate soils (ASS) across the study area and, as a consequence, the likelihood of odour impacts due to ASS would be negligible. There is the potential for odorous contaminants, such as petroleum hydrocarbons, to be contained with uncontrolled fill that is present along the alignment, and in areas of former and current agricultural land use. There are also three petrol stations, an auto repairs shop and a recycling park along the proposal alignment. There is the potential for contaminated soil to be present near these locations. Further sampling is required to determine the extent of any such contaminants. However, appropriate mitigation would likely mean odour impacts associated with the proposal would be minimal.

Operational impact assessment:

- Potential air quality impacts due to the operation of the proposal were assessed quantitatively using the GRAL air dispersion model. The assessment of the proposal was carried out based on a comparison between predicted existing ground level concentrations for the baseline scenario and the future ‘do nothing’ and ‘do something’ scenarios as follows:
  - One ‘baseline’ scenario based on the 2021 existing traffic operations with the existing traffic lane layout (single lane in each direction)
  - Two ‘do nothing’ scenarios for 2030 and 2040, which considered predicted traffic volumes without the proposal and assumed an unchanged traffic lane layout
  - Two ‘do something’ scenarios for 2030 and 2040 which included traffic volumes with the proposal and an upgraded traffic lane layout (2 lanes in each direction).
- The results of the assessment are as follows:
  - Results for all 2030 and 2040 scenarios showed ground level concentrations at sensitive receptors for all pollutants at slightly higher levels than existing 2021 baseline ground level concentrations. This is due to the anticipated increases in the volume of traffic predicted to utilise the proposal.
  - Analysis of the expected change in future pollutant concentrations show that the proposal may result in higher concentrations at sensitive receptors than are expected with the ‘do nothing’ scenarios. Due to limitations in the modelling – namely no consideration of the heavy congestion expected in the ‘do nothing’ scenarios and the exclusion of network roads in all scenarios – ‘do nothing’ concentrations were likely underpredicted in this assessment. It would be expected that actual future ‘do nothing’ concentrations would be much higher than those predicted in this assessment. Based on this, the difference between the proposal (ie the ‘do something’ scenarios) and the ‘doing nothing’ scenarios would be much less than indicated and the proposal would potentially even be beneficial to local air quality at many receptor locations.
  - Overall, air quality impacts due to the operation of the proposal are predicted to be acceptable.

Potential cumulative impacts from the construction of nearby projects were assessed in terms of their potential to impact receptors cumulatively. There were projects in the area that are likely to be under construction with similar timing to the proposal’s construction timeframe. Similar to the proposal, it is likely these projects would be constructed using appropriate dust mitigation strategies and the potential for cumulative impacts is negligible.

Potential cumulative impacts from the operation of WSA and the M12 Motorway were considered. There is the potential for moderate to high short-term concentrations of pollutants in the study area due to the operation of WSA. However, long term concentrations would be lower and unlikely to result in ‘background’ concentrations that would push the predicted cumulative proposal concentrations above their respective criteria; except in the case of annual average $PM_{2.5}$, where background concentrations are already approaching 100 per cent of the criterion. There is also the potential for increases in the background concentrations due to the operation of M12 Motorway, particularly in the area where the M12 Motorway crosses over Elizabeth Drive near Mamre Road. Despite the potential for a higher background and possible exceedances at proposal receptors due to increased background concentrations from the operation of WSA and M12 Motorway, there would be no material effect on the outcome of this assessment. This assessment showed that the proposal would only result in very minor changes to local air quality, compared with the ‘do nothing’ scenario. It was determined that a higher background due to emissions from WSA would not change this finding as the difference between the proposal (ie the ‘do something’ scenarios) and the ‘do nothing’ scenarios would remain unchanged.

A cumulative operational assessment of the proposal and the Elizabeth Drive West Upgrade project showed that cumulative impacts between the two projects would be negligible.

Mitigation measures for the construction phase of the proposal were identified, primarily aimed at reducing the generation and dispersion of dust. With the implementation of these mitigation measures, dust impacts due to the construction for the proposal are not expected to be significant.

Potential air quality impacts from the proposal would be minor when compared with potential changes from ‘doing nothing’ are considered. An assessment of potential construction and operational air quality impacts for the proposal was carried out. The outcome of the assessment indicated that construction and operational air quality impacts from the proposal are unlikely to have a significant impact on ground level air quality concentrations.

1.0 Introduction

Elizabeth Drive is the main east-west corridor between Liverpool and surrounding suburbs. Between Badgerys Creek Road, Badgerys Creek, and east of Duff Road at Cecil Hills, Elizabeth Drive is predominantly a two lane undivided road, with no footpath and no median.

Future projected and planned growth in this region of Western Sydney is expected with the planned development of the Western Sydney Aerotropolis. It is projected that an expansion of industrial and commercial precincts would be prompted in response to the development of the Western Sydney Airport (WSA) precinct, known as the Western Sydney Aerotropolis, as well as related planned land releases for residential precincts and employment zones in the area.

This projected growth would require the upgrade of Elizabeth Drive to provide increased capacity between the existing and planned road corridors in the surrounding area, and to support the projected and planned development of the Western Sydney Aerotropolis.

1.1 Proposal overview

Transport for NSW (Transport) proposes to upgrade about 7.8 kilometres of Elizabeth Drive between Badgerys Creek Road near the future M12 Motorway and about 600 metres east of Duff Road at Cecil Hills. The proposal would connect Elizabeth Drive with the future M12 Motorway connection to the proposed WSA.

The location and extent of the proposal is provided **Figure 1-1**.

FIGURE 1-1:
LOCATION OF THE PROPOSAL

Legend

- 🟥 Construction footprint
- ▭ Operational footprint
- ▭ LGA boundary
- — Road design
- — Primary road
- — Local road

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Imagery © Nearmap 2021.

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1.1 Purpose of this technical report

This air quality impact assessment report provides an assessment of the potential air quality impacts associated with the proposal and has been prepared to inform the review of environmental factors (REF). It contributes to fulfilling the requirements of Section 5.5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) which requires that Transport NSW examine and take into account to the fullest extent possible, all matters affecting or likely to affect the environment by reason of the activity.

2.0 Proposal description

2.1 Key features

Key features of the proposal would include (subject to detailed design):

- Upgrade of Elizabeth Drive from a two-lane rural road, to a four-lane road (two lanes in each direction) with provision of a central median to allow for future upgrade to six lanes
- Signalisation of intersections along Elizabeth Drive: Luddenham Road, Martin Road, Western Road, Devonshire Road, Salisbury Ave, Mamre Road, Range Road and Duff Road
- Replacement of three twin bridges along Elizabeth Drive over Badgerys Creek, South Creek and Kemps Creek
- Active transport provision along the full corridor with the inclusion of shared paths along both sides of the Elizabeth Drive corridor
- Inclusion of public transport infrastructure with bus priority at intersection and bus stops facilities
- New stormwater drainage infrastructure
- Property acquisitions and adjustments on both sides of Elizabeth Drive and some side roads.
- Relocation/adjustment of existing utilities.

2.2 Overview of construction activities

Subject to detailed design and construction planning, construction of the proposal is anticipated to take about 48 months to complete.

Four temporary construction ancillary facilities would be established to support construction of the proposal including at:

- Western Road (construction ancillary facility 1) – located 200 metres south of the Elizabeth Drive and Western Road intersection on the western side
- Bill Anderson Reserve (construction ancillary facility 2) – located on the southern side of the Elizabeth Drive within Bill Anderson Reserve
- Salisbury Avenue (construction ancillary facility 3) – located 100 metres north of the Elizabeth Drive and Salisbury Avenue intersection on the eastern side
- Mamre Road (construction ancillary facility 4) – Located 500 metres north of the Elizabeth Drive and Mamre Road intersection on the eastern side.

Each construction ancillary facility may include the following:

- Establishment of site office/s, amenities, and temporary infrastructure, such as fencing and car parking areas
- Laydown and storage areas, and delivery of plant, equipment and materials
- Secure and bunded storage areas for re-fuelling and chemical storage
- Concrete batching plant
- Material crushing
- Stockpiling areas and spoil management (topsoil, excavated natural material, contaminated material). Stockpile locations would be determined during subsequent design stages using the criteria set out in the Stockpile Management Guideline (RTA, 2015).

Construction of the proposal would involve the following general activities:

- Site establishment including set up of construction ancillary facilities
- Utility adjustments, relocations and replacements, where required

- Demolition of existing buildings/structures
- Property adjustments (eg adjustments to fencing, property accesses)
- Vegetation removal
- Earthworks and drainage work
- Adjustments to existing farm dams within the construction footprint, including dewatering and re-shaping where required
- Bridge work over Badgerys Creek, South Creek and Kemps Creek, including installation of temporary diversion (if required) and temporary creek crossing, construction of new twin bridge structures and demolition/removal of the existing bridges
- Elizabeth Drive upgrade roadwork, including intersections with local roads and walking and cycling infrastructure
- Landscaping and finishing work.

3.0 Key air quality issues for the construction footprint

3.1 Significance of road traffic pollution

Air pollution from road traffic is one of the major sources of air emissions in urban areas and can be associated with a wide range of health effects (see **Appendix A** (Pollutants of interest and their effects)). Traffic congestion increases vehicle emissions and degrades ambient air quality for individuals living near major roadways and within an airshed in general. It is therefore important to identify the key pollutants of interest associated with vehicle emissions and understand the potential air quality impacts associated with the proposal.

3.2 Pollutants of interest

Pollutants of interest from the proposal would include those generated from both the combustion of fossil fuels and from non-exhaust emission sources such as the disturbance of soil generating dust and the generation of dust from the movement of vehicles themselves. The pollutants of interest for the proposal include:

- Nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Particulate matter less than 10 microns in diameter (PM_{10})
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$)
- Volatile Organic Compounds (VOCs) including:
    - Benzene
    - Formaldehyde
    - Toluene
    - Acetaldehyde
    - Xylene
    - 1,3 butadiene
- Polycyclic Aromatic Hydrocarbons (PAHs).

Sulphur dioxide (SO_2) concentrations from vehicle emissions attributed to operation of the proposal are anticipated to be very low due to stringent diesel and petrol fuel quality standards in Australia, which limit sulphur content[1]. On this basis, SO_2 has not been considered further by this assessment.

3.3 Potential sources of air emissions

Key potential sources of air emissions from the proposal addressed in this assessment are as follows:

- Construction dust from various stages of work, including demolition, earthworks, construction activities and the movement of vehicles on the construction site
- Construction plant engine exhaust emissions
- Odour impacts from earthworks during construction
- Vehicle emissions from the operation of the proposal.

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[1] The quality of automotive fuels in Australia is regulated by the *Fuel Quality Standards Act 2000*, the *Fuel Quality Standards Regulations 2001* and the *Fuel Standard (Automotive Diesel) Determination 2001* (updated in 2019). The sulphur content in diesel fuel is limited to 10 ppm. The maximum sulphur content in fuel for petrol is currently 50ppm with a further reduction of the standard to 10ppm scheduled for 2027.

3.3.1 Construction dust

Sources of dust or particulate emissions (PM_{10} and $PM_{2.5}$) during construction can be largely divided into four main categories:

- Demolition work including activites such as:
    - Removal of existing pavement and roadway
    - Demolition of bridge barriers and supports
    - Relocation of utilities and drainage infrastructure
    - Windblown dust from exposed surfaces and stockpiles
- Earthworks including activites such as:
    - Excavation activities and materials handling associated with:
        - Topsoil stripping
        - Cut and fill work
        - Embankment work
        - Preparation of site and access for construction of bridge and widening work
        - Installation of road drainage infrastructure
    - Windblown dust from exposed surfaces and stockpiles
- Construction work, including activites such as:
    - Construction of temporary ancillary facilities
    - Bridge construction work, including:
        - Site preparation including establishment of temporary haul roads and pile and crane pads including placement of layers of crushed rock or recycled concrete.
        - Construction of substructures and super structures
    - Pavement widening work, including
        - Placement of select zone material and concrete base
        - Spreading and compaction of aggregate
    - Finishing work
    - Windblown dust from exposed surfaces and stockpiles
- Trackout including activites such as:
        - Heavy vehicle deliveries transporting dusty construction materials to site.
        - Heavy vehicles transporting dusty demolition waste material or excess cut material to suitable waste facility
        - Construction vehicle transfer dust onto the road after travelling on unpaved roads or exposed areas within the construction footprint.

Mobile and stationary plant combustion emissions during construction

Mobile and stationary plant emissions are largely attributed to exhaust emissions from fuel combustion and include gaseous pollutants such as NO_2, CO, PAHs and VOCs as well as particulates (PM_{10} and $PM_{2.5}$). Combustion emissions would also be associated with light and heavy vehicles traveling to and from the construction ancillary facilities.

Sections 6.1.4 and **6.1.6** provide an overview of construction vehicle movements and mobile and stationary plant and equipment for construction. The methodology and results of the assessment of potential air quality impacts for mobile and stationary plant combustion emissions during construction are discussed in **Section 5.6.3** and **Section 6.3** respectively.

Odour emissions during construction work

Odour emissions during construction activities are not common. However, it is possible that during construction odorous material may be encountered. These are typically associated with contaminated soil or excavated material with high organic loads that generate offensive odours. Sources of odorous emissions are commonly identified as part of the contaminated land assessment carried out for a proposal. A qualitative discussion of the potential for odorous impacts is in **Section 6.4**.

Operational vehicle emissions

Operational impacts from the proposal are due primarily to changes in vehicle numbers, vehicle speeds, vehicle fleet mix over time and changes to emission factors.

Vehicle emissions include both exhaust and non-exhaust emissions. Exhaust pollutant emissions are due to fuel combustion and include gaseous pollutants such as NO_2, CO, PAHs and VOCs as well as particulates (PM_{10} and $PM_{2.5}$). Non-exhaust emissions from vehicles are generally limited to particulates and include processes such as brake wear, tire wear and suspension or resuspension of road dust due to the movement of the vehicles on a road.

Vehicle emission estimations for pollutants of interest are discussed in **Section 5.7.5.2** and potential ground level air pollutant concentrations from the proposal are discussed in **Section 6.3**.

4.0 Existing environment

This section provides a description of the existing environment as it relates to existing air quality, local meteorology, terrain, land use and receptors.

4.1 Meteorology and climate

The closest BoM station to the proposal is located at Badgerys Creek (Station number 067108) 3 km south of Elizabeth Drive. The Badgerys Creek station is situated in similar terrain to the proposal and is close enough to the proposal to provide a good indication of wind conditions at the construction footprint.

Wind speed and direction data measured at Badgerys Creek are presented in **Figure 4-1** (all hours) and **Figure 4-2** (categorised by season and day/ night). The wind roses show the frequency of occurrence of winds by direction and strength. The bar at the top of each wind rose diagram represents winds blowing from the north (ie northerly winds) and so on. The length of the bar represents frequency of occurrence of winds from that direction. The widths of the bars correspond to wind speed categories, the narrowest representing the lightest winds.

Figure 4-1 shows that the most frequent winds at Badgerys Creek are from the southwest, with between 20 to 30 per cent of all wind blowing from this direction. The strongest winds (over 7 m/s) are typically from the southwest and west with an average wind speed of 2.8 m/s and calm conditions (winds less than 0.5 m/s) occurring about 8 per cent of the time.

The season and day/night wind roses shown in **Figure 4-2** show that the dominant wind pattern at night is from the light to moderate winds from the southwest. These winds are likely due to valley drainage effects as cool air flows downhill and down valley from the Blue Mountain foothills to the south and west of the station. The southwest winds are most pronounced in the cooler months with up to 40 to 50 per cent of night-time winds from the southwest during winter. Calm conditions are relatively common at night, with up to about 13 per cent of hours calm on summer nights, and at least 10 per cent in the other seasons. Average wind speeds at night range from 1.9 m/s in summer to 2.3 m/s in winter.

Daytime winds are much more variable than night-time winds at Badgerys Creek. Summer winds are most common from the east as onshore flows that can push winds inland from the coast. Strong winds are most common in winter and spring and blow mostly from the west and southwest. These winds are generated by low pressure systems that drag cold air up and over the continent from the south and are very common throughout central NSW. Calm conditions are not common during the daytime, with less than 4 per cent of hours calm during spring, summer and autumn. Mean daytime winds are strongest in spring at about 3.8 m/s and lightest in autumn at about 3.1 m/s.

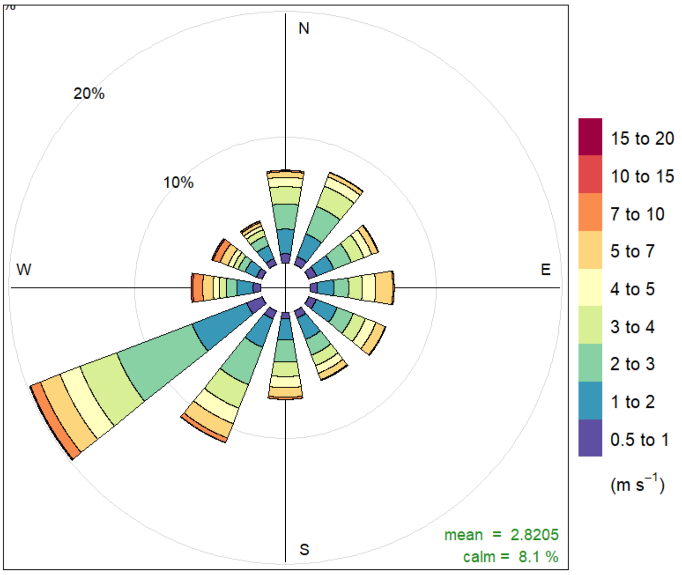

Figure 4-1 **All hours wind rose for Badgerys Creek (1998 to 2020)**

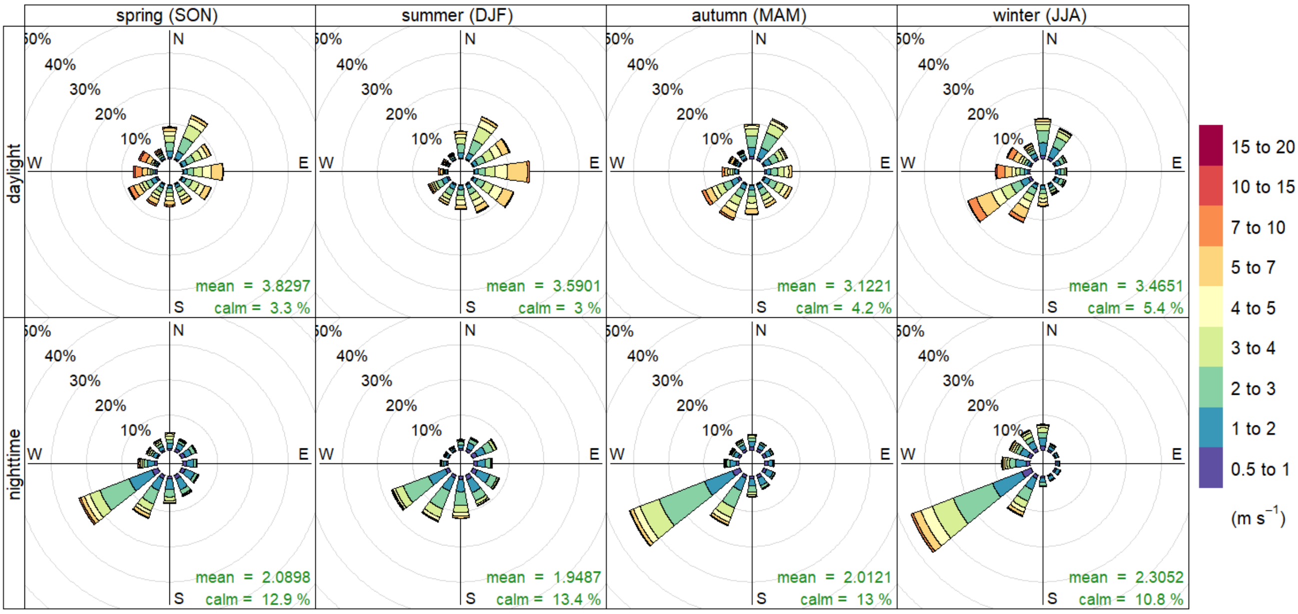

Figure 4-2 **Wind roses by season and day/night at Badgerys Creek (1998 to 2020)**

Meteorological data used in the air dispersion model are discussed in **Section 5.7.4.1**.

Long term temperature and rainfall data (1998 to 2020) recorded at Badgerys Creek is presented in **Figure 4-3**. Average temperatures range from about 5°C to 17°C in winter to about 17°C to 30°C in summer. Average rainfall is highest in February with about 120 mm and lowest in July with about 35 mm on average.

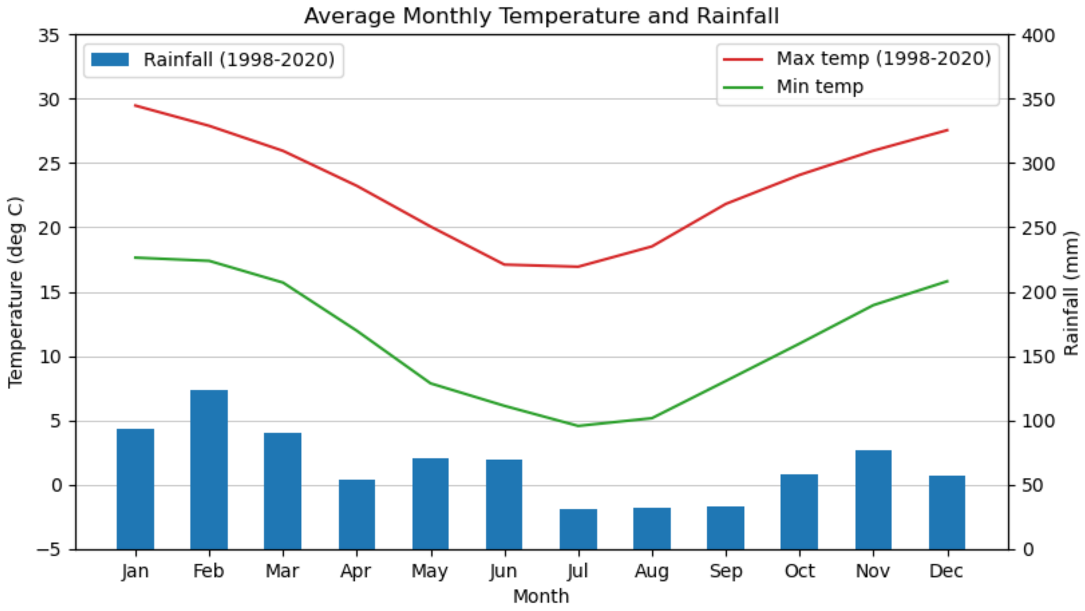

Figure 4-3 **Long term temperature and rainfall at Badgerys Creek**

4.2 Background air quality

4.2.1 Existing sources of air pollution in the construction footprint

Existing sources of air pollution in the proposal were identified via a search of the National Pollutant Inventory (NPI). Three facilities with similar pollutant emission to the proposal were identified and are presented in **Table 4-1**.

There are other sources of air pollution in the area, not limited to those listed in the NPI, including the construction of the WSA and other supporting infrastructure proposals. These sources are discussed further in **Section 7.2.**

Table 4-1 Existing local sources of air pollution listed on NPI

Facility	Address	Pollutant Emissions
PGH Bricks and Pavers Pty Ltd	69-77 Cecil Rd Cecil Park NSW	<100,000 kg/year: CO <50,000 kg/year: NOx, PM_{10}, <5,000 kg/year: VOCs <1,000 kg/year: $PM_{2.5}$, <1 kg/year: PAHs
SUEZ Elizabeth Drive Landfill	1725 Elizabeth Drive Badgerys Creek NSW	<5,000 kg/year: CO, VOCs <1,000 kg/year: PM_{10}, $PM_{2.5}$
SEI Kemps Creek Landfill Cogeneration	1725 Elizabeth Drive Kemps Creek NSW	<5,000 kg/year: NOx, CO <1,000 kg/year: PM_{10}, $PM_{2.5}$

Source: NPI – 2019/2020 emission reports

4.2.2 Existing air quality concentrations

The effect air emissions from the proposal may have on the surrounding environment must be considered in the context of the existing air pollution sources in the region. Evaluating cumulative effects requires a knowledge of the existing or background concentrations of the contaminants being assessed. This includes how background concentrations vary during the year due to seasonal or other temporal trends. It is necessary to incorporate the background concentrations of air pollutants as they provide a baseline level, to which the predicted impact of the development can be added, thus producing a cumulative air quality impact that is suitable for comparison against regulatory criteria.

The NSW DPE operates air quality monitoring stations across the Sydney basin, with the nearest to the proposal being Bringelly and St Marys monitoring stations. NO_2, PM_{10} and $PM_{2.5}$ are measured at both Bringelly and St Marys. The proximity of these stations to the proposal, means that concentrations measured at Bringelly and St Marys would be representative of conditions in the construction footprint.

The construction of WSA began in late 2021 and would likely have some influence on pollutant concentrations measured at Bringelly. The data presented here, and in the 2017 data used to calculate cumulative concentrations for the proposal, do not include that influence. The main focus of this assessment is the potential difference in pollutant concentrations from the proposal in comparison with the ‘doing nothing’ scenario, and any potential impacts of the WSA would apply to both and, therefore, have no bearing on the difference. However, the proximity of the airport means that cumulative impacts are likely and cannot be ignored and therefore the potential cumulative impacts due to WSA are discussed in **Section 7.2.1**.

The location of the DPE monitoring stations in relation to the proposal is presented in **Figure 4-4**. Note that CO is not monitored at either Bringelly or St Marys and concentrations for CO were therefore sourced from the nearest station with CO data, which was at the Liverpool DPE monitoring station.

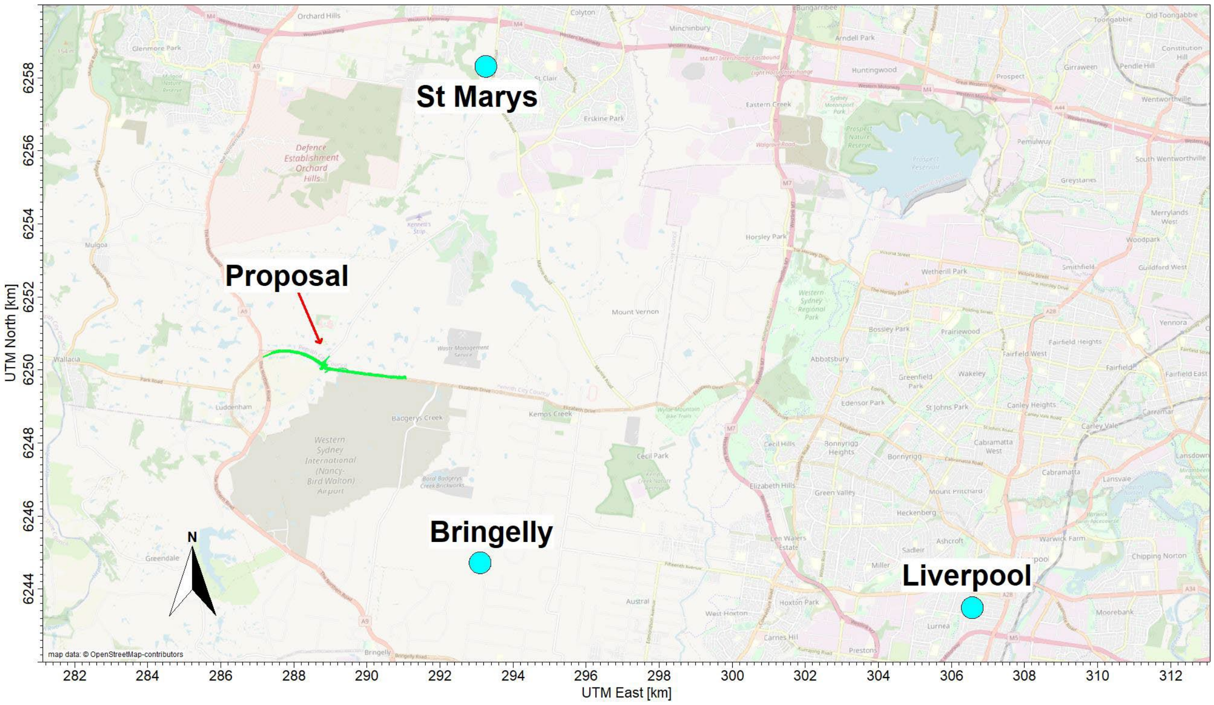

Figure 4-4 **Location of NSW DPE** monitoring stations in relation to the proposal

A summary of measurements for each pollutant of interest at the DPE stations are presented in the following sections.

4.2.2.1 Nitrogen dioxide

Measurements of 1-hour average NO_2 made at Bringelly and St Marys from 2016 to 2021 are presented in **Figure 4-5**. Measured concentrations were well below the NSW criteria for 1-hour NO_2 of 164 µg/m³ throughout the period. The highest measured concentration was 75.9 µg/m³, measured at St Marys. The highest concentration measured during this period at Bringelly was 73.8 µg/m³.

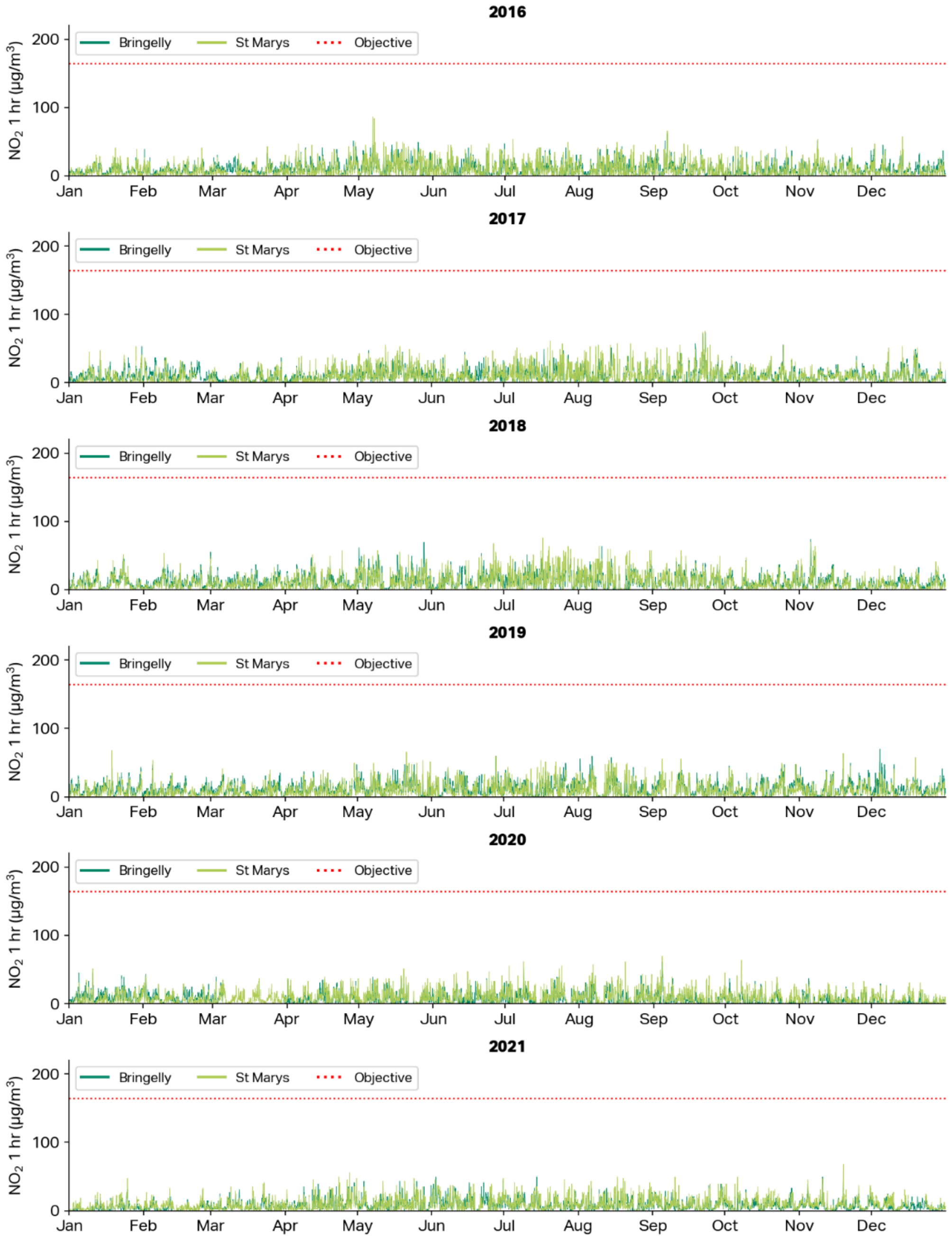

Figure 4-5 1-hour NO_2 concentrations measured at Bringelly and St Marys EES stations from 2016 to 2021

Annual average NO_2 measured at Bringelly and St Marys for 2016 to 2021 are presented in **Figure 4-6**. The annual average for each year were well below the annual criterion of 31 µg/m³. The highest annual average was 11.4 µg/m³ measured in 2018 at Bringelly.

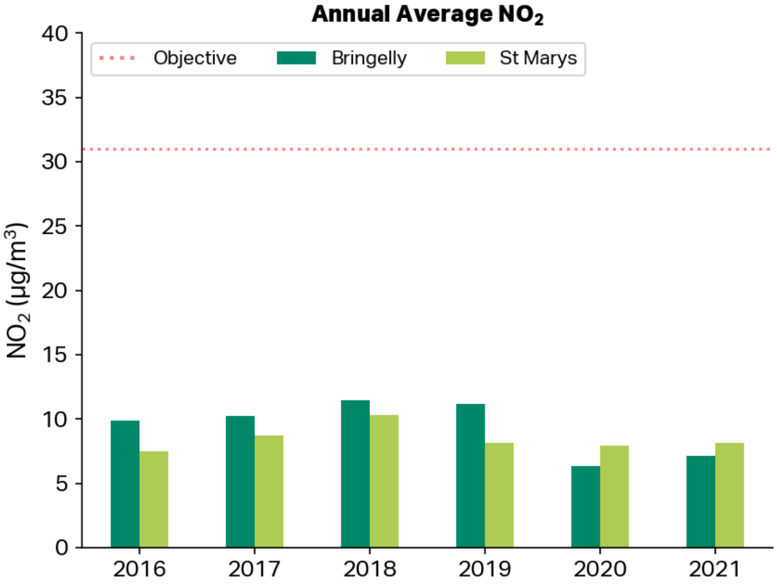

Figure 4-6 **Annual average NO_2 measured at Bringelly and St Marys– 2016 to 2021**

4.2.2.2 Carbon monoxide

CO is not measured at Bringelly or St Marys, so data was sourced from the nearest EES station that measure CO at Liverpool, about 16 km southeast of the eastern end of the proposal. Measurement of 1-hour average CO data from Liverpool are presented in **Figure 4-7**. All concentrations were well below the 1-hour CO criteria of 30,000 µg/m^3. The highest 1-hour concentration was 4,625 µg/m^3 in December 2019, which was likely due to bushfire activity. CO concentrations were typically highest during the winter months.

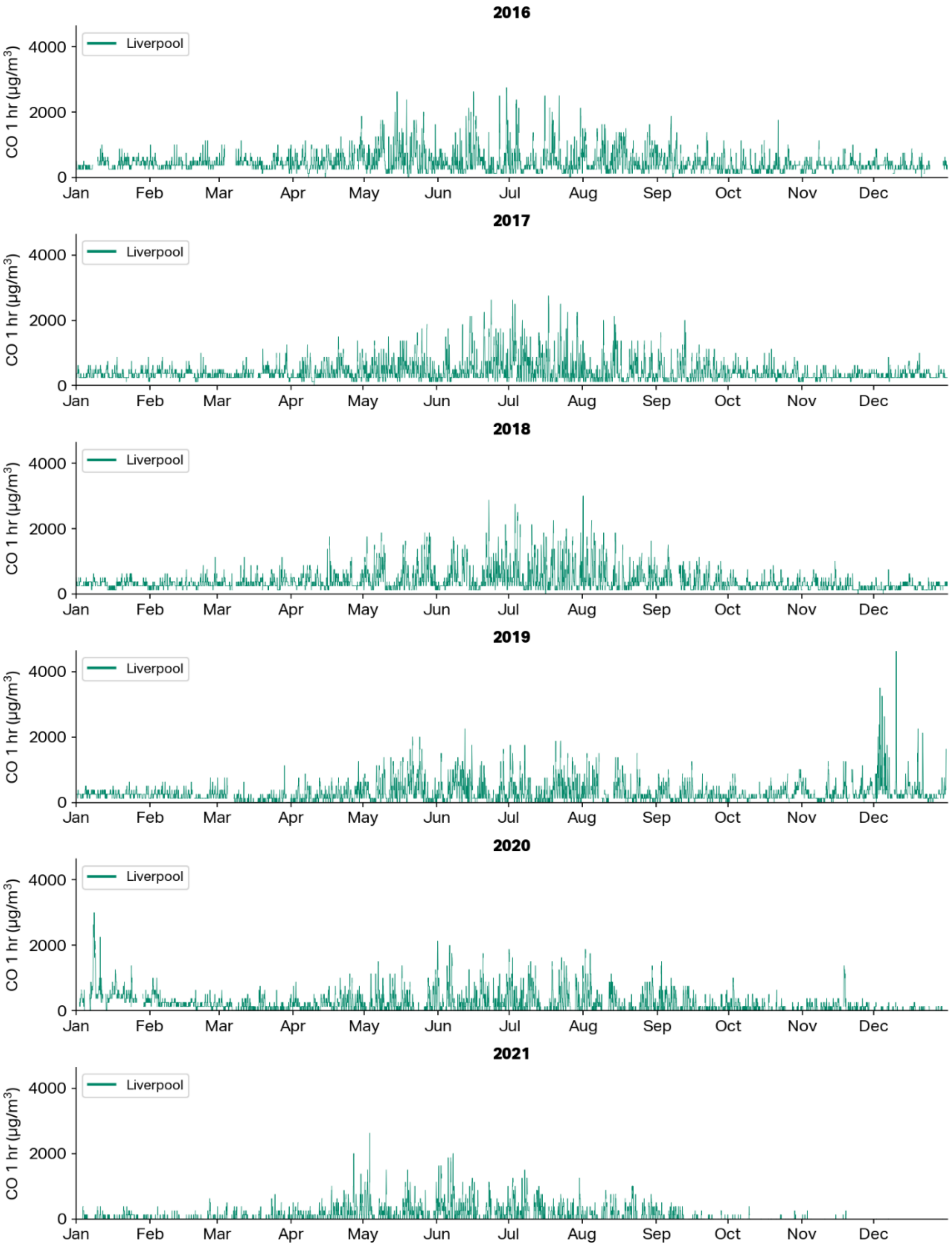

Figure 4-7 **1-hour CO measurements at Liverpool EES – 2016-2021 – criteria of 30,000 µg/m^3 not shown**

Measurements of 8-hour average CO made at Liverpool from 2016 to 2021 are presented in **Figure 4-8**. Measured concentrations were well below the 8-hour CO criteria of 10,000 µg/m^3 during the whole period. The highest measured concentration was 2,140 µg/m^3 in January 2020 and was adopted as the background 8-hour CO concentration for this assessment.

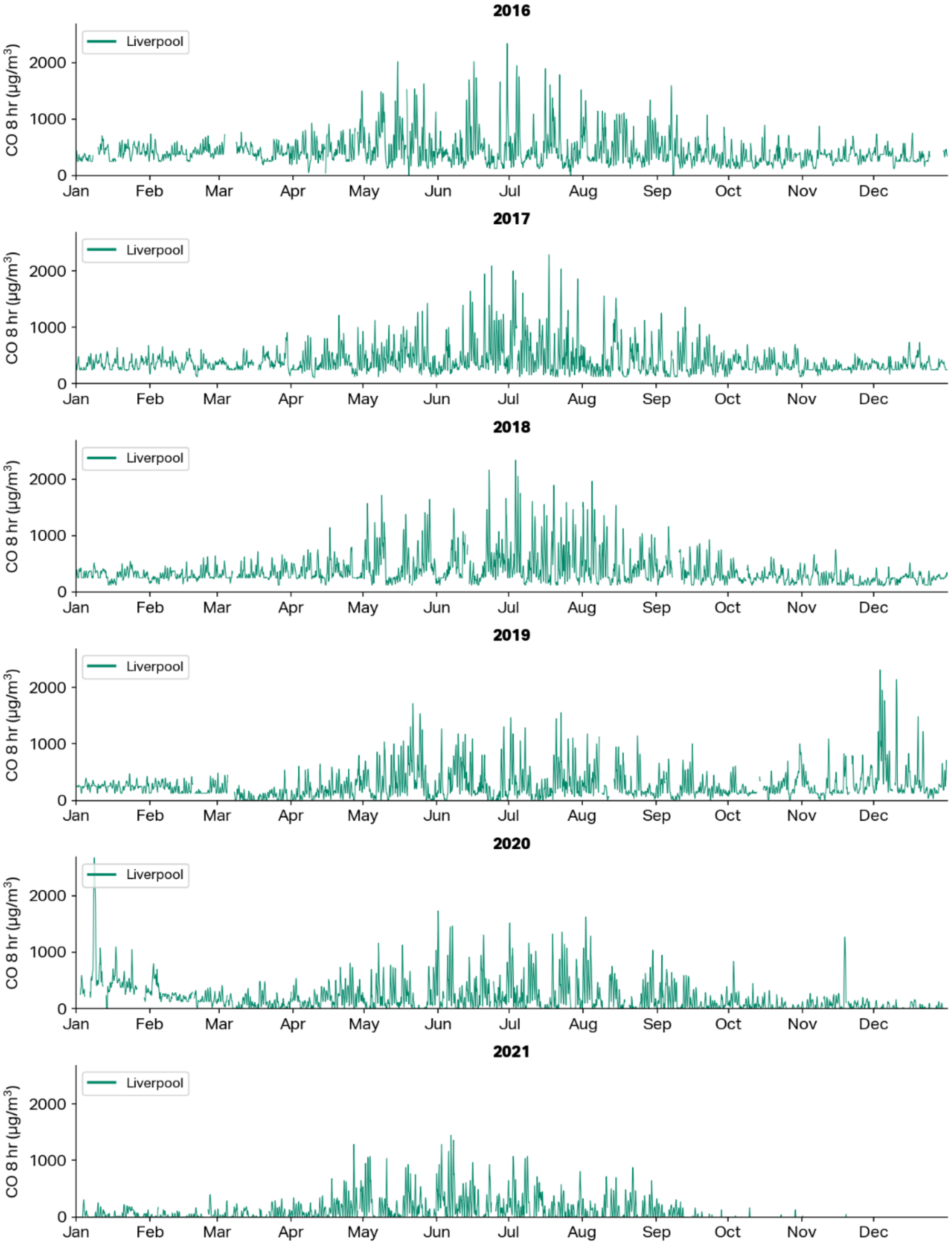

Figure 4-8 8-hour CO measurements at Liverpool EES – 2016-2021 – criteria of 10,000 µg/m³ not shown

4.2.2.3 PM$_{10}$

Measurements of 24-hour average PM$_{10}$ made at Bringelly and St Marys from 2016 to 2021 are presented in **Figure 4-9**. Measured concentrations were well below the 24-hour PM$_{10}$ criterion of 50 µg/m^3 for most days during the five-year period. However, there were multiple exceedances in late 2019 and early 2020 due to bushfires activity. This period was unprecedented in terms of the amount of smoke in the Sydney area and the concentrations measured are not considered typical and can, therefore, be ignored for the purposes of defining the existing background. In the periods not affected by the bushfires, there are occasional exceedances of the criteria; although, these are often during the cooler months and are possibly due to smoke from hazard reduction burning activities.

Figure 4-9 **24-hour average PM$_{10}$ at Bringelly and St Marys EES – 2016-2021**

A summary of the number of exceedances of the 24-hour PM$_{10}$ criterion for each year at the two EES stations presented in **Table 4-2**. Due to the occurrence of exceedances, a contemporaneous assessment of PM$_{10}$ impacts using the 2017 data from Bringelly was carried out for the proposal. There were six exceedances during 2017 at Bringelly. There were 34 exceedances of the 24-hour PM_{10} criterion at Bringelly and 35 at St Marys between late October 2019 and early February 2020 during the bushfire events.

Table 4-2 Number of 24-hour PM10 exceedances annually at Bringelly and St Marys

Year	Bringelly	St Marys
2016	3	3
2017	6	0
2018	8	2
2019	24	26
2020	11	11
2021	1	1

Source: EES

Measurements of annual average PM_{10} made at Bringelly and St Marys from 2016 to 2021 are presented in **Figure 4-10**. Concentrations in 2019 were biased by the very high concentrations associated with bushfire smoke towards the end of 2019. The use of particulate data from the 2019 calendar year in air quality assessments is not considered appropriate due to the highly atypical nature of the bushfire events. The 2019 data has therefore been ignored for this assessment. Excluding 2019, the highest annual average concentrations were generally less than 20 µg/m³, with the highest annual average of 21.2 µg/m³ measured in 2018 at Bringelly, which is below the criterion of 25 µg/m³.

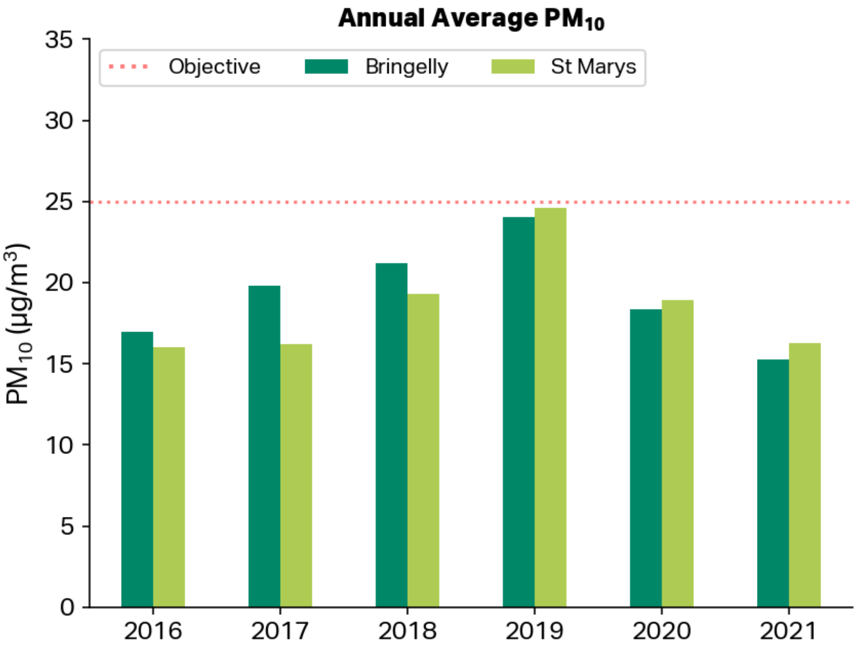

Figure 4-10 **Annual average PM_{10} measured at Bringelly and St Marys – 2016 to 2021**

4.2.2.4 $PM_{2.5}$

Measurements of 24-hour average $PM_{2.5}$ made at Bringelly and St Marys from 2016 to 2021 are presented in **Figure 4-11**. Measured concentrations were well below the 24-hour $PM_{2.5}$ criterion of 25 µg/m^3 for most days during the five-year period. The effects of the bushfire smoke can be seen in the very high $PM_{2.5}$ concentrations in late 2019 and early 2020. This period was unprecedented in terms of the amount of smoke in the Sydney area and the concentrations measured are not typical and should be ignored for the purposes of defining the existing background. Each year, mostly in the cooler months there is the occasional exceedance of the criterion. These exceedances are possibly due to smoke from hazard reduction burns in the Sydney area.

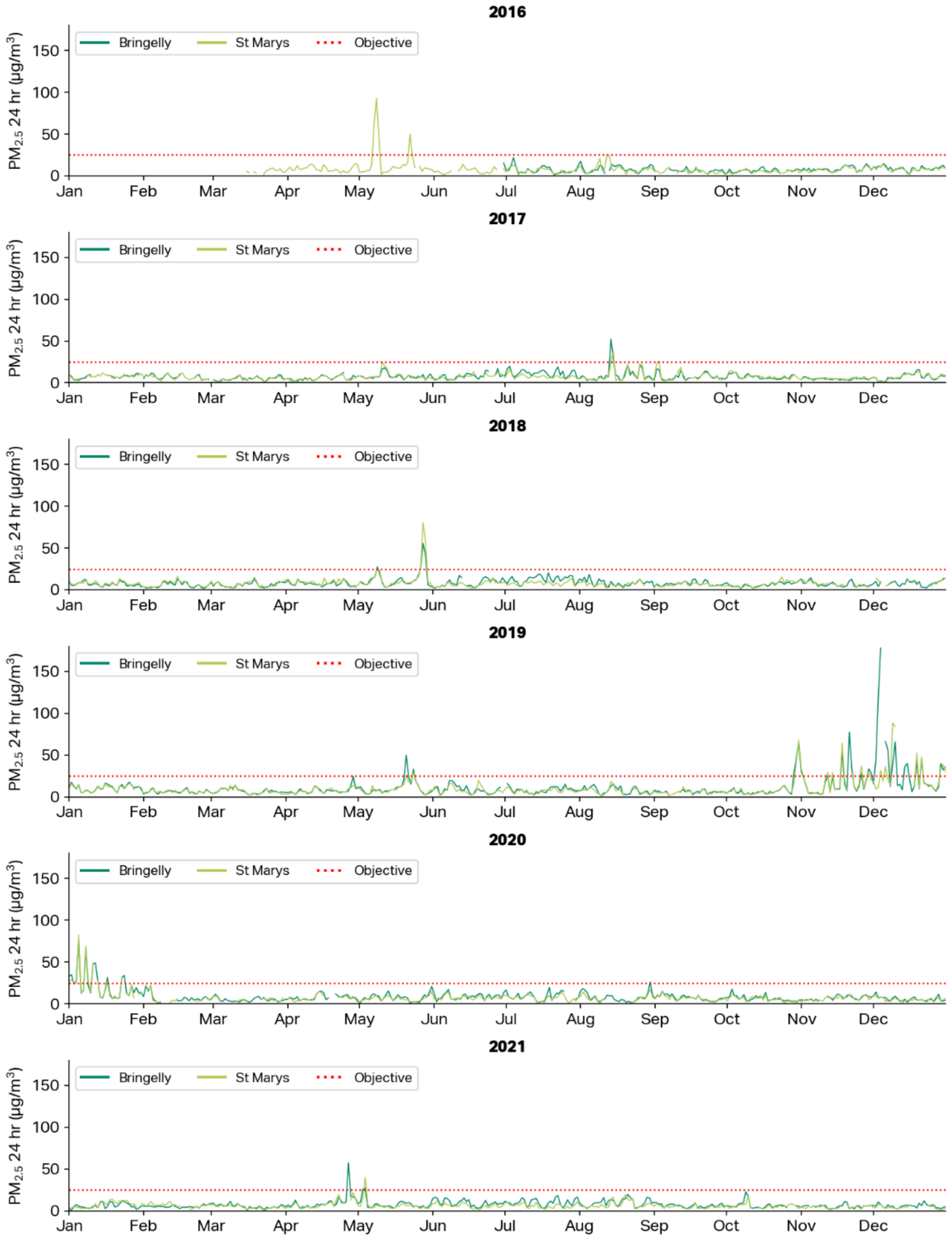

Figure 4-11 **24-hour average $PM_{2.5}$ at Bringelly and St Marys EES – 2016-2021**

A summary of the number of exceedances of the 24-hour $PM_{2.5}$ criterion for each year at the two EES stations presented in **Table 4-3**. Due to the occurrence of exceedances, a contemporaneous assessment of $PM_{2.5}$ impacts using the 2017 data from Bringelly was carried out for the proposal. There were two exceedances during 2017 at Bringelly. There were 36 exceedances of the 24-hour $PM_{2.5}$ criterion at Bringelly and 28 at St Marys between late October 2019 and late January 2020 during the bushfire events.

Table 4-3 Number of 24-hour PM2.5 exceedances annually at Bringelly and St Marys

Year	Bringelly	St Marys
2016	0	5
2017	2	3
2018	4	4
2019	27	21
2020	12	9
2021	3	1

Source: EES

Measurements of annual average $PM_{2.5}$ made at Bringelly and St Marys from 2016 to 2021 are presented in **Figure 4-12**. No annual average is presented for 2016 due to both stations having less than 75 per cent data capture for that year. Concentrations in 2019 were biased by the very high concentrations associated with bushfire smoke towards the end of 2019. The use of particulate data from the 2019 calendar year in air quality assessments is not considered appropriate due to the highly atypical nature of the bushfire events. The 2019 data has, therefore, been ignored for this assessment. Excluding 2019, the highest annual average concentrations measured at both stations were either approaching or slightly exceeding the annual criterion of 8 µg/m^3. The highest annual average of 8.5 µg/m^3 excluding 2019 was measured in 2020 at Bringelly. However, January 2020 was also heavily affected by the bushfire events and the 2020 average is, therefore, slightly elevated. The highest concentration that was not affected by the bushfire events was 8.1 µg/m^3 at Bringelly in 2018, which is still slightly above the annual criterion.

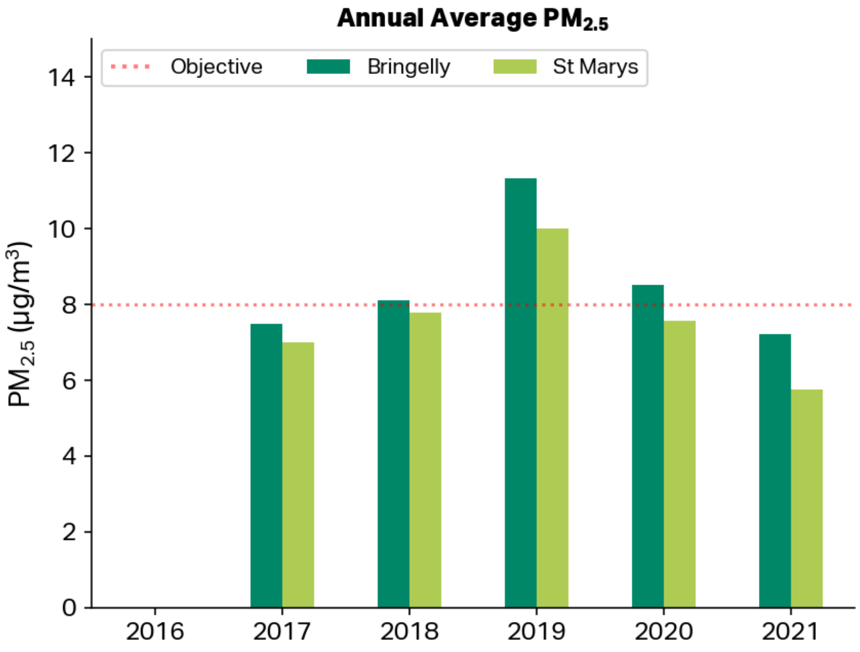

Figure 4-12 Annual average $PM_{2.5}$ measured at Bringelly and St Marys – 2016 to 2021

4.3 Terrain

Terrain surrounding the proposal is shown in **Figure 4-13**. Terrain data for the assessment was sourced from the 5m Intergovernmental Committee on Surveying and Mapping (ICSM) Elevation and Depth Foundation Spatial Data (ELVIS) website, as discussed further in **Section 5.7.4**.

Terrain elevation near the proposal varies by about 100m from a low level of about 20m. Most of the elevation in the immediate alignment area surrounding the proposal is between 50 to 100m with higher elevations generally to the east end, near the intersection with the M7 Motorway.

A minor valley aligned north-south dominates the central portion of the area. The valley branch may introduce some minor katabatic plume migration (from downslope winds) from the proposal toward the north (although this drift is likely to be minor given the low topographical relief in the area).

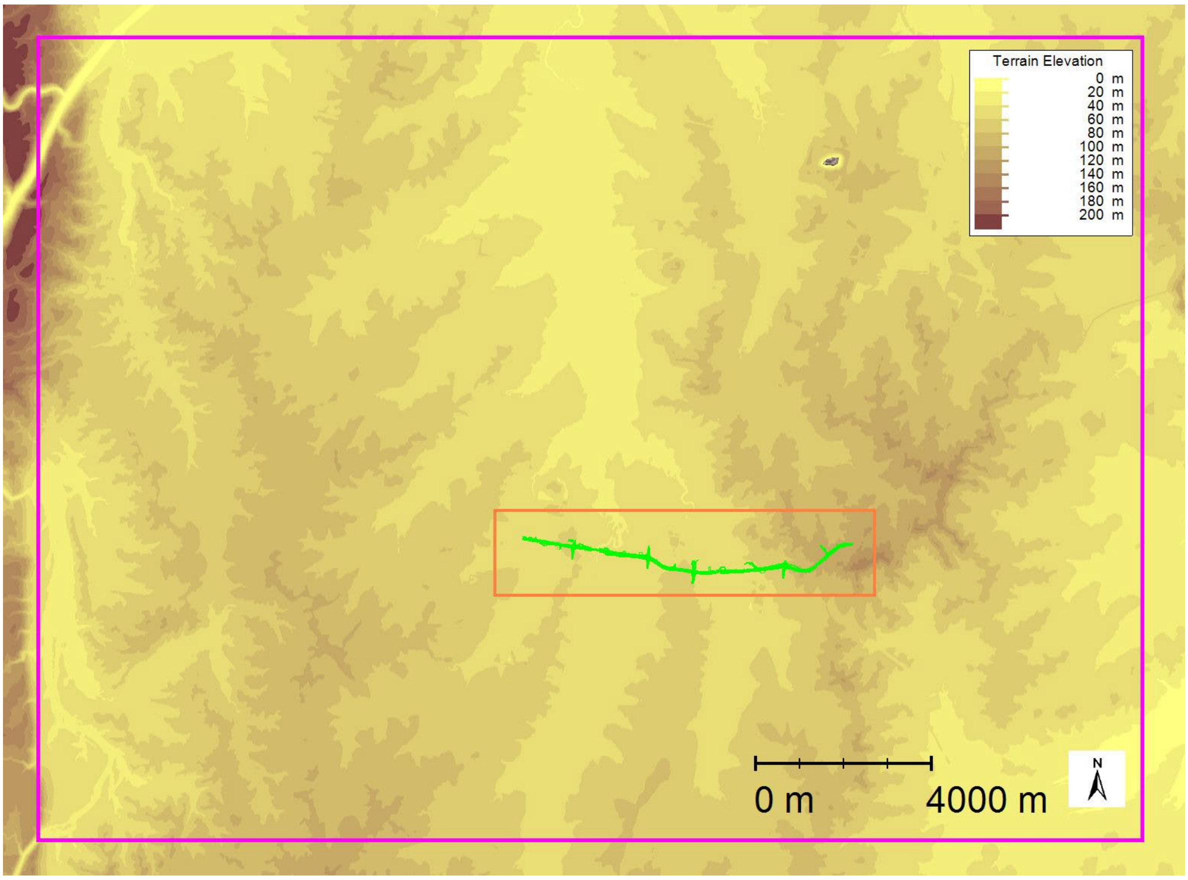

Figure 4-13 **Terrain in the region surrounding the proposal**

4.4 Land use

Land use within the study area is shown in **Figure 5-10**. Land use surrounding the proposal largely consists of agricultural land with scattered vegetation and buildings (residential, agricultural and commercial).

There are small areas of remnant vegetation, mostly along waterways and the new WSA is immediately adjacent to the south and southwest of the proposal.

4.5 Sensitive receptors

The NSW EPA defines a sensitive receptor to be “a location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area. An air quality impact assessment should also consider the location of known or likely future sensitive receptors” (NSW EPA, 2017).

Receptor locations included in the model are presented in **Appendix F**. Receptors were included at nearby representative commercial / industrial buildings along with the representative residential dwellings.

Gridded receptors were also modelled to enable the generation of concentration contours along the length of the motorway.

4.5.1 Ecological receptors

Ecological receptors are areas of ecological significance. This can include areas such as national parks, state conservation areas, nature reserves and endangered ecological communities or species. Ecological receptors can also include agricultural activities that might be vulnerable to air emissions such as fruit and vegetable farms, flower farms or vineyards.

Like human receptors increased concentrations of atmospheric pollutants has the potential to have a negative affect sensitive habitats and plant communities. Potential increases can be a result of both physical and chemical impacts such as:

- High levels of prolonged dust deposition may lead to:
    - Plant physical stress, reduced photosynthesis, respiration, and transpiration through smothering
    - Chemical changes to soils or watercourses may lead to a loss of plants or animals for example due to changes in acidity of soil or water
- Exposure to elevated NO_2 concentrations may result in changes to leaf chlorophyl and mineral ion content and changes to peroxidase activity in vegetation
- Physiological changes to vegetation because of increased pollutant concentrations may also have indirect effects such as increased susceptibility to stresses such as pathogens and air pollution.

An assessment of biodiversity constraints associated with the proposal was carried out. A number of ecological areas were determined to have ‘very high’ and ‘high’ constraints for the proposal as outlined below:

- ‘Very high’ ecological constraints:
    - Areas of existing native vegetation exist along Kemps Creek and between Western Road, Elizabeth Drive, Devonshire Road and Cross Street. The vegetation along Kemps Creek would likely need to be cleared, while the other areas are a priority conservation area.
- ‘High’ ecological constraints:
    - ‘High condition’ vegetation communities listed under the *Biodiversity Conservation Act 2016* (BC Act) and/or *Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act)
    - Potential micro-bat roost habitat in bridges/ culverts spanning larger watercourses.

Understanding the condition and significance of ecological receptors within the study area is important for the assessment of construction dust impacts in accordance with the IAQM methodology as discussed in **Section 5.6.2**. Given the high-condition state of some of the ecological receptors, the sensitivity of the area would be considered high for locations where vegetation or fauna may be affected by dust deposition or where there is a particularly important plant species and its sensitivity to dust is unknown.

5.0 Methodology

This section outlines the legislation, guidelines and policy that are relevant to the assessment and describes the method of assessment used in this technical assessment report.

5.1 Relevant legislation guidelines and policy

The proposal has the potential to increase air pollutant emissions and associated ambient air quality concentrations. Environmental assessment and management in NSW are governed through the application of legislation and regulation which define how proposals of this scale should be assessed and if acceptable, ultimately approved.

Assessment of air quality impacts are carried out through the consideration of legislation and guidance material which is tasked with reducing and managing the potential for air pollution and its exposure to the natural environment and the community.

This section provides an overview of the relevant air quality legislation (**Section 5.2**), guidance documents (**Section 5.2.2**) and ambient air quality criteria (**Section 5.4**).

This section excludes broader state-wide strategies and legislation for regulating vehicle emissions. **Appendix B** provides a description of important federal and NSW state government strategies to promote reductions in vehicle emissions through cleaner transport, engines, and fuels. It also provides a list of key legislation used to regulate light and heavy on-road vehicle emission standards in Australia.

5.2 Legislation, regulations and standards

5.2.1 National Environment Protection Council Act 1994 (Cth)

The *National Environment Protection Council Act 1994* (Cth) establishes and provides authority to the National Environment Protection Council (NEPC) to make National Environment Protection Measures (NEPMs) and to assess and report on their implementation and effectiveness in participating jurisdictions. NEPMs are a special set of national objectives designed to assist in protecting or managing aspects of the environment. Regarding concentrations of air pollutants, the two relevant NEPMs are as follows:

- *National Environment Protection (Ambient Air Quality) Measure 2021* (AAQ NEPM)
- *National Environment Protection (Air Toxics) Measure 2004* (Air Toxics NEPM).

The AAQ NEPM was designed to create a nationally consistent framework for monitoring and reporting on common ambient air pollutants. The Air Toxics NEPM provides a framework for monitoring, assessing, and reporting on ambient levels of air toxics and was designed to collect information to facilitate the development of standards for ambient air toxics. The air quality standards associated with the Ambient Air Quality and Air Toxic NEPMs are provided in **Section 5.4.1**.

The *National Environment Protection Council Act 1994* (Cth) also administers the *National Environment Protection (National Pollutant Inventory) Measure 2021* which is used the collect a broad base of information on emissions including air emissions from all industry sectors and reports and disseminates this information to the community in a useful and accessible form.

5.2.2 Protection of the Environment Operations Act 1997 (NSW) (POEO Act)

The *Protection of the Environment Operations Act 1997 (NSW*) (POEO Act) is the key piece of environment protection legislation administered by the NSW Environment Protection Authority (EPA). The object of the POEO Act is to achieve the protection restoration and enhancement of the quality of the NSW environment.

The POEO Act provides board allocation of environmental responsibilities between the NSW EPA, local councils, and other public authorities. The POEO Act also allows for the provision of Protection of the Environment Polices (PEPs), Environmental Protection Licences (EPLs) and environmental protection notices. It also has a three-tier regime relating to environmental protection offences.

The objects of the POEO Act relevant to air quality are:

- To protect, restore and enhance the quality of the environment in New South Wales, having regard to the need to maintain ecologically sustainable development
- To ensure that the community has access to relevant and meaningful information about pollution
- To reduce risks to human health and prevent the degradation of the environment using mechanisms that promote the following:
  - Pollution prevention and cleaner production
  - The reduction to harmless levels of the discharge of substances likely to cause harm to the environment
  - The making of progressive environmental improvements, including the reduction of pollution at source
  - The monitoring and reporting of environmental quality on a regular basis
- To rationalise, simplify and strengthen the regulatory framework for environment protection
- To improve the efficiency of administration of the environment protection legislation.

The POEO Act also allows for the provision of delegate legislation including the Protection of the Environment Operations (Clean Air) Regulation 2021 as described in **Section 5.2.3**

The POEO Act is supported by NSW EPA documents that provide statutory methods for assessing and sampling air pollutants including:

- Approved methods for the modelling and assessment of air pollutants in NSW
- Approved methods for the sampling and analysis of air pollutants in NSW.

5.2.3 Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW)

The Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW) (POEO Clean Air Regulation 2010) under the POEO Act prescribes the requirements for several air pollutant generating activities in NSW. Requirements include domestic solid fuel heater certification, controlled burning, and installation of pollution control devices on certain motor vehicles, petrol supply standards, emission standards for industry groups and control storage and transport of volatile organic compounds.

The POEO Clean Air Regulations refer to EPA documents that provide statutory methods for assessing and sampling air pollutants including the *Approved methods for the modelling and assessment of air pollutants in NSW* (EPA 2017) (Approved Methods). The approved methods are discussed further in **Section 5.3.1** with ambient air quality criteria discussed in **Section 5.4**.

5.3 Guidance documents

5.3.1 Approved methods for modelling and assessment of air pollutants in NSW

The Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales (EPA 2022) (The Approved Methods) under Part 5 of the POEO Clean Air Regulation 2010 provides the statutory methods for modelling and assessment from air emissions in NSW. The document outlines procedures for:

- Emissions inventories
- Meteorological data preparation
- Accounting for background data and cumulative impact assessment
- Dispersion modelling methodology
- Interpretation of modelling results
- Impact assessment criteria

- Modelling chemical transformation
- Procedures for developing site specific emission limits.

Under Section 2.1 of the approved methods two levels of impact assessment are defined for dispersion modelling:

- **Level 1**: a screening level dispersion modelling technique using worst-case input data
- **Level 2**: a refined dispersion modelling technique using site specific input data.

A Level 2 assessment of operational impacts from the proposal has been carried out in accordance with the Approved Methods methodology and is discussed further in **Section 5.7**. Interpretation of dispersion modelling results for the proposal involves comparing predicted pollutant ground level concentrations to the EPA's impact assessment criteria under the Approved Methods. Impact assessment criteria are presented in **Section 5.4**.

5.3.2 Assessment for Dust from Demolition and Construction 2014

The United Kingdom (UK) Institute of Air Quality Management Guidance on the assessment of dust from demolition and construction (IAQM 2014) document provides a qualitative risk assessment process for the potential unmitigated impact of dust generated from demolition, earthmoving, and construction activities.

The IAQM methodology assesses the risk of impacts associated with demolition and construction without the application of any mitigation measures. The assessment provides a classification of the risk of dust impacts to both human and ecological receptors which then allows the identification of appropriate mitigation measures commensurate with the level of risk.

The IAQM methodology is widely accepted for the assessment of potential dust impacts associated with demolition and construction from road proposals in NSW and other states in Australia. The IAQM methodology has been adopted to assess the potential dust impacts from the construction footprint. The methodology has been modified to account for local conditions as follows:

- Modification to the risk assessment matrix to account for more stringent PM_{10} criteria set by NSW EPA
- Additional parameters were added that apply specifically to road construction proposals. These are detailed in **Table 5-7**
- Sensitivity classification of ecological receptors has been modified to account for:
    - Protected areas in NSW based on conservational status as defined by NSW National Parks and Wildlife Service (NPWS)
    - Nationally and NSW listed Threatened ecological communities (TEC)
    - Environmental conservation areas listed under the Local Environmental Plan (LEP).

The modified IAQM methodology for assessment of construction dust impacts from the proposal is described in **Section 5.6.2**.

5.3.3 Air pollution from road transport good practice guide

As at the drafting of this document, the Transport Special Interest Group (TSIG) under the Clean Air Society of Australia and New Zealand (CASANZ) is currently drafting the Good Practice Guide for the Assessment and Management of Air Pollution from Road Transport (GPG). The GPG has been funded by transport government departments from NSW, South Australia, Western Australia, Queensland, Victoria, and New Zealand with the aim of providing a standardised approach for the assessment of road transport emissions that compliments existing local policy and procedures. The guide is currently being developed to meet the needs of environmental regulators and road agencies/authorities in Australia and New Zealand and provides:

- Enhanced consistency across proposals and jurisdictions
- Reduced risk of proposals being over or under scrutinised

- Increased cost-efficiency (ie savings in time and resources previously spent developing and justifying assessment methods)
- Presentation of a transparent process
- Clear communication of assessment procedures for regulators, proponents, community, and other stakeholders.

The assessment framework involves characterisation of the potential impacts from the construction footprint to determine the appropriate assessment methodology.

While the final guide has not yet been publicised, it is expected to outline the methodology for carrying out a detailed air quality assessment (including dispersion modelling) for the operational impacts of large proposals that include complex design features. Based on preliminary viewing of the GPG, the operational assessment methodology described in **Section 5.7** is expected to be closely aligned with the GPG.

With regards to construction assessment methodology, the GPG is also expected to include a modified IAQM approach adapted for assessment in Australia and New Zealand, with specificity to road transport proposals. While the GPG document is currently not published the proposed modified IAQM methodology adapted for the assessment of NSW proposals used in this technical report (as described in **Section 1.1** it is expected to be relatively consistent with the new methodology likely to be recommended by the GPG).

5.3.4 Australian Incremental Guideline for Particulate Matter

Health impacts associated with $PM_{2.5}$ concentrations are discussed in **Section 5.6.2.4**. There is no threshold that has been identified regarding $PM_{2.5}$ concentrations that are not associated with health impacts. It is therefore important to examine any predicted incremental increase in ground level $PM_{2.5}$ concentrations at sensitive receptors associated with the construction footprint.

There is currently no formal guidance in Australia on the health assessment of the incremental particulate impacts for proposed developments, despite the requirement to assess such impacts as part of the environmental planning process. Several other Air Quality Impact Assessments (AQIAs) for Transport proposals have used all-cause mortality risk[2] as an endpoint for assessing the potential health risk from predicted incremental increase in ground level $PM_{2.5}$ concentrations ($\Delta PM_{2.5}$). For these proposals, the highest acceptable increase in risk was an increase in annual mortality of 1 in 10,000, which equated to a value for $\Delta PM_{2.5}$ of between 1.5 µg/m^3 and 1.8 µg/m^3.

The paper ‘An Australian incremental guideline for particulate matter ($PM_{2.5}$) to assist in development and planning decisions’ (Capon, A. & Wright J. 2019) provides a recommended incremental guideline that can be used to assess the impact of $PM_{2.5}$ from infrastructure development on a population.

Like previous AQIAs in NSW, the paper utilises all-cause mortality risk[3] as an endpoint for assessing the potential health risk from predicted incremental increase in ground level $PM_{2.5}$ concentrations as also used by the US EPA and UK’s Committee on the Medical Effects of Air Pollutants.

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[2] Baseline of incidence of all-cause mortality calculated for population age of 30 years and over.

[3] Baseline of incidence of all-cause mortality calculated for population age of 30 years and over.

Annual incremental concentrations of $PM_{2.5}$ for 1 in 1,000,000, 1 in 100,000 and 1 in 10,000 mortality rates using national and state ABS population data were calculated using the following equation:

$$\Delta_{PM2.5} = \frac{\ln\left(1 + \frac{\Delta AR\ \times population\ size}{number\ of\ total\ deaths\ in\ the\ population}\right)}{\beta}$$

Where:

$\Delta_{PM2.5}$ = Change in $PM_{2.5}$ concentration

ΔAR = Change in absolute risk (AR) where the absolute risk is equal to the number of deaths divided by the population. The change in AR was calculated is equal to absolute risk between a population at the higher annual average $PM_{2.5}$ concertation (AR_H) minus the absolute risk from the same population without the predicted increase in annual average $PM_{2.5}$ concertation (AR_L).

β = slope coefficient relevant of 0.0058, based on a relative risk of all-cause mortality of 1.06 per 10 $\mu g/m^3$ change in $PM_{2.5}$ concentrations

Calculated annual $\Delta PM_{2.5}$ for 1 in 1,000,000, 1 in 100,000 and 1 in 10,000 mortality rates were then used to define risk tolerances consistent with Section 7.3 of the Approved Methods (EPA 2017). Recommended assessment criteria for annual $\Delta PM_{2.5}$ exposure are discussed further in **Section 5.4.3** and **Section 5.5**.

5.4 Ambient air quality criteria and standards

5.4.1 NEPM standards

Ambient Air Quality NEPM

The AAQ NEPM standards under the NEPC Act (see **Section 5.2.1**) are aimed at achieving adequate protection of human health and wellbeing and apply to air quality experienced by the general population within a region. Under this general exposure approach, the standards are applicable to urban sites away from specific sources of pollution such as heavily trafficked streets and industrial smokestacks. The AAQ NEPM does not prescribe sanctions for non-compliance with the air quality standards and does not compel or direct air pollution control measures (NEPC 2021 and NEPC 2021a).

The AAQ NEPM standards as recently amended on 18 May 2021 are shown in **Table 5-1.**

The May 2021 amendment to the AAQ NEPM standards included changes to the standards for NO_2, SO_2 and ozone (O_3) concentrations and averaging periods. These changes have resulted in recommended maximum 1-hour and annual average concentrations for NO_2 and maximum 1-hour and 24-hour concentrations for SO_2 that are lower than NSW EPA air quality criteria (see **Section 5.4.2)**.

In the *Key Changes to the Ambient Air Quality Measure agreed by Ministers April 2021* statement issued by the NEPC (NEPC 2021a), it was asserted that standards in the AAQ NEPM are not intended to be applied as an environmental standard by regulators without consideration of regulatory impacts in their jurisdictions. The Explanatory Statement clarifies this intent of the NEPM as a standard for reporting representative ambient air quality within an airshed, and not as a regulatory standard.

Primary pollutants of interest for the construction footprint shown in **Table 5-1** as discussed in **Section 3.2** include CO, NO_2, PM_{10} and $PM_{2.5}$.

Table 5-1 NEPM Ambient Air Quality standards as updated 18 May 2021

Item	Pollutant	Averaging period	Maximum concentration standard	
			ppm	$\mu g/Nm^3$
1	Carbon monoxide (CO)	8 hours	9.0	11,250
2	Nitrogen dioxide (NO_2)	1 hour	0.08	164
		1 year	0.015	31
3	Photochemical oxidants (as ozone)	8 hours	0.065	139

Item	Pollutant	Averaging period	Maximum concentration standard	
			ppm	µg/Nm^3
4	Sulfur dioxide (SO_2)	1 hour	0.10	286
		1 day	0.02	57
5	Lead	1 year	-	0.50
6	Particles ≤ 10 microns in diameter (PM_{10})	1 day	-	50
		1 year	-	25
7	Particles ≤ 2.5 microns in diameter ($PM_{2.5}$)	1 day	-	25
		1 year	-	8
ppm = parts per million µg/Nm^3 = micrograms per normal cubic metre (under standard temperature and pressure).				

In addition to the current standards in **Table 5-1,** reductions of the 1-hour SO_2 standard and 24-hour and annual average $PM_{2.5}$ standards are proposed from 2025. The revised $PM_{2.5}$ standards are considered relevant to the assessment of operational impacts from the construction footprint given particulates have been identified as a primary pollutant of interest in **Section 3.2**.

As discussed above, SO_2 concentrations attributed to operation of the construction footprint are anticipated to very low compared to the proposed NEPM standard due to stringent diesel and petrol fuel quantity standards in Australia that limit sulphur content[4]. This pollutant is not of concern to the construction footprint.

Proposed changes to the AAQ NEPM standards for 2025 are provided in **Table 5-2**.

Table 5-2 NEPM proposed changes for Ambient Air Quality standards scheduled for 2025.

Item	Pollutant	Averaging period	Maximum concentration standard	
			ppm	µg/Nm^3
4	Sulfur dioxide (SO_2)	1 hour	0.075	216
7	Particles ≤ 2.5 microns in diameter ($PM_{2.5}$)	1 day	-	20
		1 year	-	7
ppm = parts per million µg/Nm^3 = micrograms per normal cubic metre (under standard temperature and pressure).				

Air Toxics NEPM

The Air Toxics NEPM includes monitoring investigation levels for use in assessing the significance of monitored levels of air toxics with respect to human health. The monitoring investigation levels are levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short term, it does not mean that adverse health effects automatically occur; rather some form of further investigation by the relevant jurisdiction of the cause of the exceedance is required. The relevant monitoring investigation levels defined in the Air Toxics NEPM are listed in **Table 5-3**.

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[4] The quality of automotive fuels in Australia is regulated by the *Fuel Quality Standards Act 2000*, the *Fuel Quality Standards Regulations 2001* and the *Fuel Standard (Automotive Diesel) Determination 2001* (updated in 2019). The sulphur content in diesel fuel is limited to 10 ppm. The maximum sulphur content in fuel for petrol is currently 50ppm with a further reduction of the standard to 10ppm scheduled for 2027. Vehicle emission regulation and strategies are discussed in Annexure B.

Table 5-3 Air Toxics NEPM Air Quality monitoring investigation levels

Pollutant	Averaging period	Monitoring investigation level
Benzene	Annual average	0.003 ppm
Benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons (PAHs)	Annual average*	0.3 ng/m^3
Formaldehyde	24 hours	0.04 ppm
Toluene	24 hours Annual average	1 ppm 0.1 ppm
Xylenes (as total of ortho, meta and para isomers)	24 hours Annual average	0.25ppm 0.2 ppm
Note: All pollutants have an 8-year goal to gather sufficient data nationally to facilitate development of a standard; however, to date (June 2022) no national standards have been developed from the monitoring investigation levels.		

5.4.2 NSW EPA air quality impact assessment criteria

In NSW, air quality impact assessment criteria are listed under Section 7 of the Approved Methods (EPA 2017) as discussed in **Section 5.3.1**. The pollutant specific criteria and corresponding averaging period for individual pollutants identified in **Section 3.2** are shown in **Table 5-4**.

Assessment of individual pollutants is based on pollutant type for pollutants listed in **Table 5-4**:

- Air quality impact assessment criteria for the following pollutants are assessed at sensitive receptor locations[5]:
  - Particulate matter (PM_{10} and $PM_{2.5}$)
  - Nitrogen dioxide (NO_2)
  - Carbon monoxide (CO)
- Air quality impact assessment criteria for the following pollutants are assessed at or beyond the boundary of the site (road property boundary in this case):
  - Volatile Organic Compounds (VOCs) including:
    - Benzene
    - Formaldehyde
    - Toluene
    - Acetaldehyde (ethanal)
    - Xylene
    - 1,3 butadiene
  - Polycyclic Aromatic Hydrocarbons (PAHs) (as Benzo(a)pyrene).

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[5] Sensitive receptors under the Approved Methods are defined as a location where people are likely to work or reside, including any potential future receptors. Sensitive receptors are discussed further in Section 5.5.

Table 5-4 NSW EPA air quality criteria

Pollutant	Averaging period	Criteria (µg/m^3)
Nitrogen Dioxide	1 Hour Maximum	164
	Annual Average	31
Carbon Monoxide	1 Hour Maximum	30,000
	8 Hour Maximum	10,000
Particulate matter (PM_{10})	24 Hour Maximum	25
	Annual Average	8
Particulate matter ($PM_{2.5}$)	24 Hour Maximum	25
	Annual Average	8
Benzene	99.9th Percentile 1-hour average	29
Formaldehyde	99.9th Percentile 1-hour average	20
1,3-butadiene	99.9th Percentile 1-hour average	40
Toluene	99.9th Percentile 1-hour average	360
Acetaldehyde	99.9th Percentile 1-hour average	42
Ethylbenzene	99.9th Percentile 1-hour average	8000
Xylene	99.9th Percentile 1-hour average	190
PAHs (as Benzo(a)pyrene)	99th Percentile 1 Hour	0.4
µg/m^3 = micrograms per cubic metre		

A further reduction in the maximum 24-hour and annual average $PM_{2.5}$ standards are proposed to come in to force under the AAQ NEPM in 2025 (see **Table 5-2**). The proposed changes would result in even more stringent standards when compared to the existing NSW EPA criteria in **Table 5-4**.

It is noted that currently, air pollution in many areas of the Sydney basin already exceeds the 2021 $PM_{2.5}$ standards. Broad government action in air quality across the Sydney basin is needed to address this situation and application of this lower standard to the construction footprint is considered unlikely to change any of the conclusions or recommendations reached in this assessment.

5.4.3 Health criteria for particulates

The paper *An Australian incremental guideline for particulate matter ($PM_{2.5}$) to assist in development and planning decisions* (Capon, A. & Wright J. 2019) provides a recommended incremental guideline that can be used to assess the impact of $PM_{2.5}$ from infrastructure development on a population. Recommended risk assessment criteria for annual $\Delta PM_{2.5}$ exposure; based on risk tolerances consistent with Section 7.3 of the Approved Methods (EPA 2017) are presented in **Table 5-5**.

Table 5-5 Recommended incremental health assessment criterion for annual $PM_{2.5}$ exposure

Incremental annual average $PM_{2.5}$ concentration (µg/m^3)	Increased risk of mortality	Risk acceptability and suggested interpretation	
		Risk classification	definition
0 – 0.02	<1 in 1,000,000	**Negligible**	Development poses negligible health risk

Incremental annual average $PM_{2.5}$ concertation (µg/m^3)	Increased risk of mortality	Risk acceptability and suggested interpretation	
		Risk classification	definition
0.02 – 0.17	1 in 1,000,000 – 1 in 100,000	**Acceptable**	Development needs to show use of best practice with consideration of reasonable and feasible measures to reduce pollutant load
0.17 – 1.7	1 in 100,000 – 1 in 10,000	**Tolerable**	Only if best practice is proven and reasonable, and feasible measures have been demonstrated. At this level, costly interventions are now considered reasonable and feasible, that would not have been in the acceptable range
>1.7	> 1 in 10,000	**Unacceptable**	Development poses unacceptable level of risk to health.

Based on **Table 5-5** a predicted annual $\Delta PM_{2.5}$ exposure of greater than 1.7 µg/m^3 would pose an unacceptable level of risk for the construction footprint, while incremental increases between 0.02 µg/m^3 and 1.7 µg/m^3 are considered acceptable or tolerable and the development would be required to demonstrate best practice with feasible mitigation measures required dependant on the level of increased risk. Adopted annual $\Delta PM_{2.5}$ health risk criterion for the construction footprint is discussed in **Section 5.5**.

5.5 Adopted assessment criteria

5.5.1 NSW EPA air quality criteria

The following air quality assessment criteria for the construction footprint in **Table 5-6** has been adopted based on the ambient air quality criteria in the Approved Methods.

Table 5-6 NSW EPA Air Quality criteria

Pollutant	Averaging Period	Criteria (µg/m^3)
Particulate matter (PM_{10})	24 Hour Maximum	25
	Annual Average	8
Particulate matter ($PM_{2.5}$)	24 Hour Maximum	25
	Annual Average	8
Nitrogen Dioxide	1 Hour Maximum	164
	Annual Average	31
Carbon Monoxide	1 Hour Maximum	30,000
	8 Hour Maximum	10,000
Benzene (C_6H_6)	99.9th Percentile 1-hour average	29
Formaldehyde	99.9th Percentile 1-hour average	20
1,3-butadiene	99.9th Percentile 1-hour average	40
Toluene (C_7H_8)	99.9th Percentile 1-hour average	360 µg/m^3
Ethylbenzene (C_8H_{10})	99.9th Percentile 1-hour average	8000 µg/m^3

Pollutant	Averaging Period	Criteria (µg/m^3)
Xylene (C_8H_{10})	99.9th Percentile 1-hour average	190 µg/m^3
PAHs (as Benzo(a)pyrene)	99th Percentile 1 Hour	0.4
µg/m^3 = micrograms per cubic metre		

5.5.2 Recommended Health Risk Assessment Criteria

As discussed in **Section 5.3.4**, there is no threshold below which there are no associated health impacts for particulates. Therefore, in addition to the criteria in **Table 5-6**, particularly given the high annal $PM_{2.5}$ concentrations within the Sydney Basin, discussed in **Section 5.3.4**, incremental health assessment criteria for annual $PM_{2.5}$ exposure have also been adopted for this assessment.

The risk assessment criteria for annual $\Delta PM_{2.5}$ exposure, as presented in **Table 5-5**, are:

- Negligible: 0 – 0.2 µg/m^3
- Acceptable: 0.2 – 0.17 µg/m^3
- Tolerable: 0.17 – 1.7 µg/m^3
- Unacceptable: > 1.7 µg/m^3.

This assessment criteria are also based on risk tolerances consistent with Section 7.3 of the Approved Methods (EPA 2017). Individual receptors have been assessed based on their level of risk as defined in **Table 5-5** with a predicted annual $\Delta PM_{2.5}$ exposure of greater than 1.7 µg/m^3 considered an unacceptable level of risk for the proposal.

5.6 Construction assessment methodology

Potential impacts from dust generation during construction were assessed using the UK Institute of Air Quality Management (IAQM), 2014 *Guidance on the assessment of dust from demolition and construction*. The assessment provides a classification of the risk of dust impacts which then allows the identification of appropriate mitigation measures commensurate with the level of risk.

The methodology of the construction assessment is described in the following sections.

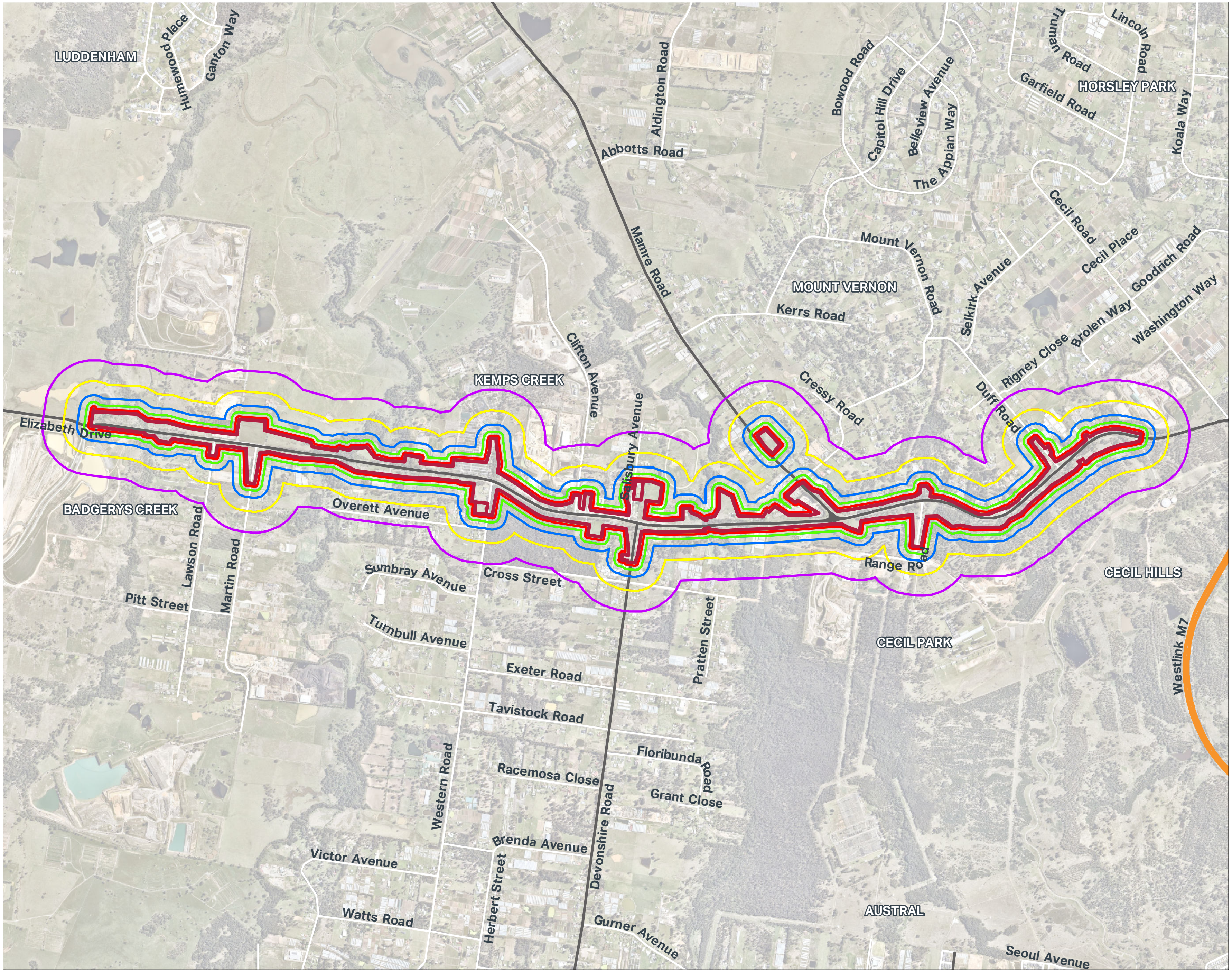
5.6.1 Study area

The proposal construction footprint including construction ancillary facilities is expected to cover an area of about 115 hectares and is shown in **Figure 5-1**.

Potential dust risk is relative to the dust sensitivity of sensitive receptors and their proximity to the construction boundary. Buffer distances of 20 metres, 50 metres, 100 metres, 200 metres and 350 metres from the construction footprint boundary have been used to define the study area for the construction assessment carried out in **Section 6.0**. Multiple buffer distances have been set to assess the potential sensitivity of receptors to dust and this is explained further in **Section 5.6.2.4**.

FIGURE 5-1:

CONSTRUCTION DUST ASSESSMENT STUDY AREA



Legend

- 🟥 Construction footprint
- 🟥 20m buffer from construction footprint
- 🟩 50m buffer from construction footprint
- 🟦 100m buffer from construction footprint
- 🟨 200m buffer from construction footprint
- 🟪 350m buffer from construction footprint
- — Motorway
- — Primary road

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5.6.2 Dust assessment methodology

IACM provides a qualitative risk assessment process for the potential unmitigated impact of dust generated from demolition, earthmoving, construction activities and trackout.

Trackout is defined in the IAQM as “the transport of dust and dirt from the construction/ demolition site onto the public road network, where it may be deposited and then re-suspended by vehicles using the network”.

The IAQM guidance process is a four-step risk-based assessment of dust emissions associated with demolition, land clearing and earth moving and construction activities. The IAQM assessment process is described in the following sections.

This assessment has been informed by construction and demolition volumes and equipment usage information as outlined in Chapter 3 of the REF.

5.6.2.1 Step 1 – screening assessment

Step 1 of the IAQM assessment requires the determination of whether there are any receptors close enough to warrant further assessment. An assessment is required where there is a human receptor within:

- 350 metres (m) from the boundary of a construction ancillary facility or boundary of construction work, or
- 50 m from the route used by construction vehicles on public roads up to 500 m from the construction work or construction ancillary facility entrance.

A detailed assessment is also required if an ecological receptor is within:

- 50m of the boundary of the site, or
- 50 m from the route used by construction vehicles on public roads up to 500 m from a site entrance.

5.6.2.2 Step 2 – dust risk assessment

Step 2 in the IAQM is a risk assessment tool designed to appraise the potential for dust impacts due to unmitigated dust emissions. The key components of the risk assessment involve defining:

- Dust emission magnitudes (Step 2A)
- The surrounding area’s sensitivity to dust emissions (Step 2B)
- Combining these in a risk matrix (Step 2C) to determine a potential risk rating for dust impacts on surrounding receptors.

Additional details on steps 2A, 2B and 2C are provided in the following sections.

5.6.2.3 Step 2A – dust emission magnitude

Dust emission magnitudes are estimated according to the scale of work being carried out classified as small, medium or large. The IAQM guidance provides examples of demolition, earthworks, construction and trackout to aid classification (refer **Table 5-7**).

It should be noted that the IAQM guidance document provides generic activity criteria for estimating dust emission magnitude from construction and demolition proposals and construction activity criteria have been modified to account for road proposals.

Table 5-7 Emission magnitudes for small, medium and large demolition and construction activities

Activity	Activity criteria	Small	Medium	Large
Demolition	Total building volume (m^3)	<20,000	20,000–50,000	>50,000
	Material type	Material with low dust generating potential	Potentially dusty material	Potentially dusty and includes crushing and screening

Activity	Activity criteria	Small	Medium	Large
	Demolition height	<10m AGL	10-20m AGL	>20m AGL
Earthworks	Total site area (m^2)	<2,500	2,500–10,000	>10,000
	Number of heavy earth moving vehicles active at one time	<5	5-10	>10
	Total material moved (tonnes (t))	<20,000	20,000–100,000	>100,000
	Bund height	< 4m	4 to 8m	> 8m
	Fine content of soil type	Low fine content (eg sand)	Moderately fine content (eg silt)	High fine content (eg clay)
Construction	Total building volume (m^3)	<25,000	25,000–100,000	>100,000
	Road length	<1km	1-2km	>2km
	Construction Duration	< 6months	6– 12 months	>12 months
	Construction ancillary facilities & laydown areas*	Temporary laydown area only	1 Construction ancillary facilities & laydown area	> 1 Construction ancillary facilities & laydown areas
	Operation of plant equipment including diesel generators.	No or minor reliance	Moderate reliance	Heavy reliance
Trackout	Number of heavy vehicle movements per day	<10	10-50	>50
	Surface material dust potential	Low fine content (eg sand)	Moderately fine content (eg silt)	High fine content (eg clay)
	Length of unpaved road access	<50m	50-100m	>100m
< represents less than *> represents greater than*				

5.6.2.4 Step 2B – sensitivity of the surrounding area

Under the IAQM Guidance document a sensitive receptor is defined as a location that may be affected by dust emissions during demolition and construction. Human receptors include locations where people spend time and where property may be impacted by dust. Ecological receptors are habitats that might be sensitive to dust.

The ‘sensitivity’ component of the risk assessment is determined by defining the surrounding areas sensitivity to dust soiling, human health effects and ecologically important areas. This is described further below.

Sensitivity of the area to dust soiling and human health effects

The IAQM methodology classifies the sensitivity of an area to dust soiling and human health impacts due to particulate matter effects as high, medium, or low. Dust soiling refers to the degradation of amenity due to dust falling out of suspension and accumulating on surfaces.

The classification is determined by a matrix for both dust soiling and human health impacts (refer **Table** 5-8 and **Table 5-9** respectively). Factors used in the matrix tables to determine the sensitivity of an area are as follows:

- Receptor sensitivity (for individual receptors in the area):
    - High sensitivity: locations where members of the public are likely to be exposed for eight hours or more in a day (eg private residences, hospitals, schools, or aged care homes)
    - Medium sensitivity: places of work where exposure is likely to be eight hours or more in a day

  - Low sensitivity: locations where exposure is transient, about one or two hours maximum (eg parks, footpaths, shopping streets, playing fields)
- Number of receptors of each sensitivity type in the area
- Distance from source
- Annual mean PM_{10} concentration (only applicable to the human health impact matrix).

Table 5-8 Surrounding area sensitivity to dust soiling effects on people and property

Receptor sensitivity	Number of receptors	Distance from the source (m)			
		<20	20 50	50 100	100 350
High	>100	High	High	Medium	Low
	10-100	High	Medium	Low	Low
	1-10	Medium	Low	Low	Low
Medium	>1	Medium	Low	Low	Low
Low	>1	Low	Low	Low	Low

The IAQM guidance provides human health sensitivities for a range of annual average PM_{10} concentrations (ie >32, 28-32, 24-28 and <24 µg/m³). It is noted in the IAQM guidance that the human health sensitivities are tied to criteria from different jurisdictions (UK and Scotland). The annual average PM_{10} criteria for Australia differ from the UK and Scotland and as such concentrations corresponding to the risk categories need to be modified to match Australian conditions.

The annual average criterion for PM_{10} in NSW is 25 µg/m³ (refer **Section 5.5**) and, therefore, the scaled criteria for NSW is:

- >25 µg/m³
- 22-25 µg/m³
- 19-22 µg/m³
- <19 µg/m³.

The background PM_{10} concentrations in the region surrounding the proposal are outlined in **Section 4.2.2.3**, which notes that regional annual average PM_{10} concentrations between 2015 and 2020 vary from about 15 µg/m³ to just below 25 µg/m³. The majority of annual PM_{10} concentrations, however, fit into the 19-22 µg/m³ range and therefore this PM_{10} category has been adopted for the IAQM assessment.

Table 5-9 provides the IAQM guidance sensitivity levels for human health impacts for the ranges outlined above for the annual average PM_{10} concentrations and highlights (in bold outline) the relevant range for NSW.

Table 5-9 Surrounding area sensitivity to human health impacts for annual average PM_{10} concentrations

Receptor sensitivity	Annual average PM_{10} concentration	Number of receptors	Distance from the source (m)				
			<20	<50	<100	<200	<350
High	>25 µg/m³	>100	High	High	High	Medium	Low
		10-100	High	High	Medium	Low	Low
		1-10	High	Medium	Low	Low	Low
	22-25 µg/m³	>100	High	High	Low	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	High	Medium	Low	Low	Low

Receptor sensitivity	Annual average PM$_{10}$ concentration	Number of receptors	Distance from the source (m)				
			<20	<50	<100	<200	<350
	19-22 µg/m^3	>100	High	Medium	Low	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	Medium	Low	Low	Low	Low
	<19 µg/m^3	>100	Medium	Low	Low	Low	Low
		10-100	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
Medium	>25 µg/m^3	>10	High	Medium	Low	Low	Low
		1-10	Medium	Low	Low	Low	Low
	22-25 µg/m^3	>10	Medium	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
	19-22 µg/m^3	>10	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
	<19 µg/m^3	>10	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
Low	-	≥1	Low	Low	Low	Low	Low

The sensitivity for each construction activity defined by the IAQM guidance is assessed for the proposal. This results in a sensitivity rating for the construction footprint along with ratings for portions of the construction footprint for each construction activity. The ratings depend on the sensitivity of the receptors and the distance from the edge of the construction footprint. As shown in **Table 5-8** and **Table 5-9** the greater the distance from the construction footprint (the source), the lower the rating. The highest rating achieved is adopted as the final rating for that group of receptors.

It should be noted that this is not a quantitative human health assessment and risks discussed in this context need to be understood in terms of the IAQM guidance. For a group of receptors, a risk rating indicates the risk that group of receptors may experience unmitigated dust concentrations above the NSW criteria, with the associated potential health effects linked to that criterion. Once mitigated through the application of air emissions mitigation measures (as part of a well-designed air quality management plan), the dust impacts would be expected to be negligible.

Sensitivity of area to ecological impacts

Ecological impacts from construction activities occur due to deposition of dust on ecological areas. The sensitivity of ecological receptors can be defined by the following:

- High sensitivity ecological receptors
    - Locations with international or national designation and the designation features may be affected by dust soiling
    - Locations where there is a community of particularly dust sensitive species
- Medium sensitivity ecological receptors
    - Locations where there is a particularly important plant species, where its dust sensitivity is uncertain or unknown
    - Locations within a national designation where the features may be affected by dust deposition
- Low sensitivity ecological receptors

- Locations with a local designation where the features may be affected by dust deposition.

The sensitivity of an ecological area to impacts is assessed using the criteria listed in **Table 5-10**. Ecological receptors are discussed in **Section 4.5.1**. The biodiversity assessment study area (refer to Section 6.3 of the REF) contains threatened ecological entities, and the area has a long history of disturbance. Given the area contains threatened entities, where its dust sensitivity is uncertain or unknown, and the study area is a location with a local designation where the features may be affected by dust deposition, the study area receptor sensitivity would be considered low to medium based on sensitivity classification listed above.

Table 5-10 Sensitivity of an area to ecological impacts

Receptor sensitivity	Distance from source (m)	
	<20	20 50
High	High	Medium
Medium	Medium	Low
Low	Low	Low

5.6.2.5 Step 2C – unmitigated risks of impacts

The dust emission magnitude as determined in Step 2A is combined with the sensitivity as determined in Step 2B to determine the risk of dust impacts with no mitigation applied. **Table 5-11** provides the risk ranking for dust impacts from construction activities for each scale of activity as listed in **Table 5-7**.

Table 5-11 Risk of dust impacts (for dust soiling and human health impacts)

Activity	Surrounding area sensitivity	Dust emission magnitude		
		Large	Medium	Small
Demolition	High	High	Medium	Medium
	Medium	High	Medium	Low
	Low	Medium	Low	Negligible
Earthworks	High	High	Medium	Low
	Medium	Medium	Medium	Low
	Low	Low	Low	Negligible
Construction	High	High	Medium	Low
	Medium	Medium	Medium	Low
	Low	Low	Low	Negligible
Trackout	High	High	Medium	Low
	Medium	Medium	Low	Negligible
	Low	Low	Low	Negligible

5.6.2.6 Step 3 – management strategies

The outcome of Step 2C is used to determine the level of management that is required to ensure that dust impacts on surrounding sensitive receptors are maintained at an acceptable level. A high or medium-level risk rating suggests that management measures must be implemented during the construction of the proposal. Mitigation measures should be specifically designed to minimise the emissions from the source to which they are applied and implemented at an appropriate level (eg low level road watering on a dry highly trafficked roadway may not reduce dust impacts by the desired amount).

5.6.2.7 Step 4 – reassessment

The final step of the IAQM methodology is to determine whether there are significant residual impacts, post mitigation, arising from a proposed development. The IAQM guidance states:

For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be "not significant".

Based on this expectation, as well as experience within Australia, construction activities with targeted mitigation measures can achieve high degrees of dust mitigation which significantly reduce dust impacts to a negligible level.

5.6.3 Combustion emissions

As discussed in the IAQM 2013, experience of assessing the exhaust emissions from onsite mobile and stationary equipment as well as construction traffic suggests they are unlikely to make a significant impact on local air quality. Therefore, quantitative assessment of combustion emissions from construction of the proposal is not required.

Potential impacts from combustion emissions from construction of the proposal has been qualitatively assessed in **Section 6.3**. The qualitative assessment of combustion emissions from site plant and on-site traffic takes into consideration the estimated daily vehicle movements and type of plant equipment required during construction as discussed in **Section 6.1.4**.

5.6.4 Odour emissions

A qualitative assessment of odour impacts from construction work associated with the proposal are provided in **Section 6.4**. Potential sources of odour would largely be limited to potential disturbance of acid sulphate soils or from uncontrolled fill along the road alignment during earthworks.

5.7 Operational assessment methodology

Assessment of operational impacts from the construction footprint was carried out as a Level 2 Assessment in accordance with the Approved Methods (EPA 2017). This section describes the operational air quality assessment methodology for the construction footprint.

Broadly speaking, the assessment of the effect of a large-scale infrastructure proposal on air quality involves the collection of a range of data which are combined with a dispersion model to predict the concentration of a pollutant at a location (whether that location is a sensitive receptor location or at an arbitrary point within the modelling domain to enable the generation of a contour plot). The data required for this study can be categorised as follows:

- ***Description of the study area***: this sets the boundaries of the overall proposal or provides context to the overall analysis that occurs later in the report.
- ***Modelling scenarios***: the modelling scenarios present the basis for each modelling run, in terms of matters such as the modelling year, proposal assumptions (eg either with the proposal or without the proposal). These scenarios then form the basis of the impact assessment comparisons (ie comparisons between with and without proposal at a certain calendar year in the future along with comparisons between future calendar year emissions and an existing scenario).
- ***Model selection discussion***: selection of a dispersion model is an important step as it provides justification for the use of the model chosen for the construction footprint. A detailed model selection justification is vital to ensuring that the selected model is appropriate for the construction footprint.
- ***Dispersion modelling inputs***: modern dispersion models require a wide range of information to ensure the results are as representative as possible of the airshed in which the model is situated. There are several different categories of input data critical to the modelling, including meteorology, terrain characteristics and receptor locations (to name but a few), which have all been discussed below.
- ***Emissions Inventory***: along with the dispersion modelling inputs outlined above, an estimate of the air pollutant emissions is required for the construction footprint. The inventory includes all

aspects of the construction footprint relevant to the emissions from the roadway, which has been divided up into a series of 'links' which represent a portion of the roadway.

The above proposal data inputs are further described in the following sections.

5.7.1 Study area

The area of interest for the proposal covers about 7.8 kilometres of Elizabeth Drive from just west of Cecil Road at Cecil Park to near Badgerys Creek Road at Badgerys Creek. The study area for the proposal consists of the domain within the GRAMM modelling domain, which is presented as a purple rectangle in **Figure 5-2.**

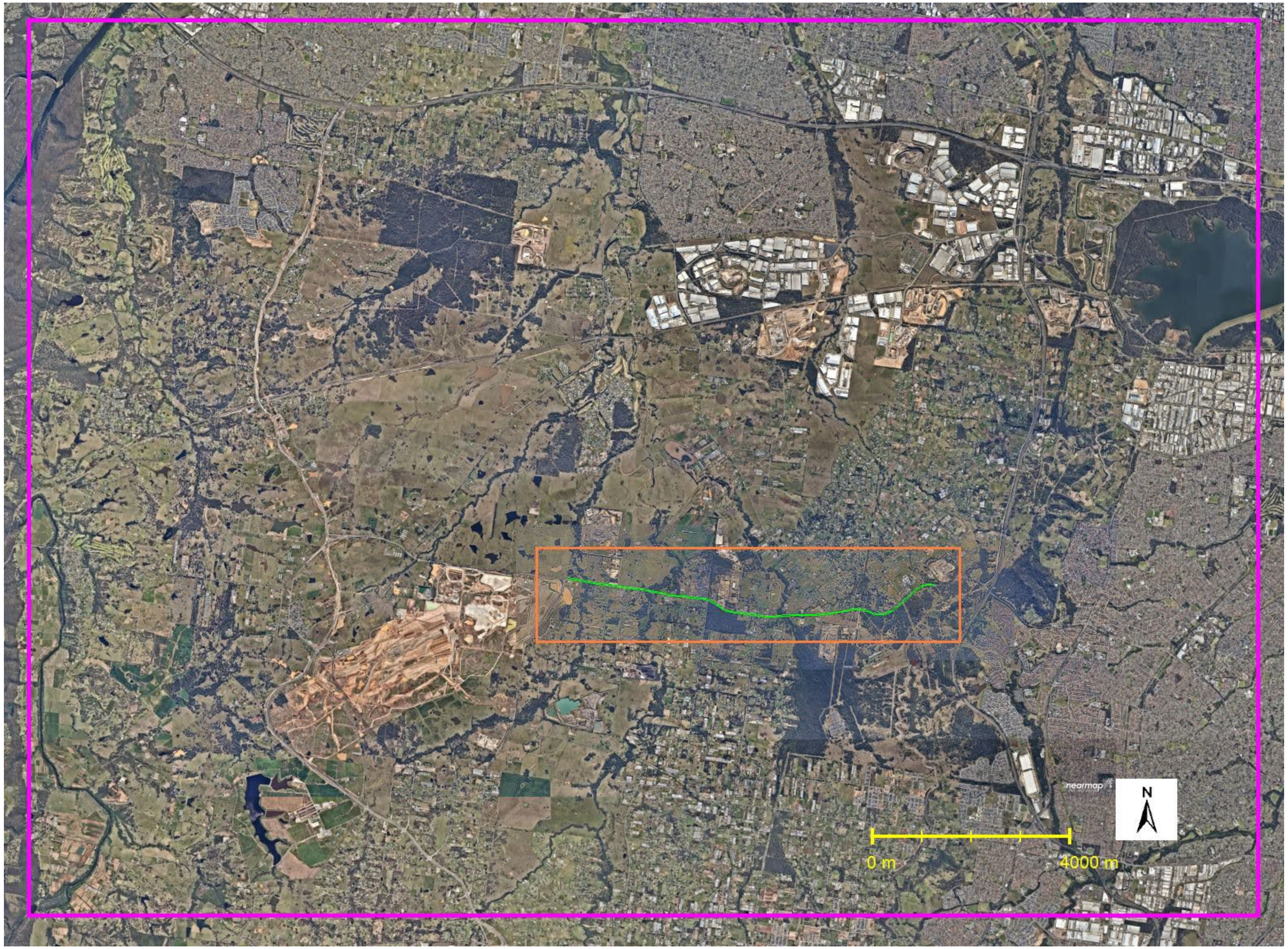

Figure 5-2 Study area (inside purple rectangle – GRAMM domain, orange rectangle depicts GRAL domain)

5.7.2 Modelling scenarios

Dispersion modelling scenarios define how the emissions from a site are combined for use in a dispersion model. Information on physical source dimensions, pollutant emission rates and variable operational modes are combined to try and ensure the scenarios represent a realistic picture of the overall emissions profile.

The scenarios modelled in this assessment were based on existing roadway emissions (based on 2021) and future roadway emissions (based on 2026 and 2036 emission factors and 2030 and 3040 traffic data both with and without the proposal).

Five modelling scenarios were investigated for the proposal to determine the potential impacts of the construction footprint from an air quality perspective. The modelling scenarios developed for this assessment are described in **Table 5-12**.

Table 5-12 Modelled scenarios

ID	Name	Description
Scenario 1	**Existing**	Traffic operations based on 2021 traffic volumes based on the existing traffic lane layout.
Scenario 2	**Do Nothing** Opening year 2030	Traffic operations based on 2030 traffic volumes without the proposal utilising existing traffic lane layout.
Scenario 3	**Proposal** Opening year 2030	Traffic operations based on 2030 traffic volumes with the proposed traffic lane layout.
Scenario 4	**Do Nothing** Opening year plus 10 – 2040	Traffic operations based on 2040 traffic volumes without the proposal utilising existing traffic lane layout.
Scenario 5	**Proposal** Opening year plus 10 - 2040	Traffic operations based on 2040 traffic volumes with the proposed traffic lane layout.

Given that Elizabeth Drive is an existing road, the focus of this investigation and the above scenarios is to demonstrate that the changes to air quality as a result of the proposal would not result in an unacceptable change to air quality in the environment surrounding the proposal. The results section and impact assessment are focused on the demonstration that the change is acceptable, not whether the roadway itself complies with environmental standards.

5.7.3 Model selection

The land use near to the proposal consists of a mixture of rural residential buildings, farmland, industrial, and commercial with riparian corridors along creek lines. Most of the buildings are low, either single or two-storey. Some of the residential receptors are very close to the existing Elizabeth Drive and the proposal. The use of a dispersion model to predict concentrations in the near field is required. The common dispersion models used for complex modelling scenarios (AERMOD and CALPUFF) do not perform well within 100 m, and, therefore, an alternative model was used. Given its ability to provide dispersion concentrations on micro-scale grids within complex building environments, the GRAL model has been used for this assessment.

GRAL is a Lagrangian Particle model developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria specifically to assess the dispersion of pollutants from roadways and tunnel portals. GRAL has been extensively evaluated against experimental data and a list of relevant validation studies for GRAL are provided in Table C-1 in Appendix A of Pacific Environment (2017).

AECOM has been in direct contact with GRAZ University and the GRAL developers to discuss the model’s evaluation procedures, scientific basis and application in Australia. Through this relationship, the model and its evaluation data have been thoroughly reviewed, providing confidence in the use of the model for proposals in Australia.

Of particular note, the GRAL model has algorithms which effectively consider the flow of air over buildings which form complex building wakes which affect the dispersion of pollutants. This is a particular advantage over Gaussian plume models.

5.7.4 Dispersion modelling inputs

The GRAMM / GRAL model requires a range of data inputs that need to be defined prior to running the model. These data can be broadly separated into the following categories:

- Meteorological data
- Terrain data
- Land use data
- Building data
- Receptor locations
- Source emissions data.

A flow chart outlining the dispersion modelling process adopted for this assessment, including input and output data is presented in **Figure 5-3**. The dispersion modelling inputs used in this assessment are described below, with the exception of source emission data which is discussed in **Section 5.7.5.** Dispersion model results are discussed in **Section 7.0**.

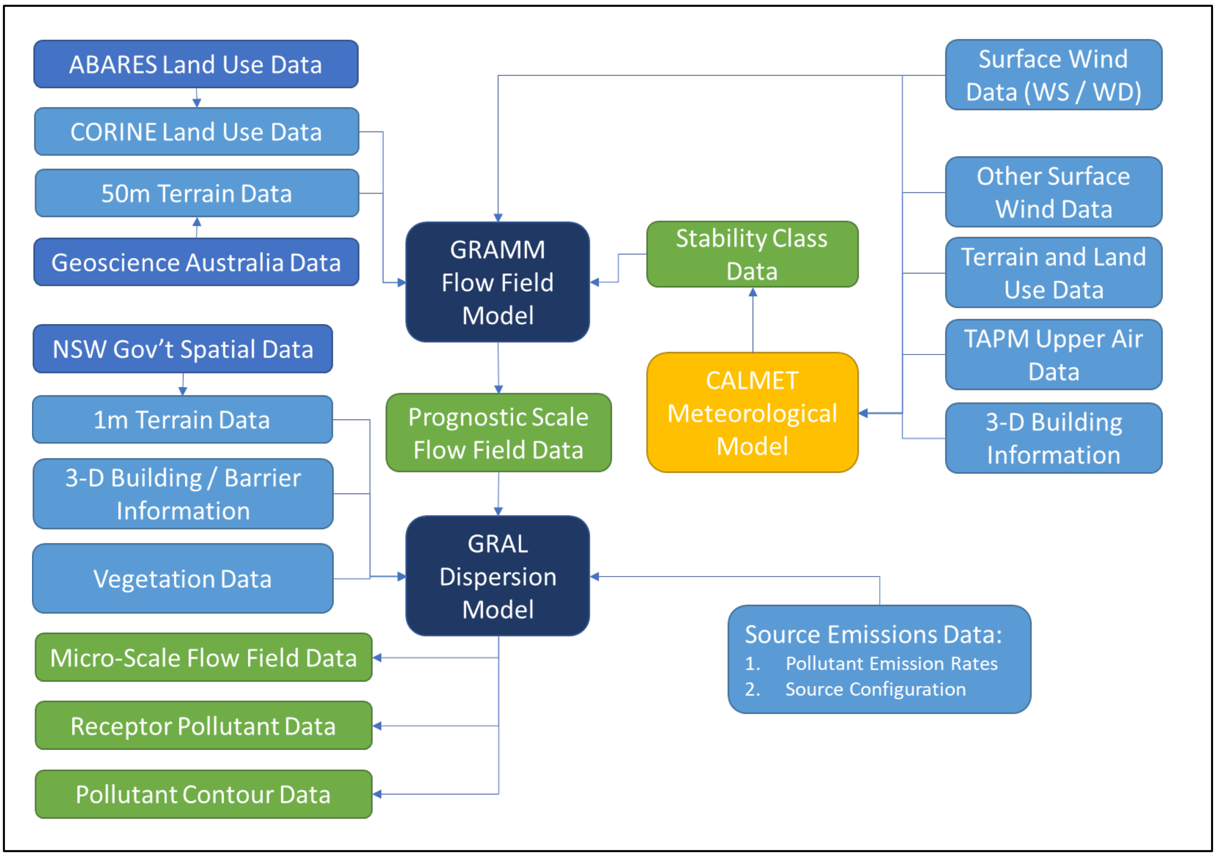

Figure 5-3 Site model program and input flow chart

5.7.4.1 Dispersion meteorology

Meteorological data is vital to a dispersion modelling proposal as it directly influences the direction that the pollution is transported from the source, the degree of mixing that occurs in the atmosphere and the size and extent of the plume as it moves away from the source.

The meteorological data used by the GRAL dispersion model is developed through the use of the meteorological data pre-processor, GRAMM, which takes raw meteorological data and geophysical information from the modelling domain and generates a three-dimensional data set ready for use in GRAL.

The GRAMM modelling process consists of a multi-step procedure aimed at generating a three-dimensional wind field that is as representative of local conditions as possible. The meteorological modelling process includes several stages of analysis and modelling which progressively develops and improves the meteorological data that is used by GRAL. The stages of data analysis and processing for GRAMM meteorological data preparation are as follows:

- Preparation of geophysical data (terrain data and land use information) for the modelling domain
- Development of a synthetic meteorological data set
- Running of the GRAMM model using the synthetic meteorological data set
- Identification and assessment of surface observation stations within the modelling domain to evaluate their applicability
- Selection of meteorological data from an appropriate time period
- Development of a CALMET dataset to enable stability classes to be generated for surface observation stations
- Match to observation (MTO) function in GRAMM is utilised using firstly synthetic flow field data and secondly observation station data to produce a refined flow field data set for use in GRAL.

The GRAMM modelling is described in the following section and in **Appendix C**.

Preparation of GRAMM domain geophysical data

Geophysical data for the GRAMM model consisting of topographical data and land use data is processed into a format accepted by the GRAMM model. Topographical data (5m digital elevation model) was sourced from the Elvis database.

Land use data was sourced from the ABARES[6] data Land Use codes which were converted manually from the ABARES values to the CORINE values that are used in GRAMM.

Development of a synthetic meteorological data set

The purpose of the synthetic meteorological data set is to provide the GRAMM model with all possible meteorological conditions from which the GRAMM model can then use to generate wind fields across the modelling domain for all possible wind situations. For this proposal, there were 4,536 synthetic meteorological conditions considered which included the following meteorological conditions:

- *Wind direction*: 36 wind sectors of 10° sectors
- *Wind Speed*: 21 wind speed categories considered including 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10.0m/s
- *Stability Class*: all stability classes considered for all wind speed and direction data.

GRAMM was run for all synthetic meteorological conditions which generated 4,536 wind fields which were evaluated by the match to observation function within the GRAMM program.

The MTO function is to find the best fit between computed wind fields and measured data for a given number of observation stations (Oettl et al, 2020). It is important to understand that the MTO function does not generate new wind fields itself, rather it looks at the observational data from the meteorological stations within a domain and selects the wind fields that best fit the observed conditions at the observational station(s). The end-product of this procedure is a time series of wind fields which is used as meteorological data for the GRAL model. This approach has been shown to generate meteorology that is much better than simply using single station meteorology for the generation of GRAMM data for use in GRAL (RMS 2017).

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[6] Land use data download - DAWE

Identification and assessment of surface observation stations

As described above, the MTO function uses observational data to develop a meteorological data set from a range of synthetic conditions. The observational data is critical to this process as the observational data serves as the basis for the statistical MTO analysis. Given the reliance of the MTO function on observational data, the data used for the analysis needs to be as representative as possible of the overall domain and where possible unaffected by localised effects which may skew the results (eg buildings or trees close to an observation station can skew wind patterns which may in turn skew the MTO function).

Several stations were identified within the two GRAMM domains that may be considered representative of the area. These stations were as follows:

- Badgerys Creek Bureau of Meteorology (BoM) station
- Horsley Park BoM Station.

Location of the BoM monitoring stations, and the corresponding GRAMM domain (purple rectangle), are shown in **Figure 5-5**. The GRAL domain is also shown in orange.

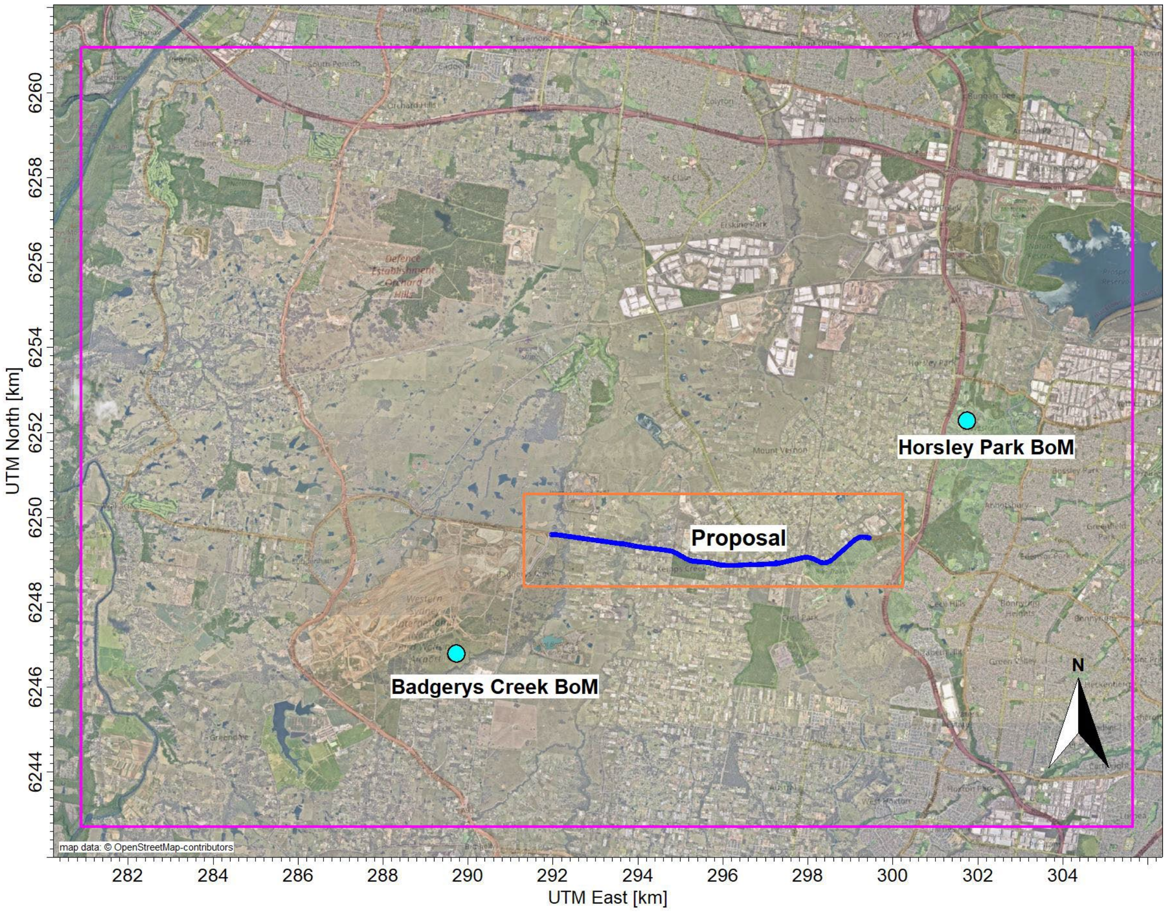

Figure 5-4 Location of BoM monitoring stations used in the GRAMM modelling

Physical characteristics and monitored data for the stations identified above were examined to determine whether these locations were acceptable for use in the modelling. A detailed analysis of each station is included in **Appendix D**. The findings of the analysis showed that reasonable results were obtained using data from both stations in the MTO analysis.

Development of a CALMET dataset

Stability class data is required as an input to the MTO process. To enable the development of stability classes, a CALMET run was carried out, and stability classes extracted at the location of the surface stations. A total of 23 meteorological stations (operated by either DPE or BoM) were identified within or close to the Sydney region surrounding the study area and were considered to be suitable for inclusion in the CALMET meteorological model. Stations used to calculate stability classes for use in the CALMET model to provide the stability classes for the GRAMM model are shown in **Figure 5-5**. A detailed analysis of the meteorological station suitability and CALMET settings are provided in **Appendix D**.

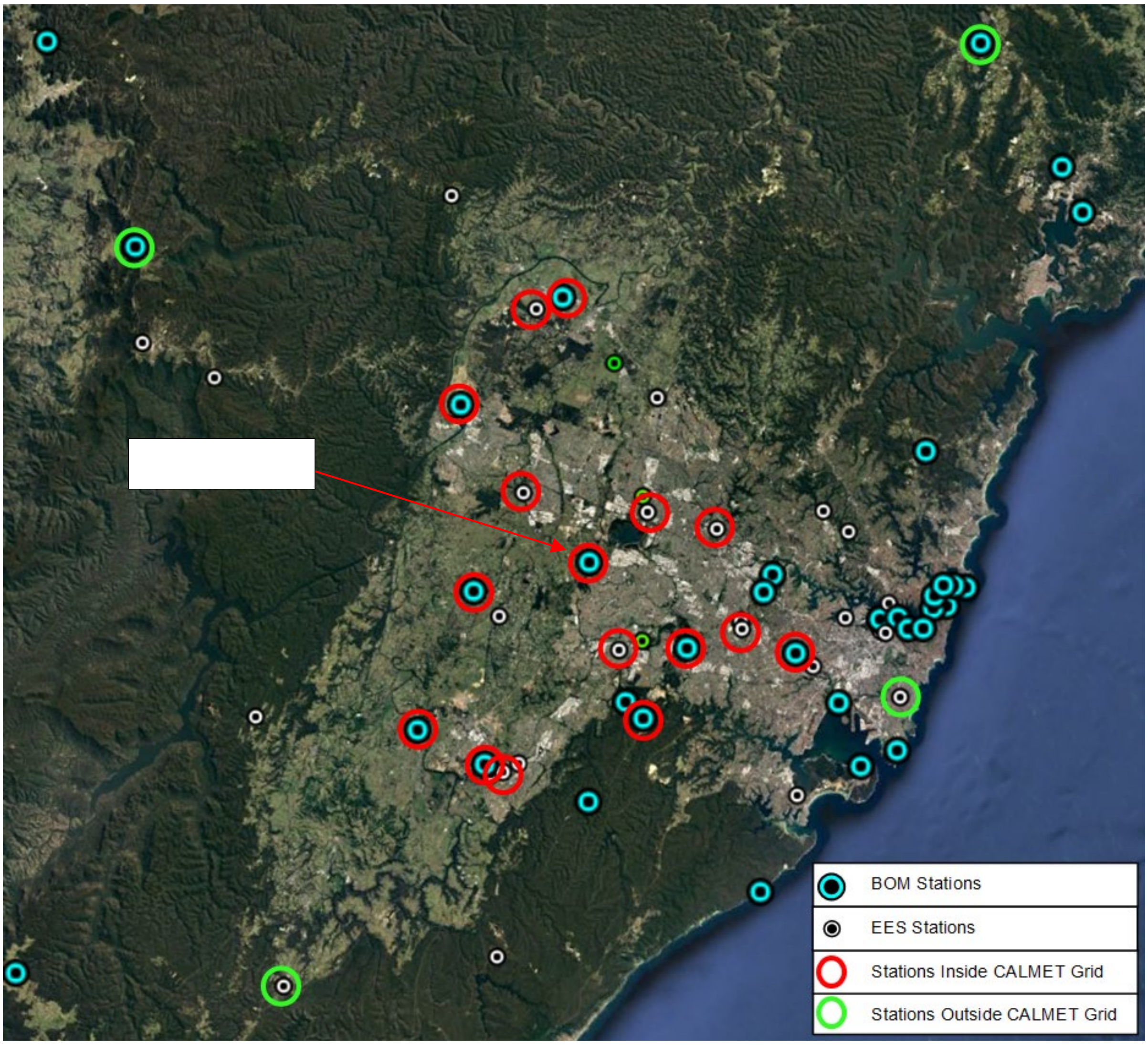

Figure 5-5 Location of Regional DPE and BoM monitoring stations used for CALMET modelling

Match to Observation Function

Following the preliminary GRAMM modelling of the synthetic meteorological data, assessment of the observation stations and the generation of stability classes from CALMET data, a meteorological data file for the 2016 to 2018 period was developed in GRAMM meteorology input format. This data was entered into the MTO function within GRAMM and a time series of meteorological conditions best matching the surface station observations generated from the MTO modelling run.

The MTO function can be adjusted using a weighting factor for each station allowing a closer, more representative station to more heavily influence the MTO process. A range of weightings were trialled for the surface stations to determine a best fit MTO outcome in GRAMM. A summary of the trialled weightings is presented in **Appendix C**. Of the options trialled and discussed, the option using the two stations with equal weighting was selected.

A further comparison of observed winds at the Horsley Park BoM station and the GRAMM MTO data at the Badgerys Creek and Horsley Park BoM station locations are presented in **Figure 5-6**. This shows that the correlation is not perfect, however, the general trends of the observations are present in the

MTO data and it is considered acceptable for use in this assessment. A detailed discussion of the MTO process and analysis of the data is provided in **Appendix C**.

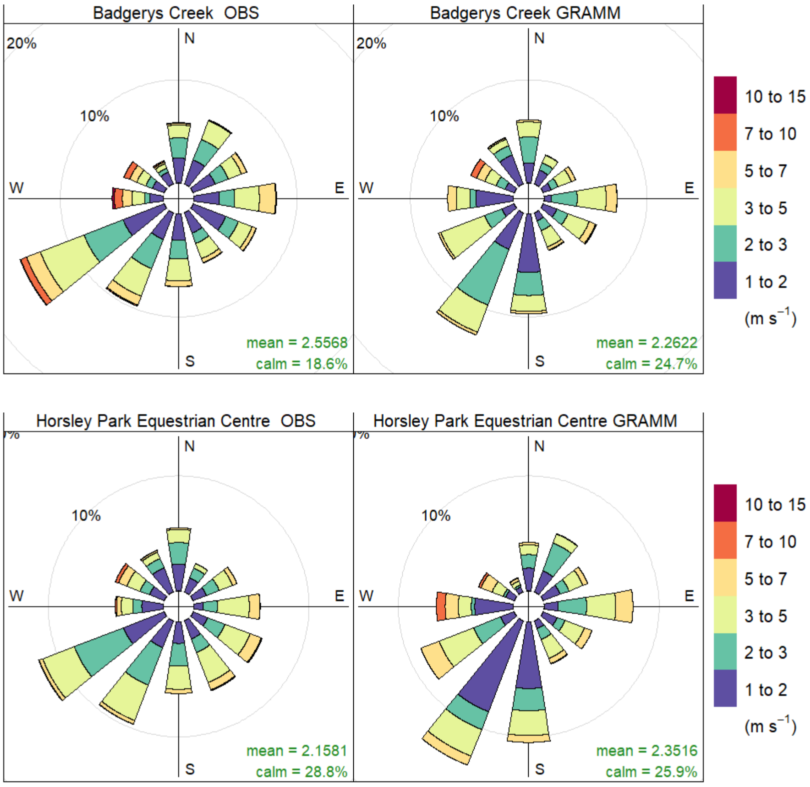

Figure 5-6 Badgerys Creek and Horsley Park measured and MTO wind rose comparison

A range of wind fields were extracted for analysis as part of the meteorological data verification process. The most frequent wind condition experienced for the MTO modelling domain is shown below in **Figure 5-7**. The GRAMM wind fields showed that winds across the study area were generally consistent for the most common wind condition and only mildly affected by terrain and land use as wind speeds change across the domain.

The corresponding GRAL wind field for the most common wind condition is presented in **Figure 5-8**. Note that this is only a small section of the GRAL domain to show the interaction of winds with the buildings in the model. The winds in this figure are extracted from GRAL at a height of five metres above ground level. Buildings taller than five metres block the winds, while buildings shorter than five metres allow the winds to pass over.

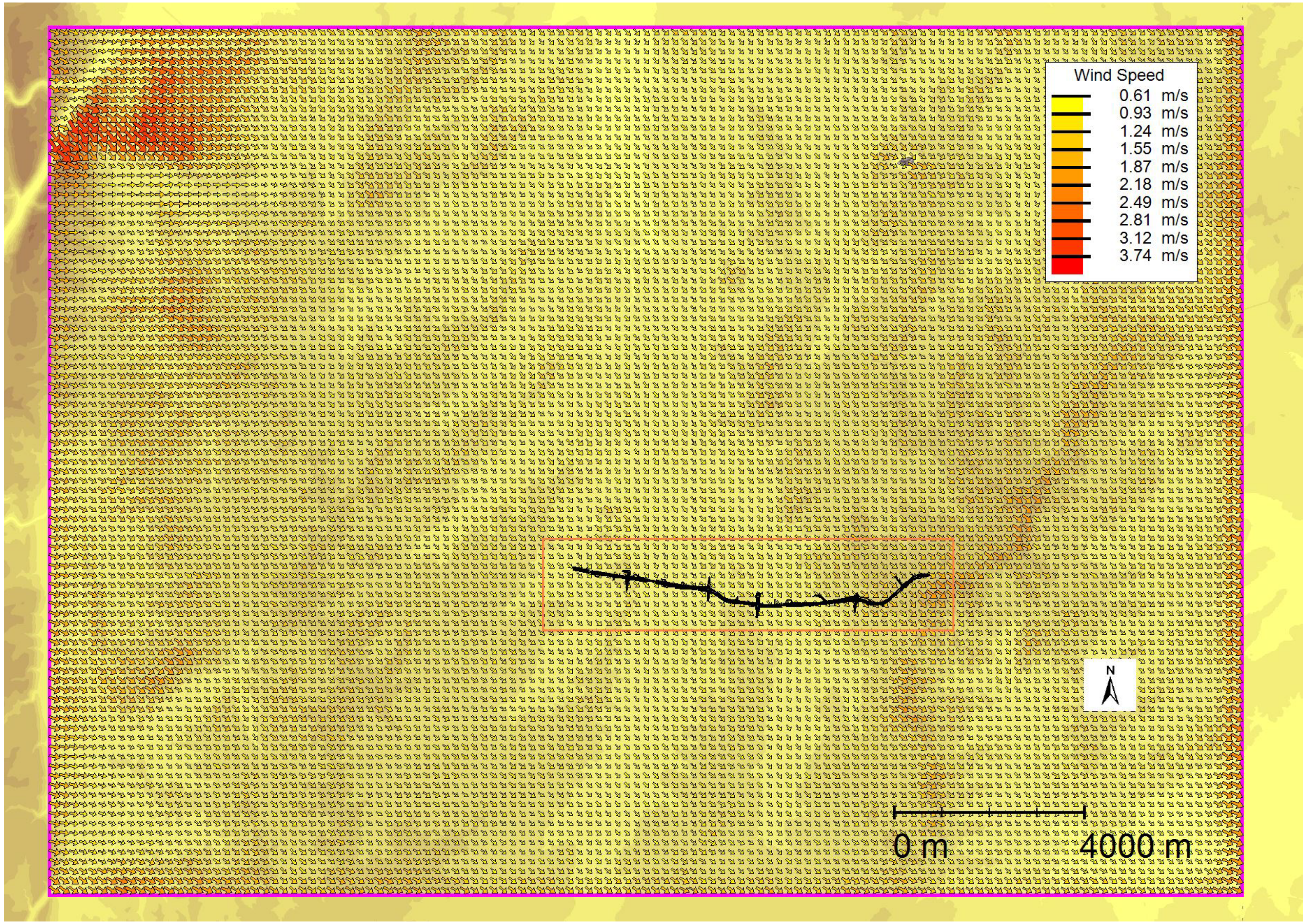

Figure 5-7 Most common GRAMM wind field – 290 degree (NW) wind at 2 m/s and stable atmospheric conditions

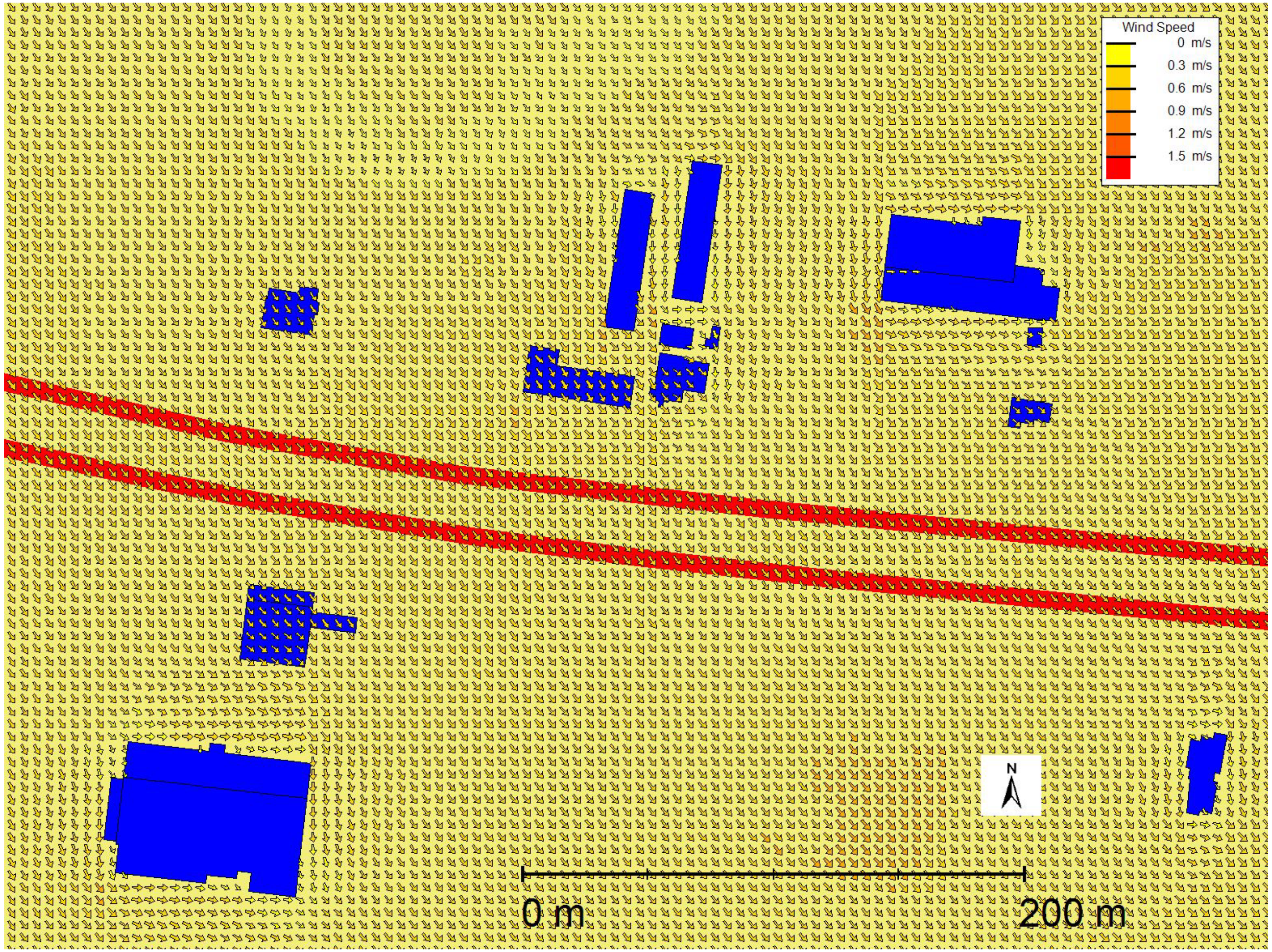

Figure 5-8 Most common GRAL wind field – 290 degree (NW) wind at 2 m/s and stable conditions at 5m height (red lines are the road sources, blue objects are buildings)

5.7.4.2 Terrain data

Terrain data has been extracted for both the GRAMM and the GRAL meteorological data development from 5m NSW Government Spatial Services Digital Elevations Models (DEMs) database. The terrain data used by the GRAMM model to develop the regional wind fields is displayed in **Figure 4-13**.

The GRAL model also produces wind fields for the dispersion calculations. GRAL wind fields are based on GRAMM wind fields as an initial guess with the winds flow around the obstacles (buildings, vegetation etc) calculated before calculations are carried out to calculate the plume dispersion.

A 5 m terrain resolution data set was used by this study which provides enough detail to accurately resolve wind flows around buildings on a small scale. A plot showing the terrain included in the GRAL modelling is shown on **Figure 5-9**, along with the proposal.

Figure 5-9 GRAL terrain data representation (5m resolution)

Terrain data used for the CALMET data generation was obtained from the SRTM 30 m Global Terrain Database. This data was used to establish the overall terrain height used to generate the meteorology extracted from CALMET for use in the GRAMM model and the CALPUFF model. The terrain for the CALMET domain is discussed in **Appendix D**.

5.7.4.3 Land use data

Changes in land use can affect how air moves across the earth's surface with factors such as surface roughness, soil moisture, albedo (measure of the diffuse reflection of solar radiation), and heat conductivity all influencing wind speed and direction over the modelling domain. A more detailed description of the land use scheme and the effects of the different settings is provided in the GRAL documentation.

GRAMM model uses the CORINE land use scheme which outlines land uses according to 44 different categories as defined in the GRAMM user manual. Data for use in the modelling was extracted using GIS techniques from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) 'Catchment Scale Land Use of Australia', December 2018 version. Cross checks with recent satellite imagery showed a good match with the ABARES data across the Southern and Northern modelling domains and surrounding areas.

The land use categories which were applicable for the GRAMM domain for this assessment are shown in **Table 5-13**. Spatial distribution of land use in the GRAMM domain are presented in **Figure 5-10**.

Table 5-13 CORINE codes adopted in the Sydney basin

CORINE Code	Land use description
111	Continuous urban fabric
112	Discontinuous urban fabric
121	Industrial or commercial units
122	Road and rail networks and associated land
124	Airports
131	Mineral extraction sites

CORINE Code	Land use description
132	Dump sites
141	Green urban areas
211	Non-irrigated arable land
212	Permanently irrigated land
221	Vineyards
222	Fruit trees and berry plantations
223	Olive groves
231	Pastures
241	Annual crops associated with permanent crops
242	Complex cultivation patterns
313	Mixed forest
321	Natural grasslands
324	Transitional woodland-shrub
421	Salt marshes
511	Water courses
512	Water bodies
522	Estuaries

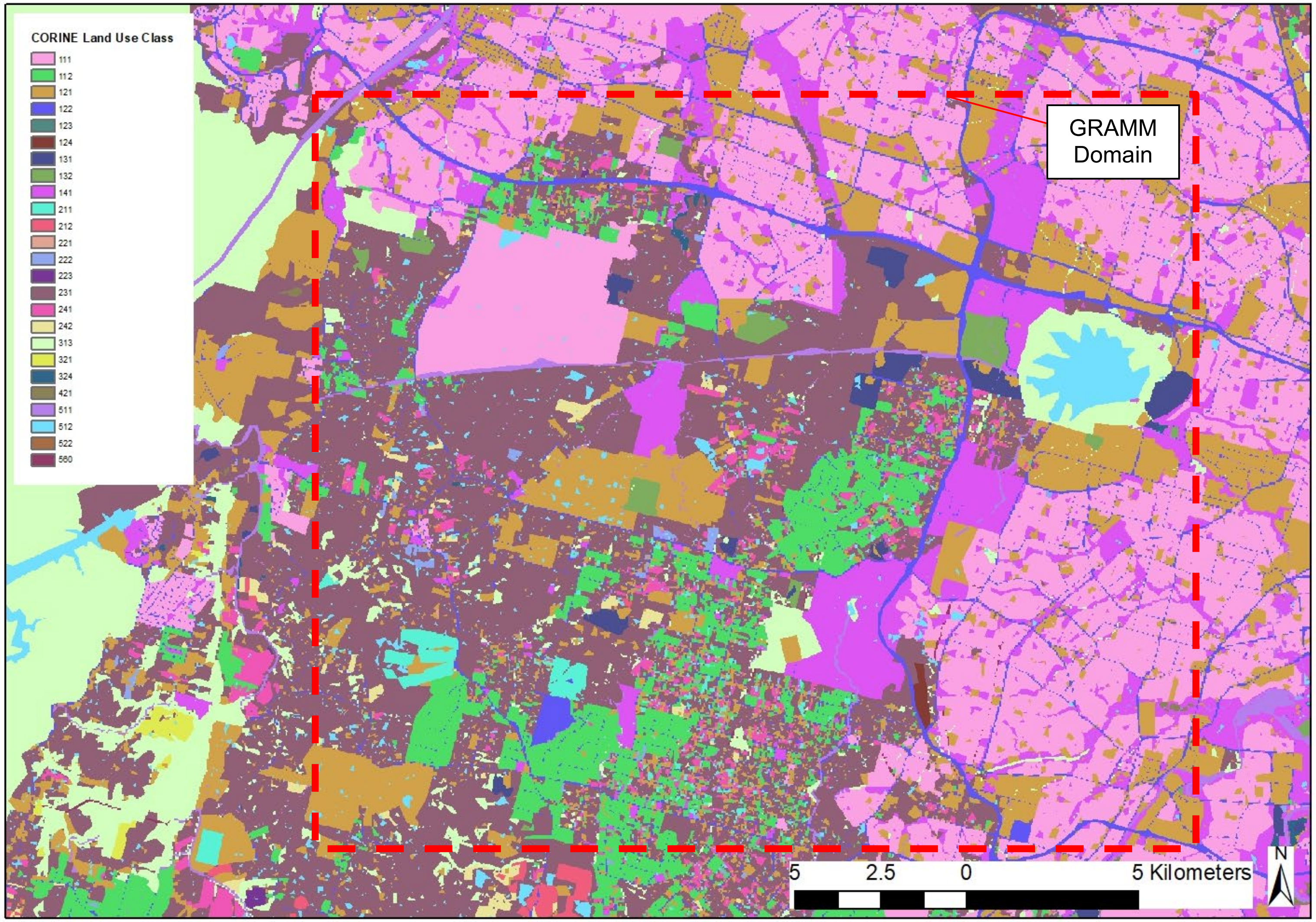

Figure 5-10 GRAMM land use data representation

5.7.4.4 Building data

Building data are critical to the flow of air around the buildings neighbouring the roadway. Buildings need to be considered as part the air quality assessment to ensure the effect of the buildings on the plume dispersion are appropriately considered. GRAL accepts building heights, ground elevation, building vertices, and roof area. These data were obtained from GIS databases, aerial photography and observations of buildings along the proposal. The locations of buildings used in GRAL are presented graphically in **Figure 5-11**.

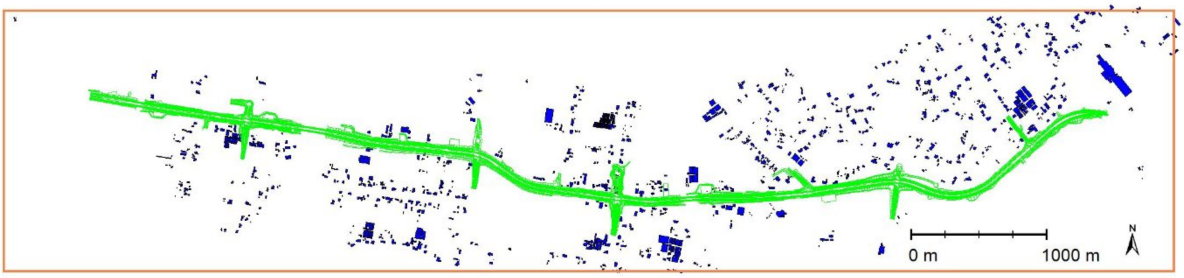

Figure 5-11 Buildings included in the GRAL domain

5.7.4.5 Discrete receptors

Receptors for the proposal were placed at representative locations along the length of the roadway with results presented in terms of the concentrations at these locations. Discrete receptor locations included in the modelling are presented in **Figure 5-12**. Details of the receptor IDs and geographic coordinates are provided in **Appendix F**. A grid of arbitrary receptor locations was also included in the assessment to enable the preparation of concentration contours.

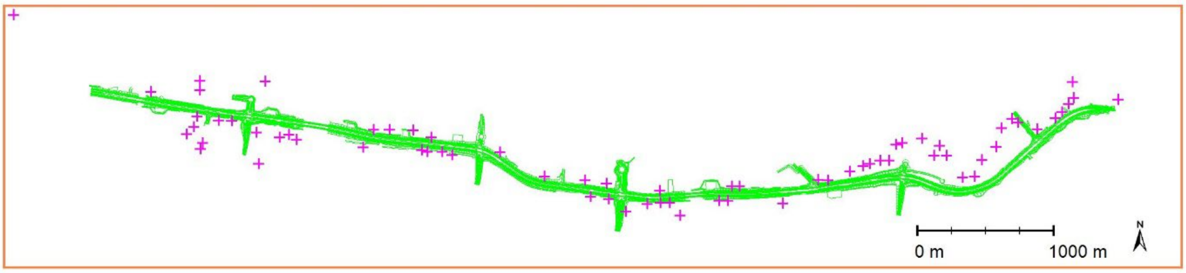

Figure 5-12 Modelled sensitive receptors (receptors shown as purple crosses)

5.7.4.6 GRAMM and GRAL settings

GRAMM and GRAL model parameters used for this assessment are presented in **Table 5-14** and **Table 5-15**, respectively. The settings were selected based on guidance provided in Ottl et. Al. (2020) and the GRAL and GRAMM manuals for the March 2022 release.

Table 5-14 GRAMM model settings

Parameter	Value
Version	March 2022
Meteorological grid domain	25.0 x 18.2km
Horizontal grid resolution	200 m
Reference grid coordinate (origin)	281000m, 6242800m
Vertical thickness of first layer	10 m
Number of vertical layers	15
Vertical stretching factor	1.3
Relative layer height	(Layer 15) 1683 m

Parameter	Value
Surface meteorology coordinates	Badgerys Creek (289920m, 6246952m) Horsley Park (301708m, 6255298m)
Simulation length	1 Year (2017)
Number of synthetic wind speed categories	24
Synthetic wind speed categories	0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0m/s
Number of meteorological conditions[1]	1162
Maximum time step	10 seconds
Modelling time	3600 seconds
[1] Number of meteorological conditions reflects the number of binned conditions (common meteorological conditions after MTO process), not the number of conditions used to calculate results. Number of hours considered for the calculation of modelling statistics is 8760 hours (hours in 2017 calendar year).	

Table 5-15 GRAL model settings

Parameter	Value
Version	March 2022
Flow field grid domain	8,600 x 1,910m
Horizontal grid resolution	5m
Reference grid coordinate (origin)	291340m, 6248355m
Vertical thickness of first layer	2m
Number of vertical layers (prognostic cells)	40
Vertical stretching factor	2-20m AGL – 1.02, 20-50m AGL – 1.05 50-150m AGL – 1.10 150-250m AGL – 1.20 250m+ AGL – 1.20
Number of horizontal slices	1 (2m)
Relative layer height	79 (11297m maximum layer height)
Dispersion time	3600 seconds
Particles per second	400
Surface roughness	0.2
Roughness of building walls	0.01m
Latitude	-34
Modelled height of receptors	2 m
Number of source groups	14 (existing roads)/ 26 (proposal)
Terrain	Complex terrain – original terrain data used for GRAL (see data presented in **Section 5.7.4.2**)

5.7.5 Emissions inventory

The air quality assessment considers emissions to air due to the operation of motor vehicles on the existing and proposed configurations. Motor vehicles create emissions to air from the combustion and evaporations of fuels to power the vehicles and non-combustion processes such as tyre, brake and road wear.

To enable a spatially accurate emissions profile along the length of the proposal, the surface road and the on/off access ramps were divided into a series of unique links to allow for changes in the road profile and traffic behaviours.

The emissions calculation methodology was consistent between scenarios. Emissions rates for each unique link were calculated as summarised by the below high-level generic formula:

$$Total\ Emission\ Rate = \{(Base\ Hot\ EF\ \times Speed\ Factor\ \times Grade\ Factor) +\ non-exhaust)\ \}\ \text{x Traffic Volume}$$

Cold start emissions were not considered and vehicles were assumed to be at operating temperature before entering the proposal. Evaporative emissions were also not considered due to the complexity of quantifying them at an hourly resolution, whilst also being largely controlled by vehicle emissions systems, rendering the emissions insignificant in comparison to combustion emissions.

There are several factors which need to be considered when determining the emissions from a vehicle fleet. The factors relevant to this investigation are summarised below in **Table 5-16**, and described further in **Section 5.7.5.2**.

Table 5-16 Emission rate dependencies

Parameter	Dependencies	Comment
Base emission factor	Source of emission factors	NSW EPA Air Emissions Inventory 2013 Calendar Year: On road mobile air emissions inventory (AEI)
	Year of assessment (2021, 2030, 2040)	2021 scenario used 2016 base emission factors 2030 scenario used 2026 base emission factors 2040 scenario used 2036 base emission factors
	Fleet mix (traffic composition)	Modelled based on traffic fleet mix as provided by traffic engineers for existing and future scenarios.
	Pollutant	Emission factors are calculated individually for each pollutant for entry into the model
	Vehicle class	Emissions vary by vehicle class (ie light vs heavy vehicles). Light and heavy vehicles have been further spit according to the different sub-variants of the traffic fleet mix.
	Fuel type	Emissions vary by fuel type (ie petrol vs diesel and emissions have been calculated to reflect variability in fuel usage across the fleet).
	Road type	Road type variability has been considered by the emissions calculations (ie congested traffic vs free flowing traffic for a given average speed)

Parameter	Dependencies	Comment
	Road grade	Variability in road grade affects emissions from vehicles on the road. Emissions rates have been calculated taking into consideration the road grade.
	Non-exhaust emissions	Non-exhaust generated pollutants generated from the non-combustion sources (ie brake, tyre and road wear).
	Evaporative losses[1]	Emissions of VOCs not due to combustion
	Cold start emissions[1]	Additional emissions, due to the vehicles running 'richer' (and other inefficiencies) before reaching normal operating temperature
Speed factor	Source of speed factor data	AEI, 6th order polynomial calculations considering road type base speed, and modelled speed, per link, per hour of day.
	Traffic speed	Emission rates vary by vehicle speed. Data used in the modelling was based on expected average speed for a one-hour period for each road link.
Grade factor	Source of grade factors	PIARC (2019), Road Tunnels: Vehicle Emissions and Air Demand for Ventilation
	Grade	Factor varies by road grade (ie varies between -6% to 6%)
Traffic volume	Source of traffic volumes	2021 scenario traffic numbers obtained from traffic count data. 2030/2040 traffic numbers obtained from traffic modelling
	Total volume	AADT data calculated for all road links and scenarios.
	Traffic data resolution	Weekday 24-hour cycle

[1] : These emissions are not included in the emission rate calculations

Below is a generic example of all inputs required to calculate a single road link emission rate for a single emission year (2021), single pollutant (PM_{10}) and single vehicle class (diesel truck), which would form a part of an emission rate model input timeseries.

$$\begin{aligned} ER\ (kg.h.km) \quad &= \{Hot\ Base\ EF\ (2021 * PM_{10} * Truck * Diesel * Highway * 2\%)\} \\ &\times \{Speed\ Factor\ (80kmh * PM_{10} * Truck * Diesel * Highway)\} \\ &\times \{Grade\ Factor\ (80kmh * PM_{10} * Truck * Diesel * 2\%)\} \\ &+ \{Non_{exhaust}(PM_{10} * Truck * Highway)\} \\ &\times \{1\ hour\ Traffic\ Volume\ (2018 * 7am * Truck * Diesel)\} \end{aligned}$$

5.7.5.1 Dispersion modelling road input data

Each unique road link (length of road between two know points) is entered into the model individually and modelled at 1kg/hr to create a prediction timeseries for each link covering every hour of the day for a one-year period. Each road link model input group is known as a 'source group'. Emission rates for each link were extracted from the traffic model in the same units of kg/hr for each hour of the day to create 'scaling factors' to apply to a timeseries of data for each source group. These scaling factors were applied to the modelled data to create a 'scaled' results timeseries for each link / source group which aligns with each of the scenarios for the assessment (ie year and with or without proposal).

Results from each individual link were then summed to determine the ground level concentration at each gridded and sensitive receptor. Additionally, ‘difference’ timeseries were generated by subtracting the ‘no proposal’ timeseries from the ‘with proposal’ timeseries to determine the effects of the proposal on air quality at each receptor location.

Road links as defined in the model are presented in **Appendix G**.

5.7.5.2 Emission factors

Hot running base emission factors and non-exhaust emission factors were obtained from the DPE / NSW EPA in Microsoft Excel worksheet format as a simplified version of the NSW EPA Air Emissions Inventory for the Greater Metropolitan Region in NSW On Road Mobile Emissions model for the 2013 calendar year (AEI). The AEI comprehensively compared and reviewed emissions from multiple models, public resources and Australian based testing campaigns to determine the published emission factors. The AEI is considered one of the most comprehensive and up to date resources for vehicle emissions in NSW and was considered suitable for the assessment as the proposal traffic was well represented by the AEI vehicle classes.

Base emission factors required adjustment through the calculation of correction factors to determine specific emission rates for each unique road link. The correction factors account for the terrain, the vehicle class and driving behaviours. Each influencing factor is introduced below and discussed in the following sections:

- Year of assessment and emissions year
- Pollutants
- Vehicle classes
- Fuel types
- Road types
- Road grade (± per cent slope) – correction factor
- Speed – correction factor
- Non-exhaust emissions
- Cold start emissions (not modelled)
- Evaporative emissions (not modelled).

Year of assessment and emissions year

Year of assessment or emissions year influences emission rates as vehicle emissions standards in Australia are based on the vehicles Australian Design Rule (ADR), which is assigned based on the manufacture date of the vehicle. Generally, emissions standards increase in stringency over time; however, the base hot emission factors do not align exactly with the ADR emission standards for the emission year as there is a lag between more stringent emission standards coming into effect and reduced emissions from vehicles on the road, due to the replacement rate of vehicles. This results in equivalent classed vehicles (eg petrol passenger vehicles) having varying emission rates due to their age and emissions standards at the time of their manufacture.

The years assessed for the proposal were:

- 2021 – baseline
- 2030
- 2040.

Deterioration of vehicle components because of age and kilometres travelled is another factor that can influence emission rates, and these have also been considered in the AEI base emission factors.

The AEI base emission factors generally reduce over time, driven by the replacement of older vehicles resulting in a higher proportion of vehicles complying with more stringent emissions standards.

The AEI emission factor years selected to represent the emission years were:

- 2016 for the 2021 existing scenario
- 2026 for the 2030 proposal scenario
- 2036 for the 2040 proposal scenario.

An additional layer of conservatism is also applied to this assessment as proposed emission factors for the 2040 proposal scenarios do not include draft mandates to vehicle emission standards discussed in **Appendix B**. Specifically, when implemented the draft Regulatory Impact Statement (RIS) for Light and Heavy Vehicle Emissions (Commonwealth Government 2020 and 2020a) would result in a lowering of emission rates for NO_2, PM_{10} and $PM_{2.5}$ from July 2027 onward. As such emission factors for the 2036 scenario are expected to be conservative.

Pollutants

The base pollutant emission factors sourced from the AEI were as follows:

- Oxides of nitrogen (Nox)
- Hydrocarbons (HC) – termed Total Volatile Organic Compounds (TVOC) in this assessment
- Carbon monoxide (CO)
- Particulate matter <10µm (PM_{10}) – exhaust.
- Particulate matter <10µm (PM_{10}) – non-exhaust
- Particulate matter <2.5µm ($PM_{2.5}$) – non-exhaust.

PM2.5 – exhaust

$PM_{2.5}$ – exhaust was calculated as a ratio of PM_{10} – exhaust, specific to vehicle class and fuel type for exhaust emissions in the Sydney region. The ratios were developed from annual emissions data sourced from the AEI. The ratios used are presented below:

Table 5-17 $PM_{2.5}$: PM_{10} ratios for vehicle and fuel classes

Vehicle Class	$PM_{2.5}$:PM_{10} ratio
Petrol Passenger Vehicle (PPV)	95.2%
Diesel Passenger Vehicle (DPV)	96.8%
Petrol Light Commercial Vehicle (PLCV)	95.4%
Diesel Light Commercial Vehicle (DLCV)	96.8%
Rigid Truck (RIG)	97.0%
Articulated Truck (ART)	97.0%
Diesel Bus (BUSD)	97.0%

Speciated VOCs

VOC’s are modelled as total VOC (TVOC) and are speciated by applying a speciation profile (ratio) to determine the concentrations of individual compounds. Speciation profiles are based on the 2013 AEI reported annual emissions for the Sydney region due to on-road mobile sources.

The speciation profile applied to TVOC’s is presented below in **Table 5-18**.

Table 5-18 TVOC speciation profile

Species	Per cent of TVOC
1,3 Butadiene	0.55%
Acetaldehyde	0.56%
Benzene	2.38%

Species	Per cent of TVOC
Formaldehyde	1.41%
Toluene	4.97%
Xylene	3.70%

Polycyclic Aromatic Hydrocarbons (PAH's)

PAH's are calculated as a ratio from TVOC emissions using annual totals for on road mobile emissions.

The method for calculation was as follows:

- Determined the ratio of total PAH:VOC from the summary data in the 2008 and 2013 AEI, for Sydney (SYD) and the greater metropolitan region (GMR). The PAH totals are reported in 'as emitted' masses and as such are not directly applicable to the ground level concentration criteria, as the mass emission has not been converted to benzo[a]pyrene equivalent (PAH$_{b[a]p}$).
- Speciated PAH emission data from the 2008 AEI (speciated data not publicly available in the 2013 AEI) is converted to PAH$_{b[a]p}$ by using potency equivalency factors (PEF), in order of preference, from:
  - NSW EPA Approved Methods
  - Office of Environmental Health Hazard Assessment (OEHHA)
  - Tasmanian EPA

  Where a PEF was not available for an individual PAH species, the species was considered insignificant to health impacts and removed from any further calculations. The following values were calculated:

  - Total PAH (as non- b[a]p equivalent) sum of only the species that had PEF's
  - PAH$_{b[a]p.}$ (sum of all species with PEF's as b[a]p)
  - A ratio was calculated from the two values, Total PAH: PAH$_{b[a]p,}$ which created a factor to convert PAH to PAH$_{b[a]p}$

    Note removing the species that don't have PEF's creates a level of conservatism by creating a lower total PAH to PAH$_{b[a]p}$ ratio
- The final PAH$_{b[a]p}$:VOC ratio was calculated by multiplying the ratios from the above two steps, which converts the total PAH to PAH$_{b[a]p}$ to ratio against total VOCs, as per the below equation:

$$\mathrm{PAH}_{b[a]p}:\mathrm{VOC} \; = \; \mathrm{PAH}:\mathrm{VOC} \; \times \; \mathrm{PAH}:\mathrm{PAH}_{b[a]p}$$

The PAH$_{b[a]p}$:VOC ratio was then applied to VOC predictions to generate PAH$_{b[a]p}$ predictions as necessary to assess against the PAH$_{b[a]p}$ criteria.

Data from the 2008 and 2013 AEI, for Sydney and the GMR was compared to determine the most conservative PAH$_{b[a]p}$:VOC ratio. The data is summarised below in **Table 5-19**, with the ratio used in the assessment denoted in bold.

Table 5-19 PAH to VOC ratio

Statistic	Unit	SYD, 2008	SYD, 2008	GMR, 2008	GMR, 2013
PAH total	kg	89,800	54,281	117,000	70,756
VOC total	kg	23,512,000	12,641,062	29,504,000	16,123,791
Total PAH:VOC	%	0.38%	0.43%	0.40%	0.44%
PAH:PAH$_{b[a]p}$	%	0.52%	0.52%	0.52%	0.52%
PAH$_{b[a]p}$:VOC	%	0.0020%	0.0022%	0.0021%	**0.0023%**

Note: Previous road assessments in the Sydney region have used the benzo[a]pyrene species alone from a reduced speciated list of PAH's (Environment Australia, 20003) to determine a $PAH_{b[a]p}$:VOC ratio, as opposed to the method detailed above. The method detailed above was preferred as the emission data is more recent, specific to Sydney and the GMR and considers all AEI reported species of PAH.

Base hot running emission factors used in the assessment are presented in **Appendix H**.

Vehicle class

The fleet mix (traffic composition) of vehicles was provided as 'light' and 'heavy' from traffic count data for the 2021 scenario, and traffic modelling for the 2026 and 2036 scenarios. To best quantify vehicle emissions, light and heavy vehicles were further refined to the seven AEI vehicle classes shown in **Table 5-20** below, along with the equivalent modelled data class.

Table 5-20 Vehicle classes

AEI class	Modelled data class
PPV	Light
DPV	Light
PLCV	Light
DLCV	Light
RIG	Heavy
ART	Heavy
BUSD	Heavy

To enable the conversion from simple light and heavy vehicles to the seven AEI vehicle classes, further statistics were considered.

The Australian Bureau of Statistics (ABS), Survey of Motor Vehicle Use, Australia (ABS, 2020) data was used to determine vehicle class split, within the categories light and heavy. For example, for 'light' vehicles, 81 per cent are passenger vehicles (PV) and 19 per cent are light commercial vehicle (LCV). The passenger and light commercial vehicles were then further refined using AEI proposed fuel splits by emission year (ie 2016, 2026, 2036). For example, of total PV in 2016, 87 per cent are petrol and 13 per cent are diesel. All heavy vehicles were modelled as diesel as alternatively fuelled heavy vehicles numbers are insignificant.

The vehicle class composition data was equally adjusted to total 100 per cent to account for the omitted alternatively fuelled vehicle classes, such as LPG fuelled vehicles, motorcycles, hybrid vehicles etc. For example, if PV's were 49.5 per cent petrol, 49.5 per cent diesel and 1 per cent LPG, the fuel split data would be adjusted to 50 per cent petrol and 50 per cent diesel to ensure total vehicle emissions are calculated and modelled.

The data used to define the vehicle classes is presented below in **Table 5-21**.

Table 5-21 Vehicle class statistics

Data ID	ABS data	AEI ID	AEI fuel split			Final composition[1]		
			2016	2026	2036	2016	2026	2036
LIGHT	PV 81%	PPV	87%	79%	66%	71%	64%	54%
		DPV	13%	21%	34%	10%	17%	28%
	LCV 19%	PLCV	34%	14%	26%	6%	3%	5%
		DLCV	66%	86%	74%	12%	16%	14%

Data ID	ABS data	AEI ID	AEI fuel split			Final composition[1]		
			2016	2026	2036	2016	2026	2036
HEAVY	RIG 73%	RIG	100%	100%	100%	73%	73%	73%
	ART 15%	ART	100%	100%	100%	15%	15%	15%
	BUS 12%	BUSD	100%	100%	100%	12%	12%	12%

1: $Final\ Composition = ABS\ data\ \times AEI\ fuel\ split$

Fuel type

Petrol and diesel combustion emissions were calculated based on the traffic modelling for fleet mix for 2021, 2026 and 2036. As detailed above, emissions from alternatively fuelled vehicles were not calculated as they were considered to contribute only a minor contribution to total fleet emissions.

This simplification is expected to result in a conservative estimate as generally alternatively fuelled electric and LPG vehicles would be expected to have lower emissions than petrol and diesel vehicles.

Road type

The AEI included five road types to tailor emissions due to the expected driving behaviour, presented in **Table 5-22**. The AEI code used for this assessment was 'Arterial' as a best fit for the proposal.

Table 5-22 Road definition

Road type	AEI code	definition/description
Local/Residential	Centroid Conn	Secondary roads with prime purpose of access to property. Characterised by low congestion and low levels of heavy vehicles. Generally one lane each way, undivided with speed limits of 50 km/h maximum. Regular intersections, mostly unsignalised, low intersection delays.
Arterial	Local/Coll	Provide connection from local roads to arterial roads and may provide support role to arterial (RTA defined) roads for movement of traffic during peak periods. Distribute traffic within residential, commercial and industrial areas. Speed limits 50-70 km/h, 1-2 lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than Residential, but significant congestion impact at high volume to capacity ratios (V/C).
Commercial arterial	Sub-Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to high congestion in peak periods. Speed limits 60-80 km/h, typically dual carriageway. Regular intersections, many signalised, characterised by stop-start flow, moderate to high intersection delays and queuing with higher V/C ratios.
Commercial highway	Arterial	Major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to moderate congestion in peak periods. Speed limits 70-90 km/h, predominantly dual carriageway. Lesser intersections than commercial arterial with smoother flow, but subject to some congestion at high V/C.
Freeway/Motorway	MW/FWY	High volume arterial roads with primary purpose of inter-regional traffic movement with strict access control (ie no direct property access). Speed limits 80-110 km/h, predominantly 2+ lanes and divided. Relatively free flowing and steady in non-congested, slowing with congestion approaching V/C limit, but minimal stopping.

Road grade

The AEI does not include correction factors to account for grade (slope of the road) (ie emissions variability due to traveling uphill or downhill). Generally travelling on a positive grade (uphill) creates higher emissions than travelling on flat or negative grade (downhill) as vehicle engines need to work harder, requiring additional fuel, which in turn creates additional emissions.

Correcting for grade was considered important for this proposal as there are terrain influences across the ~3.6km length of the proposal and for this reason grade factors were sought from other sources. The Tool for Roadside Air Quality (TRAQ) includes grade factors calculated from PIARC's *Road Tunnels: Vehicle Emissions and Air Demand for Ventilation* report, as have other AQIAs for recent road proposals in NSW. PIARC (2019) data was used to calculate grade factors for this construction footprint. The PIARC emission factors and, therefore, calculated grade factors, consider:

- Vehicle class
- Fuel type
- Pollutant
- Speed
- Grade.

Example Grade Factor Calculation

$$Example\ data: \{PV, 60kmh, NOx.\ 0\%\ grade = \ 132.8g.h\ \&\ 2\%\ grade = 191.4g.h\}$$

$$\therefore PV, 60kmh, NOx, 2\%\ grade\ factor = \frac{132.8}{191.4} = 1.44\ (no\ unit)$$

The calculations were repeated to create specific grade factors for all combinations of vehicle class, fuel type, speed, pollutant and grade. Note PIARC does not have emission rates for TVOC; therefore, CO grade factors were assumed for TVOC.

By applying grade factors to the AEI base emission factors, a refined emission factor was developed which considers the terrain influences for unique each road link.

An average road grade was calculated for each road link using Google Earth elevation data to determine the rise or fall, expressed as a percentage.

Speed

Speed data for existing 2021 were provided as actual 24-hour traffic counts measured in October and November 2021. Traffic data for the 2030 and 2040 'do nothing' and proposal scenarios were provided as predictions for two-hour peak periods (7 and 8 am and 4 and 5 pm). Future speeds in the hours outside of the peak hour ranges were assumed to be identical to the existing counts for the 'do nothing' scenarios and the posted speed limit (80 km/h) for the proposal scenarios.

The AEI provides speed correction factor (SCF) coefficients specific to vehicle class and fuel type in the form of 6th order polynomials, with the below formula used to calculate the correction factors:

$$\begin{aligned}
&SCF = aV^6 + bV^5 + cV^4 + dV^3 + eV^2 + fV^1 + g \\
&where: \\
&a - g = \ SCF\ coefficients \\
&V = speed
\end{aligned}$$

The fleet composite base emission factors already consider a single base speed dependant on the road type. Therefore, to determine a further refined speed correction factor a multi-step calculation using the above formula is required to determine the ratio between the base speed and the defined speed, the calculation steps were:

- Calculate 'SCF_{base}' using road type speed (eg.highway = 56kmh)
- Calculate 'SCF_{link}' using specific traffic data (eg 60kmh)
- Calculate the 'SCF_{final}' using the below formula:

- $SCF_{final} = SCF_{link} \div SCF_{base}$
- Apply the SCF_{final} to the base emission rate.

The use of the calculated final speed correction factors from 24-hour speed data profile results in a further refined emission rate specific to each unique link. This provides a level of refinement above using only the road type average speed.

SCF performance

SCF_{final} factors were generated and plotted using the methodology detailed above to visualise the effects of speed on emission rates relative to the baseline road type speed, defined in the AEI as 56kmh for highway road type. The curves generally follow a ‘U’ shape where slower or faster than the baseline speed results in an increasing SCF_{final} as the difference between the base speed and link speed increases.

Non-exhaust emissions

Non-exhaust emissions due to tyre, brake and road wear were sourced from the AEI and are specific to vehicle class, fuel type and road type. The emissions were added to the base emission factors for PM_{10} and $PM_{2.5}$.

Evaporative losses

Emissions of VOCs not due to combustion were not included in the assessment as they are overly complex to estimate and generally would not equate to quantities likely to cause a material impact to air quality along the length of the proposal.

Cold start emissions

Cold start emissions factors were not applied to the base emission factors, as vehicles were be assumed to be at operating temperature.

Traffic volume

The hot running base emissions factors represent the emissions of a single vehicle over a distance (grams per kilometre). The emissions factors are multiplied by the traffic volume per hour to determine total mass of emissions per road link, per hour. To get the required level of detail for the hourly diurnal cycle, the 2021, 2030 and 2040 traffic volume data includes:

- Hourly traffic volume by road link to determine the typical diurnal cycle, to ensure peak and non-peak periods are accurately modelled:
  - For 2021 the hourly traffic data was sourced from traffic counters
  - For 2030 and 2040 the predicted hourly traffic data covered the peak hours of 7 and 8 am and 4 and 5 pm, with scaling from the existing 2021 counts used to estimate the remaining hours to create a 24-hour diurnal pattern. This is considered acceptable as existing hourly traffic counts enable data generation specific to the assessment area.

Sample diurnally varying traffic volume data used in the emission inventory are presented in **Figure** 5-13 (2030) and **Figure 5-14** (2040). On these figures, the x axes presents indicative traffic volumes (number of vehicles) and y axes presents the time of day (hours). These represent the total traffic number predicted to travel along the section of Elizabeth Drive between Cecil and Duff Road. This sample shows that the in general, the proposal would have more traffic travelling along it compared with the ‘do nothing’ scenarios.

This is only a small sample of the data for the purposes of the air quality impact assessment and does not show the split between heavy and light vehicles.

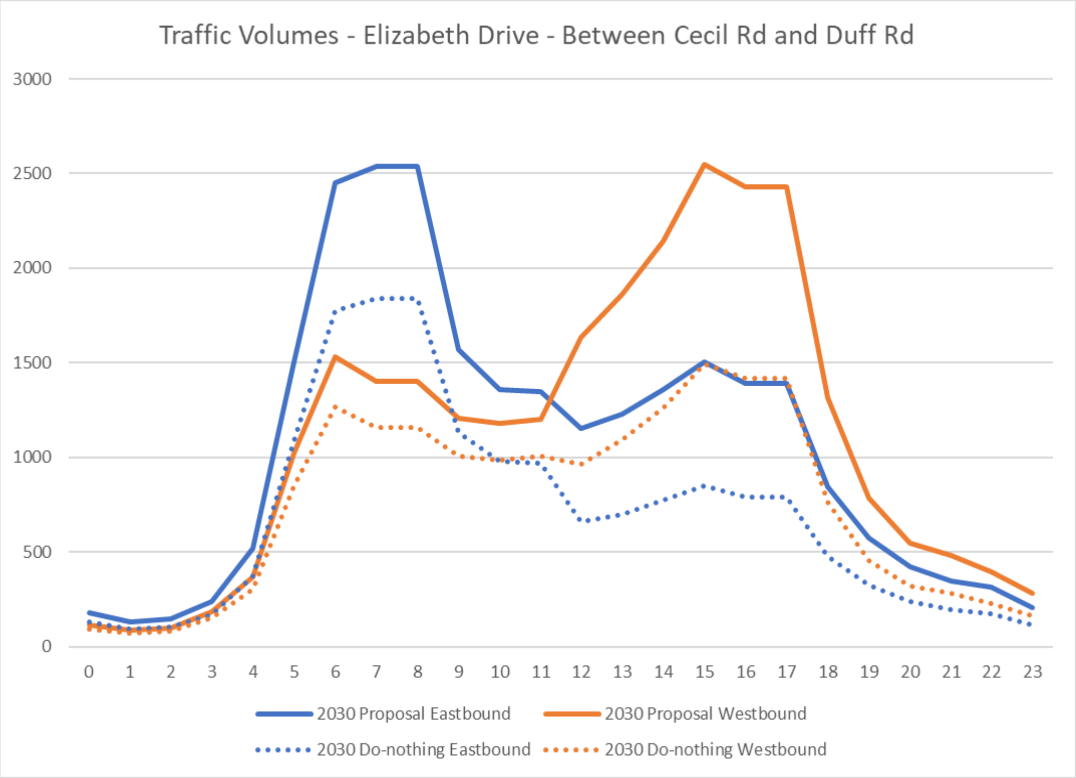

Figure 5-13 Traffic volume data, 2030, between Cecil Road and Duff Road

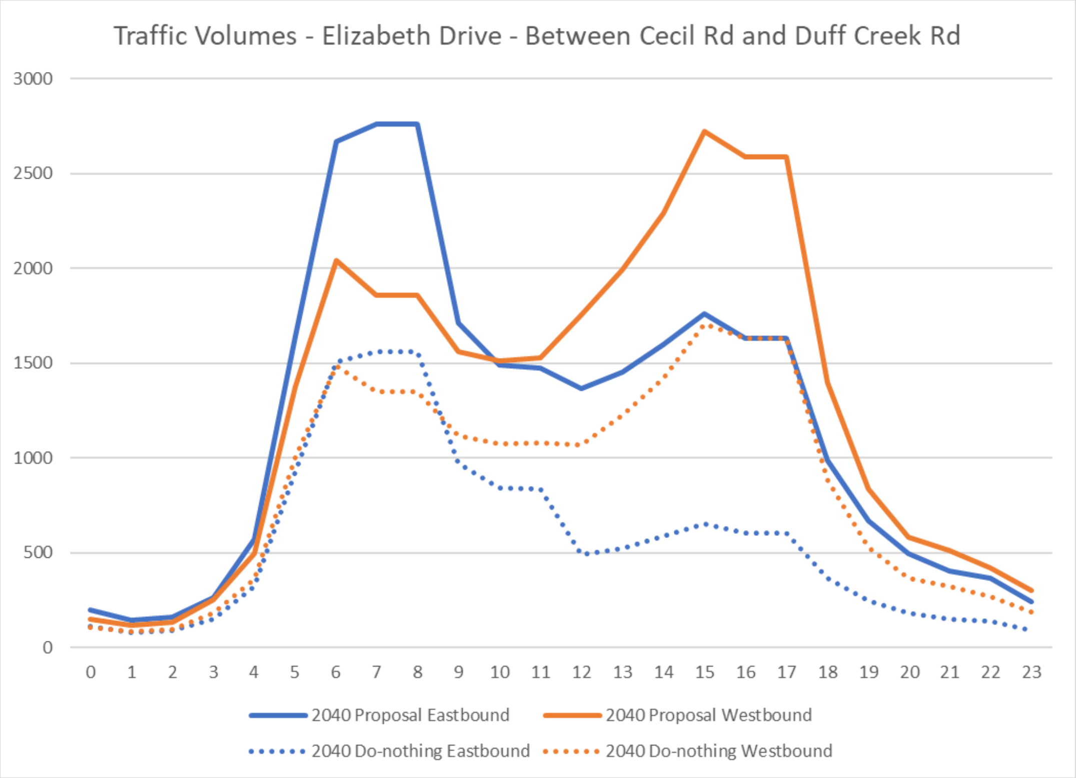

Figure 5-14 Traffic volume data, 2040, between Cecil Road and Duff Road

The above figures present assumptions for the air quality impact assessment. An assessment of traffic impacts of the proposal is provided in Appendix F of the REF.

5.7.6 Intersection queuing

The proposal includes the installation of traffic lights at major intersections. Traffic would be expected to queue at these lights up to a certain length depending on the traffic volume at the time of day. GRAL does not have an inbuilt function to model intersections; however, intersections can be modelled in GRAL using a single road source leading into the intersection to represent queuing. For this assessment, an estimation of the maximum queue length for each proposal scenario was made, and this length applied to each hour of the day as a conservative measure. The queue length was calculated using equations listed in the CAL3QHCR model manual (US EPA 1995) for under-saturated conditions. The calculation used was as follows:

Nu = MAX [q * D + r/2 * q, q * r]

Where:

Nu = average queue per lane at the beginning of the green phase un under-saturated conditions [vehicles/lane]

Q = vehicle arrival rate [vehicles/lanes/s]

D = average vehicle approach delay {s/vehicle}

R = length of red phase [s]

Parameters used in the calculations are presented in **Table 5-23**. Note that these are just assumptions and are not based on measured data.

Table 5-23 Parameters used in the queue length equations

Parameter	Value
Green phase length	120 s
Red phase length	60 s
Average vehicle length in queue	6 m

Calculated maximum queue lengths for each intersection in the model are presented in **Table 5-24**.

Table 5-24 Modelled queue lengths

Intersection	Modelled queue length (m)	
	2030	2040
Martin Rd – eastbound	66	96
Western Rd – eastbound	66	96
Devonshire Rd – eastbound	78	90
Mamre Rd – eastbound	90	102
Range Rd – eastbound	114	120
Duff Rd – eastbound	114	120
Duff Rd – westbound	132	138
Range Rd – westbound	120	126
Mamre Rd – westbound	120	126
Devonshire Rd – westbound	84	114
Western Rd – westbound	78	108
Martin Rd – westbound	66	102

These parameters represent assumptions for the purposes of the air quality impact assessment only. Traffic and transport impacts are assessed separately in Appendix F of the REF.

5.7.7 Traffic network analysis

The AQIA methodology for the proposal as described in **Section 5.7.1** to **Section 5.7.5** has been carried out assuming emissions from the proposal (ie traffic on Elizabeth Drive) only.

Broader network air quality modelling was not carried out to account for the potential changes in road traffic volumes in the surrounding road network which may be influenced by the proposal. As such, a qualitative assessment of and how those potential changes could impact the air quality predictions made by the AQIA was carried out.

While a detailed quantitative assessment of the redistribution of air pollutants within the regional airshed within the context of the wider road network has not been carried out. **Section 7.2** provides a brief qualitative analysis of potential air quality impacts associated with the surrounding road network.

5.7.8 Background data interpolation

Existing background concentrations of pollutants are required to add to predicted model results to assess the potential cumulative impacts of air emission from a proposal. This is typically done using either a single background value or a timeseries of background values that are added to model predictions at every sensitive receptor, without consideration of spatial variation across the modelling domain.

For this assessment, the latter was selected. Hourly data for NO_2, PM_{10} and $PM_{2.5}$ were obtained from the Bringelly and St Marys DPE stations and used to generate a timeseries of interpolated pollutant concentrations specific to each modelled receptor location. These timeseries were then combined with predicted model concentrations for each sensitive receptor to enable the calculation of total cumulative receptor concentrations. Predicted cumulative concentrations for NO_2, PM_{10} and $PM_{2.5}$ are discussed in **Appendix H**.

The interpolation process for NO_2, PM_{10} and $PM_{2.5}$ is further detailed in **Appendix E**. Due to the existing low ground level concentrations for CO localised variability is of lower significance. Assumed maximum 1-hour and 8-hour background concentrations for CO are based on worst case observational data discussed in **Section 4.2.2.2**.

5.7.9 NO_X conversion methodology

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed, including nitric oxide (NO) and nitrogen dioxide (NO_2).

One of the challenges of modelling NO_x emissions is how to determine the amount of NO_2 at a receptor given that NO reacts (oxidises) in the atmosphere to form NO_2 over time. Early studies (Hegg *et al.*, 1977) showed that the rate of oxidation is controlled by the rate of plume mixing rather than by gas reaction kinetics. Ozone is usually the chemical that is responsible for most of the oxidation, but other reactive atmospheric gases can also oxidise NO. GRAL assumes that the pollutants are inert, neutrally buoyant gases (ie the model does not account for any chemical transformations or heavy gas effects). As such, the transformation of NO_x to NO_2 needs to be done in the post-processing stage.

NO generally comprises 95 per cent of the volume of NO_X at the point of emission. The remaining NO_X consists of NO_2. The conversion of NO to NO_2 requires ozone to be present in the air, as ozone is critical to photochemical reaction from NO to NO_2. Ultimately over time, however, much of the NO emitted into the atmosphere will be oxidised to NO_2 and then further to other higher oxides of nitrogen.

There are several methodologies outlined in the NSW EPA Approved Methods document for the calculation of NO_2 concentrations from predicted NO_X concentrations and other methods that have been developed since the publication of the Approved Methods. Three common methods utilised in road proposals are:

- Method 1: Assumption of 100 per cent of the NO_X reports as NO_2. This is a highly conservative assumption and should only be used in situations where emissions of NO_X are low

- Method 2: US EPA Ozone Limiting Method (OLM). The OLM assumes that about 10 per cent of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 per cent of the predicted NO_X concentrations, all the NO_X is assumed to be converted to NO_2, otherwise NO_2 concentrations are predicted using the equation $NO_2 = \{0.1 * NO_X + 46/48 * O_3\}$. This method assumes instant conversion of NO to NO_2 in the plume, which overestimates concentrations close to the source since conversion usually occurs over periods of hours. This method is described in detail in DEC (2005a)
- Method 3: NO_2/NO_x Ratio method using empirical relationship. This method uses observational data from the Sydney basin to develop a NO_2/NO_x ratio. There are two types of empirical methods that can be utilised for the conversion of NO_X data to NO_2 concentration. The two methods are:
  - A constant NO_2/NO_x ratio is assumed. This is referred to as the US EPA's Ambient Ratio Method (ARM)
  - An empirical NO_2/Nox ratio is calculated based on measured NOX and NO2 concentrations in an airshed.

Method 1 above was not considered appropriate for use in this proposal given that it is over-conservative and likely to significantly overpredict NO_2 concentrations.

Method 2 was not considered realistic as its assumptions regarding instantaneous conversion of NO to NO_2 are not expected to be accurate over the small distance between the roadway and the receptors alongside the proposal.

Method 3 (the variable ratio method) considers NO_X:NO_2 ratios at a range of distances from the roadside across the Sydney basin and is considered to provide a reasonable estimate of the upper bound of NO conversion to NO_2. On this basis the variable NO_2/NO_x ratio method was adopted and the equations obtained from the analysis were used to predicted ground-level NO_2 concentrations from the construction footprint. The equation utilised in the assessment are as follows:

For $[NO_X]_{Total}$ concentrations less than 140µg/m^3,

$$\frac{[NO_2]_{Total}}{[NO_X]_{Total}} = 1.0$$

For $[NO_X]_{Total}$ concentrations greater than 140µg/m^3 and less than or equal to 1,375µg/m^3:

$$\frac{[NO_2]_{Total}}{[NO_X]_{Total}} = a \times [\mathrm{NO}_X]_{Total}{}^{b}$$

Where:

a = 52

b = -0.80

For $[NO_X]_{Total}$ concentrations greater than 1,375µg/m^3,

$$\frac{[NO_2]_{Total}}{[NO_X]_{Total}} = 0.16$$

This methodology is consistent with the methodology used for other recent large road infrastructure projects in the Sydney basin including WestConnex M4 East and the Warringah Freeway upgrade. Existing development cumulative impact assessment

5.8 Existing development cumulative impact assessment

A qualitative cumulative air quality assessment was carried out for construction and operation of the proposal in **Section 6.5** (construction), **Section 7.2** (operation with respect to Elizabeth Drive Upgrade West). The cumulative construction phase impact assessment considers nearby proposals that would coincide with the construction timing of the proposal.

5.9 Limitations

The atmosphere is a complex, physical system, and the movement of air in a given location is dependent on a number of different variables, including temperature, topography and land use, as well as larger-scale synoptic processes. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations. The model equations necessarily involve some level of simplification of these very complex processes based on our understanding of the processes involved and their interactions, available input data, and processing time and data storage limitations.

These simplifications come at the expense of accuracy, which particularly affects model predictions during certain meteorological conditions and for source emission types. For example, the prediction of pollutant dispersion under low wind speed conditions (typically defined as those wind speeds less than 1 m/s) or for low-level, non-buoyant sources, is problematic for most dispersion models. To accommodate these known deficiencies, the model outputs tend to provide conservative estimates of pollutant concentrations at particular locations.

While the models contain a large number of variables that can be modified to increase the accuracy of the predictions under any given circumstances, the constraints of model use in a commercial setting, as well as the lack of data against which to compare the results in most instances, typically precludes extensive testing of the impacts of modification of these variables. With this in mind, model developers typically specify a range of default values for model variables that are applicable under most modelling circumstances. These default values are recommended for use unless there is sufficient evidence to support their modification.

As a result, the findings of dispersion modelling provide an indication of the likely level of pollutants within the modelling domain. While the models, when used appropriately and with high quality input data, can provide very good indications of the scale of pollutant concentrations and the likely locations of the maximum concentrations occurring, their outputs should not be considered to be representative of exact pollutant concentrations at any given location or point in time. However, as stated above, the model predictions are typically conservative, and tend to over predict maximum pollutant concentrations at receiver locations.

This assessment was carried out with the data available at the time of the assessment.

6.0 Construction impact assessment

This section provides a detailed description of the construction activities and details the assessment of construction impacts from the proposal.

6.1 Detailed construction activities

A detailed description of construction work associated with the proposal is included in Chapter 3 of the REF.

The construction footprint including construction ancillary facilities is expected to cover an area of about 115 hectares. Construction hours are generally expected to be between 7am to 6pm on weekdays and 8am to 1pm on Saturdays. To minimise disruption to daily traffic and disturbance to surrounding landowners and businesses, it would be necessary to carry out some work outside of standard construction work hours(refer further to Section 3.3 of the REF for detail on proposed construction work hours).

Key construction activities would include:

- Site establishment and demolition
- Earthworks
- Utility and drainage work
- Bridge widening work
- Pavement work
- Finishing work.

Key construction activities relating to demolition, earthworks and material handling, construction, vehicle movements and plant equipment relevant to this technical report are summarised in the following subsections.

6.1.1 Demolition

The construction of the proposal would require the demolition and removal of existing structures and infrastructure located within the construction footprint. This would include:

- Disconnecting existing utilities where required
- Identification and removal of asbestos or other contaminated materials
- Removal of fittings and other reusable elements using hand tools
- Progressive demolition of the building structures
- Sorting and temporary storage of demolition material into recyclable and waste components
- Loading and transporting recyclable and waste material to a licensed waste/recycling facility
- Demolition of existing bridges over Badgerys Creek, South Creek and Kemps Creek.

6.1.2 Earthworks

Earthworks would be required to facilitate the proposal and would involve excavation to accommodate road widening within the existing median and outside lane shoulders and placement and compaction of fill material. Earthworks would occur specifically in relation to:

- Stripping, stockpiling and management of topsoil, subsoil, and material unsuitable for re-use
- Excavation and filling to the road formation levels, including excavation for embankments and cuttings
- Disposal of unsuitable and surplus material to a licensed facility, and important of fill as required to meet cut/fill requirements

- Installation of temporary drainage infrastructure for construction (eg temporary sediment basins, earth bunds, channels and protection of existing stormwater pits)
- Installation of permanent drainage infrastructure.

It is estimated that earthworks would entail 338,700 m^3 of cut material 517,200 m^3 of fill material, with 178,500 m^3 of the fill material requiring import as additional fill.

6.1.3 Construction work

The following provides a summary of the main construction work for the proposal relating to bridge and pavement construction and finishing work.

Bridge construction

The proposal would involve construction of three new twin bridge structures across Badgerys Creek, South Creek and Kemps Creek to carry eastbound and westbound traffic, and removal of the existing bridges in these locations.

Construction of the new bridge structures would be staged to allow continued operation of Elizabeth Drive during the construction work. It is anticipated that bridge work would generally involve:

- Establishment of construction site access arrangements. This would include construction of a temporary access track and access ramp to the southern/eastern embankments for each creek (the northern/western embankment would be accessed directly from the existing Elizabeth Drive)
- Stripping and stockpiling of topsoil, and management of material unsuitable for re-use
- Establishment of a crane pad near the creek bank to place pre-cast bridge structural components
- Temporary diversion of the creek channel if required to allow construction work to be carried out within the existing creek channel
- Construction of a temporary creek crossing including culvert and rock access platform within the existing creek channel, to provide access for construction of the in-creek pier and stabilisation work as required. Temporary waterway crossings would be designed in accordance with the requirements of the Policy and Guidelines for Fish Habitat Conservation and Management (NSW Department of Primary Industries, 2013)
- Installation of concrete piers within the existing creek channel to support the bridge structures
- Construction of the bridge structure, including placement of pre-cast segments lifted into place using a crane or gantry from either side of the creek
- Return of the creek to its original channel, removal of temporary construction work and rehabilitation of disturbed areas.

Construction of the three new twin bridge structures, and removal of the existing bridges, would involve similar construction activities, plant and equipment.

Pavement work

The pavement for the carriageways would be constructed on the completed earthworks formation and would follow a typical road construction process including:

- Rolling and grading of road formation foundation
- Placement and compaction of bound gravel road pavement
- Installation of subsoil inter-pavement drainage with connections to existing and new drainage pits
- Placement of a bitumen material over the bound gravel road pavement
- Placement of an asphalt wearing course and compaction with a roller.

Finishing work

Following the pavement work landscaping and finishing work would be carried out. This would include removal of temporary construction ancillary facilities and rehabilitation of disturbed areas.

Landscaping and finishing work would include:

- Line marking and installation of raised reflective pavement markers
- Installation of street lights, road and street furniture including signage, noise walls, headlight screens and roadside safety barriers
- Rehabilitation of disturbed areas and landscaping in accordance with the urban design and landscape plan for the proposal.

6.1.4 Construction vehicle movements

During construction of the proposal, it is anticipated that peak traffic generation would include about 200 light vehicles and 70 heavy vehicles per day. Construction traffic would be distributed across the construction ancillary facilities and along the proposal alignment, depending on the stage of construction and progression of construction activities. Heavy vehicle movements, which are likely to have the largest impact, would mainly be related to earthworks or spoil movement, but would also include other movements such as girder delivery and plant delivery.

6.1.5 Indicative haul routes

The Northern Road, the M7 Motorway and the future M12 Motorway have been identified as potential heavy vehicle haulage routes. These roads would be utilised during construction for transportation of materials and spoil between different locations within the construction footprint. The proposed haulage routes have been designed to minimise use of local roads where possible, and are subject to detailed design.

6.1.6 Construction equipment

Construction plant and equipment required for the proposal would be determined during detailed design and construction planning. Indicative plant and equipment likely to be used for various construction activities is summarised in **Table 6-1**.

Table 6-1 Indicative construction equipment

Construction activity	Indicative plant and equipment
Earthworks – clearing and grubbing	Graders, excavators, articulated dump trucks, bulldozers, watercarts, mulchers, chainsaws
Earthworks – strip topsoil	Elevating scrapers, graders, excavators, trucks, watercarts
Earthworks – bulk excavation	Bulldozers, front end loaders, off-road dump trucks, excavators (including hammers), graders, watercarts
Earthworks – levelling and material haulage	Graders, vibrating padfoot rollers, vibrating smooth drum rollers, excavators, dump trucks, truck and dogs, watercarts
Road pavement	Paving machines, rollers, truck and dogs
Bridges	Piling rigs, mobile cranes, excavators, telehandlers, concrete pumps and finishers, water pumps

6.2 Dust impact assessment

Construction of the proposal is anticipated to take about 48 months to complete; covering an estimated construction footprint area of area of about 115 hectares. Potential dust impacts during the construction period have been determined based on the IAQM construction dust assessment guidance documentation and the expected scale of the of construction activities outlined in **Section 3.3**.

This assessment has been carried out conservatively assuming that all construction related activities would occur at the same location at the same time. In reality, these activities would be spaced out over the 7.8 kilometre footprint and would occur at different times, meaning that potential dust impacts would be lower than indicated in this assessment.

6.2.1 Stage 1 screening assessment

An initial screening assessment was carried out for the construction to identify whether there were any:

- Human receptors within a 350m of the construction footprint boundary
- Ecological receptors within 50m of the construction footprint boundary
- Human or ecological receptors within 50m of the route used by construction vehicles on public roads up to 500m from the construction site.

Screening lines of 50m and 350m were drawn around the proposal construction footprint boundary and are shown in **Figure 6-1**. There are both human and ecological receptors within 350m and 50m, respectively, from the construction footprint boundary which trigger the requirement for a Stage 2 assessment.

A summary of the proximity of both human and ecological receptors examined as part of the Stage 1 Screening assessment are also presented in **Table 6-2.**

Table 6-2 Stage 1 IAQM screening assessment for construction zones.

Stage 1 assessment
• Human receptors within 350m of the site. Land use is primarily rural residential and rural commercial with some industry use. • Ecological receptors within 50m of the site including residual native vegetation.

In addition to the 50m and 350m screening lines **Figure 6-1**, **Figure 6-2** and **Figure 6-3** show additional buffer zones of 20m, 100m and 200m. These distances have been used to estimate receptor sensitivity for the Stage 2 assessment and are referred to in **Section 6.2.2**.

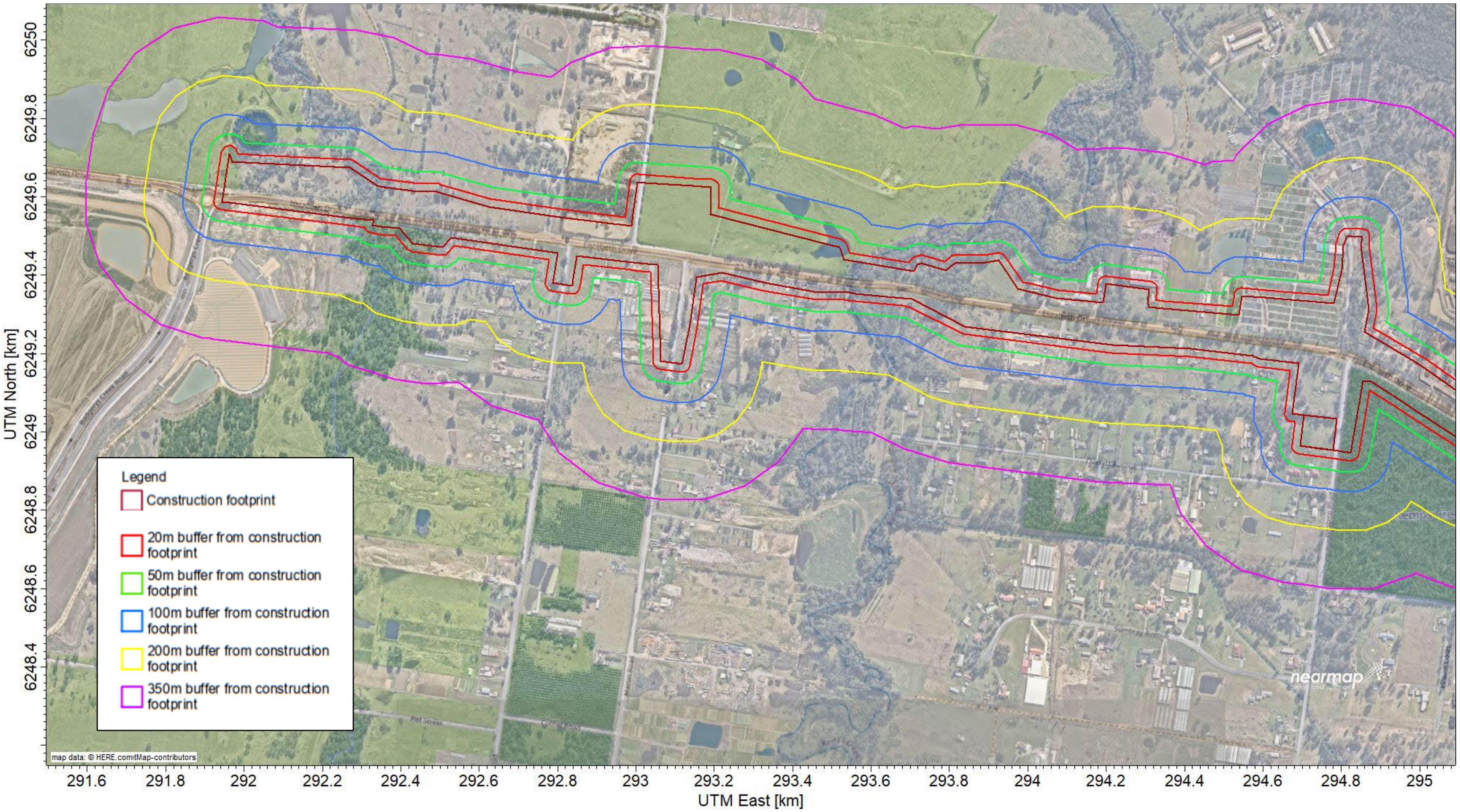

Figure 6-1 Construction buffers – 1 of 3

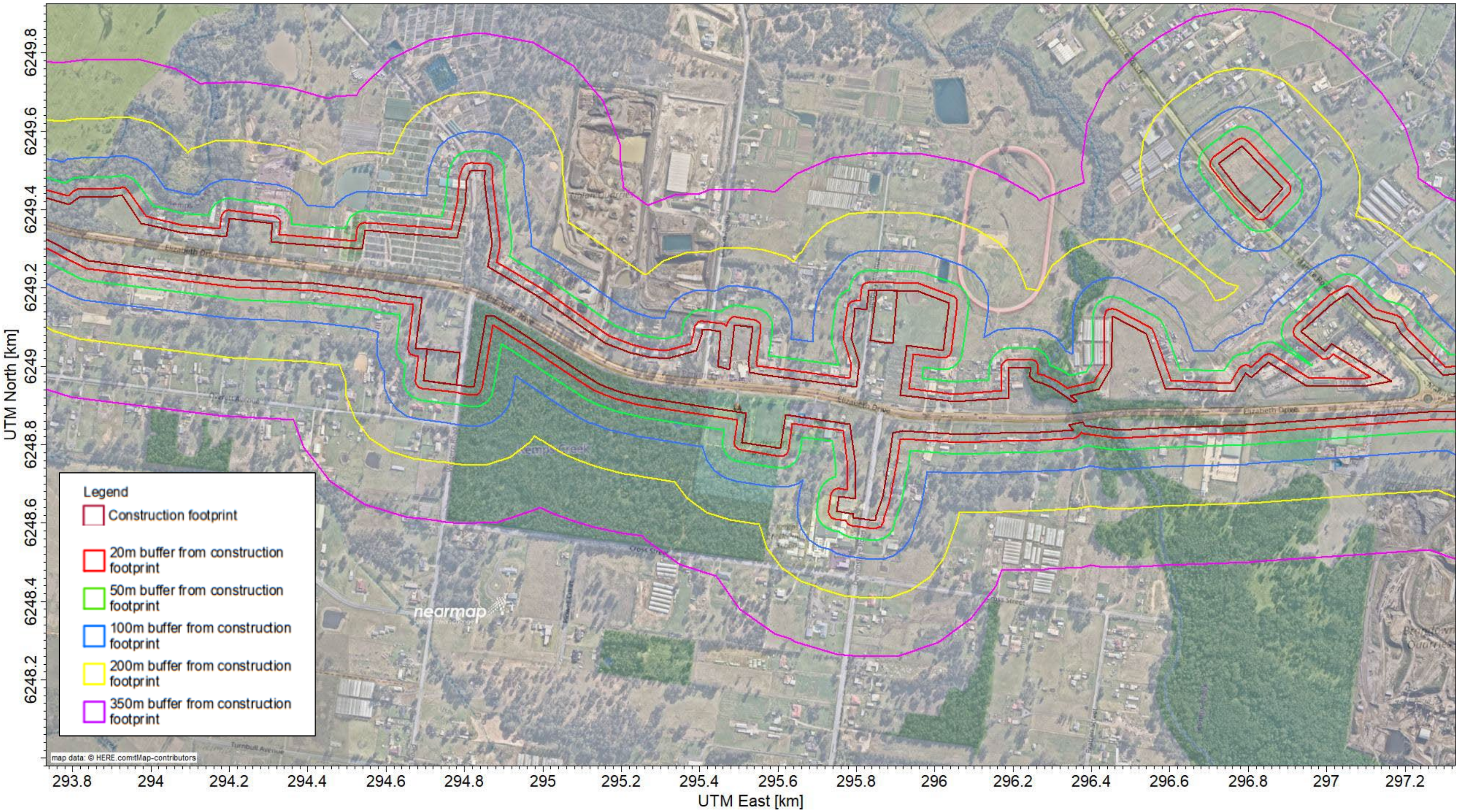

Figure 6-2 Construction buffers – 2 of 3

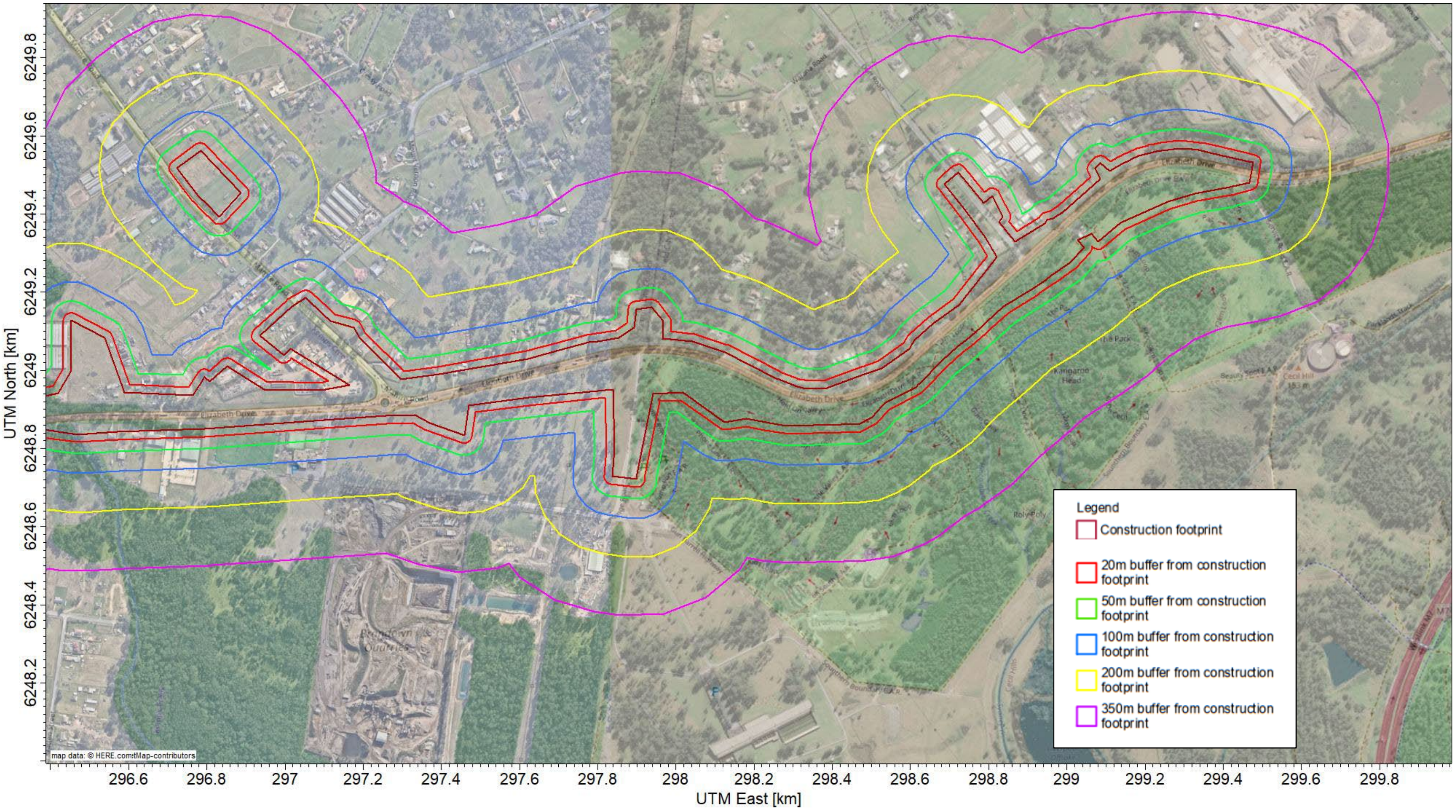

Figure 6-3 Construction buffers – 3 of 3

6.2.2 Stage 2 screening assessment

The Stage 1 screening assessment of the IAQM assessment in **Section 6.2.1** identified the need for a Stage 2 assessment. The Stage 2 below assessment considers the proposal construction footprint shown in **Figure 6-1** and provides an assessment of the potential for dust impacts due to unmitigated dust emissions from the proposal as described in **Section 5.6.2.2**.

Construction activity magnitudes

Construction activity magnitudes for each construction zone are presented in **Table 6-3**. The magnitudes have been estimated based on IAQM guidance provided in **Table 6-3** and construction activities discussed in **Section 6.1.**

- Demolition volume was estimated to be less than 20,000m^3 as there would only be relatively few structures that would require demolition, including three bridges. Each bridge is about 30 m in length and 9 m in width. Assuming a deck thickness of about 1 m, the volume for demolition of each bridge is only about 270 m^3.

  Demolition would include dusty material and may require onsite crushing of concrete and waste material

  Overall, demolition magnitude was rated as medium
- Earthworks are expected to be substantial and were rated large as they involve:
  - 855,900 m^3 of total earthworks including both cut and fill material from excavation work, including about 338,700 m^3 of cut material
  - Substantial earth moving and materials handling equipment required as listed in **Section 6.1.6**
- Construction work is extensive with the construction footprint covering an area of about 115 hectares and a road length of more than two kilometres and was therefore rated large
- Trackout for construction work has been rated large due to an estimated peak heavy vehicle movement of 70 per day.

Table 6-3 Stage 2 IAQM assessment construction activity magnitudes

Construction activity magnitudes			
Demolition	Earthworks	Construction	Trackout
Medium	Large	Large	Large

Sensitivity to dust soiling

Sensitivity to dust soiling risks are presented in **Table 6-4**. Dust risk ratings were estimated based on IAQM guidance provided in **Table 5-8** and surrounding land use as discussed in **Section 5.6.2.4** and **Table 6-2**.

From **Table 6-4** the following has been concluded:

- A high risk of dust soiling (prior to mitigation) due to the proximity of highly sensitive receptors close to the construction boundary – there are 33 residential receptors within 20 metres of the construction boundary, which fits into the highlighted 10-100 category.

Table 6-4 Assessment of sensitive receptor risk from dust spoiling (prior to mitigation)

Receptor sensitivity	Distance from construction site boundary			
	< 20 m	< 50 m	< 100 m	< 350 m
High	10-100 [1](High Risk)	10-100 (Medium Risk)	10-100 (Low Risk)	>100 (Low Risk)
Medium	>1 **(**Medium Risk)	>1 (Low Risk)	>1 (Low Risk)	>1 (Low Risk)
Low	>1 (Low Risk)	>1 (Low Risk)	>1 (Low Risk)	>1 (Low Risk)

1. Number of receptors

Sensitivity to exposure to dust for human receptors

Sensitivity to dust (as PM_{10}) for human health risks are reported in **Table 6-5**. Dust health risk ratings for human receptors are determined by the number of receptors within a certain distance from the construction boundary and the sensitivity of the receptors based on IAQM guidance provided in **Table** 5-9**.** An annual average PM_{10} range of between 19 and 22 μg/m^3 was used for the determination, as discussed in **Section 5.6.2.4**.

From **Table 6-5** the following has been concluded:

- A low risk to human health (prior to mitigation) due to the proximity of highly sensitive receptors close to the construction boundary – there are 33 residential receptors within 20 metres of the construction boundary, which falls into the highlighted 10-100 category.

Table 6-5 Assessment of sensitive receptor risk from exposure to dust (PM_{10}) for human receptors (prior to mitigation)

Receptor sensitivity	Distance from construction site boundary				
	< 20 m	< 50 m	< 100 m	< 200m	< 350 m
High	10-100[1] (High Risk)	10-100 (Medium Risk)	10-100 (Low Risk)	>100 (Low Risk)	>100 (Low Risk)
Medium	**1-10 (**Low Risk)	**>10 (**Low Risk)	**>10 (**Low Risk)	**>10 (**Low Risk)	**>10 (**Low Risk)
Low	≥1 (Low Risk)	≥1 (Low Risk)	≥1 (Low Risk)	≥1 (Low Risk)	≥1 (Low Risk)

1. Number of receptors

Sensitivity to exposure to dust for ecological receptors

Dust sensitivity risks for ecological receptors are provided in **Table 6-6**. Dust risk ratings for ecological receptors are determined by the risk rating attributed to the proposal (low as discussed in **Section 4.5.1**) and were estimated based on IAQM guidance provided in **Table 5-10**. An overall dust impact risk rating for ecological receptors of **High** was determined based on the risk matrix.

Table 6-6 Assessment of sensitive receptor risk for ecological receptors (prior to mitigation)

Receptor sensitivity	Distance from construction site boundary	
	< 20 m	20 50 m
High	High Risk	Medium Risk
Medium	Medium Risk	Low Risk
Low	Low Risk	Low Risk

Overall dust risk ratings

The potential risks for the construction of the proposal were found to be Medium to High, as summarised in **Table 6-7**.

Table 6-7 Summary of unmitigated risk assessment

Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of unmitigated dust impacts		
		Dust soiling	**Human health**	**Ecological**	**Dust soiling**	**Human health**	**Ecological**
Demolition	Medium	High	High	High	Medium	Medium	Medium
Earthworks	Large	High	High	High	High	High	High
Construction	Large	High	High	High	High	High	High
Trackout	Large	High	High	High	Medium	Medium	Medium

The unmitigated risk rating of 'medium' to 'high' for the proposal, means that specific activity-based mitigation measures are recommended to reduce the risk of dust generation and hence impact on the surrounding environment. Mitigation measures are described in **Section 8.0**.

6.3 Combustion emission impact assessment

The source of combustion emissions during the proposal construction phase would be due to the combustion of petrol and diesel fuel by light and heavy vehicles traveling to and from site as well as onsite, mobile construction equipment and stationary equipment such as diesel generators. Emissions are expected to depend on the nature of the emissions source (ie size of the equipment, usage rates, duration of operation etc). Pollutants emitted by construction vehicles are likely to include CO, particulate matter (PM_{10} and $PM_{2.5}$), NO_2, SO_2, VOCs, and PAHs.

Construction traffic is expected to fluctuate over the course of the construction program with estimated peak traffic number expected to reach up to 200 light vehicles movements and 70 heavy vehicles per day (140 two-way movements).

Given the existing volume of traffic utilising Elizabeth Drive, combustion emissions from construction traffic on Elizabeth Drive and the adjacent road network are unlikely to result in a notable reduction in ambient air quality at nearby sensitive receptors based on the construction traffic volume contribution.

Combustion emissions from diesel operated mobile equipment as listed in **Section 6.1.6** would also result in air pollutant emissions. Diesel generators would also be used to provide onsite power to construction ancillary facilities and equipment where access to the electrical grid may not be readily available.

Given the typically transitory nature of construction traffic, as well as use of mobile and stationary plant and equipment, exhaust emissions are unlikely to have a significant impact on local air quality. Typical mitigation and maintenance measures for operation of construction vehicles and plant equipment are discussed in **Section 8.0** and when applied adverse air quality impacts from the operation of construction vehicles and plant equipment are not expected.

6.4 Odour emissions assessment

Potential odour impacts from the site during construction would be temporary in nature. Potential sources of odour would primarily occur from the potential disturbance of acid sulphate soils (ASS) or contaminated soils during earthworks. ASS naturally occur in soils and sediments that contain iron sulphides. When exposed to air the iron sulphides in the soil react with oxygen and water to produce a variety of iron compounds and sulphuric acid, which are generally odorous. ASS would potentially be present in waterways associated with pilings and footings of bridge structures.

Based on the findings of the Phase 1 Contamination Assessment for the proposal in Appendix M to the REF, the probability of intercepting ASS across the study area is extremely low.

There is the potential for odorous contaminants, such as petroleum hydrocarbons to be contained with uncontrolled fill that is present along the alignment, and in areas of former and current agricultural land use. There are also three petrol stations, an auto repairs shop and a recycling park along the proposal alignment. There is the potential for contaminated soil to be present near these locations. More information is required through the collection of samples to characterise this potential source.

In the event ASS or contaminated soils are encountered during excavation work good management would prevent the generation of odours. Potential impacts and management measures are discussed in greater detail in the Phase 1 Contamination Assessment for the proposal in Appendix M to the REF. General air quality management measures are also discussed in **Section 8.0** of this report.

6.5 Cumulative impact assessment

6.5.1 Scoping assessment

Table 6-8 provides a qualitative cumulative assessment of construction impacts associated with other projects in the vicinity of the proposal.

Table 6-8 Cumulative assessment of construction Air Quality impacts with other proposals

Project Name and ID	Pollutants of interest	Cumulative assessment
M7 Motorway Widening	NO_2, CO, PM_{10}, $PM_{2.5}$, VOCs & PAHs	Concurrent construction with M12 construction expected until 2025 and would therefore not overlap with the construction of the proposal.
M12 Motorway SSI-9364	NO_2, CO, PM_{10}, $PM_{2.5}$, VOCs & PAHs	Concurrent construction with M12 Motorway construction expected until 2025 and would therefore not overlap with the construction of the proposal.
Sydney Metro – Western Sydney Airport SSI-10051	NO_2, CO, PM_{10}, $PM_{2.5}$, VOCs & PAHs	Construction of Sydney Metro – Western Sydney Airport is expected to be completed by 2026. It has been assumed the majority of construction would be complete by the time the construction of the proposal commences and overlapping construction activities are expected to be limited in duration. Sydney Metro – Western Sydney Airport is located 5km west of the site as such any cumulative impacts from construction vehicle emissions are likely to be minor.
Western Sydney Airport	NO_2, CO, PM_{10}, $PM_{2.5}$, VOCs & PAHs	Construction of WSA is expected to be completed by 2026. It has been assumed the majority of construction would be complete by the time the construction of the proposal commences and overlapping construction activities are expected to be limited in duration. Construction dust would be managed appropriately for WSA and offsite impacts of dust were expected to be 'not significant' (DIRD 2016). Cumulative impacts with the proposal are therefore not expected to be significant.
Elizabeth Drive West Upgrade	NO_2, CO, PM_{10}, $PM_{2.5}$, VOCs & PAHs	The proposed Elizabeth Drive West Upgrade consists of the widening of the existing Elizabeth Drive between The Northern Road at Luddenham and Badgerys Creek Road at Badgerys Creek. Construction is expected to overlap with the construction of the proposal. Consideration of

Project Name and ID	Pollutants of interest	Cumulative assessment
		cumulative construction impacts are presented in **Section 6.5.2** and cumulative operational impacts are presented for receptors at the western end of the proposal in **Section 7.2**.

6.5.2 Key proposal analysis

Of the above proposals listed in **Table 6-8**, most are located at a distance sufficiently removed from the proposal construction footprint. As a result, the potential cumulative impacts are expected to be negligible.

The Elizabeth Drive West Upgrade proposal is the closest of the proposals and due to its proximity (about 730 m between the proposal and Elizabeth Drive West Upgrade construction footprints) and concurrent timing, there may be cumulative impacts associated with the construction phase of that proposal. Construction impacts from the proposal would be managed in accordance with the mitigation measures listed in **Section 8.0**. It is anticipated that similar mitigation measure would be applied to the Elizabeth Drive West Upgrade proposal. With these measures in place, it is likely that any cumulative air quality impacts associated with the two proposals would be negligible.

7.0 Operational impact assessment

This section provides an assessment of operational air quality impacts from the construction footprint.

7.1 Air quality assessment of pollutants

The following section provides a discussion of the change in concentrations for predicted pollutants between modelled scenarios. The relative change in ground level pollutant contribution has been discussed within the context of:

- Change in predicted ground level concentrations for the following future scenarios compared to the existing baseline scenario (Scenario 1) and the:
  - ‘Do Nothing’ year 2030 (Scenario 2)
  - Proposal year 2030 (Scenario 3)
  - ‘Do Nothing’ year 2040 (Scenario 4)
  - Proposal 2040 (Scenario 5)
- Change in predicted ground level concentrations between:
  - ‘Do Nothing’ (Scenario 2) and the proposal (Scenario 3) for 2030
  - ‘Do Nothing’ (Scenario 4) and the proposal (Scenario 5) for 2040.

Existing ground level concentrations for some pollutants (NO_2, PM_{10} and $PM_{2.5}$) are predicted to result in moderate concentrations at sensitive receptors close to the road and in some instances elevated background concentrations further exacerbate the elevated concentration. The assessment considered the relative change in ground level pollution concentrations compared to existing levels because of the proposal. Assessment of the results have been discussed in the context of the change in predicted ground level contribution to:

- Distinguish between existing and future changes in ground level pollution concentrations that are not directly tied to the proposed area but are a direct result of changing emission standards as discussed in **Section 5.7.5**
- Distinguish between predicted ground level pollution concentrations for 2026 and 2036 with and without the construction footprint; to understand the potential impacts directly associated with the construction footprint.

Predicted road contributions (or incremental contributions) from road traffic in isolation for all pollutants as well as cumulative concentrations for pollutants NO_2, CO, PM_{10} and $PM_{2.5}$ for all modelled scenarios are assessed against relevant EPA criteria in **Appendix H**.

7.1.1 Nitrogen dioxide

The following section provides a discussion on predicted change in maximum 1-hour and annual average NO_2 ground level concentrations at sensitive receptors. Predicted NO_2 ground level concentrations are discussed within the context of the difference between the construction footprint and existing baseline conditions; as well as the differences with and without the construction footprint for the design opening year (2030) and ten years after opening (2040).

This section provides a detailed discussion on the predicted changes in maximum 1-hour and annual average NO_2 concentrations within the modelling domain. A comparison of predicted ground level concentrations with and without the proposal are assessed based on the relative percentage change in relation to the 1-hour maximum and annual average criteria. This includes a discussion based on the differences at sensitive receptors and based on concentration contours for gridded receptors within the study area. A summary of the predicted changes in NO_2 concentrations at sensitive receptors for the study area is also provided in the text box below.

NO_2 concentrations were based on the concentration of NO_X and the conversion ratio outlined in **Section 5.7.9**.

Predicted road contributions (or incremental contributions) from traffic in isolation for NO_2 along with cumulative concentrations for all modelled scenarios are assessed against relevant EPA criteria in **Appendix I**.

Summary of potential impacts

The predicted ground level NO_2 concentration (1-hour maximum and annual average) in 2030 and 2040 are predicted to increase when compared to existing ground level concentrations. This is due to a general increase in vehicle numbers for the proposal compared with existing traffic.

The proposal may result in slightly higher 1 hour maximum and annual average NO_2 concentrations at sensitive receptors compared with the ‘do nothing’ scenario. However, the differences are likely overstated due to limitation in the modelling, namely the exclusion of queues in the ‘do nothing’ scenarios and side roads in all scenarios.

Predicted changes in 1-hour maximum and annual average NO_2 concentrations for 2030 and 2040 with and without the proposal at sensitive receptors have been plotted as the difference with baseline concentrations (Scenario 1) in **Figure 7-1** and **Figure 7-2**.

Figure 7-1 shows that predicted 1-hour maximum concentrations at sensitive receptors in 2030 and 2040 with the proposal are generally slightly higher than existing concentrations. Future ‘do nothing’ concentrations were predicted to be slightly lower than the existing baseline.

Figure 7-2 shows that annual average concentrations at sensitive receptors in 2030 and 2040 with the proposal are expected to be slightly higher than modelled baseline conditions. Future ‘do nothing’ concentrations were predicted to be slightly lower than the baseline.

The predicted future increases in 1-hour maximum and annual average NO_2 concentrations observed in **Figure 7-1** and **Figure 7-2** for the proposal are largely attributed to higher vehicle numbers (see **Figure** 5-13 and **Figure 5-14**).

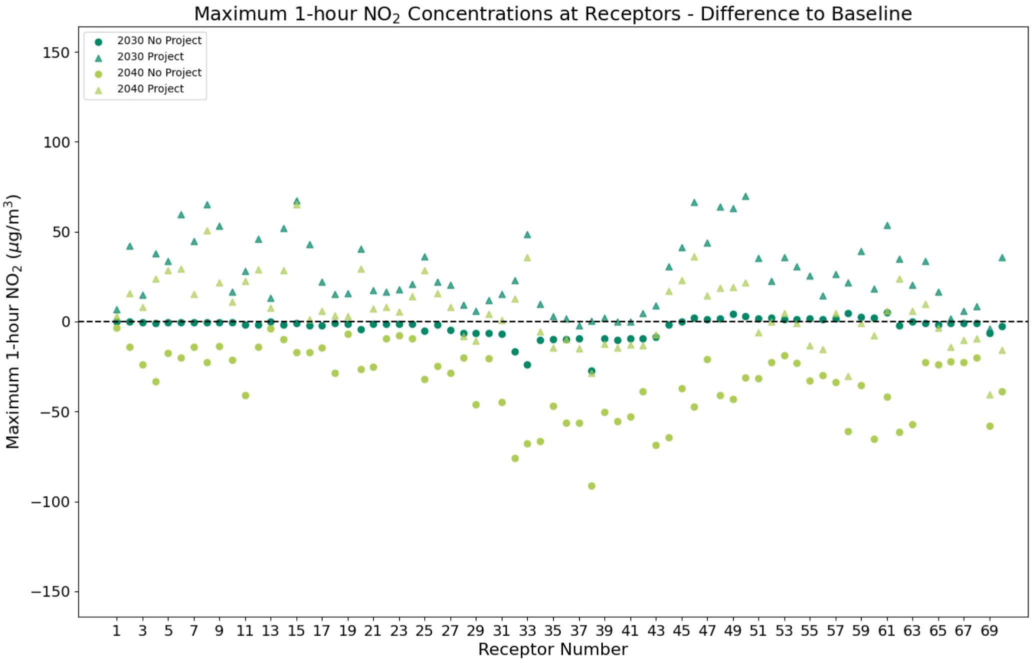

Figure 7-1 Predicted changes in maximum 1-hour NO_2 contribution from baseline

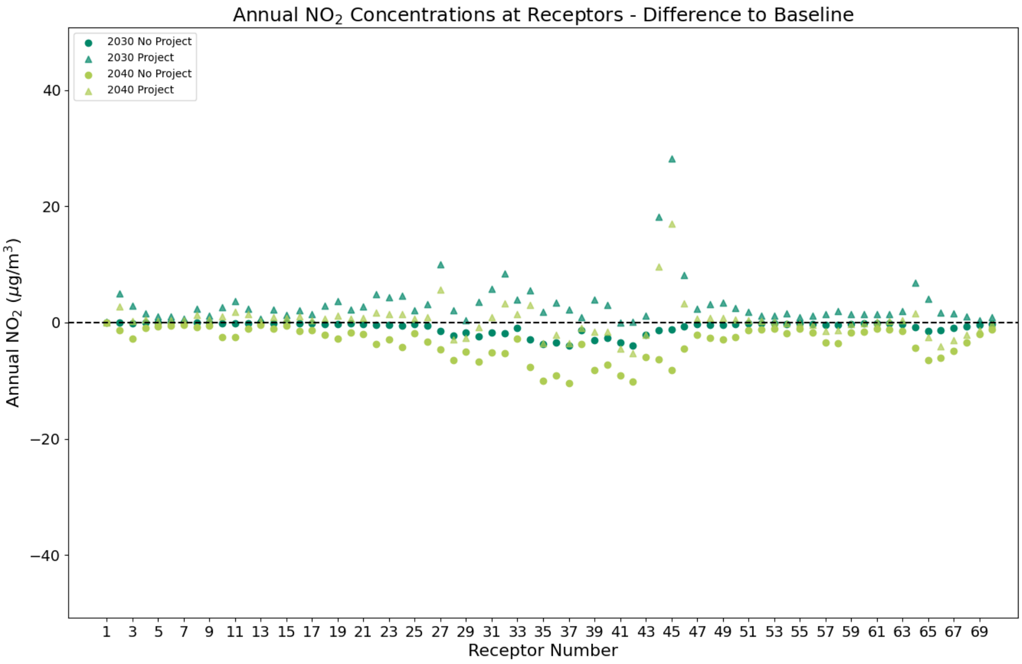

Figure 7-2 Predicted changes in annual average NO_2 contribution from baseline

Figure 7-3 and **Figure 7-4** show the difference in 1 hour maximum and annual average NO_2 concentrations at sensitive receptors between the ‘Do nothing’ and proposal scenarios. Predicted differences in the 1-hour maximum NO_2 concentrations for the southern modelling domain are also presented as contour plots in **Figure 7-7 and Figure 7-8** for 2030 and 2040, respectively.

Figure 7-3 shows that in at most receptors, concentrations would be higher with the proposal compared with the ‘do nothing’ scenarios. The highest changes are about 100 µg/m^3 in 2040.

Observed differences between with proposal and without proposal modelled scenarios are significant when compared to the EPA criterion of 164 µg/m^3, with the highest difference in concentration between the proposal and the ‘do nothing’ scenario equated to about 60 per cent of the criterion. The differences in concentrations are attributed primarily to increased vehicle numbers modelled as part of the proposal (see **Figure 5-13** and **Figure 5-14**). In reality, the differences here are likely to be smaller due to limitations in the modelled traffic numbers and that queuing was not modelled for the ‘do nothing’ scenarios. This is further discussed in **Section 7.3**.

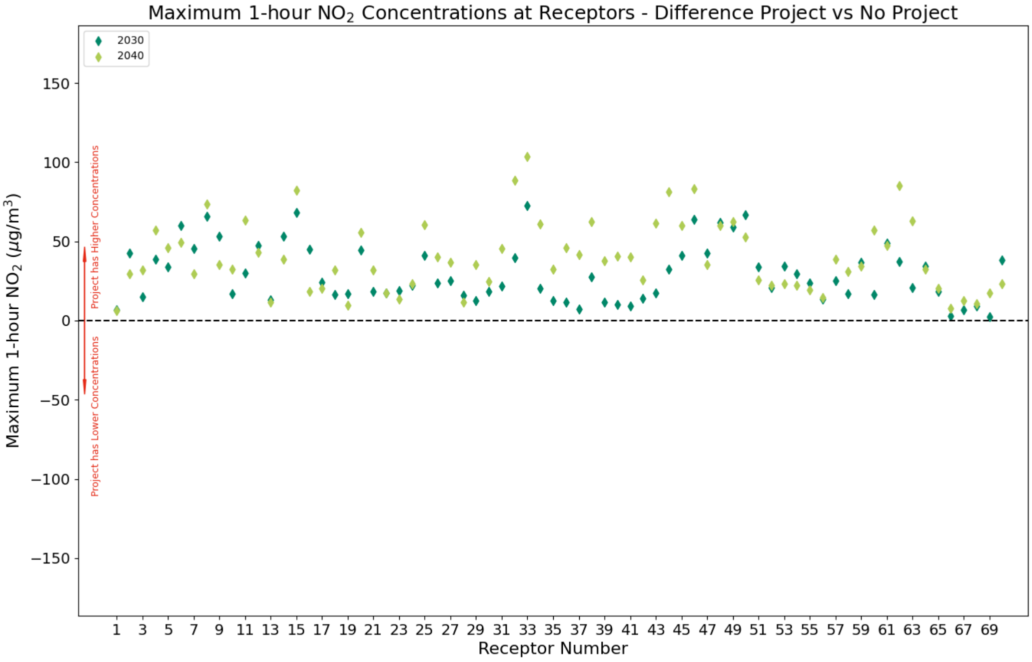

Figure 7-3 Predicted difference between proposal and no proposal maximum 1-hour NO_2 contributions

Difference in the predicted annual average NO_2 concentrations in **Figure 7-4** indicate that predicted ground level concentrations are generally a little higher for the proposal at almost all receptor locations.

Observed differences in annual average concentrations at most receptors between the proposal and ‘do nothing’ modelled scenarios are relatively small within the context of the EPA annual average criterion of 31 µg/m³. However, the difference at Receptors 44 and 45 were relatively high, with up to about 90per cent of the criterion predicted in 2030 for Receptor 45.

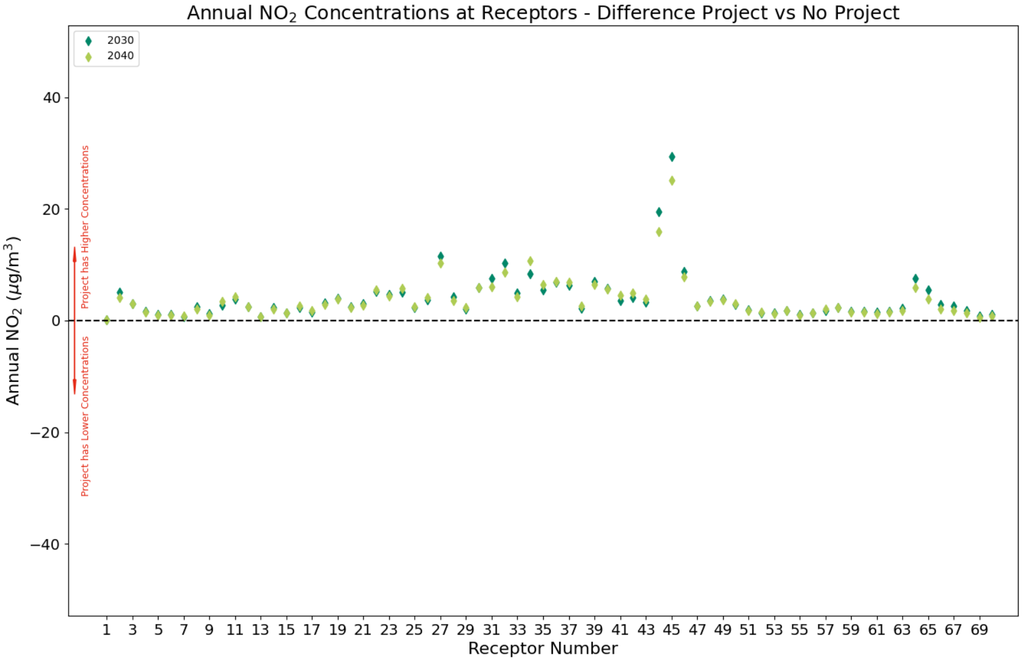

Figure 7-4 Predicted difference between proposal and no proposal annual average NO_2 contributions

The cause of the large difference in annual average NO_2 concentrations at receptors 44 and 45 is due to the eastbound proposal lanes being considerably closer to these receptors compared with the existing Elizabeth Drive (as shown in **Figure 7-5**). Receptor 45 is about 25 metres from the proposal eastbound lane curb, and 55 meters from the existing road. The proximity to the queues modelled in the proposal scenarios also likely contributes to the difference.

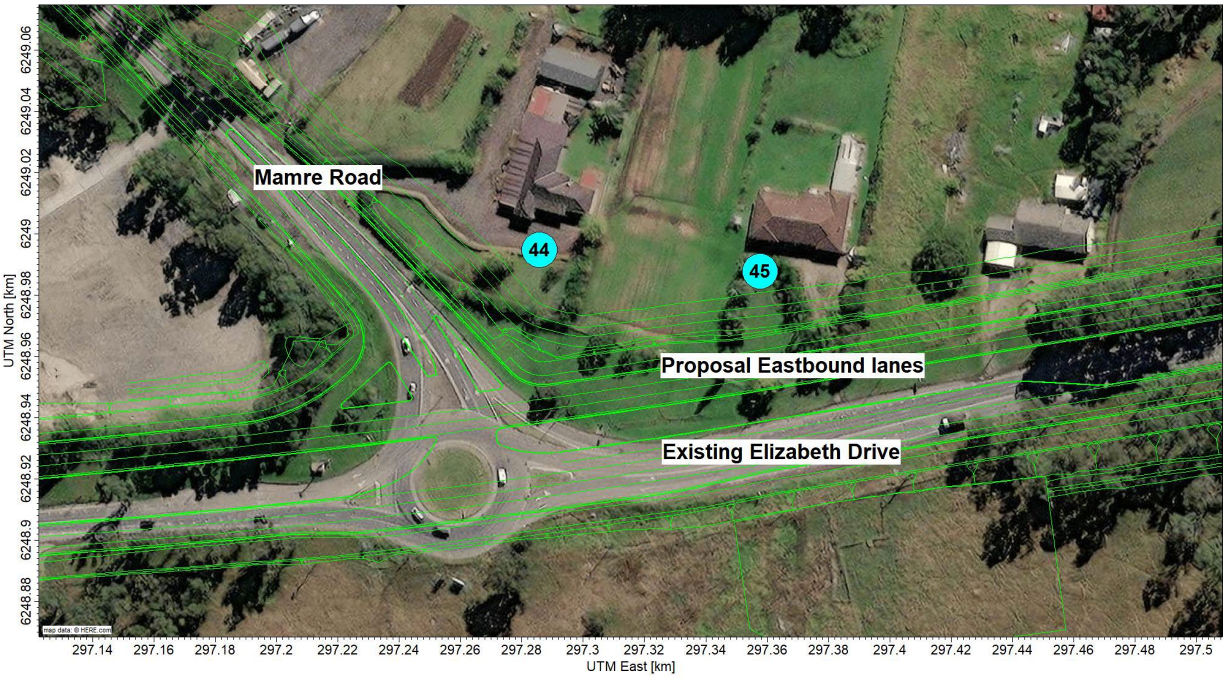

Figure 7-5 Location of Receptors 44 and 45 compared with the existing road and proposal

A representation of the difference in NO_2 concentrations at Receptor 45 is presented in **Figure 7-6**. This shows that there are about 1,000 hours in the year that have a difference over 80 µg/m^3, or about half of the 1-hour criterion. The annual average difference of 29.4 µg/m^3 is also shown. As discussed below in **Section 7.3**, the inclusion of queues and side roads in the 'do nothing' models would likely mean much higher concentrations for the 'do nothing' scenarios. The results presented here are, therefore, conservative and actual differences with the 'do nothing' scenario would likely be much lower.

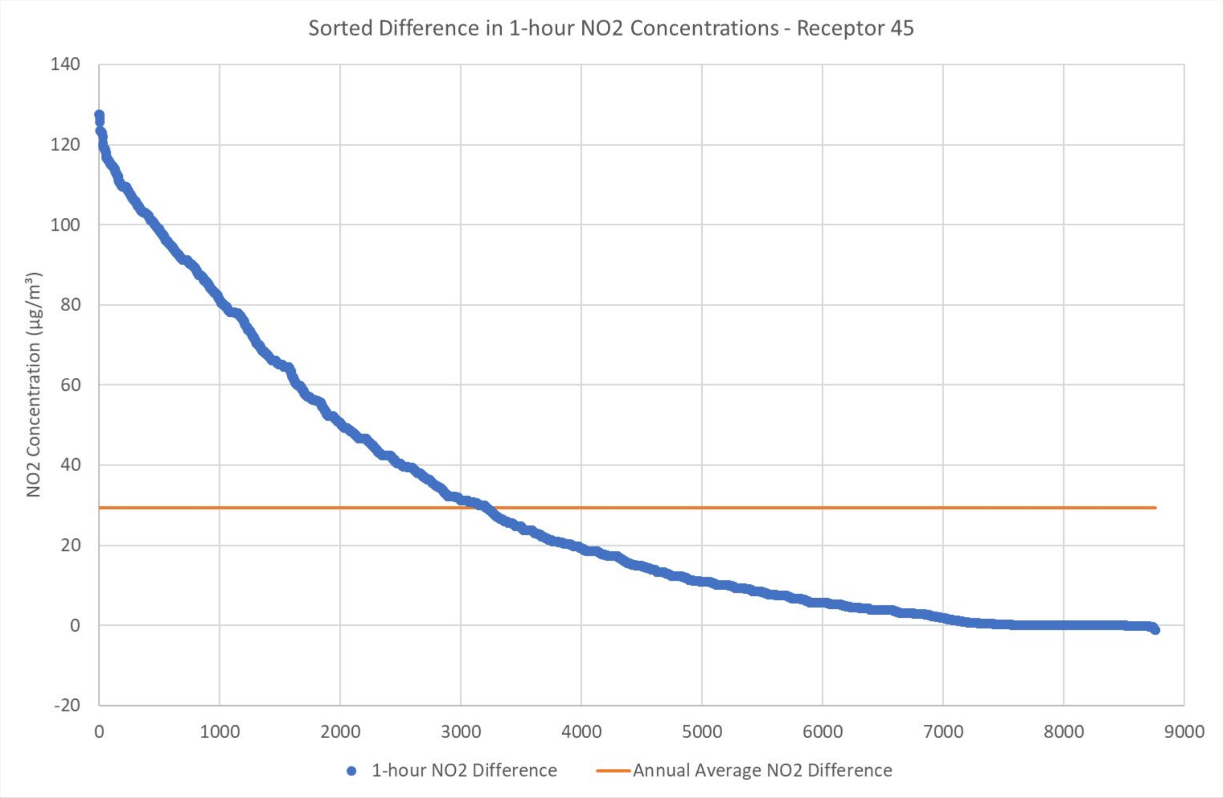

Figure 7-6 Difference in NO_2 concentrations between the proposal and 'do nothing' scenario in 2030 at Receptor 45

Difference contours showing the predicted difference in maximum 1-hour NO_2 concentrations between the proposal and 'do nothing' scenarios are presented in **Figure 7-7** (2030) and **Figure 7-8** (2040). The highest differences are in the area surrounding the proposed signalised intersections, especially near to the east side of the Range Road intersection where traffic volumes would be relatively high and the queues longest. The highest differences are predicted to be in the order of about 100 µg/m^3. Again, as discussed in **Section 7.3**, the inclusion of queues and side roads in the 'do nothing' models would likely mean much higher concentrations for the 'do nothing' scenarios and the differences presented in these figures would likely be much lower, with larger areas of negative differences possible (ie proposal has lower concentrations than 'do nothing' scenario).

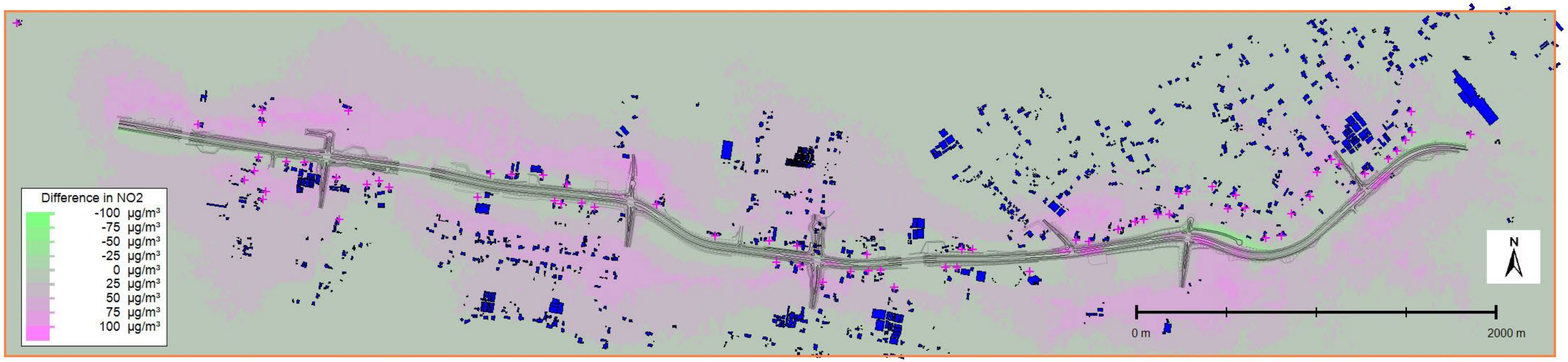

Figure 7-7 Predicted difference in maximum 1-hour NO_2 between the proposal and 'do nothing' scenario in 2030

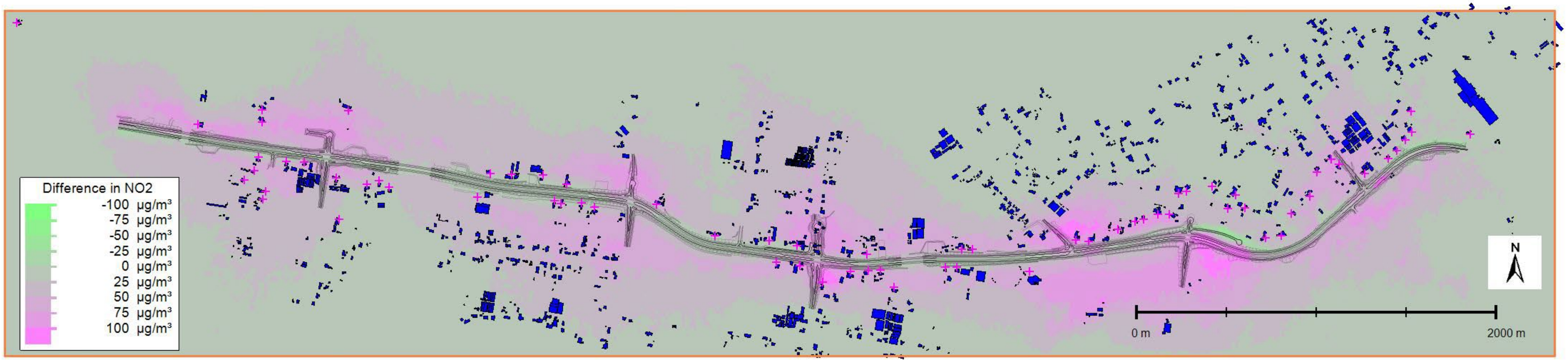

Figure 7-8 Predicted difference in maximum 1-hour NO_2 between the proposal and 'do nothing' scenario in 2040

7.1.2 Carbon monoxide

The following section provides a discussion on predicted change in maximum 1-hour and 8-hour CO ground level concentrations at sensitive receptors. Predicted CO ground level concentrations are discussed within the context of the difference between the proposal and existing baseline conditions; as well as the differences with and without the proposal; for 2030 and 2040.

This section provides a detailed discussion on the predicted changes in maximum 1-hour and 8-hour CO concentrations within the modelling domain. Comparison of predicted ground level concentrations with and without the proposal are assessed based on the relative percentage change in relation to the 1-hour and 8-hour maximum criteria. A summary of the predicted changes in maximum 1-hour and 8-hour CO concentrations at sensitive receptors for the study area is also provided in the text box below.

Predicted road contributions (or incremental contributions) from road traffic in isolation for CO as well as cumulative concentrations for all modelled scenarios are assessed against relevant EPA criteria in **Appendix H**.

Summary of potential impacts

Ground level CO concentrations (1 hour maximum and 8 hour maximum) in 2030 and 2040 are predicted to increase when compared to existing ground level concentrations. This is due to a general increase in vehicle numbers for the proposal compared with the baseline.

Predicted incremental and cumulative CO 1-hour and 8-hour maximum concentrations were well below EPA criteria at all sensitive receptors and are discussed further in **Appendix I**.

The proposal may result in slightly higher 1-hour and 8-hour maximum CO concentrations at sensitive receptors compared with the ‘do nothing’ scenarios. However, the highest predicted increases were very minor in terms of the respective EPA criteria.

Predicted changes in 1-hour and 8-hour maximum and annual average CO concentrations for 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against baseline concentrations (Scenario 1) in **Figure 7-9** and **Figure 7-10**.

Predicted 1-hour and 8-hour maximum CO concentrations at sensitive receptors for 2030 and 2040 with and without the proposal are generally higher than existing concentrations. Future concentrations under the ‘do nothing’ scenarios were generally slightly lower than the baseline, although increases at some receptors were also predicted.

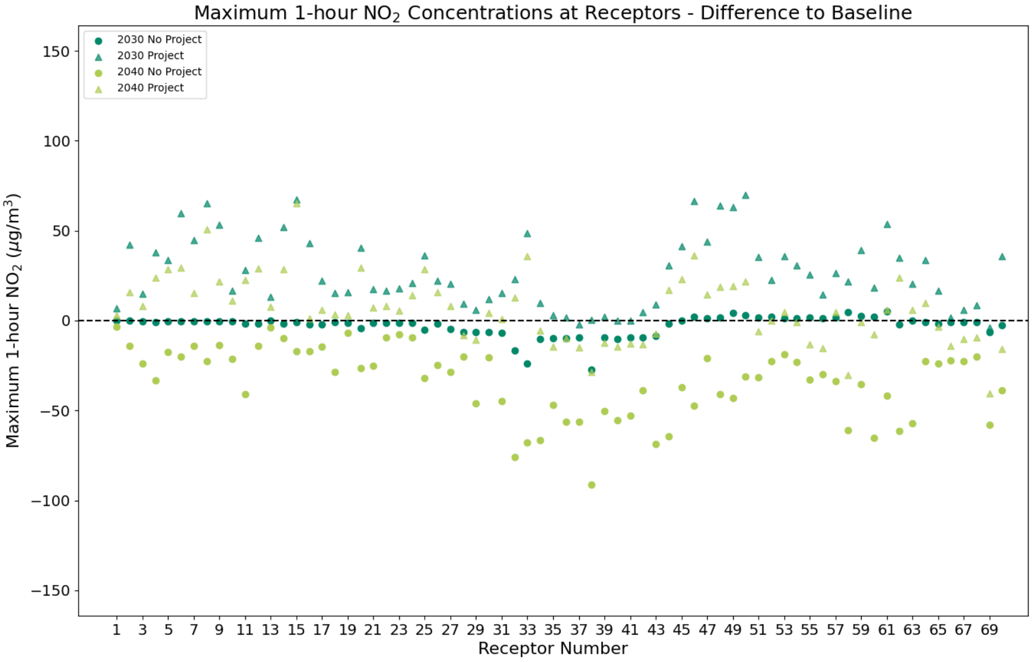

Figure 7-9 Predicted changes in maximum 1-hour CO contribution from baseline

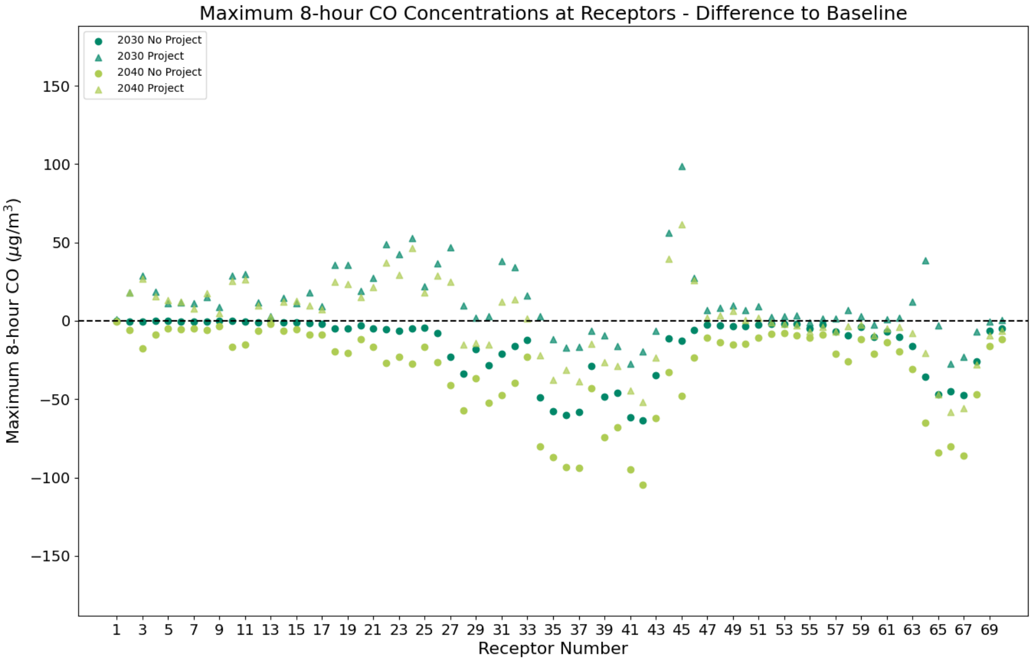

Figure 7-10 Predicted changes in maximum 8-hour CO contribution from baseline

Figure 7-11 and **Figure 7-12** shows the difference in 1 hour and 8-hour maximum CO concentrations at sensitive receptors with and without the proposal.

A minor increase in the predicted maximum 1-hour and 8-hour maximum CO concentrations was predicted at most receptors for 2030 and 2040 with the proposal compared to the 'do nothing' scenarios. These changes are very minor within the context of the EPA criteria of 30,000μg/m^3 and 10,000μg/m^3; and equate to about one per cent at the worst affected sensitive receptors.

Predicted incremental and cumulative concentrations at all sensitive receptors for CO within the southern domain were well below 1-hour and 8-hour maximum EPA criteria and are discussed further in **Appendix I**.

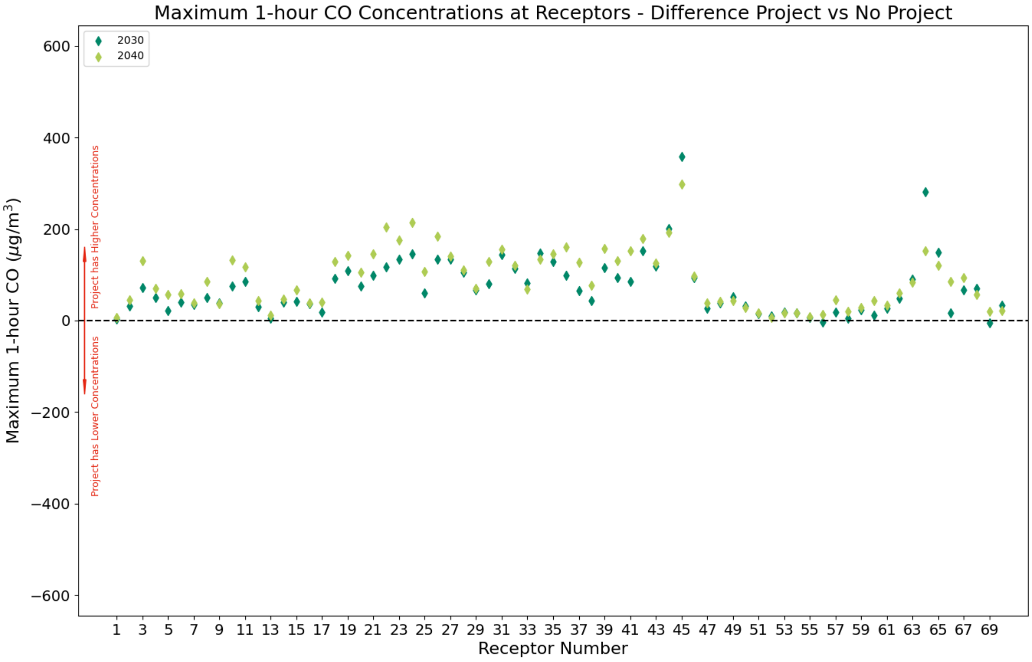

Figure 7-11 **Predicted difference between proposal and no proposal maximum 1-hour CO contributions**

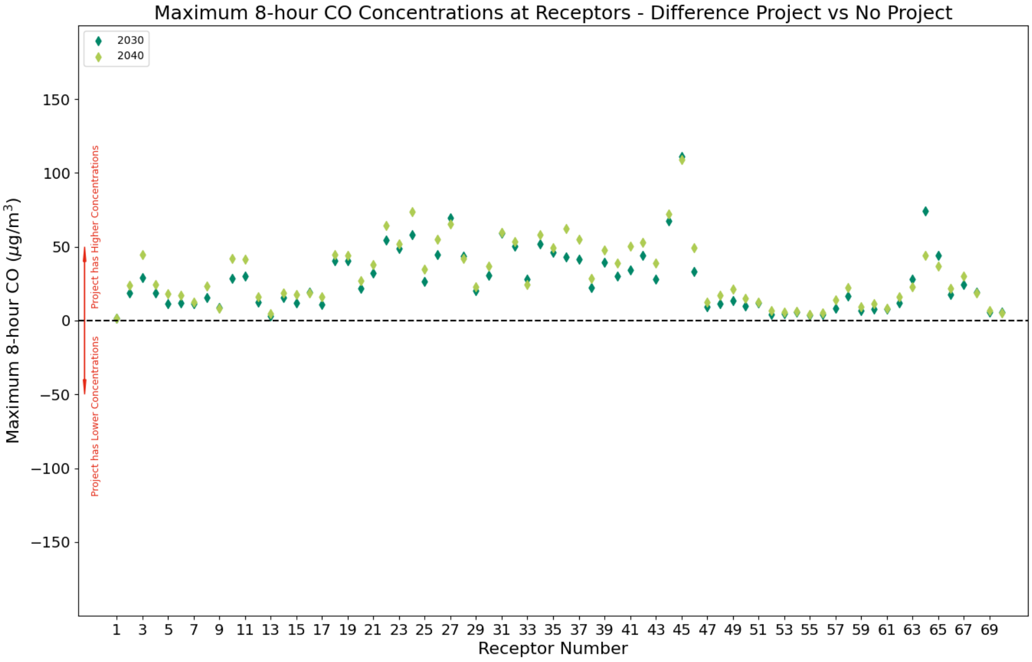

Figure 7-12 **Predicted difference between proposal and no proposal maximum 8-hour CO contributions**

7.1.3 Particulate matter (PM_{10})

The following section provides a discussion on predicted change in maximum 24-hour and annual average PM_{10} ground level concentrations at sensitive receptors. Predicted PM_{10} ground level concentrations are discussed within the context of the difference between the proposal and existing baseline conditions; as well as the differences with and without the proposal; for 2030 and 2040.

This section provides a detailed discussion on the predicted changes in maximum 24-hour and annual average PM_{10} concentrations within the modelling domain. Comparison of predicted ground level concentrations with and without the proposal are assessed based on the relative percentage change in relation to the 24-hour maximum and annual average criteria. A summary of the predicted changes in PM_{10} concentrations at sensitive receptors for the study area is also provided in the text below.

Predicted road contributions (or incremental contributions) from road traffic in isolation for PM_{10} as well as cumulative concentrations for all modelled scenarios are assessed against relevant EPA criteria in **Appendix I**.

Summary of potential impacts

Ground level PM_{10} concentrations (24 hour maximum and annual average concentrations) in 2030 and 2040 are predicted to increase when compared to existing ground level concentrations. This is due to a general increase in vehicle numbers for the proposal compared with the baseline.

Analysis of changes in contribution of 24 hour maximum and annual average PM_{10} concentrations indicate that the proposal may result in slightly higher concentrations at sensitive receptors than without the proposal. These increases, however, are very minor when compared to the EPA criteria.

Predicted changes in 24-hour maximum and annual average PM_{10} concentrations for 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against baseline concentrations (Scenario 1) in **Figure 7-13** and **Figure 7-14**.

Predicted 24-hour maximum and annual average PM_{10} concentrations at sensitive receptors for 2030 and 2040 with and without the proposal are generally higher than existing concentrations. Future concentrations under the ‘do nothing’ scenarios were generally slightly lower than the baseline.

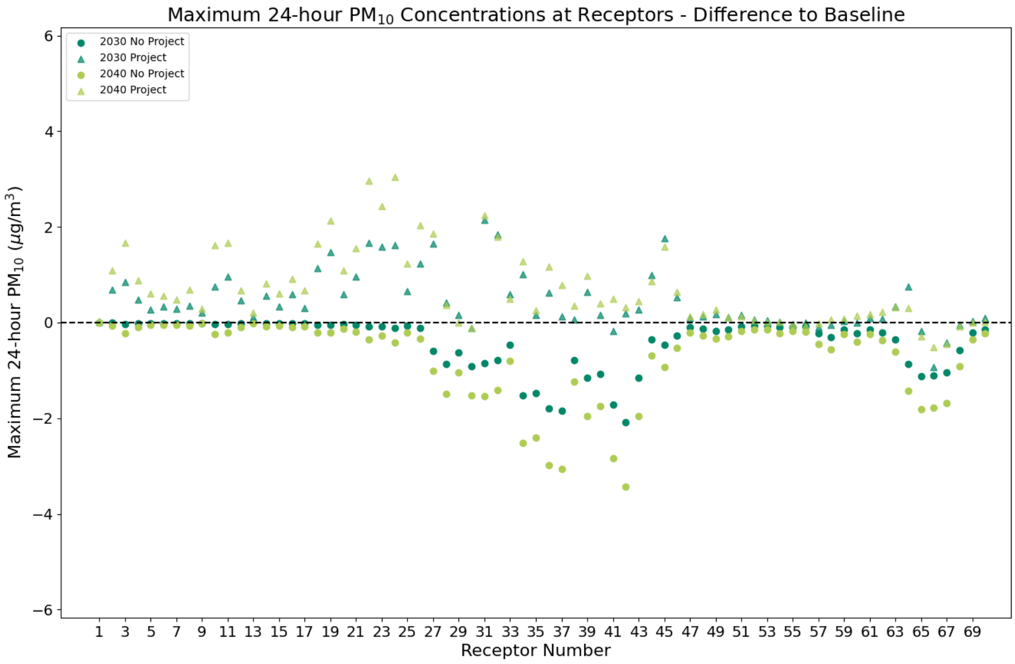

Figure 7-13 **Predicted changes in maximum 24-hour PM_{10} contribution from baseline**

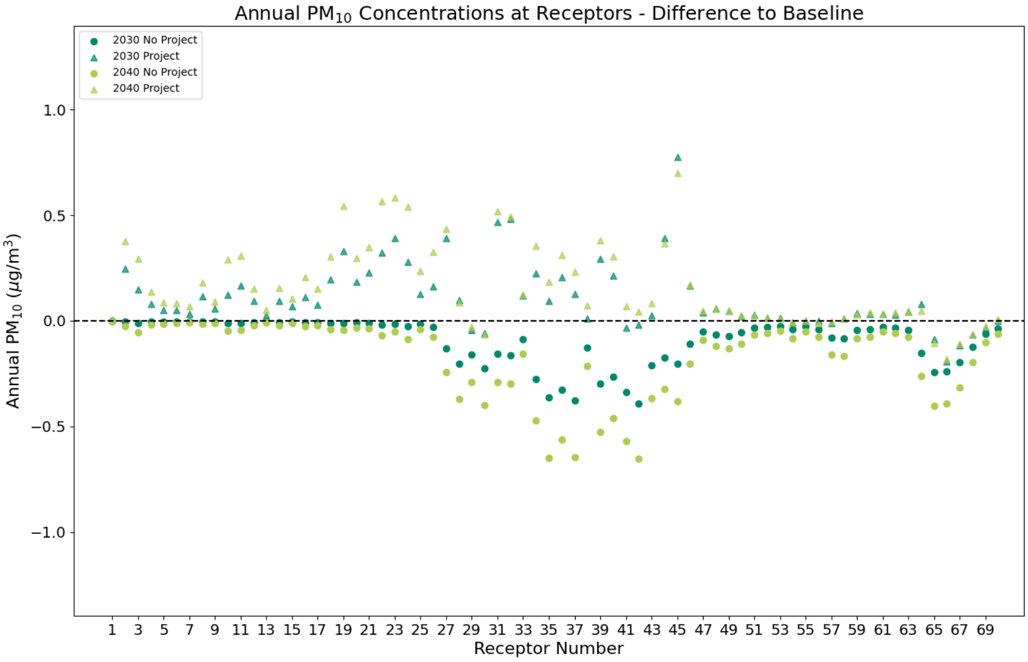

Figure 7-14 **Predicted changes in annual average PM_{10} contribution from baseline**

Figure 7-15 and **Figure 7-16** show the difference in 24-hour maximum and annual average PM_{10} concentrations at sensitive receptors between the proposal and ‘do nothing’ scenarios.

Figure 7-15 and **Figure 7-16** also show that there are minor increases in the predicted maximum 24-hour and annual average PM_{10} concentrations for 2030 and 2040 at most receptors for the proposal compared to the ‘do nothing’ scenarios. The increases, however, are minor, equating to about eight per cent of the 24-hour criterion of 50 µg/m^3 and about four per cent of the annual average criterion of 25 µg/m^3.

Predicted incremental and cumulative concentrations at all sensitive receptors for 24-hour maximum and annual average PM_{10} concentrations are discussed further in **Appendix I**.

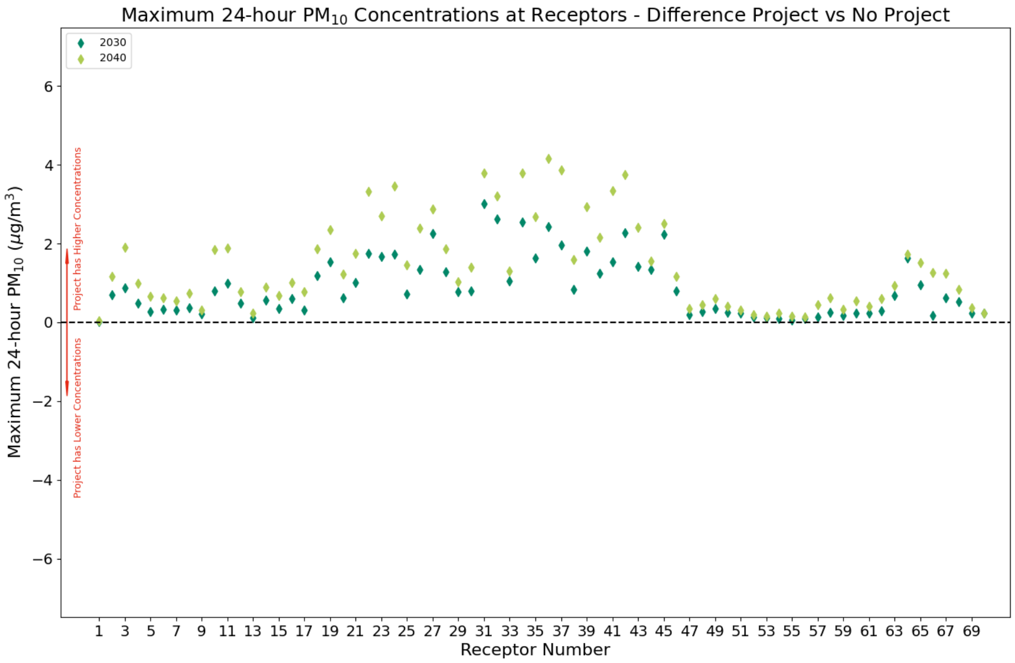

Figure 7-15 Predicted difference between proposal and no proposal maximum 24-hour PM_{10} contributions

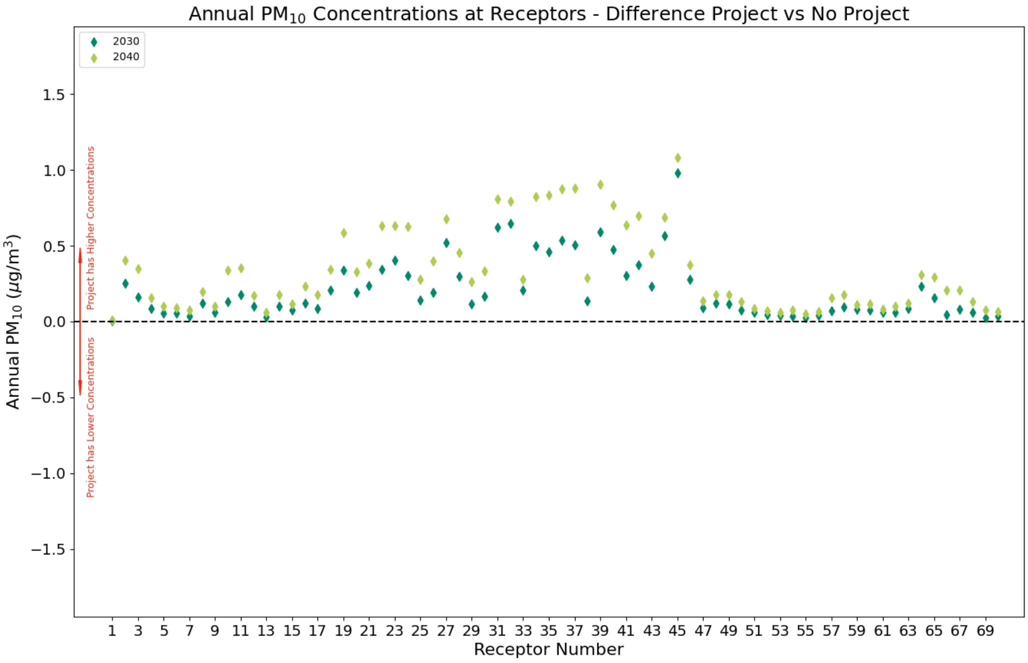

Figure 7-16 Predicted difference between proposal and no proposal annual average PM_{10} contributions

7.1.4 Particulate matter ($PM_{2.5}$)

The following section provides a discussion on predicted change in maximum 24-hour and annual average $PM_{2.5}$ ground level concentrations at sensitive receptors. Predicted $PM_{2.5}$ ground level concentrations are discussed within the context of the difference between the proposal and existing baseline conditions; as well as the differences with and without the proposal; for 2030 and 2040.

This section provides a detailed discussion on the predicted changes in maximum 24-hour and annual average $PM_{2.5}$ concentrations within the modelling domain. Comparison of predicted ground level concentrations with and without the proposal are assessed based on the relative percentage change in relation to the 24-hour maximum and annual average criteria. A summary of the predicted changes in $PM_{2.5}$ concentrations at sensitive receptors for the study area is also provided in the text box below.

As discussed in **Section 4.2.2.4**,existing annual average $PM_{2.5}$ concentrations within the study area are already elevated. Modelling results with and without the proposal for $PM_{2.5}$ have also been assessed against recommended $\Delta PM_{2.5}$ health assessment criteria (see **Section 5.4.3**). Assessment of incremental annual average $\Delta PM_{2.5}$ are discussed in **Section 7.1.4.1**.

Predicted road contributions (or incremental contributions) from road traffic in isolation for $PM_{2.5}$ as well as cumulative concentrations for all modelled scenarios are assessed against relevant EPA criteria in **Appendix I**.

Summary of potential impacts

Ground level $PM_{2.5}$ concentrations (24 hour maximum and annual average) in 2030 and 2040 are predicted to increase when compared to existing ground level concentrations. This is due to a general increase in vehicle numbers for the proposal compared with the baseline.

Analysis of changes in contribution of 24 hour maximum and annual average $PM_{2.5}$ concentrations indicate that the proposal may result in slightly higher concentrations at sensitive receptors than without the proposal. The highest increases, however, were minor when compared to the EPA criteria.

Predicted annual average $\Delta PM_{2.5}$ values for the proposal were also examined for future scenarios; and compared against recommended guidelines to assess incremental health risk. At the worst affected sensitive receptors, annual average $\Delta PM_{2.5}$ indicated changes to $PM_{2.5}$ concentrations would be considered acceptable; with most sensitive receptors lying within the Acceptable Risk category. There were no sensitive receptors with an annual $\Delta PM_{2.5}$ value deemed an unacceptable risk.

Predicted changes in 24-hour maximum and annual average $PM_{2.5}$ concentrations for 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against baseline concentrations (Scenario 1) in **Figure 7-17** and **Figure 7-18**.

Predicted 24-hour maximum and annual average $PM_{2.5}$ concentrations at sensitive receptors for 2030 and 2040 with and without the proposal are generally higher than existing concentrations. Future concentrations under the ‘do nothing’ scenarios were generally slightly lower than the baseline.

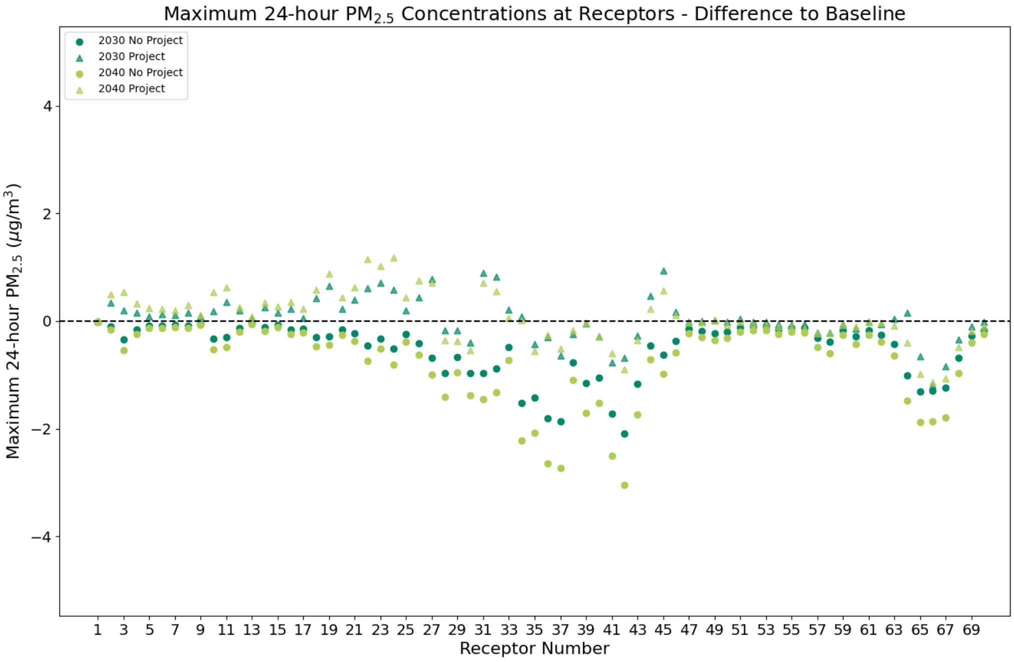

Figure 7-17 **Predicted changes in maximum 24-hour $PM_{2.5}$ contribution from baseline**

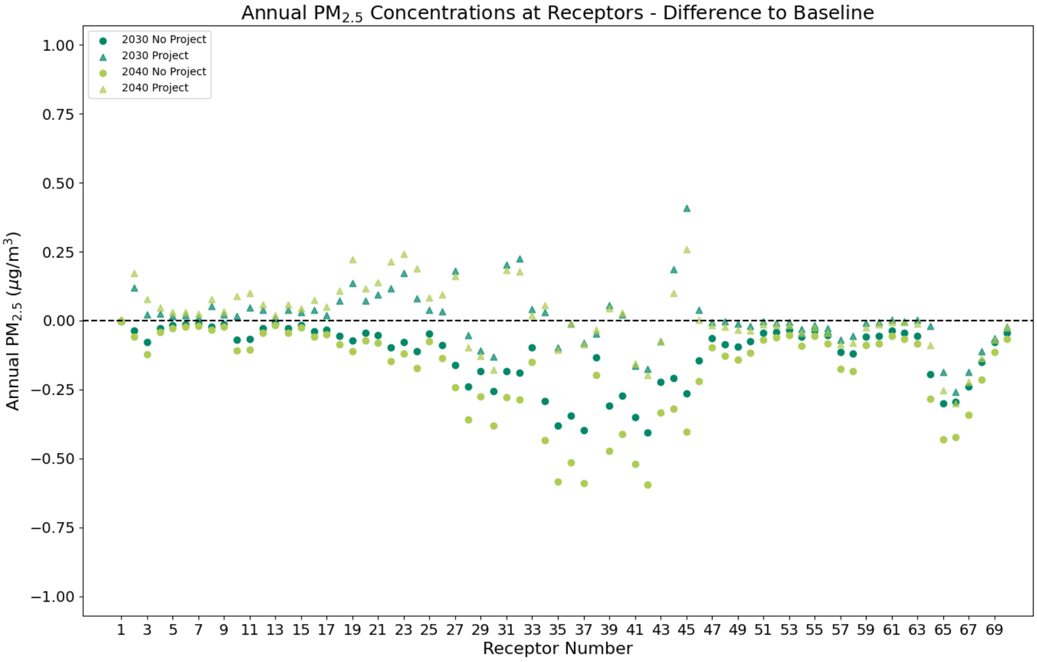

Figure 7-18 **Predicted changes in annual average $PM_{2.5}$ contribution from baseline**

As the predicted decreases in 24-hour maximum and annual average $PM_{2.5}$ concentrations when compared to the baseline are generally attributed to lower emission factors used for future vehicle fleets, further examination of predicted $PM_{2.5}$ concentrations with and without the proposal was required. **Figure 7-19** and **Figure 7-20** show the difference in 24-hour maximum and annual average $PM_{2.5}$ concentrations at sensitive receptors with and without the proposal.

Figure 7-19 and **Figure 7-20** show that there are some increases in the predicted maximum 24-hour and annual average $PM_{2.5}$ concentrations for 2030 and 2040 when the proposal is compared to the ‘do nothing’ scenarios. These increases, however, are relatively minor, equating to about nine per cent of the 24-hour criterion of 25 µg/m^3 and about nine per cent of the annual average criterion of 8 µg/m^3. The increases are generally attributable to higher traffic numbers for the proposal.

The predicted annual average $\Delta PM_{2.5}$ for 2026 and 2036 modelled scenario are discussed within the context of the recommended guidelines for health assessment criteria in **Section 7.1.4.1**. Predicted incremental and cumulative concentrations at all sensitive receptors for 24 hours maximum and annual average $PM_{2.5}$ concentrations are discussed further in **Appendix I**.

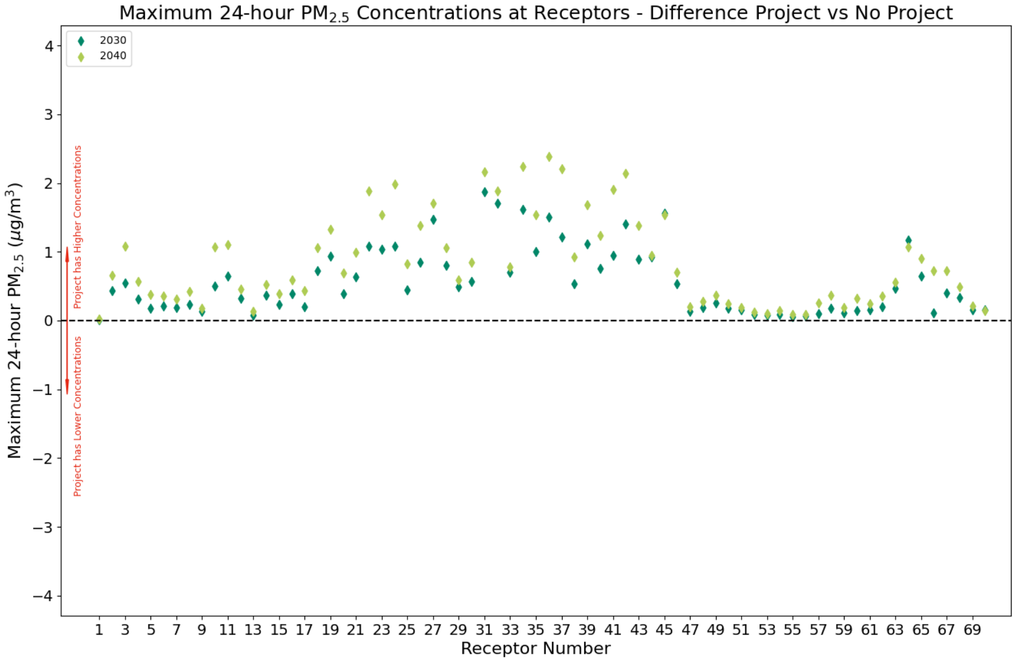

Figure 7-19 Predicted difference between proposal and no proposal maximum 24-hour $PM_{2.5}$ contributions

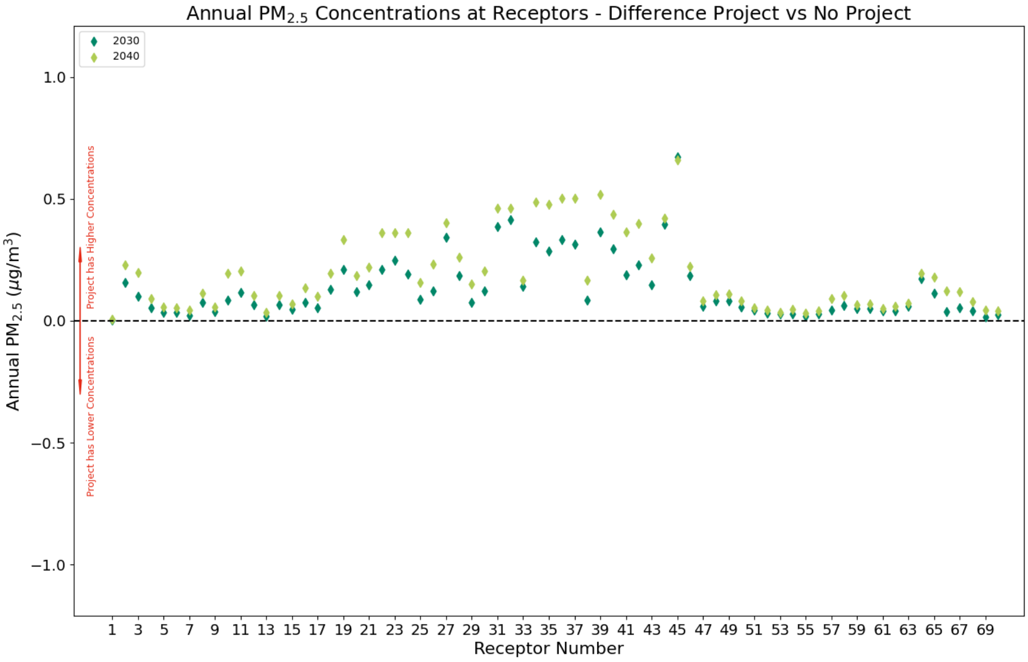

Figure 7-20 Predicted difference between proposal and no proposal annual average $PM_{2.5}$ contributions

7.1.4.1 Incremental health assessment ($\Delta PM_{2.5}$)

As discussed in **Section 4.2.2.4**, existing annual average $PM_{2.5}$ concentrations are already elevated within the study area. As such, recommended incremental guidelines in *An Australian incremental guideline for particulate matter ($PM_{2.5}$) to assist in development and planning decisions* (Capon, A. & Wright J. 2019) have been used to assess the impact of $PM_{2.5}$ from the proposed area.

Based on the guidelines as described in **Table 5-5** the following $\Delta PM_{2.5}$ categories have been used to define the level of risk from the construction footprint:

- **Negligible Risk** for $\Delta PM_{2.5}$ < 0.02µg
- **Acceptable Risk** for $\Delta PM_{2.5}$ between 0.02 – 0.17µg
- **Tolerable Risk** for $\Delta PM_{2.5}$ between 0.17 – 1.7µg
- **Unacceptable Risk** for $\Delta PM_{2.5}$ between >1.7µg.

Figure 7-20 above shows changes in predicted annual $PM_{2.5}$ concentrations for the proposal for 2030 and 2040 at sensitive receptors; also referred to as the predicted $\Delta PM_{2.5}$. The worst affected sensitive receptors have an annual $\Delta PM_{2.5}$ concentration of about 0.7 µg/m^3 which corresponds to the **Tolerable Risk** category. All sensitive receptors for both 2030 and 2040 fall within either the **Acceptable Risk** or **Tolerable Risk** categories.

Predicted annual $\Delta PM_{2.5}$ values for gridded receptors for 2030 (**Figure 7-21**) and 2040 (**Figure 7-22**) are presented with contours based on the four risk categories. Both modelled years are similar, although 2040 shows a slightly higher difference compared with 2030. For both years, within the study area near the kerb of the road at sensitive receptors, most ground level annual average $\Delta PM_{2.5}$ values fall within the **Acceptable Risk** or **Tolerable Risk** categories (ie between 0.02 µg/m^3 and 1.7 µg/m^3). The only areas within the Unacceptable Risk category are within the confines of the road itself.

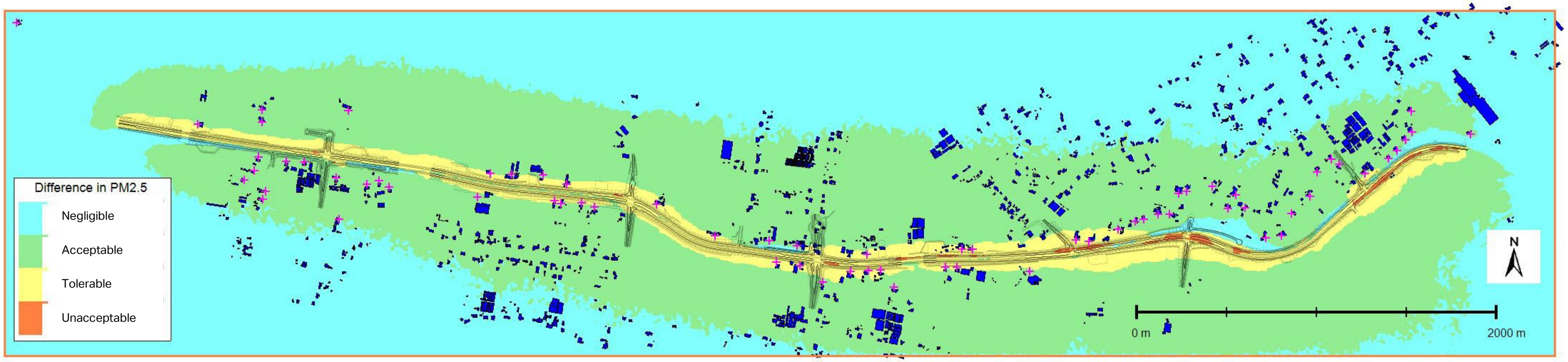

Figure 7-21 Predicted difference in annual average $PM_{2.5}$ between the proposal and 'do nothing' scenario in 2030

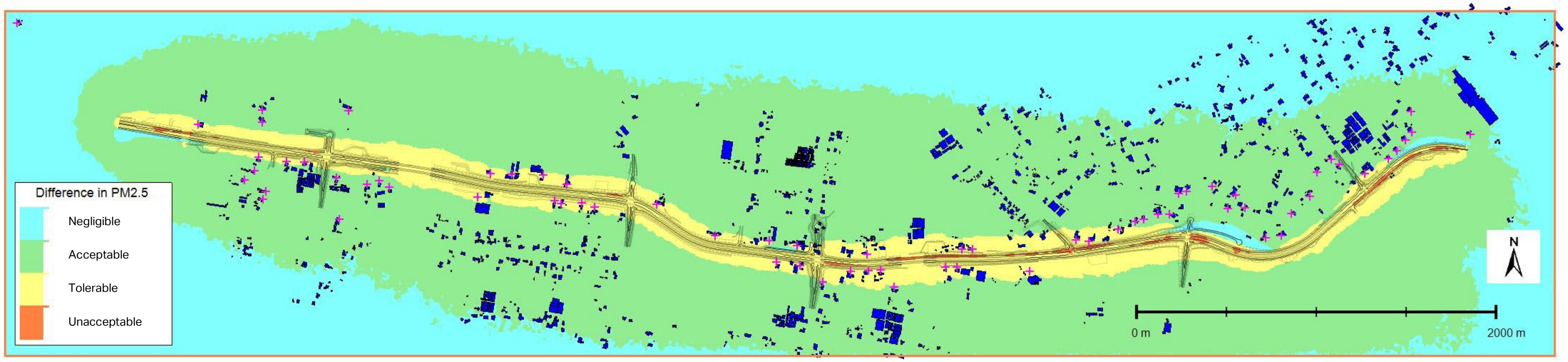

Figure 7-22 Predicted difference in annual average $PM_{2.5}$ between the proposal and 'do nothing' scenario in 2040

7.1.5 Volatile organic compounds (VOCs)

The following section provides a discussion on predicted change in the 1 hour 99.9th percentile ground level concentrations for VOCs at sensitive receptors. Predicted VOC ground level concentrations are discussed within the context of the difference between the proposal and existing baseline conditions; as well as the differences with and without the proposal; for 2030 and 2040.

Of the VOC's listed key pollutants of interest listed in **Section 3.2**, benzene and formaldehyde have the lowest 1-hour 99th percentile criteria of 29 µg/m^3 and 20 µg/m^3, respectively, of all the VOC's Analysis is focused on these pollutants in this Section with results for toluene, acetaldehyde, xylene and 1,3 butadiene reported in **Appendix I**.

The following sections provide a detailed discussion on the predicted changes to 1 hour 99.9th percentile concentrations for benzene and formaldehyde within the modelling domain. Comparison of predicted ground level concentrations with and without the proposal are assessed based on the relative percentage change in relation to EPA criteria for benzene and formaldehyde. A summary of the change in predicted changes in VOC ground level concentrations at sensitive receptors for the study area is also provided in the text box below.

Predicted road contributions (incremental contributions) for VOCs for all modelled scenarios are assessed against relevant EPA criteria in **Appendix I**.

Summary of potential impacts

Analysis of changes in contribution of predicted 1-hour 99.9th percentile benzene and formaldehyde concentrations indicate there is no significant difference in predicted ground level VOC concentrations at sensitive receptors with or without the proposal for 2030 and 2040. Predicted changes in contribution for both benzene and formaldehyde were found to be about one per cent of the individual VOC species criteria.

7.1.5.1 Benzene

Predicted changes in 1-hour 99.9th percentile concentrations for benzene 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against baseline concentrations (Scenario 1) in **Figure 7-23**.

Figure 7-23 shows that predicted 1-hour 99.9th percentile concentrations for benzene at sensitive receptors for 2030 and 2040 with and without the proposal are lower than modelled baseline concentrations. Predicted decreases in the future scenarios are primarily associated with lower emission factors associated with uptake of vehicles which adhere to more stringent emission standards as discussed in **Section 5.7.5**.

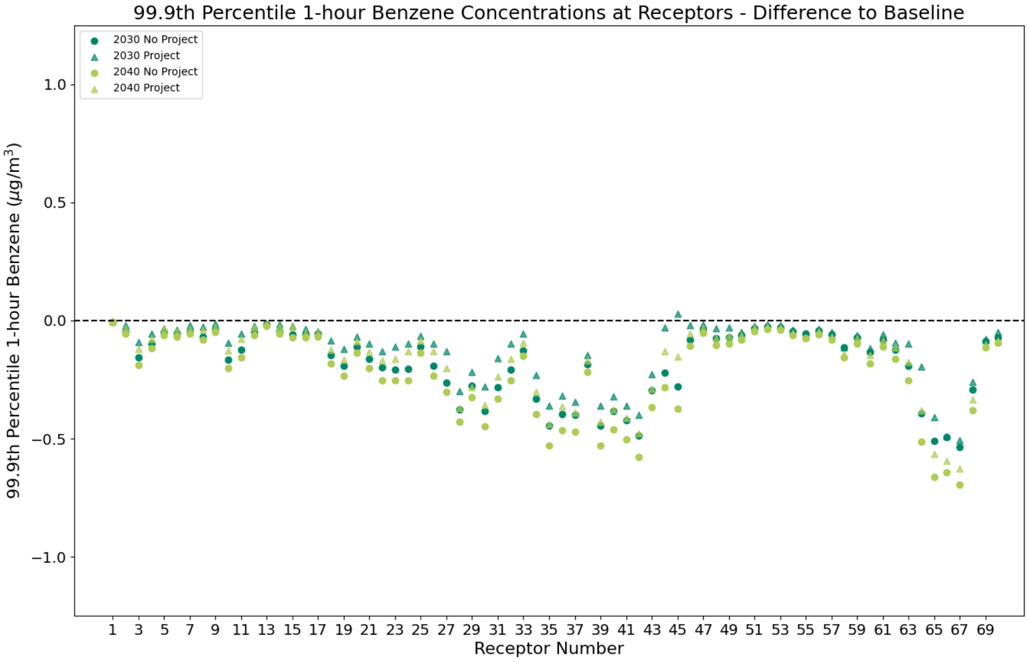

Figure 7-23 **Predicted changes in 99.9th%ile 1-hour benzene contribution from baseline**

Predicted changes in the 1-hour 99.9th percentile benzene contributions between the proposal and 'do nothing' scenarios for 2030 and 2040 were also reviewed to assess the potential impacts from the proposal.

Figure 7-24 shows that predicted change in benzene concentration between the proposal and 'do nothing' scenarios are up to about 0.3 μg/m^3, which equates to about one per cent of the EPA criterion of 29 μg/m^3. The predicted change in benzene contribution associated with the proposal at sensitive receptors is therefore considered negligible.

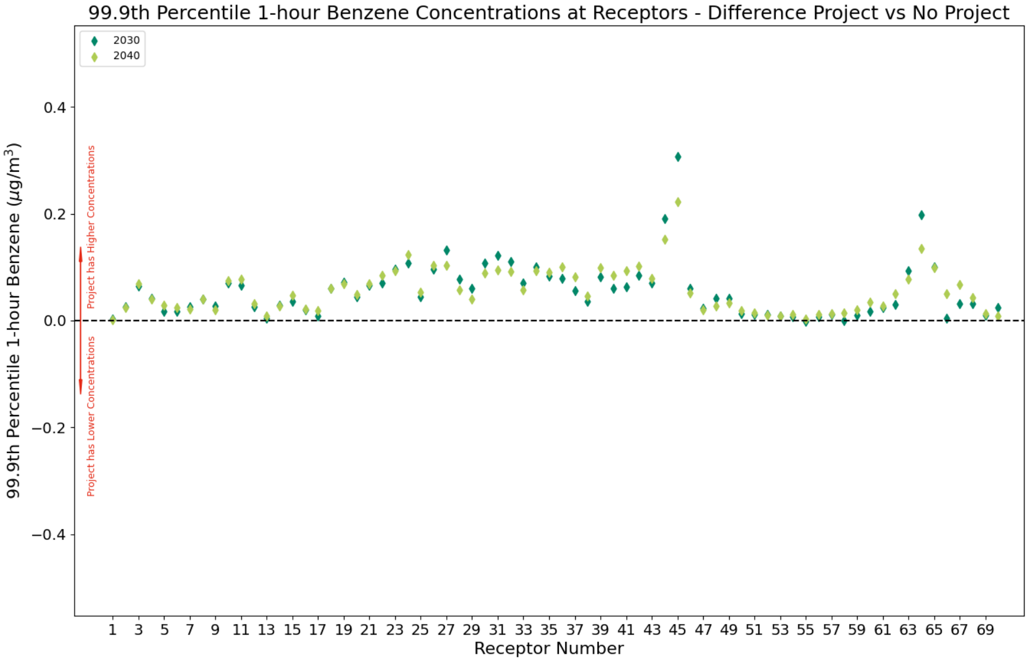

Figure 7-24 **Predicted difference between proposal and no proposal 99.9th%ile 1-hour benzene contributions**

7.1.5.2 Formaldehyde

Predicted changes in 1-hour 99.9th percentile concentrations for formaldehyde 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against existing concentrations (Scenario 1) in **Figure 7-25**.

Concentrations for formaldehyde at sensitive receptors for 2030 and 2040 with and without the proposal were predicted to be lower than baseline concentrations. Predicted decreases in future scenarios are primarily associated with lower emission factors associated with uptake of vehicles which adhere to more stringent emission standards as discussed in **Section 5.7.5**.

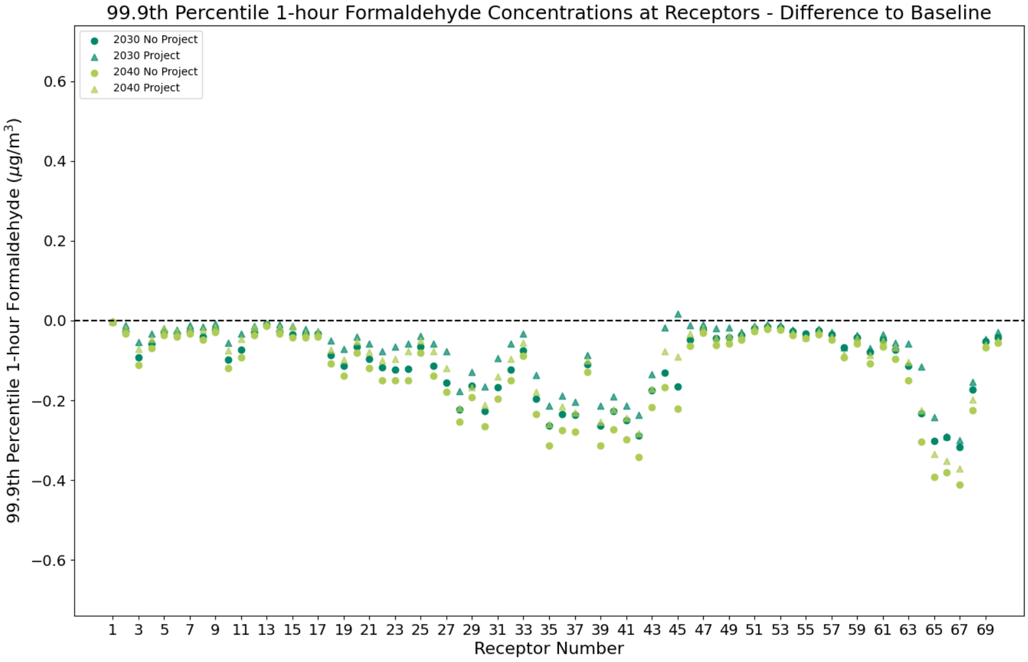

Figure 7-25 **Predicted changes in 99.9th%ile 1-hour formaldehyde contribution from baseline**

Predicted changes in the 1-hour 99.9th percentile formaldehyde contributions between the proposal and the 'do nothing' scenarios for 2030 and 2040 were also reviewed to assess the potential impacts from the proposal.

Figure 7-26 shows that predicted change in formaldehyde concentration between the proposal and 'do nothing' scenarios were up to about 0.2 μg/m^3, which equates to about one per cent of the EPA criterion of 20 μg/m^3. The predicted change in formaldehyde contribution associated with the proposal at sensitive receptors is therefore considered negligible.

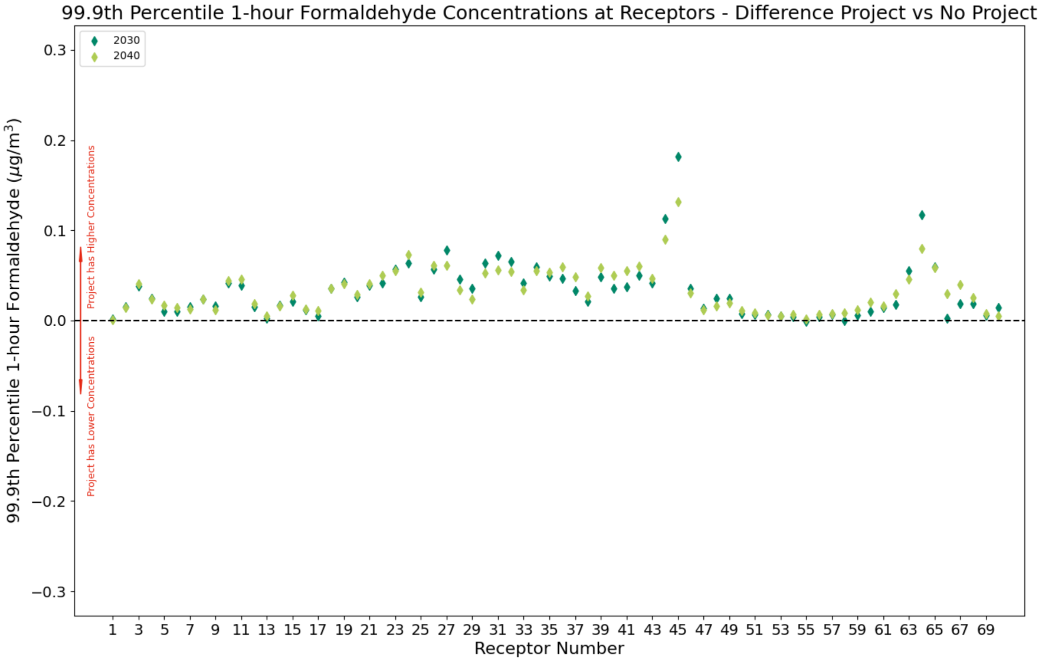

Figure 7-26 Predicted difference between proposal and no proposal 99.9th%ile 1-hour formaldehyde contributions

7.1.6 Polycyclic aromatic hydrocarbons (PAHs)

The following section provides a discussion on predicted change in the 1 hour 99.9th percentile ground level concentrations for total PAHs at sensitive receptors. Total PAHs reported have been expressed as benzo[a]pyrene (BaP) calculated using the potency equivalency factors for PAHs as described in **Section 5.7.5.2**. Modelled PAH ground level concentrations are discussed based on the difference between the proposal and existing baseline conditions; as well as the differences with and without the proposal for 2030 and 2040.

This section provides a detailed discussion on the predicted changes in 1 hour 99.9th percentile concentrations for PAHs within the modelling domain. Comparison of predicted ground level concentrations with and without the proposal were assessed based on the relative percentage change in relation to EPA criteria for PAHs (as BaP).

Predicted road contributions (incremental contributions) for PAHs for all modelled scenarios are assessed against relevant EPA criteria in **Appendix I**.

Summary of potential impacts

Analysis of changes in contribution of predicted 1-hour 99.9th percentile PAH concentrations indicate there is no significant difference in predicted ground level total PAH concentrations (as BaP equivalent) at sensitive receptors with or without the proposal for 2030 and 2040. Predicted changes in contribution for total PAHs were found to be less than one per cent of the EPA criteria.

Predicted changes in 1-hour 99.9th percentile concentrations for PAHs (as BaP) 2030 and 2040 with and without the proposal at sensitive receptors have been plotted against baseline concentrations (Scenario 1) in **Figure 7-27**. Predicted 1-hour 99.9th percentile concentrations for PAHs at sensitive receptors for 2030 and 2040 with and without the proposal were lower than modelled baseline concentrations. Predicted decreases in future scenarios are primarily associated with lower emission factors associated with uptake of vehicles which adhere to more stringent emission standards as discussed in **Section 5.7.5**.

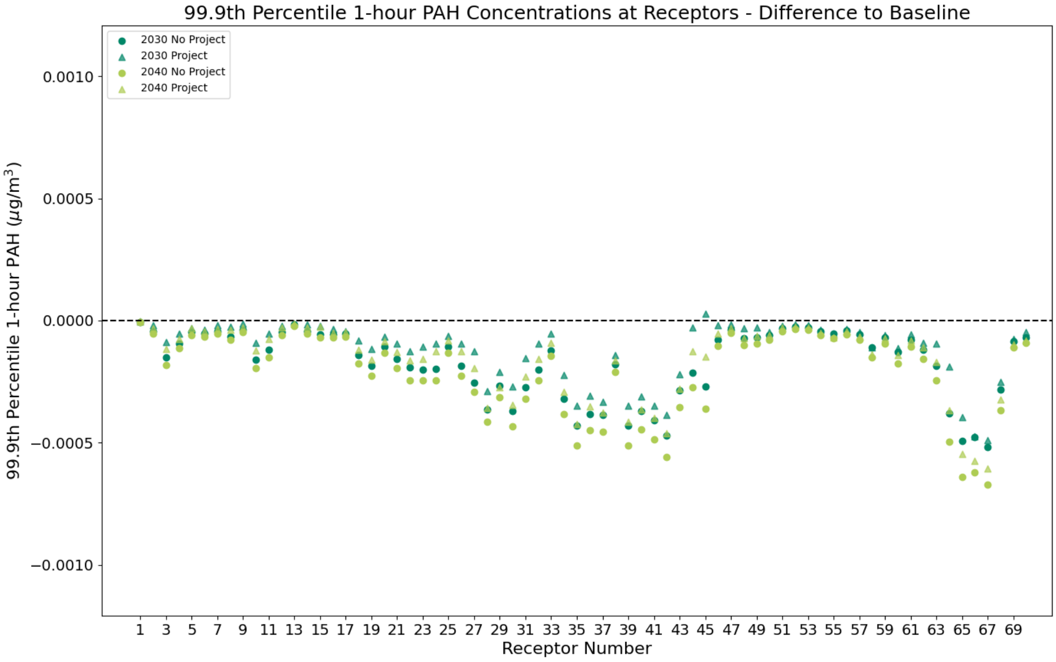

Figure 7-27 **Predicted changes in 99.9th%ile 1-hour PAH (as BaP) contribution from baseline**

Differences between the proposal and ‘do nothing’ scenarios for 2030 and 2040 were also reviewed to assess the potential impacts from the proposal.

Figure 7-28 shows that predicted change in total PAH (as BaP) concentration between the proposal ‘do nothing’ scenarios were up to about 0.0003 µg/m³, which equates to less than one per cent of the EPA criterion of 0.4 µg/m³. The predicted change in PAH contribution associated with the proposal at sensitive receptors is therefore considered negligible.

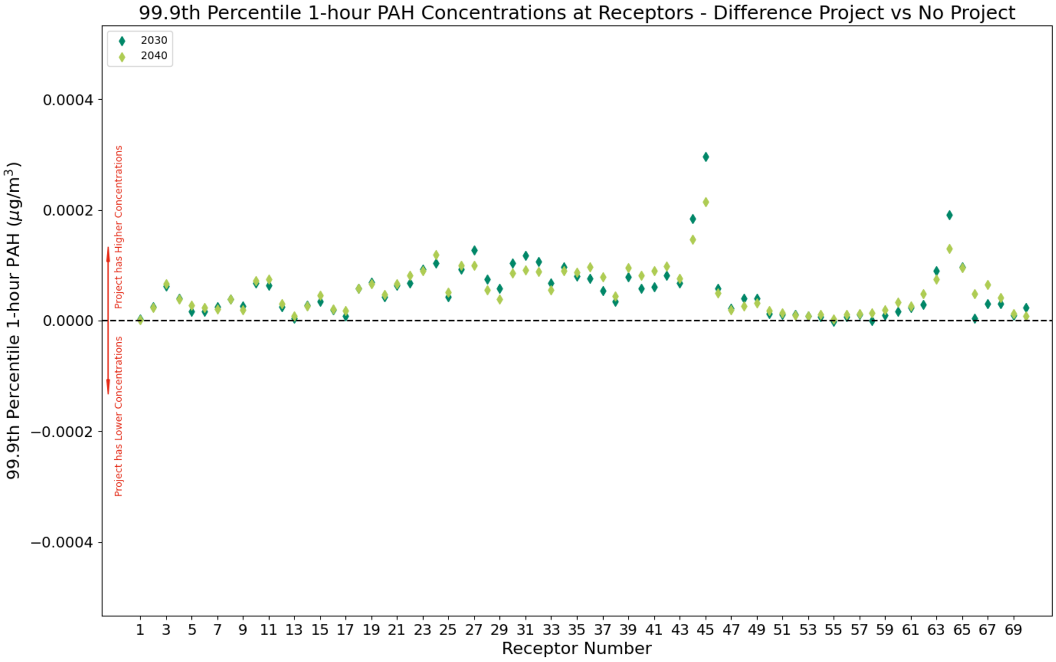

Figure 7-28 Difference between proposal and no proposal 99.9th%ile 1-hour PAH (as BaP) contributions (note scale on y-axis is 10^{-5-} µg/m^3)

7.2 Cumulative impacts with nearby proposals

7.2.1 Western Sydney Airport

Operation of WSA (beyond 2026) would coincide with the operation of the proposal. Operational emissions from WSA would primarily consist of combustion emissions associated with fuel use. Predictions of operational air quality impacts were made in the AQIA for the WSA Environmental Impact Statement (EIS) for WSA (DIRD 2016). Emissions from WSA would likely increase the measured background concentrations that were used in this assessment, thus pushing the predicted cumulative concentrations that are provided in **Appendix I** higher. Emissions from WSA would have no effect on proposal-only emissions. Potential increases in the background based on operations at WSA are discussed below.

The WSA EIS predicted potential increases in concentrations of CO, NO_2, PM_{10}, $PM_{2.5}$, and to the north of the WSA site at locations within the proposal study area.

Short term (1-hour maximum) NO_2 were predicted to be elevated, up to and above the criterion, based on incremental WSA emissions only. Short term pollutant concentrations tend to be sporadic, and it is unlikely that these high concentrations would persist for more than an hour or two at any given location. It is also unlikely that these concentrations would coincide with the maximum concentrations from the proposal. Despite that, there is the possibility of exceedances at proposal receptors, mostly at the western end of the proposal. These would, however, likely be due primarily to the combination of existing background concentrations and additional contribution from WSA. The likelihood of the occurrence of any exceedances would be similar for both the proposal and ‘do nothing’ scenarios.

Long term (annual) NO_2 concentrations for incremental WSA emissions were predicted to be up to about 60 per cent of the criteria at receptors common to the proposal.

Long term (beyond 2030) annual concentrations of $PM_{2.5}$ were predicted to be up to about 0.8 µg/m^3 in the construction footprint, north of the WSA. There is the possibility of exceedances of the annual average criteria based on this, given the already high existing concentrations.

Despite the potential for a higher background and possible exceedances at proposal receptors due to increased background concentrations from the operation of WSA, there would be no material effect on the outcome of this assessment, as these would not affect the emissions from the proposal and the difference between the proposal and 'do nothing' scenarios would remain unchanged.

7.2.2 M12 Motorway

The M12 Motorway would be operational concurrently with the proposal and shares sensitive receptors with the proposal. The M12 Motorway is proposed to cross over the proposal near Mamre Road and an increase in background concentrations would be expected due to operation for the M12 Motorway for receptors in this area.

An air quality impact assessment was prepared for the M12 Motorway as part of the EIS process (Transport for NSW 2019). The assessment was carried out using Transport for NSW's Tool for Roadside Air Quality (TRAQ). TRAQ is a first-pass tool which uses worst-case scenarios to predict conservative ground level pollutant concentrations[7]. As noted on the TRAQ website, TRAQ can only be used to determine whether further, more detailed modelling is required. The results presented in the EIS are therefore conservative and actual ground level concentrations would likely be much lower.

Similar to the WSA, the M12 Motorway EIS demonstrated that there is the potential for an increase in background pollutant concentrations due to operation of the M12 Motorway, particularly in the area where the M12 Motorway crosses over the proposal near Mamre Road. This increase would potentially cause additional exceedances of the short-term and long-term NO_2 and $PM_{2.5}$ criteria at proposal receptors. However, there would be no material effect on the outcome of this assessment, as the increase in background concentrations would not affect the magnitude of emissions from the proposal and the difference between the proposal and 'do nothing' scenarios would remain unchanged.

7.2.3 Elizabeth Drive West Upgrade

The Elizabeth Drive West Upgrade (EDU West) proposal would be operating concurrently with the proposal and, therefore, potential cumulative effects of the two projects were considered. Receptors that could potentially be affected by the two projects were identified and included in the modelling for both this assessment and the EDU West modelling. The locations of these receptors are presented in **Figure 7-29**.

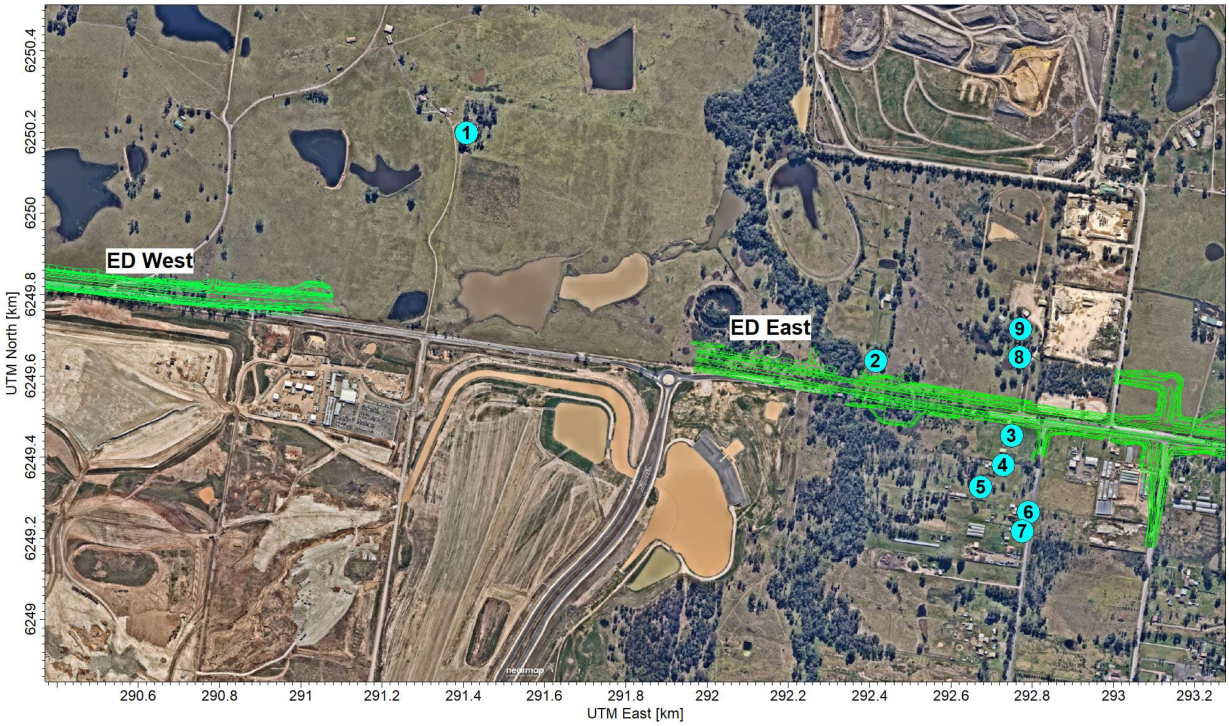

Figure 7-29 Receptors considered for the cumulative assessment with Elizabeth Drive West Upgrade Cumulative concentrations of maximum 1-hour NO2 and annual average PM2.5 were examined to determine whether cumulative effects would be significant. Only the proposal scenarios for both projects were considered (ie the 'do nothing' scenarios were not examined).

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[7] https://roads-waterways.transport.nsw.gov.au/about/environment/air/traq/index.html

Maximum 1-hour NO_2 concentrations for the proposal and the Elizabeth Drive West Upgrade project are presented in **Figure 7-30** for each of the nine receptors for both 2030 and 2040, with-proposal scenarios. Results show that for both 2030 and 2040, the cumulative concentrations between the two projects are essentially unchanged from the highest contribution from each of the projects, as the maximum NO_2 concentrations at each would occur at different times for each of projects in isolation. Potential cumulative short-term impacts from Elizabeth Drive West Upgrade project are negligible.

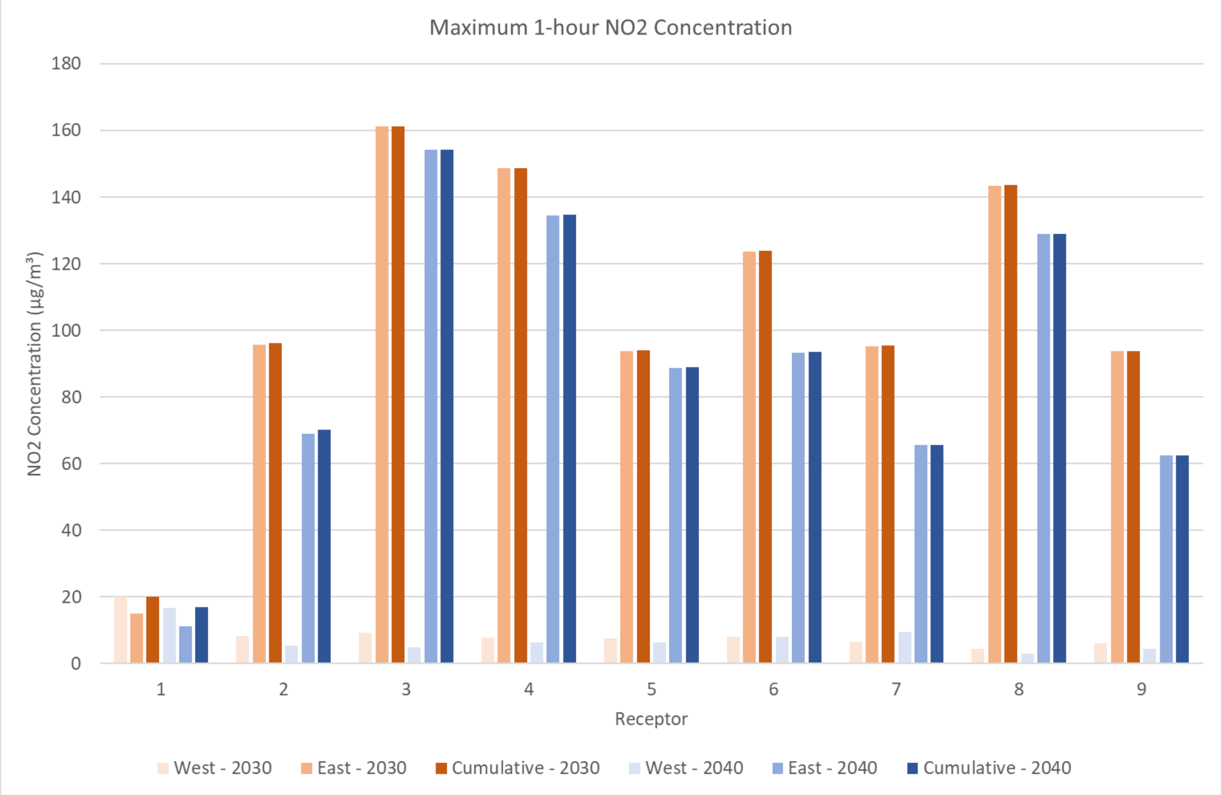

Figure 7-30 Maximum 1-hour NO_2 concentrations for Elizabeth Drive East Upgrade, Elizabeth Drive West Upgrade project and cumulatively

Annual average $PM_{2.5}$ concentrations for the proposal and the Elizabeth Drive West Upgrade are presented in **Figure 7-31** for each of the nine receptors for both 2030 and 2040, with-proposal scenarios. This shows that the cumulative concentrations would be very slightly higher than the highest of the two project contributions for each year. Potential cumulative long-term $PM_{2.5}$ impacts from Elizabeth Drive West Upgrade are negligible.

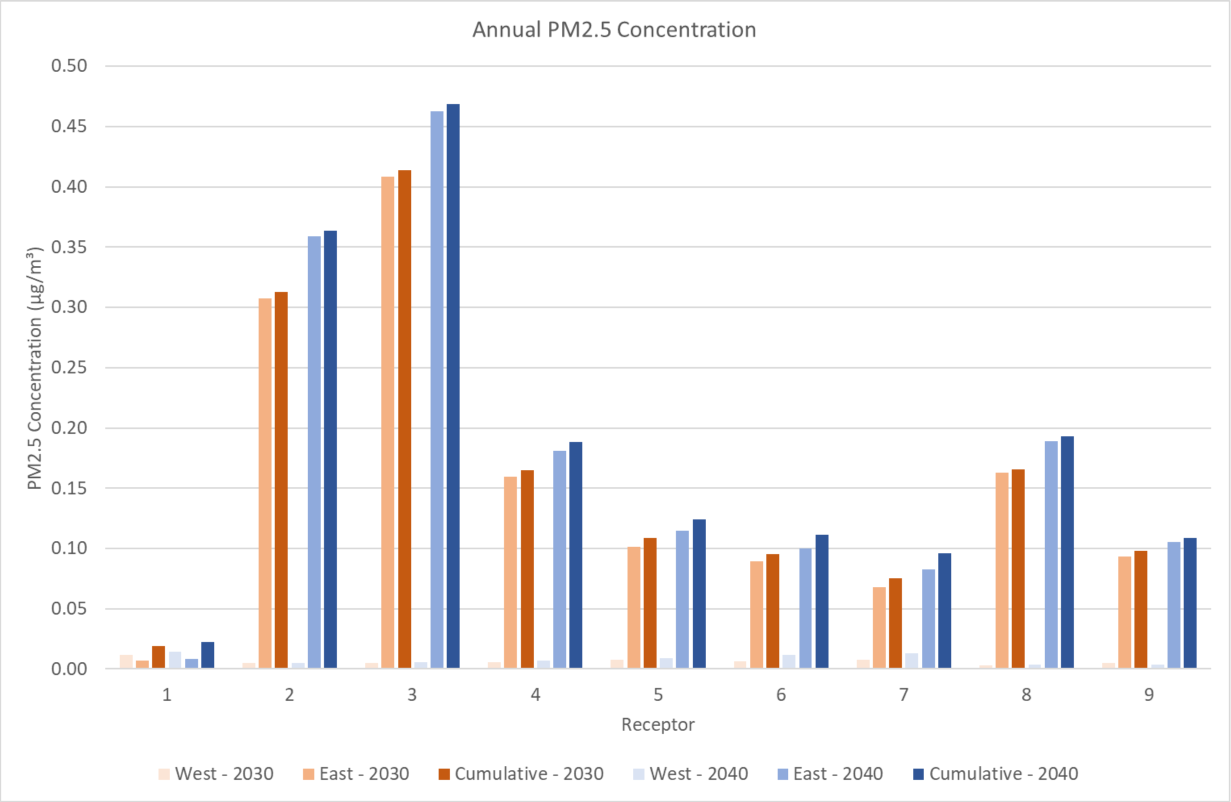

Figure 7-31 **Annual average $PM_{2.5}$ concentrations for Elizabeth Drive East Upgrade, Elizabeth Drive West Upgrade and cumulatively**

In general, the results show that there would be very little change in concentrations when both the proposal and Elizabeth Drive West Upgrade are operating concurrently, compared with the two projects operating in isolation. Potential cumulative effects of the Elizabeth Drive West Upgrade project would therefore be negligible as there is about 900 m separating the two projects and road-based emission tend to disperse quickly from the roadside.

7.3 Traffic network analysis and discussion of results

The results of the air dispersion modelling conducted for the proposal as discussed in **Section 7.1** are based on estimated vehicle emissions from traffic within the proposal section of Elizabeth Drive only. This section provides a qualitative analysis of changes to the road network surrounding Elizabeth Drive as discussed in **Section 5.7.6**.

A key objective of the proposal as well as for other approved (or proposed) road upgrade proposals within the surrounding network is to improve network efficiency. Upgrading or improving the existing road network; can reduce congestion and associated vehicle emissions within some areas of the network. Changes in traffic numbers as part of road infrastructure upgrades may also influence the spatial distribution of air pollutants within a local air shed.

Traffic modelling has predicted that there would be an increase in road traffic on Elizabeth Drive as a result of the proposal, as discussed in **Section 5.7.5**. This increase in traffic has resulted in the air pollutant predictions at several locations showing a small increase in pollutant concentrations at sensitive receptors (despite an increase in vehicle speed and efficiency) as discussed in **Section 7.1**. This is due to increased traffic numbers and queuing on Elizabeth Drive close to these receptor locations.

The side roads connecting with Elizabeth Drive were not included in the modelling; however, there are predicted changes in traffic numbers on these roads which would potentially impact air quality at receptors. The most important aspect of this is queuing on the side roads as vehicles wait to enter Elizabeth Drive. Wait times over 250 seconds were predicted at some of these intersections as outlined in Section 6.0 of Appendix F (Traffic and Transport Assessment Report) of the REF. Wait times for the proposal were considerably lower due to the design of the signalised intersections. This would mean higher emissions on the side roads for the ‘do nothing’ scenarios. Additionally, the congestion on the side roads meant that about 10 per cent of vehicles were unable to be included in the ‘do nothing’ traffic models (ie ‘unreleased traffic’). Unreleased trips refer to traffic that is being held outside the extents of the study area due to congested entry points. This resulted in lower traffic volumes along Elizabeth Drive for the 2030 and 2040 ‘do nothing’ scenarios than might be expected.

Significant congestion along Elizabeth Drive was also predicted in the traffic models for the ‘do nothing’ scenarios in 2030 and 2040, resulting in predicted travel times along the proposal to more than double in the eastbound direction in 2040. This congestion was not modelled for the ‘do nothing’ scenarios (ie no queuing) due to the difficulties in estimating queue lengths in these situations. It is anticipated that doing so would make the predicted concentrations in the future ‘do nothing’ scenarios significantly higher than those predicted in this assessment (low vehicle speeds equates to higher air emissions), and therefore potentially higher than the predicted proposal concentrations. Based on this, the proposal would likely be more beneficial to air quality in comparison to the doing nothing than the results of this assessment suggest.

In addition to the congestion effects described above, the modelled results do not include the potentially beneficial changes in road traffic volumes on the surrounding road network which may be influenced by the proposal. It would be expected that in the airshed immediately surrounding the proposal, that the distribution of air pollutant emissions would change as a result of the proposal. These changes would be expected to result in some areas experiencing higher traffic volumes and hence higher impacts while other locations would experience lower traffic numbers and hence lower pollutant concentrations as vehicles which may have used alternative routes instead use the more free-flowing upgraded Elizabeth Drive. The effect of the proposal across the airshed would be expected to be broadly balanced with some areas experiencing minor increases while others experience minor decreases. As such, the cumulative modelling results presented in **Appendix I** are considered conservative and actual air pollutants in some areas along the proposal may be slightly lower than existing and modelled levels.

8.0 Safeguards and management measures

This section describes safeguards and management measures to address the potential impacts of the proposal identified in this assessment. These measures will be incorporated into the detailed design, construction and/or operation stages of the proposal where relevant. The recommended safeguards and management measures are described in **Table 8-1**.

Table 8-1 Safeguards and management measures

Impact	Environmental safeguards / management measures	Responsibility	Timing
Air quality	An Air Quality Management Plan will be prepared and implemented as part of the CEMP. The Air Quality Management Plan will include, but not be limited to: • Potential sources of air pollution • Air quality management objectives consistent with any relevant published EPA and/DPE guidelines • Mitigation and suppression measures to be implemented including: - Use of water-assisted dust sweeper(s) - Covering of vehicles - Provision of vehicle clean down areas - Methods to manage work during strong winds or other adverse weather conditions • A progressive rehabilitation strategy for exposed surfaces	Contractor	Detailed Design / Pre-construction
Combustion emissions	Use of diesel- or petrol-powered generators will be avoided where practicable and mains electricity or battery powered equipment will be used where practicable.	Contractor	Construction
	Vehicles and plant will be switched off when engines are stationary. Idling vehicles will be avoided where practicable	Contractor	Construction
Dust emissions	During periods of high potential for increased air quality impacts and/or prolonged dry or windy conditions, the frequency of site inspections will be increased by the construction contractor's environmental representative or accountable personnel for air quality and dust issues	Contractor	Construction
	At each construction zone, the site arrangement will be planned so that dust generating activities are carried out to minimise dust at nearby receptors. Measures may include stockpiles located as far away from receptors as possible; dust barriers being erected around dusty activities/site boundary, or similar	Contractor	Construction
	A maximum speed limit of 15 kilometres per hour on unsurfaced roads and construction work areas will be imposed and signposted	Contractor	Construction
	Adequate water supply will be provided on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate	Contractor	Construction

9.0 Conclusion

This air quality assessment assesses the potential impacts of construction and operation of the proposed area on ground level air quality concentrations at nearby sensitive receptors and identifies appropriate mitigation and management measures to address identified impacts.

9.1 Construction impact assessment

A qualitative assessment of construction impacts from the proposal was carried out to assess potential impacts from construction dust, combustion emissions and odour. The qualitative dust risk assessment was carried out in accordance with the IAQM UK 2014 methodology found that unmitigated dust risks for demolition, earthworks, construction and track out were rated as low for dust soiling and human health and low for ecological risks. Specific activity-based dust mitigation measures recommended to reduce dust generation should be incorporated into the construction environmental management plans. Residual dust impacts are not anticipated to be significant with the application of mitigation measures.

Qualitative assessment of combustion emissions from the proposals found that given the typically transitory nature of construction traffic, as well as use of mobile and stationary plant equipment, exhaust emissions are unlikely to make a significant impact on local air quality. Typical mitigation measures for maintenance and minimising combustion emissions from construction vehicles are also recommended as part of the construction environmental management plans.

A qualitative assessment of odour impacts from earthworks found that there is the potential for odour emissions from earthworks if contaminated soil is uncovered. Further soil sampling would be carried out for the proposal to determine the extent of any potential contamination. With good practice mitigation strategies aimed at reducing the possibility of impacts should contaminated soil be present, odour impacts are not considered likely.

A cumulative assessment of construction impacts identified with several nearby approved projects was also carried out. Provided potential construction air quality impacts from the proposal are appropriately managed in accordance with recommend mitigation measures, and assuming that other projects also have appropriate dust mitigation in place, no significant cumulative impacts are anticipated.

9.2 Operational impact assessment

Quantitative assessment of construction impacts was carried out as a Level 2 Assessment in accordance with the Approved Methods using the dispersion model GRAL. Modelled scenarios were included which considered both existing traffic volumes and future traffic volumes for the years 2030 and 2040.

Modelled scenarios included:

- One ‘baseline’ scenario based on the 2021 existing traffic operations with the existing traffic lane layout (single lane in each direction)
- Two ‘do nothing’ scenarios for 2030 and 2040, which considered predicted traffic volumes without the proposal and assumed an unchanged traffic lane layout
- Two ‘do something’ scenarios for 2030 and 2040 which included traffic volumes with the proposal and an upgraded traffic lane layout (2 lanes in each direction).

Given that this assessment examines an upgrade to an existing roadway, the assessment of the proposal was carried out based on a comparison between predicted existing ground level concentrations and the future ‘do nothing’ and ‘do something’ scenarios. Results for all 2030 and 2040 scenarios showed ground level concentrations at most sensitive receptors for all pollutants at slightly higher levels than existing baseline ground level concentrations. This overall increase was due to the anticipated increase in traffic numbers using the proposal in the future scenarios.

A cumulative operational assessment of the proposal and the operation of the Elizabeth Drive West Upgrade project showed that cumulative impacts between the two projects would be negligible.

Analysis of the expected change in future pollutant concentrations show that the proposal may result in higher concentrations at sensitive receptors than are expected with the ‘do nothing’ scenarios. Due to limitations in the modelling, namely no consideration of the heavy congestion expected in the ‘do nothing’ scenarios and the exclusion of network roads in all scenarios, ‘do nothing’ concentrations were likely underpredicted in this assessment. It would be expected that actual future ‘do nothing’ concentrations would be much higher than those predicted. Based on this, the difference between the proposal and the ‘doing nothing’ scenario would be much less than indicated and the proposal would potentially even be beneficial to local air quality at many receptor locations.

9.3 Summary

Potential air quality impacts from the proposal are considered to be acceptable when predicted pollutant ground level concentrations are compared with and without the proposal in 2030 and 2040. Potential impacts from construction; including cumulative impacts with construction work at adjoining intersections can also be appropriately managed though standard mitigation measures and are not expected to result in significant impacts. In conclusion, construction and operational air quality impacts from the proposal are unlikely to have a significant impact on ground level air quality concentrations.

10.0 References

Australian Bureau of Statistics (ABS) 2021. Motor Vehicle Census, Australia. https://www.abs.gov.au/statistics/industry/tourism-and-transport/motor-vehicle-census-australia/31-jan-2021. Accessed on 3 November 2021

ABS (2020) *Regional Population 2019-20: Population Grid*, Australian Bureau of Statistics, Accessed 5 November 2021: https://absstats.maps.arcgis.com/apps/MapSeries/index.html?appid=b2fa123c0032456a8d47fbd0203a3dec

ABS (2018) *2033.0.55.001 Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2016, IRSD Interactive Map*, Accessed 4 November 2021:

Barclay, J. & Scire, J. (2011). *Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.* Office of Environment and Heritage NSW: Sydney.

BoM (2021) Bureau of Meteorology Monitoring Data; http://www.bom.gov.au

Capon, A. & Wright J. (2019) *An Australian incremental guideline for particulate matter (PM2.5) to assist in development and planning decisions*, Public Health Research and Practice, December 2019, Volume 29(4): e2941928

Commonwealth of Australia (2020) *Light Vehicle Emission Standards for Cleaner Air Draft Regulation Impact Statement*, October 2020, Commonwealth of Australia, Canberra, Australia

Commonwealth of Australia (2020a) *Heavy Vehicle Emission Standards for Cleaner Air Draft Regulation Impact Statement*, October 2020, Commonwealth of Australia, Canberra, Australia

Commonwealth of Australia (2021) *Future Fuels Strategy: Discussion Paper, Powering Choice*, February 2021, Department of Industry, Science, Energy and Resources, Commonwealth Australia, Canberra, Australia.

Department of Infrastructure and Regional Development (DIRD) 2016. Western Sydney Airport EIS – Local Air Quality and Greenhouse Gas Assessment

EPA (2012). Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2008 Calendar Year. On-Road Mobile Emissions: Results.

EPA (2017) *Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales*, NSW Environment and Protection Authority, Sydney, Australia.

EPA Victoria (2022), *Guideline for Assessing and Minimising Air Pollution in Victoria*, Publication 1961, 2022, EPA Victoria, Carlton Victoria, Australia

DPE (2021) Search Air Quality Data, NSW Office of Environment and Heritage :http://www.environment.nsw.gov.au/AQMS/search.htm

IAQM (2014) *Assessment dust from demolition and construction 2014*, Version 1.1, Institute of Air Quality Management, London, United Kingdom

Jacobs (2020) *Sydney International Speedway, Air Quality Assessment, Technical Paper 4, July 2020*, Jacobs Group (Australia) Pty Ltd, Newcastle West, NSW, Australia Accessed 8 July 2022: Sydney International Speedway - Tech Paper 4 - Air Quality (nsw.gov.au)

NEPC (2021) *Summary of Public Submissions and National Environment Protection Council Response; Variation to the National Environment Protection (Ambient Air Quality) Measure*, April 2021 National Environment Protection Council, Commonwealth of Australia; Accessed 3 June 2021: http://www.nepc.gov.au/system/files/pages/d2a74405-16f6-4b06-baf1-7c2fc1c1e12f/files/aaq-nepm-variation-summary-public-submissions-and-response.pdf

NEPC (2021a) *Key Changes to the Ambient Air Quality Measure agreed by Ministers April 2021*, National Environment Protection Council, Commonwealth of Australia; Accessed 3 June 2021:

http://www.nepc.gov.au/system/files/pages/d2a74405-16f6-4b06-baf1-7c2fc1c1e12f/files/key-changes-aaq-measure-agreed-ministers-april-2021.pdf

Pacific Environment (2017). *Optimisation of the application of GRAL in the Australian context*. Prepared for Roads and Maritime Services

Transport for New South Wales (2019). *M12 Motorway Environmental impact statement*

Ottl, Kuntner, Manasala (2020). Recommendations when using the GRAL/GRAMM modelling system. Version 20.03

Appendix A

Pollutants of interest and their effects

Appendix A Pollutants of interest and their effects

Table A-10-1 provides a description of the acute (short term) and chronic (long term) human and ecological health effects for the following idented pollutants of interest for the proposal:

- Nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Particulate matter less than 10 microns in diameter (PM_{10})
- Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$)
- Volatile Organic Compounds (VOCs) including:
    - Benzene
    - Formaldehyde
    - Toluene
    - Acetaldehyde
    - Xylene
    - 1,3 butadiene
- Polycyclic Aromatic Hydrocarbons (PAHs).

Table A-10-1 Human and ecological health effects of ambient air pollution

Pollutant	Human Health Impacts	Environmental Impacts
Nitrogen dioxide (NO_2)	Nitrogen oxides (NOx) emitted from combustion sources are comprised mainly of nitric oxide (NO, about 95% at the point of emission) and nitrogen dioxide (NO_2, about 5% at the point of emission). Nitric oxide is much less harmful to humans than NO_2 and is not generally considered a pollutant with health impacts. NOx may be inhaled or absorbed through the skin. People who live in areas of high motor vehicle usage may be exposed to higher levels of nitrogen oxides. Acute exposure to low levels of NO_2 can irritate eyes, nose, throat, and lungs, possibly leading to coughing, shortness of breath, tiredness and nausea. Exposure can also result in a build-up of fluid in the lungs for 1-2 days after exposure. Breathing high levels of NO_2 can cause rapid burning, spasms and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, a build-up of fluid in the lungs, and in extreme cases death.	Excessive levels of the NOx, particularly NO_2, can cause death in plants and roots and damage the leaves of many agricultural crops. NO_2 is the damaging component of photochemical smog. Excessive levels increase the acidity of rain (lower the pH), and thus lower the pH of surface and ground waters and soil. The lowered pH can have harmful effects, possibly even death, on a variety of biological systems. In the atmosphere, NOx is rapidly equilibrated to NO_2, which eventually forms acid rain. In the stratosphere, oxides of nitrogen play a crucial role in maintaining the levels of ozone. Concern with nitric oxide relates to its transformation to nitrogen dioxide and its role in the formation of photochemical smog.
Carbon monoxide (CO)	Carbon monoxide can enter the body by inhalation and be rapidly absorbed by the bloodstream from the lungs. Typical levels in urban and rural areas are, however, unlikely to cause ill effects. People can be exposed to CO through using malfunctioning equipment and using poorly vented vehicles. Acute exposure to levels of 200 parts per million (ppm) or more for 2 to 3 hours can lead to headache, dizziness, light-headedness and fatigue. Exposure to higher concentrations (say, 400 ppm or more) of CO can cause sleepiness, hallucinations, convulsions, collapse, loss of consciousness and even death. It can also cause personality and memory changes, mental confusion and loss of vision. Extremely high exposures to carbon monoxide can cause the formation of carboxyhaemoglobin and decrease the body's ability to transport oxygen. This can cause a bright red colour to the skin and mucous membranes causing	Carbon monoxide, through complex atmospheric chemical reactions, can affect the amount of other greenhouse gases, which are linked to climate change. Additionally, high levels of CO may cause adverse health impacts for birds and animals, similar to the effects are experienced by humans, although high levels are unlikely to be experienced in rural environments, except in extreme events such as bushfires.

Pollutant	Human Health Impacts	Environmental Impacts
	trouble breathing, collapse, convulsions, coma and possibly death. Long term (chronic) health effects can occur from exposure to low levels of carbon monoxide. These effects may produce heart disease and damage to the nervous system. Exposure of pregnant women to carbon monoxide may result in low birth weights and other defects in the offspring.	
Particulate matter	Particles within the PM_{10} fraction generally enter the body via inhalation. In the lungs particles can have a direct physical effect and/or be absorbed into the blood. Airborne particulate matter can be generated by vehicles from direct emissions from the burning of fuels (especially diesel-powered vehicles) and from wear of tyres or vehicle-generated air turbulence on roadways. Particles may also be generated from earthworks, wind erosion, and construction activities. The factors that may influence the health effects of exposure to particles include: • The chemical composition and physical properties of the particles. • The mass concentration of the airborne particles. • The size of the particles (smaller particles may be associated with more adverse effects due to increased likelihood of deep inhalation into the lungs). • The duration of exposure (acute and long term). Recent epidemiological research suggests that there is no threshold at which health effects do not occur. The health effects include irritation of mucous membranes, toxic effects by absorption of the toxic material into the blood and increased respiratory symptoms, aggravation of asthma and premature death.	Particles are easily entrained into the air by wind or disturbances. Airborne particulate matter may also react with other substances in the atmosphere, reduce visibility, increase the possibility of precipitation, fog and clouds and reduce solar radiation. Additionally, particulate matter may cause similar respiratory impacts in animals as to humans. High levels of prolonged dust deposition may lead to plant physical stress and reduced photosynthesis, respiration, and transpiration through smothering. Dust deposition may also lead to chemical changes to soils or watercourses may lead to a loss of plants or animals for example via changes in acidity
Benzene	Benzene is a VOC released into the air from sources including car exhaust, Evaporation of vehicle fuels from motors and vehicle fuel tank, smoke from tobacco and bushfires and from industry. Most people are exposed	Benzene has a high acute toxic effect on aquatic life. Long-term effects on marine life can mean shortened lifespan, reproductive problems, lower fertility and changes in appearance or behaviour. It can cause death in plants

Pollutant	Human Health Impacts	Environmental Impacts
	outdoors to low levels of benzene from tobacco smoke and car exhaust. Worksafe Australia classifies benzene as a toxic health hazard. Exposure can result in symptoms such as skin and eye irritations, drowsiness, dizziness, headaches, and vomiting and even death at high levels of exposure. Benzene is carcinogenic and has been linked to leukemia. Chronic exposure at various levels can affect normal blood production and can be harmful to the immune system. Benzene has also been linked with birth defects in animals and humans.	and roots and damage to the leaves of many agricultural crops. Benzene is a precursor to hydrocarbon leading to the formation of photochemical smog. It generally breaks down in the atmosphere over a few days and reacts with other chemicals in the atmosphere to produce phenol, nitrophenol, nitrobenzene, formic acid and peroxyacetyl nitrate. Precipitation can also remove benzene from the air before evaporating, continuing to pollute the air
Formaldehyde	Vehicle exhaust is a major source of formaldehyde. Acute exposure to low levels of formaldehyde can cause eyes, nose and throat irritation and allergies affecting the skin and lungs. Higher exposure levels can cause throat spasms and a build-up of fluid in the lungs, leading to death. Formaldehyde can cause an asthma-like respiratory allergy causing shortness of breath, wheezing, cough and/or chest tightness. Repeated exposures may cause bronchitis, with coughing and shortness of breath. Formaldehyde has also been identified as a potential carcinogen.	In air, formaldehyde decomposes relatively quickly (within 24 hours) to form formic acid and carbon monoxide. Formaldehyde does not bioaccumulate in plants and animals. Chronic effects in animals may include shortened lifespan, reproductive problems, lower fertility and changes in appearance or behaviour. Chronic effects can be seen a long time after first exposure to a toxic chemical. Formaldehyde has high chronic toxicity to aquatic life. Formaldehyde may cause cancer and other chronic illnesses in rodents. Birds and terrestrial animals exposed to formaldehyde could contract similar diseases. Insufficient data are available to evaluate or predict the long-term effects of formaldehyde in plants.
Toluene	Toluene is VOC used as a component of petrol and in paints and cleaning agents. Exposure to toluene is most likely to occur through vehicle emissions, cigarette smoke or use of consumer products such as paint or varnish. Toluene generally breaks down in the atmosphere after a few days. Acute exposure to toluene results first in light-headedness and euphoria, followed by dizziness, sleepiness, unconsciousness, and in some cases death. Long-term exposures at low levels can result in kidney damage and permanent brain damage including problems with speech, vision, and hearing, loss of muscle control, loss of memory and balance and reduced scores of psychological tests.	Toluene is moderate acute and chronic toxicity to aquatic organisms. Chronic and acute effects on birds or land animals have not been determined. Toluene is expected to minimally bioaccumulate. Toluene can also cause membrane damage to the leaves in plants.

Pollutant	Human Health Impacts	Environmental Impacts
Acetaldehyde	Acetaldehyde is a VOC and sources of acetaldehyde include fuel combustion emissions from stationary internal combustion engines and power plants that burn fossil fuels, wood, or trash, oil and gas extraction, refineries, cement kilns, lumber and wood mills and paper mills. Acetaldehyde in the air degrades rapidly in a matter of hours due to photochemical oxidation and reaction with hydroxyl radicles and is, therefore, unlikely to be transported far from the emission source. Acetaldehyde is an irritant of the skin, eyes, mucous membranes, throat and respiratory tract. Symptoms of exposure to this compound include nausea, vomiting, headache, dermatitis and pulmonary oedema. It has a general narcotic action and large doses cause death by respiratory paralysis. It may also cause drowsiness, delirium, hallucinations and loss of intelligence. Exposure may also cause slow mental response, severe damage to the mouth, throat and stomach; accumulation of fluid in the lungs, chronic respiratory disease, kidney and liver damage, throat irritation, dizziness, reddening and swelling of the skin and sensitisation. It may cause photophobia and is a potential carcinogen.	In sufficient concentrations acetaldehyde can affect animals in a similar way to humans.
Xylene	Xylene is an aromatic volatile organic compound chemicals produced during incomplete combustion of fossil fuels. Other sources include commercial and household painting and woodfire heaters. Xylenes may irritate the eyes, nose and throat. They may cause stomach problems, drowsiness, loss of memory, poor concentration, nausea, vomiting, abdominal pain and incoordination. High levels may cause dizziness, passing out, and death. Repeated exposures may damage bone marrow, which causes a low blood cell count. Xylenes may damage a developing foetus.	Xylene has high acute (short-term) and chronic (long-term) toxicity to aquatic life and can bioaccumulate in fish. There is not sufficient data to predict the acute or chronic toxicity of xylene on birds or land animals. Xylene can also cause injury to various agricultural and ornamental crops
1,3 butadiene	1-3 butadiene is a volatile organic compound and is formed as a product of incomplete combustion of fossil fuels and biomass. The main sources of 1-3 butadiene are from vehicle emissions and cigarette smoke. Although 1,3-	1-3-Butadiene has moderate acute (short-term) and slight chronic (long term) toxicity to aquatic life. Long term exposure to 1-3 butadiene may cause adverse health impacts for birds and

Pollutant	Human Health Impacts	Environmental Impacts
	butadiene breaks down quickly in the atmosphere, it is usually found in ambient air at low levels in urban and suburban areas. Acute exposure at low levels can lead to irritation of the eyes, throat, nose, and lungs and at high levels can cause damage to the central nervous system or cause symptoms such as distorted blurred vision, vertigo, general tiredness, decreased blood pressure, headache, nausea, decreased pulse rate, and fainting. Long term exposure to 1,3-butadiene may lead to increased risk of cardiovascular diseases and cancer.	animals, like the effects are experienced by humans,
Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs comprise of over 100 different chemicals produced during incomplete combustion of fossil fuels, garbage or other organic material. Key sources of PAHs include vehicle emissions, cigarette smoke and residential woodfires and bushfires. PAHs in air are usually not found singularly, but as mixtures with many different types present at the same time. This makes assessing the health effects of individual PAHs very difficult. Short term exposure effects from PAHs include eye and skin irritation, nausea and vomiting, diarrhoea and confusion. Long term exposure effects from chronic or long-term exposure to PAHs include cataracts, kidney and liver damage and skin damage and photosensitisation (sensitisation to light). Long term exposure also increases the risk of skin, lung and bladder cancer as well as gastrointestinal issues.	PAHs can be toxic for aquatic organisms and birds. Studies have shown animals exposed to levels of some PAHs over long periods long term have developed lung cancer from inhalation, stomach cancer from ingesting PAHs in food and skin cancer from skin contact. PAH contamination also has an adverse effect on water and nutrient uptake by plants by impacting seed germination, plant establishment and growth.

Appendix B

Vehicle emission regulation and strategies

Appendix B Vehicle emission regulation and strategies

Overview

This annexure provides a description of the relevant government strategies and legislation used to regulate vehicle emissions in Australia. Specifically, it provides:

- A description of important federal and NSW state government strategies to promote reductions in vehicle emissions through cleaner transport, engines, and fuels
- A list of key federal legislation, regulations, and standards used to regulate light and heavy on-road vehicle emission standards in Australia.

Strategies

Future Fuels and Vehicles Strategy: Powering Choice 2021 (Cth)

The Australian Governments Department of Industry, Science, Energy and Resources (DISER) released the *Future Fuels and Vehicles Strategy: Powering Choice* (DISER 2021) in November 2021. The strategy sets out how the Australian Government aims to support a technology-led approach to reduce emissions in the transport sector by enabling the private sector to commercially deploy low emissions road transport technologies at scale. The government aims to leverage more private sector investment by focusing on the following four streams of key infrastructure and technology investment:

- Public electric vehicle charging and hydrogen refuelling infrastructure
- Heavy and long-distance vehicle fleets
- Light vehicle commercial fleets
- Household smart charging.

In partnership with the private sector the strategy focuses on five priority initiatives to address barriers and provide confidence to consumers to support the uptake of low emission vehicles including:

- Electric vehicle charging and hydrogen refuelling infrastructure where it is needed to
- Early focus on commercial fleets
- Improving information for motorists
- Integrating battery electric vehicles into the electricity grid
- Supporting Australian innovation and manufacturing.

The five initiatives support the uptake of low emissions road transport technologies, which would in turn alter the future fleet makeup on Australian Roads and support *Australia’s Long Term Emission Reduction Plan 2021*.

NSW Clean Air Strategy 2021-2030 (NSW)

The *NSW Clean Air Strategy 2021-2030* (DPE 2022) aims to promote ongoing reductions in air quality impacts in NSW by:

- Setting out the evidence that underpins and guides NSW Government action on air quality
- Outlining existing policy, regulatory framework and the measures aimed at managing air quality
- Proposing actions to achieve further health gains for communities across NSW.

The strategy identifies five key actions to improve outcomes for air quality and health including:

- Better preparedness for pollution events
- Cleaner industry
- Cleaner transport, engines, and fuels

- Healthier households
- Better places.

Proposed actions relating to the transport sector under Action 3 include:

- Integrating air quality improvements into transport planning, programs, and proposals
- Progress policies and incentives to increase uptake of zero and low exhaust emission vehicles
- Support sustainable, healthy, and smart travel choices
- Improve regulation of vehicle and fuel emissions
- Drive emission reductions from non-road diesel vehicles and equipment.

NSW Electric Vehicle Strategy 2021-2030 (NSW)

The *NSW Electric Vehicle Strategy 2021* (DPE 2021) outlines the NSW's governments key strategies to increase the uptake of electric vehicles. These include:

- Reducing upfront costs of electric vehicles by introducing rebates, removal of stamp duty and providing fleet incentives
- Developing a world class electric vehicle charging network by investing in ultra-fast charging infrastructure and destination infrastructure near commuter carparks, transport hubs and regional tourist locations
- Updating policies and legislation to allow electric vehicle drivers to use transit lanes (such as T2 and T3 lanes) for a limited time to increase uptake
- Promote investment in minerals required to produce electric vehicle batteries
- Support continued growth of regional tourism by catering for increased electric vehicle volumes and roll pout of 'EV Tourist Drives' across the state to promote scenic regional driving routes.

Legislation, regulations and standards

Fuel Quality Standards Act 2000

The *Fuel Quality Standards Act 2000* (Cth) as amended in June 2021 provides the legislative framework for setting national fuel quality and fuel quality information standards in Australia for petrol, diesel, biodiesel and Autogas. The aim of the Fuel Quality Standards act is to regulate the quality of fuel supplied in Australia to reduce air emissions associated with fuel use and facilitate adoption of emission control technology.

Under the *Fuel Quality Standards Act 2000* (Cth) the following legislative instruments set specifications for fuel standards in Australia:

- *Fuel Quality Standards (Autogas) Determination 2019* (Cth)
- *Fuel Quality Standards (Automotive Diesel) Determination 2019* (Cth)
- *Fuel Quality Standards (Biodiesel Diesel) Determination 2019* (Cth)
- *Fuel Quality Standards (Ethanol) Determination 2019* (Cth)

The Fuel Quality Standards set specifications for a range of pollutants such as sulphur content, PAHs and heavy metals.

Road Vehicles Standards Act 2018

The *Road Vehicles Standards Act 2018* (RVSA) (Cth) which commenced on 1 July 2021 supersedes the *Motor Vehicle Standards Act 1989* (Cth) (MVSA) and was introduced to improve the safety, environmental and anti-theft performance of all road vehicles.

New on-road motor vehicle emissions are determined by the Commonwealth Government via the Australian Design Rules (ADRs). National road vehicle standards relating to road emissions originally made under Section 7 of the MVSA continue in force as if they were a national road vehicle standard under Section 12 of the RVSA[8].

Third Edition Australian Design Rules (ADRs) (Cth)

Exhaust and evaporative emission requirements for new on-road vehicles are administered under:

- *Vehicle Standard (Australian Design Rule 79/00 – Emission Control for Light Vehicles) 2005*
- *Vehicle Standard (Australian Design Rule 80/00 – Emission Control for Heavy Vehicles) 2005*.

Australia currently mandates the following emission standards:

- Euro IV emission standards for newly approved models first manufactured from 1 November 2013 and for all light vehicles manufactured from 1 November 2016
- Euro V emission standards for newly approved heavy vehicle models manufactured from 1 January 2010 and for all heavy vehicles manufactured from January 2011.

While Euro IV light vehicle emission standards and Euro V heavy vehicle emission standards has and is continuing to reduce air emissions from new light vehicles entering the Australian fleet, many other countries have introduced increasingly stringent vehicle emission standards. The Commonwealth Government is currently evaluating the implementation of more stringent emission standards to achieve a reduction in transport related air pollution and ensure the Australian vehicle market keeps pace with international technological developments. Draft regulatory impact statements for the implementation of more stringent light and heavy vehicle emission standards are discussed below.

Light Vehicle Emission Standards for Cleaner Air Draft RIS 2020 (Cth)

Australia currently mandates the Euro 5 emission standards for newly approved vehicle models manufactured from 1 November 2012, and for all light vehicles manufactured from November 2016. The draft Regulatory Impact Statement (RIS) for Light Vehicle Emission Standards proposed by the Commonwealth Government in October 2020 evaluates whether the Australian Government should mandate more stringent standards (Euro 6) to reduce noxious emissions from light road vehicles (Commonwealth of Australia 2020).

The key changes under the Euro 6 emission standards when compared to Euro 5 are:

- 55 per cent reduction in emission limits for NOx for light diesel vehicles
- A particle limit number to reduce fine particulates from direct injection petrol vehicles
- Tighter thresholds for on-board diagnostic systems that monitor the performance of emission control systems.

The draft RIS found that the mandating Euro 6d (the most recent version of Euro 6) emission standards for light vehicles would bring Australian vehicle standards closer to international standards and provide significant benefits to the Australian community through improved air quality by mandating Euro 6d for new light vehicles. The Draft RIS recommends phasing in of Euro 6d standards from 1 July 2027 for new model light vehicles and from July 2028 for all new light vehicles.

A final recommendation to Government on the implementation of new light vehicle emission standards will be made following consideration of feedback received during the targeted consultation period with key stakeholders which closed in February 2021.

Emission factors for 2026 and 2036 discussed in **Section 5.7.5.2** of this technical report account for changes in the vehicle fleet including mandated vehicle emission standards. Consideration of future mandates such as the draft Regulatory Impact Statement (RIS) for Light Vehicle Emission Standards have not been accounted for. Implementation of this mandate would result in a lowering of emission rates for NO_2 and particulates; thus, modelled emission factors for light vehicles in this technical report are considered conservative.

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[8] See Schedule 3, Part 2, item 2 of the Road Vehicle Standards (Consequential and Transitional Provisions) Act 2018

Heavy Vehicle Emission Standards for Cleaner Air Draft RIS 2020 (Cth)

Australia currently mandates the Euro V emission standards for newly approved heavy vehicle models manufactured from 1 January 2010, and for all heavy vehicles manufactured from January 2011. The draft Regulatory Impact Statement (RIS) for Heavy Vehicle Emission Standards proposed by the Commonwealth Government in October 2020 evaluates whether the Australian Government should mandate more stringent standards to reduce noxious emissions from heavy road vehicles (Commonwealth of Australia 2020a).

The key changes under the Euro VI emission standards when compared to Euro V are:

- A reduction in emission limits for NOx of up to 80 per cent
- A reduction in emission limits for particulate by up to 60 per cent
- A new particulate number limit to reduce ultrafine particle emissions
- A new more representative engine bench test and new on-road emissions test.

The draft RIS found that the mandating VI emission standards for heavy vehicle models manufactured from July 2027 and for all new heavy vehicles manufactured from July 2028 would result in significant health benefits from the reduction in diesel emissions. The Draft RIS recommends mandating Euro VI standards in Australia for new heavy vehicle models from 1 July 2027 and from 1 July 2018 all new heavy vehicles.

A final recommendation to Government on the implementation of new heavy vehicle emission standards will be made following consideration of feedback received during the targeted consultation period with key stakeholders which closed in February 2021.

Proposal emission factors for 2026 and 2036 discussed in **Section 5.7.5.2** of this technical report account for changes in the vehicle fleet including mandated vehicle emission standards. Consideration of future mandates such as the draft RIS for Heavy Vehicle Emission Standards have not been accounted for. Implementation of this mandate would result in a lowering of emission rates for NO_2 and particulates; thus, modelled emission factors for heavy vehicles in this technical report are considered conservative.

Appendix C

MTO analysis

Appendix C MTO analysis

This appendix presents the iterative process that was involved with selecting a suitable set of GRAMM winds fields for use in the model via the Match to Observations (MTO) analysis. A total of three options (one two-station options and two single-station options) were investigated and the best-matching MTO option was selected for use in the assessment. The three options are discussed in this appendix and the rationale for the selection of the MTO option used in the modelling described.

The matched MTO winds are drawn from GRAMM at the location of the BoM stations and should correlate as close as possibly with the observed data. Statistics for each MTO option are also included in tables with the per cent of situations that fit within a vectorial error of 10 per cent, 20 per cent, 40 per cent and 60 per cent and a stability class error of 0 or ±1 classes presented.

Two-Station MTO – Badgerys Creek and Horsley Park

The first MTO option for analysis attempted to match the synthetic GRAMM wind fields the Badgerys Creek and Horsley Park station observed data with a weighting of 50-50. The statistical outcome of the MTO run are presented in **Table C-2**. As shown the match between wind vectors ranges from 19 per cent (within 10 per cent error at Horsley Park) to 74 per cent (within 60 per cent error at Badgerys Creek). The stability classes match quite well with about 90 per cent or above of hours within a stability class error of 1.

Table C-10-2 MTO statistics – 2 station 50/50 weighting

Two Station MTO Statistics Weighting Factors 0.5/0.5						
Station	V 10%	V 20%	V 40%	V 60%	SC 0	SC 1
Badgerys Creek	22	42	63	74	67	97
Horsley Park	19	39	63	72	55	90

The GRAMM MTO process includes an option to reduce the number of wind conditions that are matched to the observed data. More wind conditions means more computation time in GRAL, so reducing the number of conditions, especially for large modelling domains is highly beneficial. However, reducing the number of conditions generally has a detrimental effect on the quality of the match with the observed data. A value of 18 was selected by trial and error, which maintained an acceptable match, whilst reducing the number of conditions that need to be modelled. The final number of wind conditions to be modelled was 1162.

Wind roses comparing the matched GRAMM winds and the observed data at each BoM station are presented in **Figure C-1**. This figure uses a calms threshold of 0.5 m/s, such that winds less than 0.5 m/s are treated as calm and are not presented on the plots. The obvious difference between the GRAMM winds and the BoM observations is the introduction of winds from the northwest. It appears under almost-calm conditions (slightly under 0.5 m/s), GRAMM is matching the observed data with winds from the northwest in the range 0.5 to 1.0 m/s. This is confirmed in **Figure C-2**, which shows only winds at 1.0 m/s or above, and shows that the wind roses are much more similar between GRAMM and the BoM observations. Apart from the very light northwest winds, all other wind directions and speeds appear to be represented in the predicted GRAMM winds.

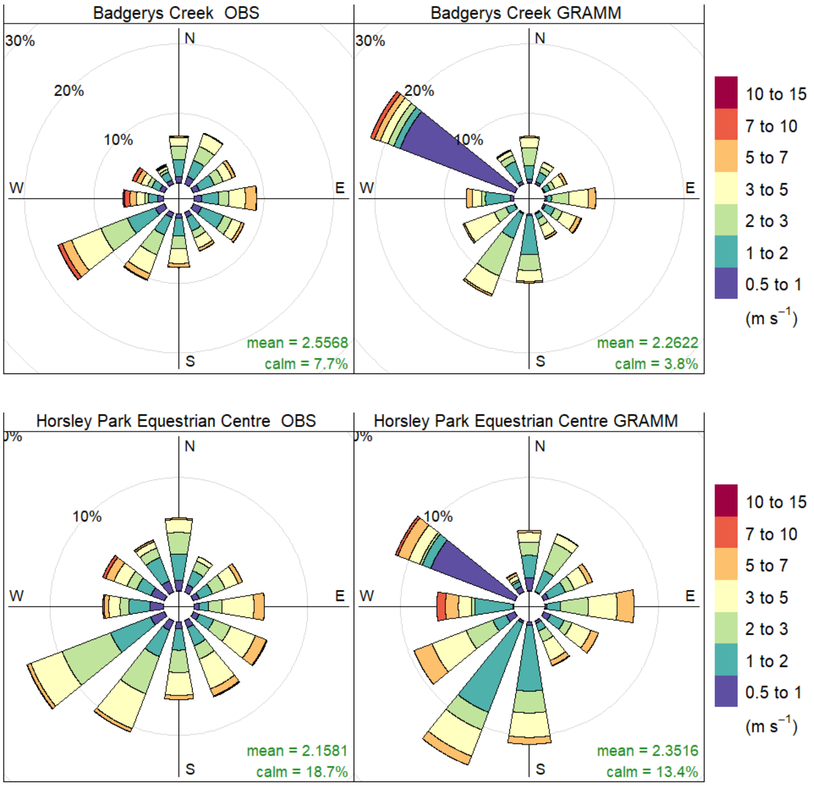


Figure C-1 Wind rose comparison between GRAMM (left) and observed (right)– calms <0.5 m/s

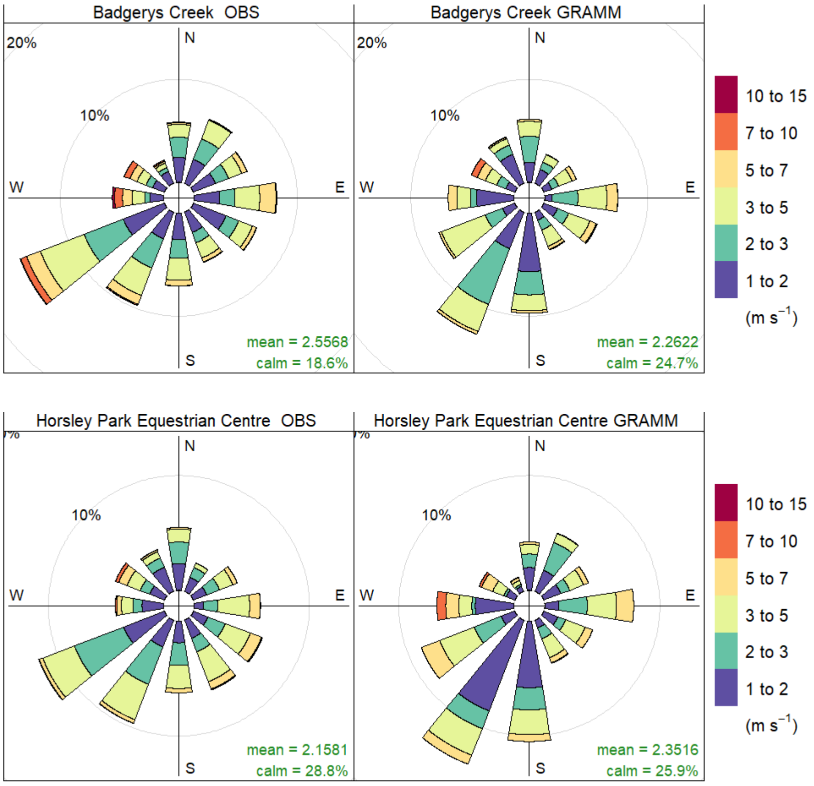


Figure C-2 Wind rose comparison between GRAMM (left) and observed (right)– calms <1 m/s

A plot comparing wind speed distribution for the predicted GRAMM winds and the BoM observations is presented in **Figure C-3**. This shows wind speed distribution for all hours, daylight hours and night-time hours separately. The figure shows that there is a good match at the lower wind speeds, especially during the daytime. Night-time winds do not match perfectly, however, the correlation is still within an acceptable range. Higher wind speeds above about 6 m/s are not matched particularly well in GRAMM with the highest winds in the GRAMM data set about 7 m/s, compared with about 12 m/s in the observation data. This is not a concern for the modelling, however, with little change in dispersion expected once wind speeds are above about 6 m/s.

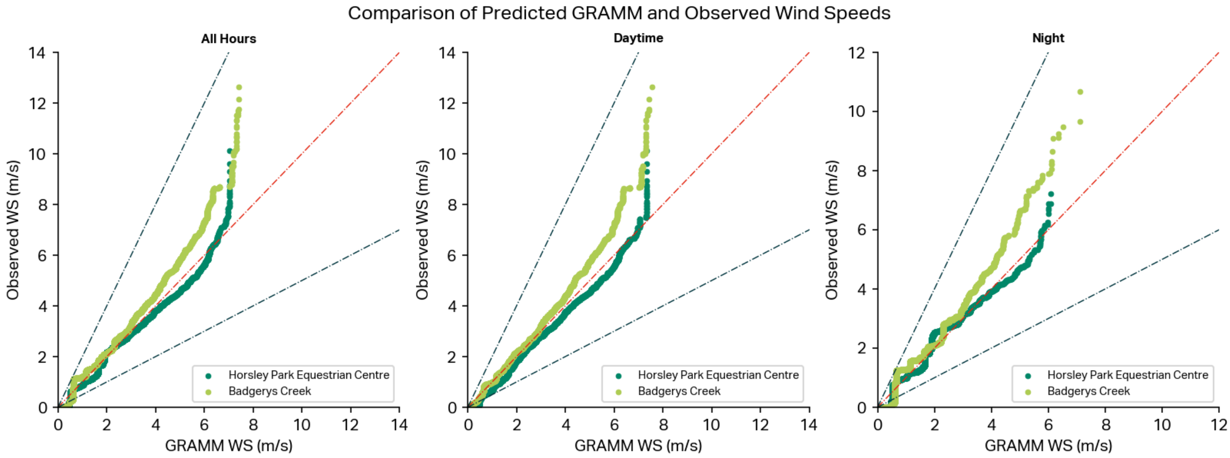


Figure C-3 Comparison of GRAMM wind speeds with observed wind speeds

MTO Single Station – Badgerys Creek only

The second MTO option for analysis attempted to match the synthetic GRAMM wind fields to the Badgerys Creek observed data without consideration of the Horsley Park data. The statistical outcome of the MTO run is presented in **Table C-10-3**. As shown the match between wind vectors ranges from about 72 per cent (within 10 per cent error) to 96 per cent (within 60 per cent error). This is a better match at Badgerys Creek compared with the two-station option. The stability classes don't match quite as well as the two-station option, however, with about 80 per cent or so of hours within a stability class error of 1.

Table C-10-3 MTO statistics – 1 station – Badgerys Creek only

Two Station MTO Statistics						
Station	**V 10%**	**V 20%**	**V 40%**	**V 60%**	**SC 0**	**SC 1**
Badgerys Creek	72	87	94	96	47	80

Wind roses comparing the matched GRAMM winds and the observed data at each BoM station are presented in **Figure C-4**. This figure uses a calms threshold of 0.5 m/s, such that winds less than 0.5 m/s are treated as calm and are not presented on the plots. As expected, the Badgerys Creek data matches very well, in terms of wind speed and direction and calms percentage. The Horsley Park wind speed and direction predictions look reasonable too, even though there was no matching attempted at this location. The calms, however, at Horsley Park are obviously underpredicted in the GRAMM data with only 3.4 per cent of winds under 0.5 m/s compared with 18.7 per cent in the BoM observations. **Figure C-5** presents the same wind roses with winds under 1.0 m/s removed. In this case the Horsley Park low winds speeds (under 1.0 m/s) are still not very well represented, with about half of the percentage compared with the BoM Data.

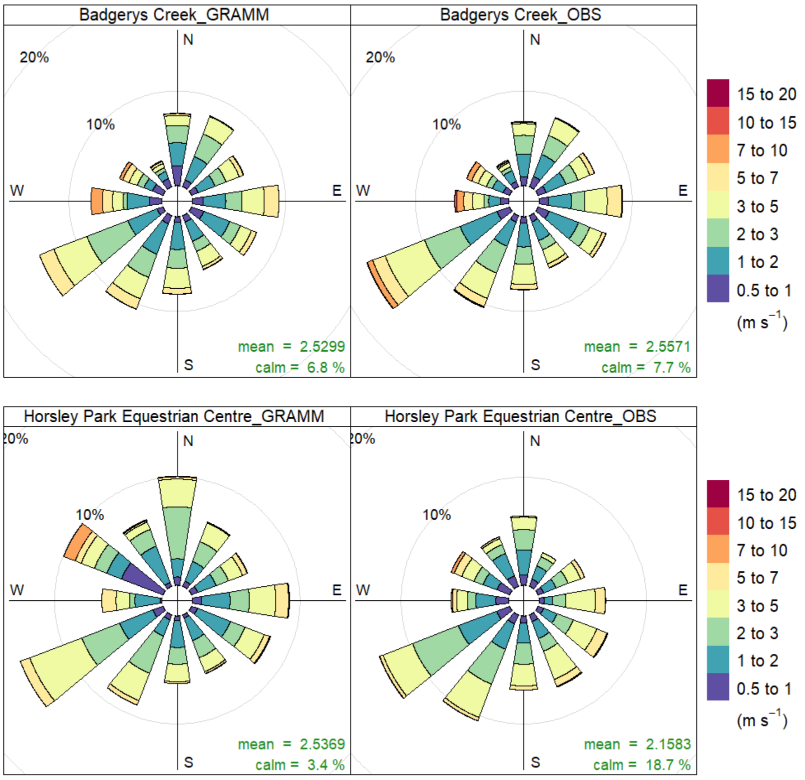


Figure C-4 Wind rose comparison between GRAMM (left) and observed (right)– calms <0.5 m/s

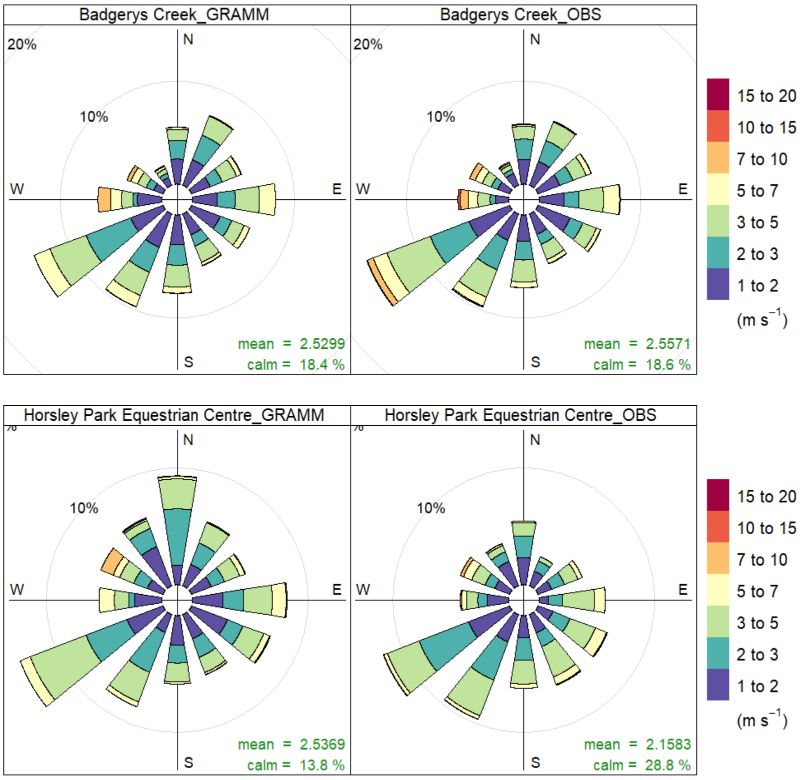


Figure C-5 Wind rose comparison between GRAMM (left) and observed (right)– calms <1 m/s

A plot comparing wind speed distribution for the predicted GRAMM winds and the BoM observations is presented in **Figure C-6**. This shows that daytime winds are well predicted and matched at both BoM locations. The Night-time low wind speeds (less than 1.5 m/s) at Horsley Park, however, are not matched well (as seen in the low calms percentage in **Figure C-4**) with an obvious poor correlation with the BoM winds at very low wind speeds.

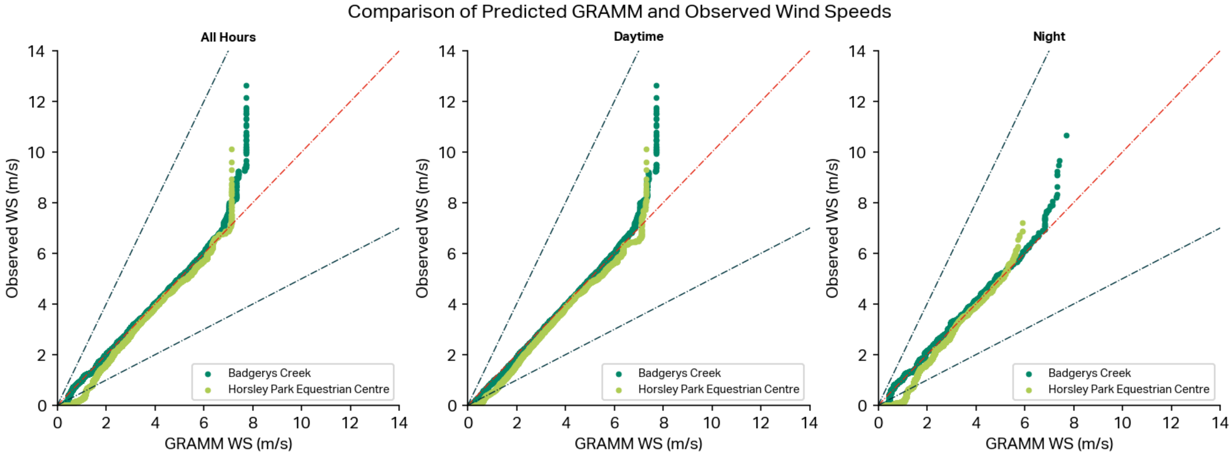


Figure C-6 Comparison of GRAMM wind speeds with observed wind speeds

MTO Single Station – Horsley Park only

The second MTO option for analysis attempted to match the synthetic GRAMM wind fields to the Horsley Park observed data without consideration of the Badgerys Creek data. The statistical outcome of the MTO run is presented in **Table C-10-4**. The match between wind vectors ranges from about 78 per cent (within 10 per cent error) to 96 per cent (within 60 per cent error). This is a better match at Badgerys Creek compared with the two-station option. The stability classes don't match quite as well as the two-station option, however, with about 77 per cent or so of hours within a stability class error of 1.

Table C-10-4 MTO statistics – 1 station – Horsley Park only

Two Station MTO Statistics						
Station	**V 10%**	**V 20%**	**V 40%**	**V 60%**	**SC 0**	**SC 1**
Horsley Park	78	89	94	96	46	77

Wind roses comparing the matched GRAMM winds and the observed data at each BoM station are presented in **Figure C-7**. This figure presents a calms threshold of 0.5 m/s, such that wind speed lower than 0.5 m/s are treated as clam and are not presented on the plots. As expected, the Horsley Park data matches very well, in terms of wind speed and direction and calms percentage. The Badgerys Creek wind speed and direction predictions look reasonable, although there are less northerly winds than in the BoM data and the obvious southwest winds are lower in frequency. The calms, however, at Badgerys Creek are obviously overpredicted in the GRAMM data with 18.3 per cent of winds under 0.5 m/s compared with 7.7 per cent in the BoM observations. **Figure C-8** presents the same wind roses with winds under 1.0 m/s removed. In this case the Badgerys Creek low winds speeds (under 1.0 m/s) are still not very well represented, with almost double the percentage compared with the BoM Data.

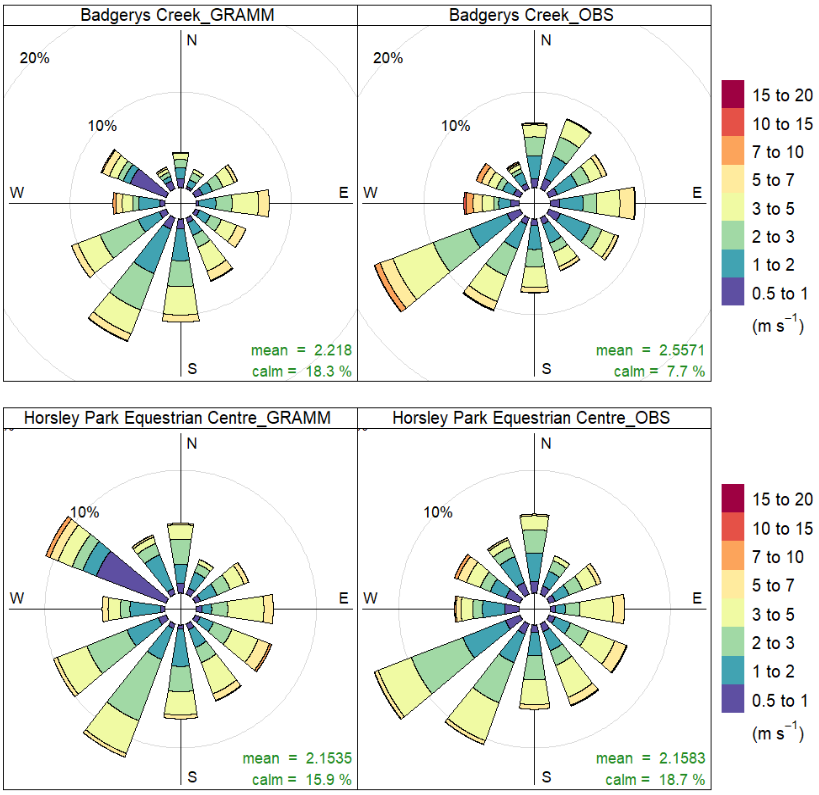


Figure C-7 Wind rose comparison between GRAMM (left) and observed (right)– calms <0.5 m/s

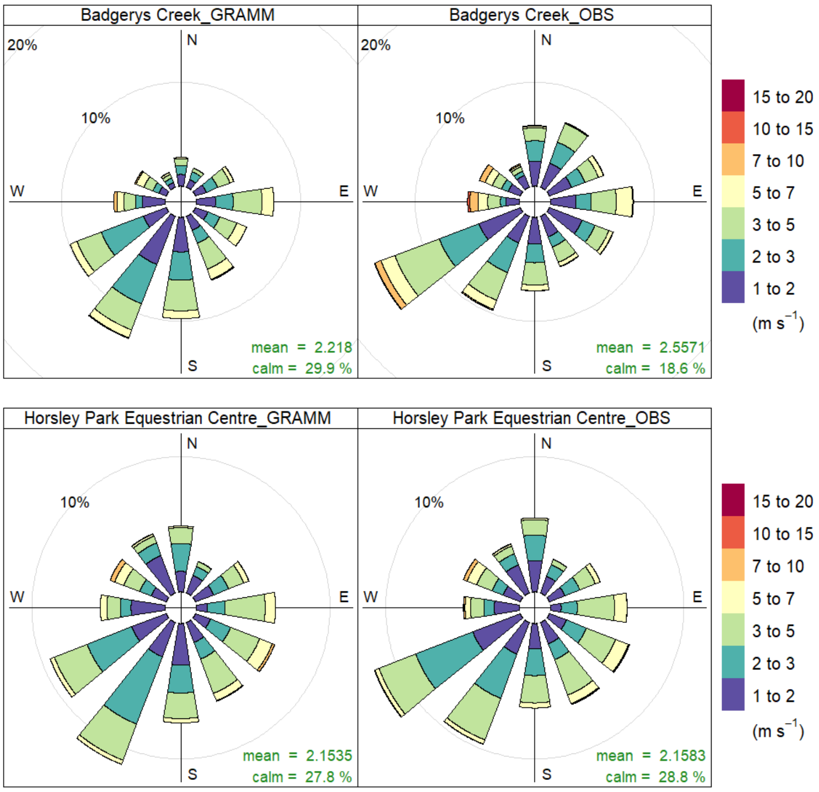


Figure C-8 Wind rose comparison between GRAMM (left) and observed (right)– calms <1 m/s

A plot comparing wind speed distribution for the predicted GRAMM winds and the BoM observations is presented in **Figure C-9**. This shows that daytime winds are well predicted and matched at both BoM locations. The Night-time low wind speeds (less than 1.5 m/s) at Badgerys Creek, however, are not matched well (as seen in the high calms percentage in **Figure C-7**) with an obvious overprediction of very low wind speeds.

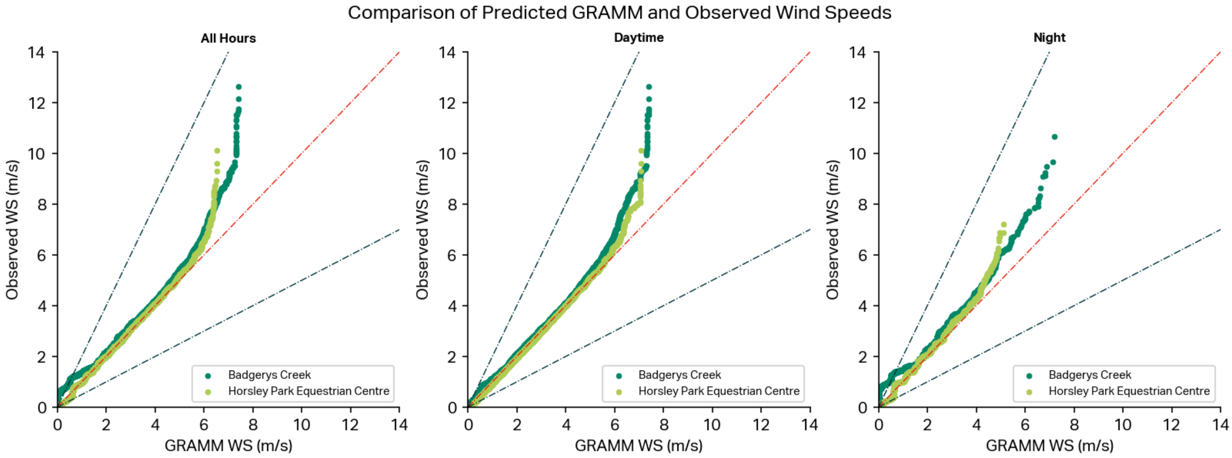


Figure C-9 **Comparison of GRAMM wind speeds with observed wind speeds**

Discussion and Selection of MTO Option

The two single-station MTO options both matched winds quite well at their respective BoM locations, but were unable to produce a good match at the other, non-matched location. This makes sense, as there are differences in terrain and wind patterns at the two locations are would be difficult to match perfectly in a prognostic wind model.

The two-station matched dataset, while not perfectly matched at both stations, showed a reasonable correlation with the observed winds at both stations, in particular in terms of low winds speeds (which the single-station options could not produce). The proposal is in between the two stations and modelled meteorology would likely benefit from a combination of the two BoM datasets..

Based on the above considerations, the two-station option, incorporating matched winds at both the Badgerys Creek and Horsley Park stations was selected for use in the model.

Appendix D

Meteorological data analysis

Appendix D Meteorological data analysis

Selection of modelling meteorological year

Meteorological data

A 12-month meteorological data set was developed based on surface observations at nearby weather stations from the 2017 calendar year. When selecting a single year of meteorological data for use in the modelling, care must be taken to ensure the source data's suitability for modelling purposes. An analysis of weather data from nearby weather stations covering the period 2010 to 2019 was carried out to select the best year for the construction footprint. Consideration was given to weather parameters, pollutants concentrations from nearby air quality monitoring stations, and terrain features of the proposal and surrounding area.

Selection of Meteorological Stations

The NSW Department of Planning and Environment (DPE) and Bureau of Meteorology (BoM) operate several automatic weather stations (AWS) in the construction footprint. The nearest station is Badgerys Creek, operated by BoM. The two other AWS considered for this proposal were located at Horsley Park (BoM) and St Mary's (DPE). The locations of the three stations and their distance from the proposal are presented in **Table D-10-5**.

Table D-10-5 Details of weather stations considered for the modelling

Station	Latitude/ Longitude	Distance from proposal	Operator
Badgerys's Creek	-33.897, 150.728	3 km	BoM
Horsley Park	-33.851, 150.857	9 km	BoM
St Mary's	-33.795, 150.767	8 km	DPE

The three AWS are discussed below.

AWS Siting

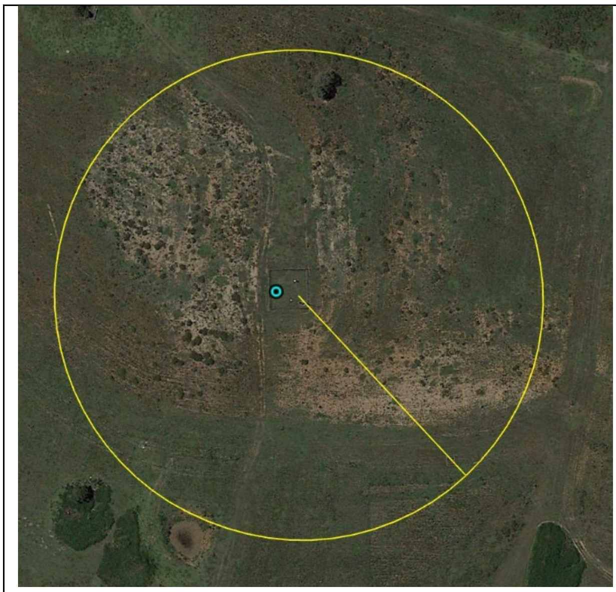
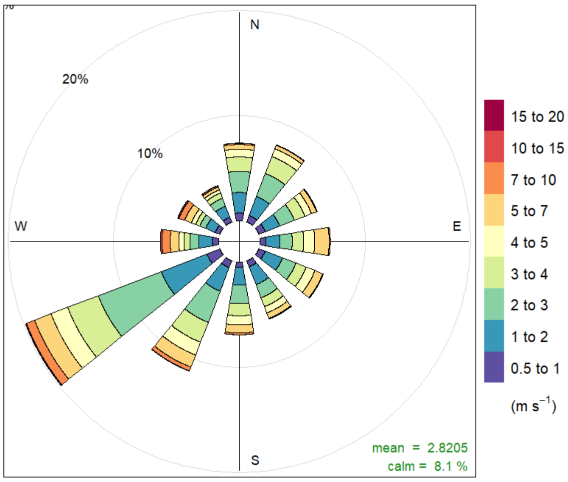
The AWS considered for the assessment in close proximity to Elizabeth Drive are:

- Badgerys Creek, about 3km south
- Horsley Park, about 9km to the north-east (measured from the centre of Elizabeth Drive)
- St Mary's, about 8km to the north.


St Mary's AWS
Great Western Hwy
M4
M4 Western Motorway
Erskine Park Rd
The Horsley Dr
Horsley Park AWS
Mamre Rd
← Elizabeth Drive →
Elizabeth Dr
Westlink M7
M7
Cowpasture Rd
Devonshire Rd
Badgery's Creek AWS

Badgerys Creek

BOM ID 067108

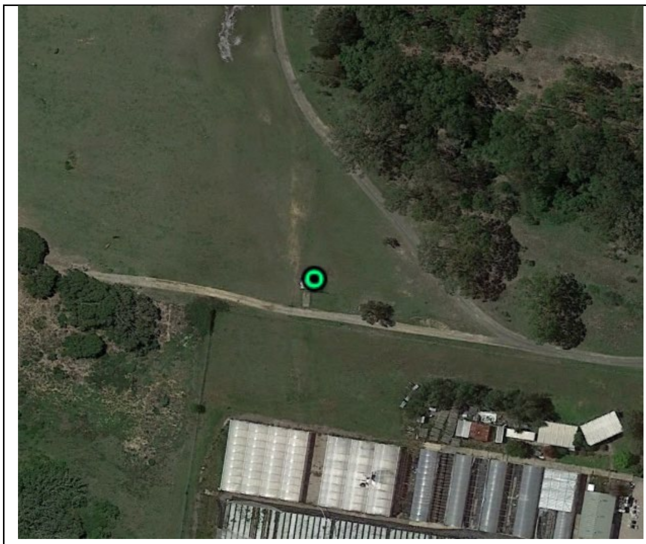
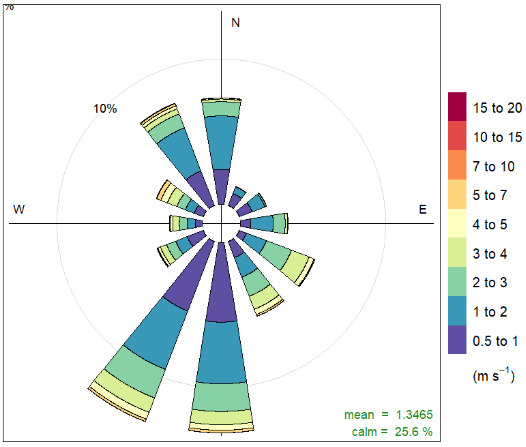
	 Frequency of counts by wind direction (%)
AWS siting	All hours wind rose

Comments:

No trees or obstacles close to the met station. All obstacles well outside the siting distance recommended by AS3580-14 (10x Tree height or 10x Building height).

St Marys

OEH/EES

	 Frequency of counts by wind direction (%)
AWS siting	All hours wind rose

Comments:

There is a large stand of tall trees ~40m to the northeast of the met tower. These trees are all likely to be much taller than the tower and may affect the wind direction in the northeast sector. There is a smaller frequency of winds from the northeast for the St Marys met tower which may suggest an influence by the tree line in that direction.

There are some large buildings to the south; however, wind patterns suggest significant winds from the south which appear unaffected by the buildings in terms of direction.

Horsley Park

BOM ID 067119

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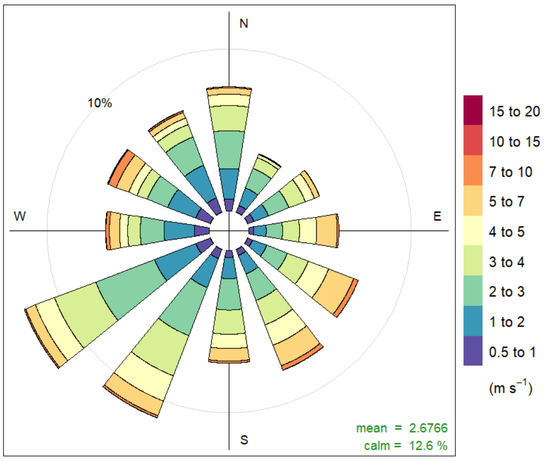
<td>

Frequency of counts by wind direction (%)</td>
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<tr>
<td>AWS siting</td>
<td>All hours wind rose</td>
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<tr>
<td>AWS siting</td>
<td>Obstacles – Shipping containers</td>
</tr>
</table>

Comments:

There are scattered trees along a road ~40m – 60m to the north of the met tower. The spacing of the trees and nature of the trees (thinly leafed variety) suggest that they are unlikely to significantly affect the wind measurements. The wind rose shows relatively unimpeded winds from the north.

The shipping containers to the southwest of the tower are unlikely to be high enough to affect the air flow measured at the tower.

The three AWS locations close to the proposal location vary considerably in terrain setting and wind distribution patterns. The St Mary's AWS is situated at the bottom of a valley, and though the valley is only of moderate relief the location experiences strong north-south wind patterns as influenced by the orientation of the valley. The Horsley Park AWS is situated on comparatively elevated ground for the area and exhibits a relatively even distribution of winds. The Badgerys Creek AWS is situated in an area of low topographical relief and experiences winds from all directions; however, with a higher frequency of winds from the south-east, influenced by the elevated terrain to the south-west.

St Mary's is located within different terrain features to the two BoM stations, has different wind distribution patterns and is, therefore, not expected to be representative of the proposal. The St Marys station was therefore excluded from further consideration.

Based on the explanation above, surface meteorological measurements from the Badgerys Creek and Horsley Park stations were initially selected for use in the GRAMM modelling.

Selection of the Meteorological Year

Once a set of representative surface weather stations are selected, the next step in developing the 1-year modelling meteorological data set is to select a representative calendar year. A range of measured meteorological and air quality parameters from calendar years between 2010 and 2019 were considered and ranked for suitability in terms of how closely they match long terms trends and how important the parameters are to dispersion modelling. The analysis was carried out using either a probability density function approach (PDF) or a frequency of occurrence analysis. A ranking for each year was developed to enable the selection of an ideal meteorological year.

The analysis determined the likelihood of occurrence for values for each measured parameter, and then combines all parameters to give a raw ranking of suitability for each calendar year. The raw ranking is then scaled according to the importance of each parameter (for example wind speed and direction hold a higher importance to the modelling than humidity or atmospheric pressure) to provide a weighted rank.

A score of 1-10 (1 being best fit) was given for each parameter for each station. Scores were aggregated to provide a raw calendar year ranking. The raw ranking was then scaled according to which parameters are more important to the assessment. A summary of the scale factors applied to each parameter are presented in **Table D-10-6**.

Table D-10-6 Factors used to scale the ranks for each meteorological parameter

Parameter	Scale Factor (lower means more important parameter)	Comment
Southern Oscillation Index	1	Critical parameters.
Data availability	1	
Wind speed	1.5	Vital for plume dispersion
Wind direction	1.5	
Calms (total)	2	Secondary importance – important to overall assessment but not critical for plume dispersion
Calms (9 am)	2	
Calms (3 pm)	2	
PM10 24-hour concentration	2	
PM2.5 24-hour concentration	2	
NO2	2	
Temperature	4	Low importance – parameters that only make minor differences to overall proposal
Humidity	4	
Pressure	4	

Southern Oscillation Index (SOI) data is presented in **Figure D-10**, with monthly averages at the top and yearly averages at the bottom. This shows that the years 2012, 2017 and 2018 were the most neutral with an average SOI index of close to zero and no large fluctuations in monthly average SOI. This indicates that meteorological data for these years were less likely to be impacted by an El Nino/La Nina event.

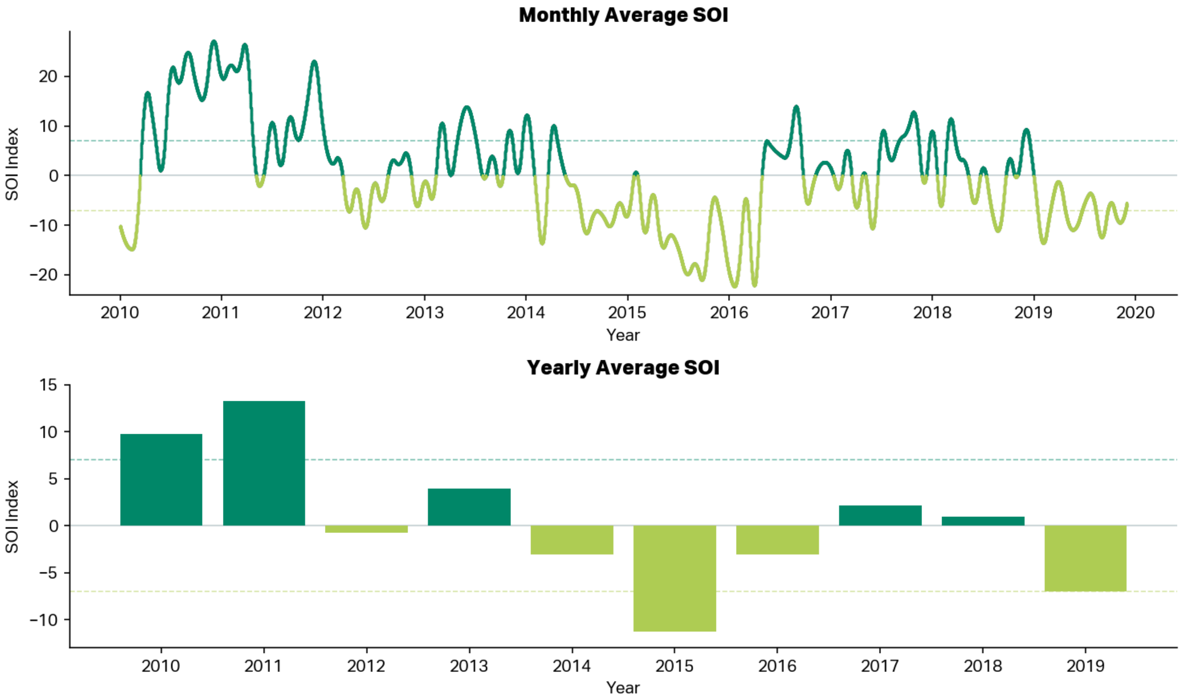


Figure D-10 Monthly and year average SOI index for 2010 to 2019

Data availability for Badgerys Creek and Horsley Park are presented in **Figure D-11** and **Figure D-12** respectively. All years have greater than 90 per cent data availability at both locations; however 2016 and 2018 do have significant periods of missing wind data at Badgerys Creek, as do 2014, 2015 and 2016 at Horsley Park. Data availability is very good for 2012, 2013, 2017 and 2019 which remain candidate years for the modelling.


Badgerys Creek AWS WD (deg)

Badgerys Creek AWS WS (m/s)

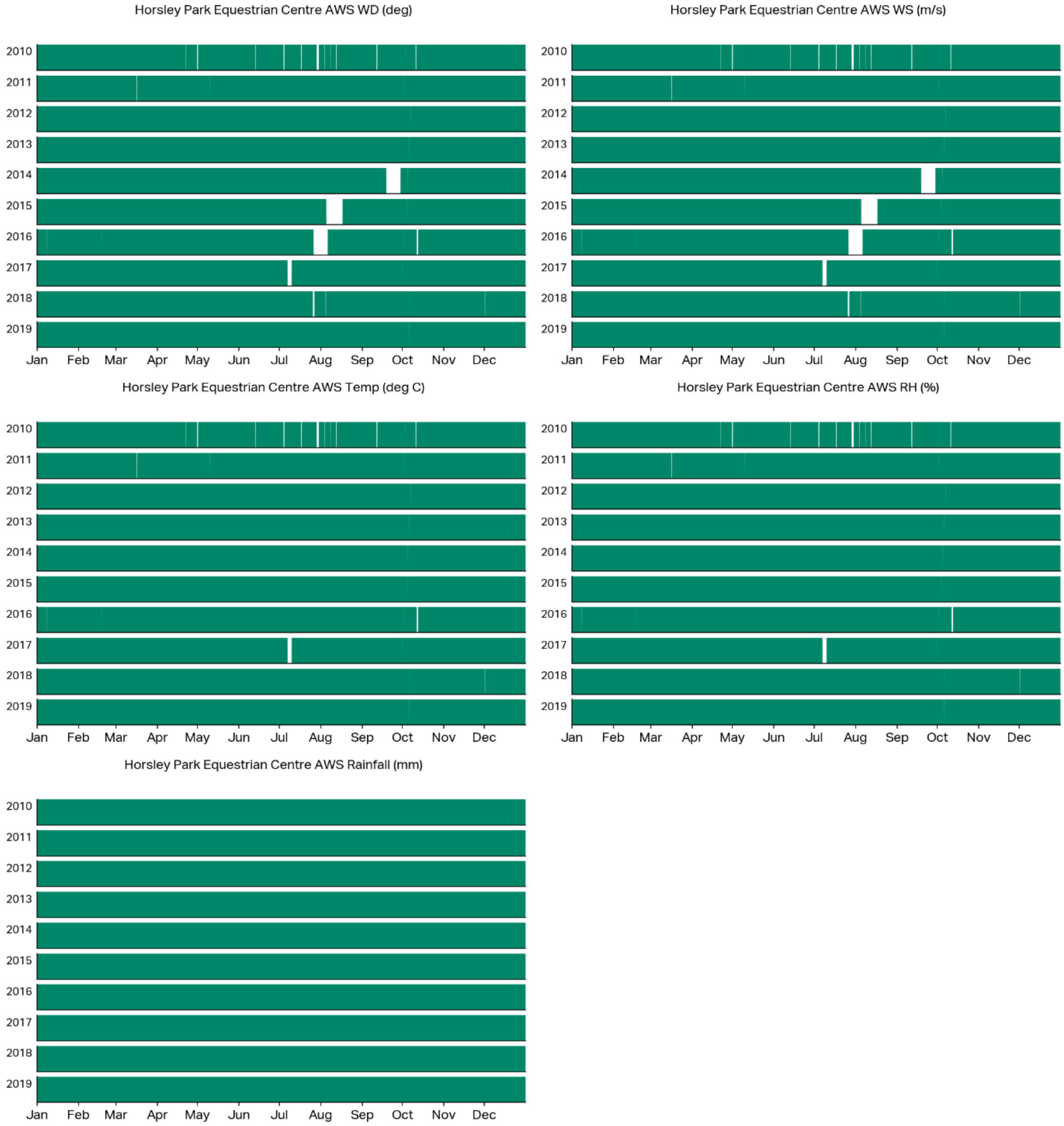
Badgerys Creek AWS Temp (deg C)

Badgerys Creek AWS RH (%)

Badgerys Creek AWS Rainfall (mm)

Badgerys Creek AWS Pressure (hPa)

Figure D-11 **Badgerys Creek data availability (white indicates missing data) for various parameters**



Horsley Park Equestrian Centre AWS WD (deg)

Horsley Park Equestrian Centre AWS WS (m/s)

Horsley Park Equestrian Centre AWS Temp (deg C)

Horsley Park Equestrian Centre AWS RH (%)

Horsley Park Equestrian Centre AWS Rainfall (mm)

Figure D-12 Horsley Park data availability (white indicates missing data) for various parameters

Next, wind direction and wind speed data were analysed. Wind speed was analysed using the PDF method to calculate a rank in terms of ‘best fit’ against long term averages. An example graphical representation of the wind speed PDF data is presented in **Figure D-13** for Badgerys Creek. Wind direction was analysed according to frequency of occurrence (per cent variance from long term mean) for categorised wind directions (10 degree bins). An example graphical representation of the wind direction is presented in **Figure D-14** for Badgerys Creek. The years 2010, 2011, 2012 and 2016 were the best performing years for this analysis.

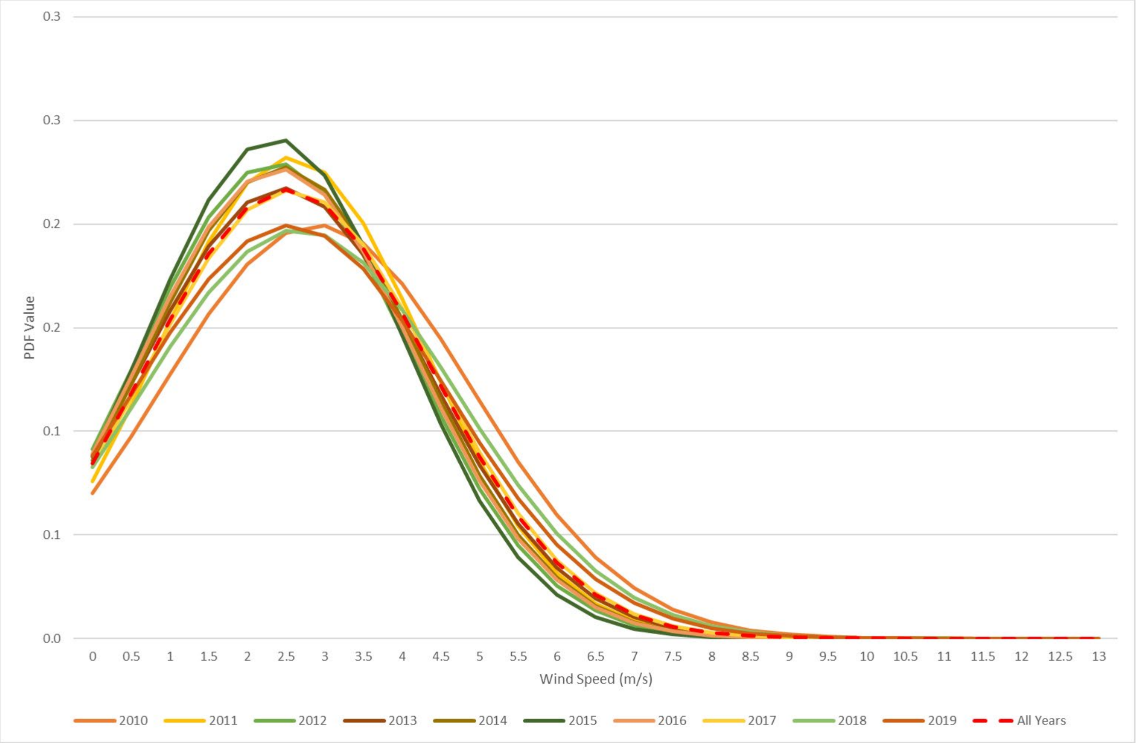


Figure D-13 PDF values for wind speed at Badgerys Creek station for 2010 to 2019

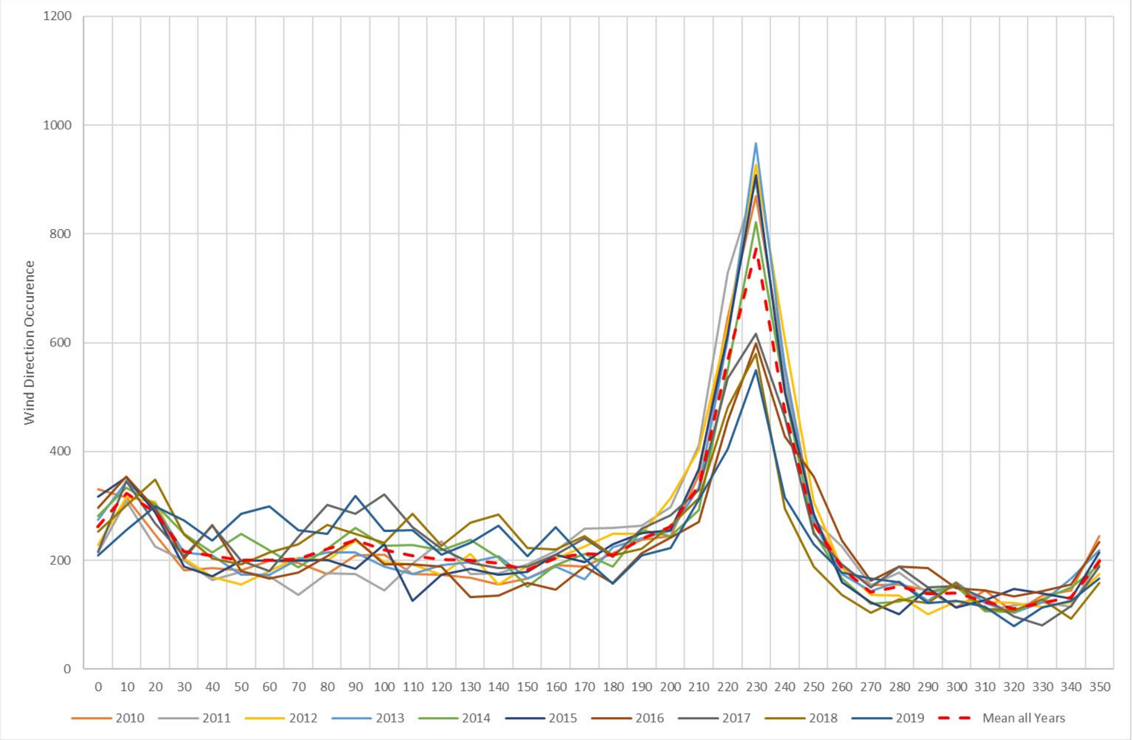


Figure D-14 Occurrence hours for wind direction at Badgerys Creek station for 2010 to 2019

Of secondary importance are calms and background pollutant data. Note that pollutant data for Badgerys Creek was taken from Bringelly and pollutant data for Horsley Park was taken from Prospect due to the availability of pollutant monitoring stations. An example graphical representation of the background pollutant concentration PM_{10} PDF data from Bringelly is presented in **Figure D-15**. The best performing years for this analysis were 2012, 2013, 2014 and 2015. Note that the 2019 data was heavily skewed due to widespread bushfires.

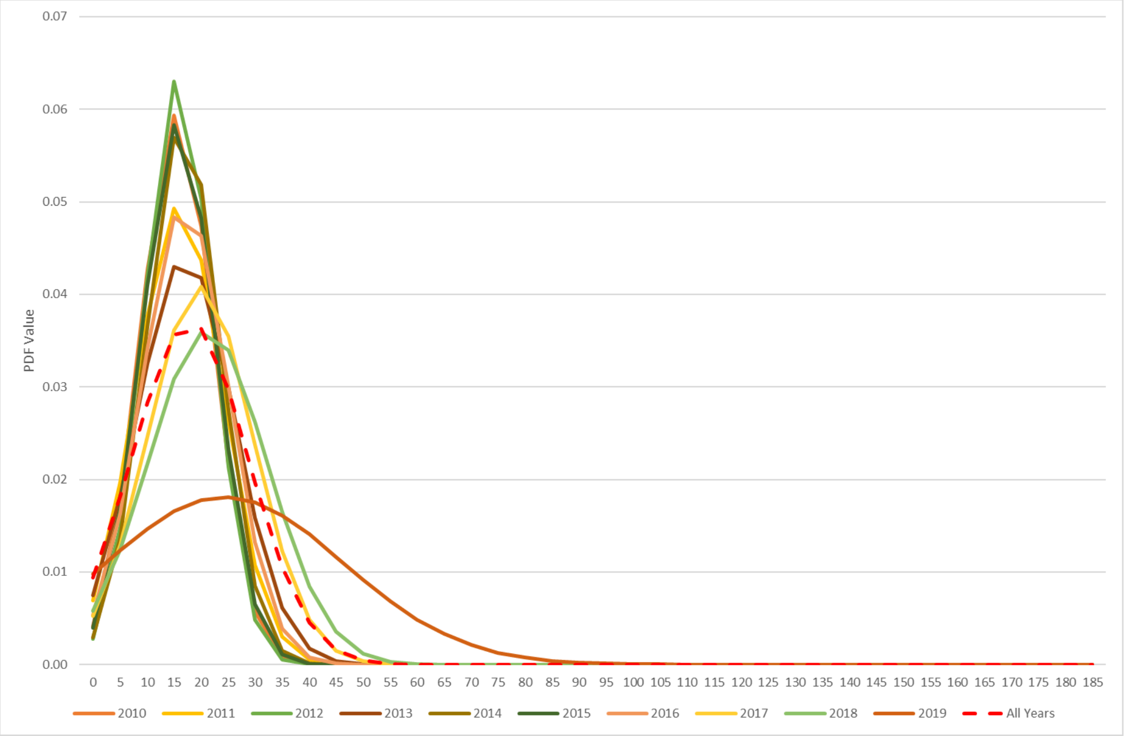


Figure D-15 **PM10 concentrations at Bringelly station for 2010 to 2019**

Of lowest importance are temperature, humidity and pressure. An example graphical representation of temperature PDF data for Badgerys Creek is presented in **Figure D-16**. The best performing years for the analysis were 2011, 2012, 2017 and 2018 were the best performing years for this analysis.

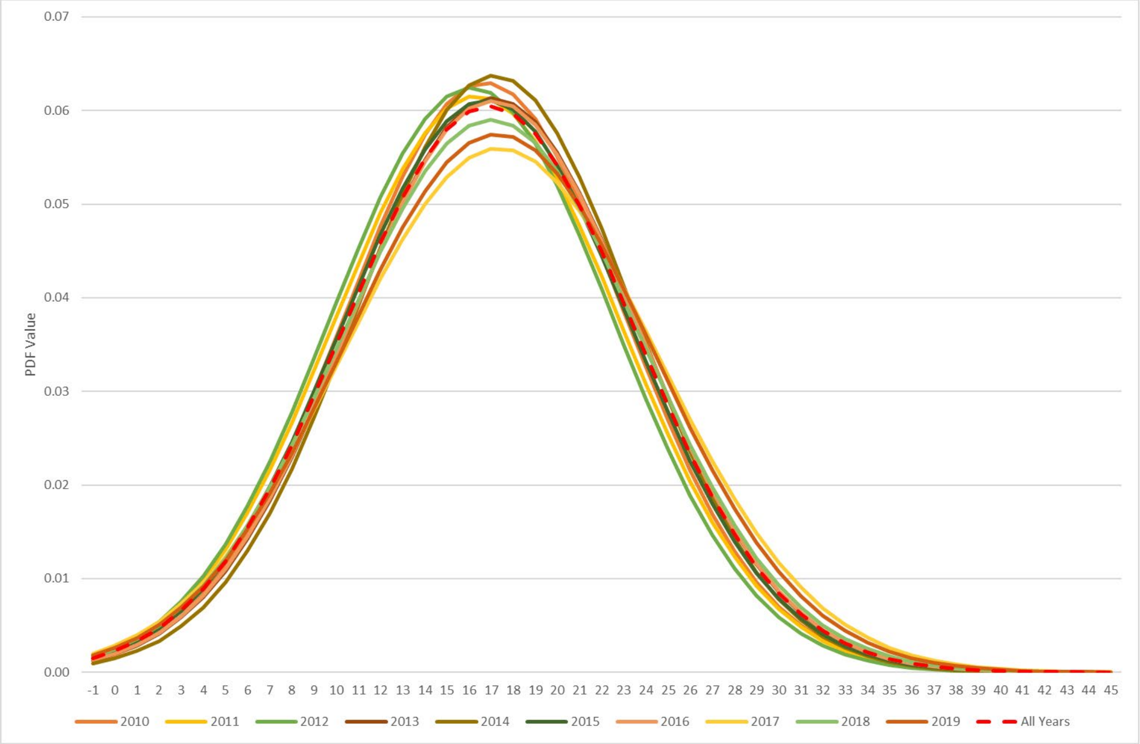


Figure D-16 **Temperature at Badgerys Creek station for 2010 to 2019**

A summary of the aggregated scores for each parameter category, total score, and scaled ranking (from 1 to 10) for each calendar year is presented in **Table D-10-7**. Overall, the calendar year 2012 was ranked best, with 2017 ranking second.

Table D-10-7 Scaled ranking scores for all parameters – Badgerys Creek and Horsley Park

Year	Aggregate Score					Scaled Rank
	Critical	Vital	Secondary	Low Importance	Total Score	
2010	216	21	109	100	446	8
2011	208	30	137	68	443	7
2012	4	23	93	64	184	1
2013	16	42	106	180	344	6
2014	18	38	100	148	304	4
2015	308	35	84	136	563	10
2016	28	26	107	160	321	5
2017	17	45	132	80	274	2
2018	16	33	150	76	275	3
2019	210	39	162	88	499	9

Although it was ranked second in the above analysis, the 2017 calendar year was chosen for use in the assessment. The selection was based on the availability of background $PM_{2.5}$ monitoring data for the 2017 year. Background $PM_{2.5}$ data was not available for the 2012 calendar year so despite 2012 being the best calendar year in terms of meteorology, 2017 has been selected as the best meteorological data year for the assessment.

CALMET model development

Meteorological data modelling procedure and settings

In the absence of site-specific meteorological data required by the GRAL dispersion model (stability class), a meteorological dataset has been prepared using a combination of regional meteorological observations from Bureau of Meteorology (BoM) and NSW Office of Environment and Heritage (OEH) stations, databases of terrain and land use, as well as gridded meteorological data from the CSIRO TAPM prognostic meteorological model. An overview of the assumptions made and data used to develop the required stability classes is provided below.

TAPM configuration

Upper air data for the CALMET model was derived from The Air Pollution Model (TAPM). For the purpose of this assessment, upper air data was extracted from the generated TAPM data at three locations for input into the CALMET model. TAPM settings and the locations of the extracted upper air data used in CALMET are provided in **Table D-10-8**.

Table D-10-8 TAPM settings

Parameter	Setting
TAPM Version	4.0.5
Grid coordinates (km UTM)	301.163, 6248.699
Date parameters	2017 01 01 to 2017 12 31
Number of grid points	nx = 40
	ny = 40
Grid spacing	Outer = 30,000 m
	Inner = 1,000 m
Number of grid domains	4
Number of vertical grid levels	nz = 25
Observation file	Not used
Locations of upper air data extracted for CALMET (km UTM)	290.663, 6236.199; 296.663, 6255.199; 313.663, 6244.199;

The modelling domains generated in the TAPM model provide prognostic data across four nested grids. The first outer grid covers an area of 1,440,000 km^2 at 30 km resolution. The nested grids step down progressively in dimensions, to the final innermost grid, which covers an area of 1,600 km^2 at a resolution of 1,000 m. In the vertical direction there are 25 levels (40 layers) from the surface to 100 hPa. The lowest layer is about 10 m above the ground.

CALMET configuration

CALMET was ran for the 2017 calendar year to determine stability classes that were used in the GRAMM Match to Observation process. This section presents the setting and input data used in CALMET.

The CALMET meteorological modelling domain has been configured to encompass the region surrounding the proposal, covering nearby sensitive receptors and key terrain features.

Table D-10-9 presents a summary of the domain settings along with key model parameters used within CALMET to generate the meteorological fields. Explanations of these parameters are available in the following guidance document:

TRC, 2011, Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia'.

Table D-10-9 CALMET modelling parameters for the proposal domain

Parameter	Value
Meteorological grid domain	40 km x 40 km
Meteorological grid resolution	250 metre resolution (160 x 160 grid cells)
Reference grid coordinate (SW corner)	281.100 km E, 6231.700 km S
Cell face heights in vertical grid (m)	0,20,40,80,160,320,640,1200,2000,3000,4000
Simulation length	1 year (2017)
Surface meteorological stations	Holsworthy Aerodrome (BoM) Bankstown Airport (BoM) Horsley Park Equestrian Centre (BoM) Badgerys Creek (BoM) Penrith Lakes (BoM) Rouse Hill (EES) St Mary's (EES) Prospect (EES) Parramatta (EES) Bringelly (EES) Liverpool (EES)
Upper air meteorology	3 TAPM derived up.dat files (see **Table D-10-8** for locations)
CALMET Modelling Mode	Observations mode
Terrain data	Terrain elevations were extracted from NASA Shuttle Radar Topography Mission Version 3 data set (SRTM1 30 metre resolution).
Land use Data	USGS 1km GLCC land use dataset
Wind field guess	Computed internally
Seven critical CALMET parameters	TERRAD = 5 km RMAX1 = 5 km R1 = 5 km RMAX2 = 10 km R2 = 10 km IEXTRP = -4 BIAS = -1, -0.5, 0, 0.5, 1, 1, 1, 1, 1, 1

The CALMET model showing terrain, locations of upper and surface stations, and the radius of Influence that were used is presented in **Figure D-17**.

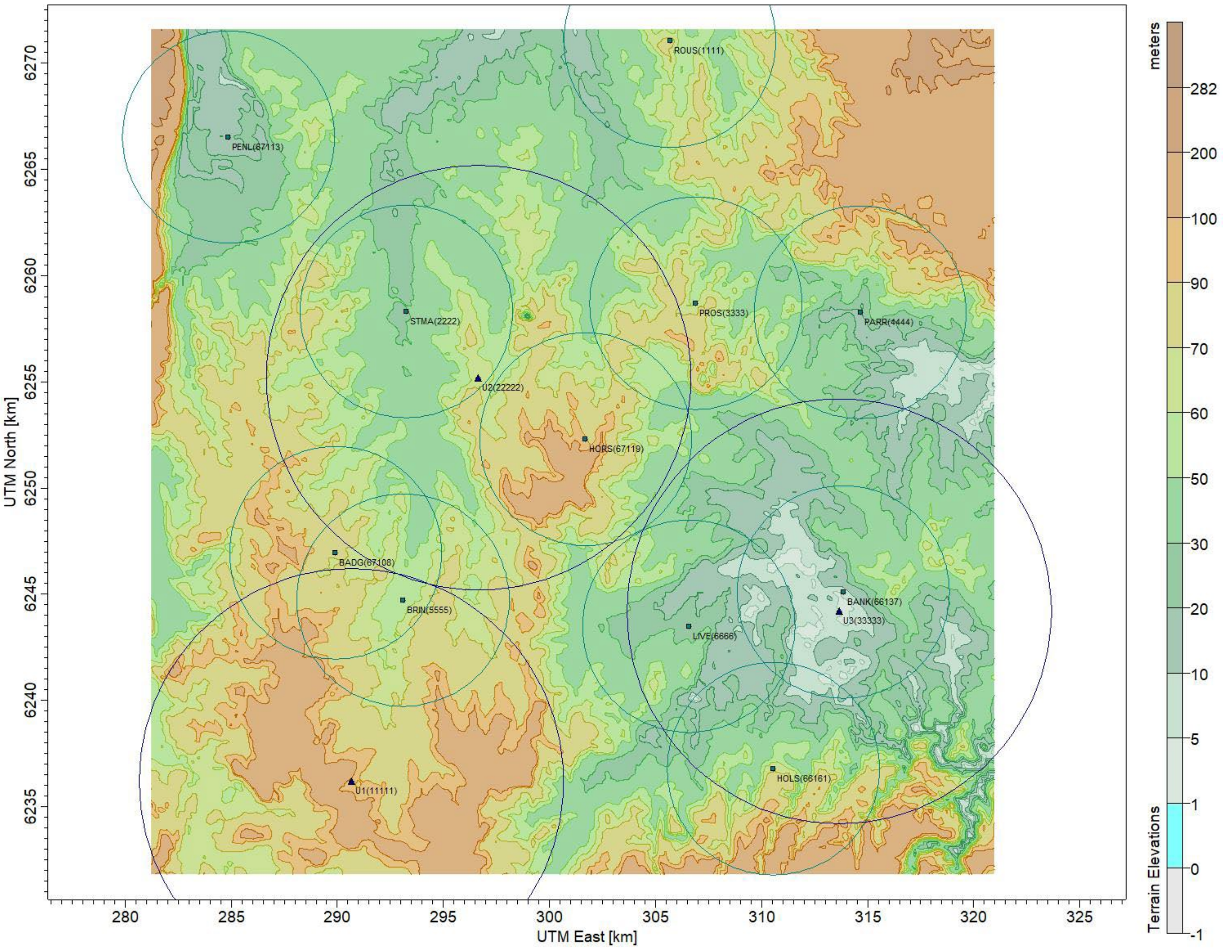


Figure D-17 **CALMET terrain and stations with radius of influence**

CALMET atmospheric stability analysis

Stability is a measure of the convective properties of a parcel of air. Stable conditions occur when convective processes are low, while unstable conditions are associated with stronger convective processes, which are associated with potentially rapid changes in temperature. Stable atmospheres occur when a parcel of air is cooler than the surrounding environment, so the parcel of air (and any pollution within it) sinks. Conversely, unstable atmospheres occur when a parcel of air is warmer than the surrounding environment, making the parcel of air buoyant and, subsequently, leading to the parcel of air rising.

Stability class data extracted from the CALMET files for use in the GRAMM MTO process were analysed to ensure they provide expected results. The following charts shown in **Figure D-18** (Badgerys Creek BoM station location) and **Figure D-20** (Horsley Park BoM station location) indicates stability classes designated as A to F, which correspond to the Pasquill-Gifford A – F stability class designations. Classes A, B and C represent unstable conditions, with class A representing very unstable conditions and C representing slightly unstable conditions. Class D stability corresponds to neutral conditions, which typically occur on overcast days. Classes E and F correspond to slightly stable and stable conditions respectively, which mostly occur at night.

As expected, the stability classes indicate stable conditions during the night hours and neutral or unstable conditions during the day at both locations.

The stability classes were plotted by wind speed as shown in **Figure D-19 (**Badgerys Creek) and **Figure D-21** (Horsley Park). As expected, the highest wind speeds (> 4 m/s) were associated with neutral conditions. Lower wind speeds (<3 m/s) are mostly associated with neutral or stable conditions. This represents a typical pattern of stability and shows that CALMET is performing well. The stability classes data from CALMET was therefore considered suitable for use in the GRAMM MTO process.

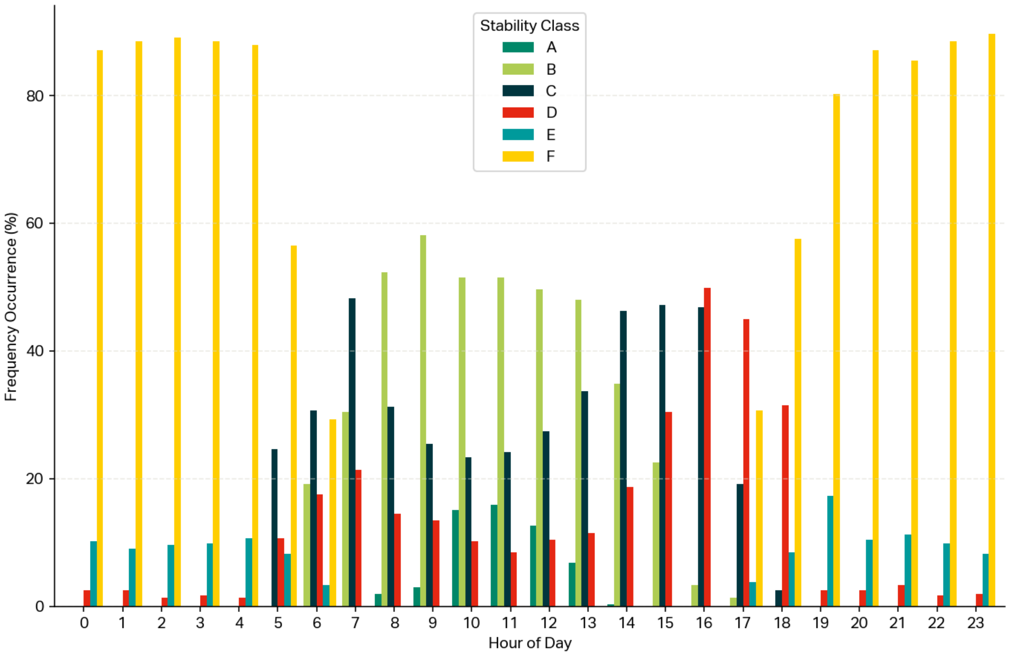


Figure D-18 CALMET hourly stability class frequency at the Badgerys Creek BoM station location

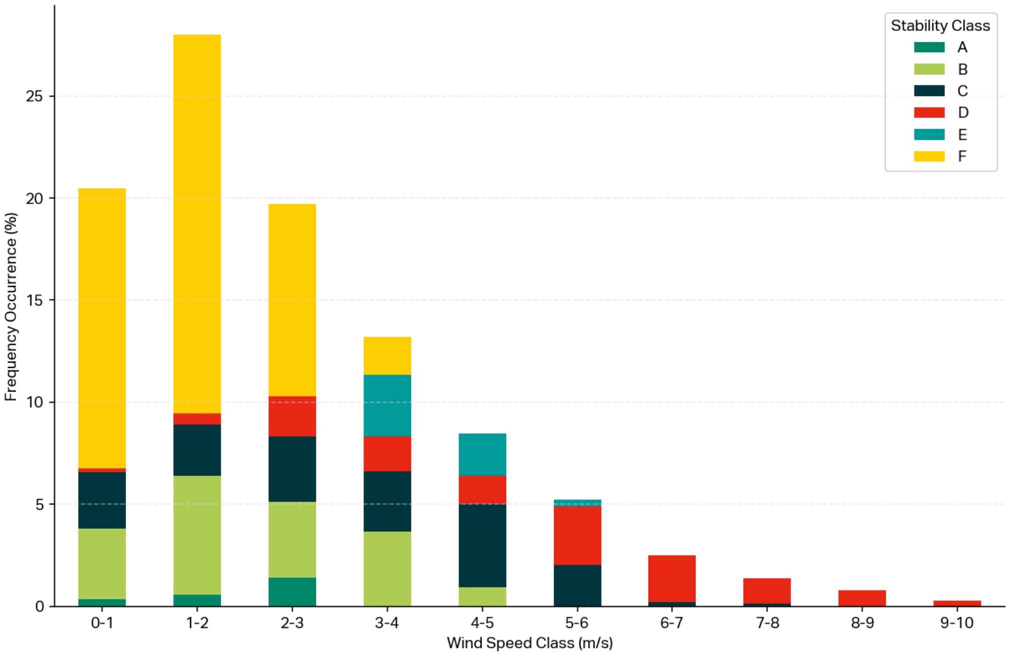


Figure D-19 CALMET stability class frequency by wind speed at the Badgerys Creek BoM station location

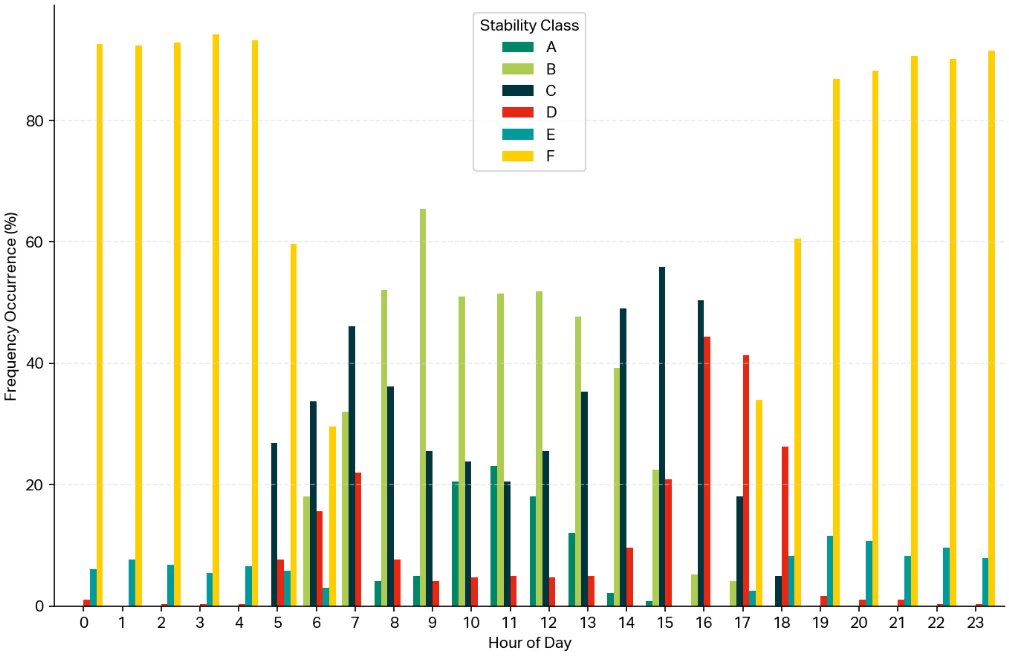


Figure D-20 CALMET hourly stability class frequency at the Horsley Park BoM station location

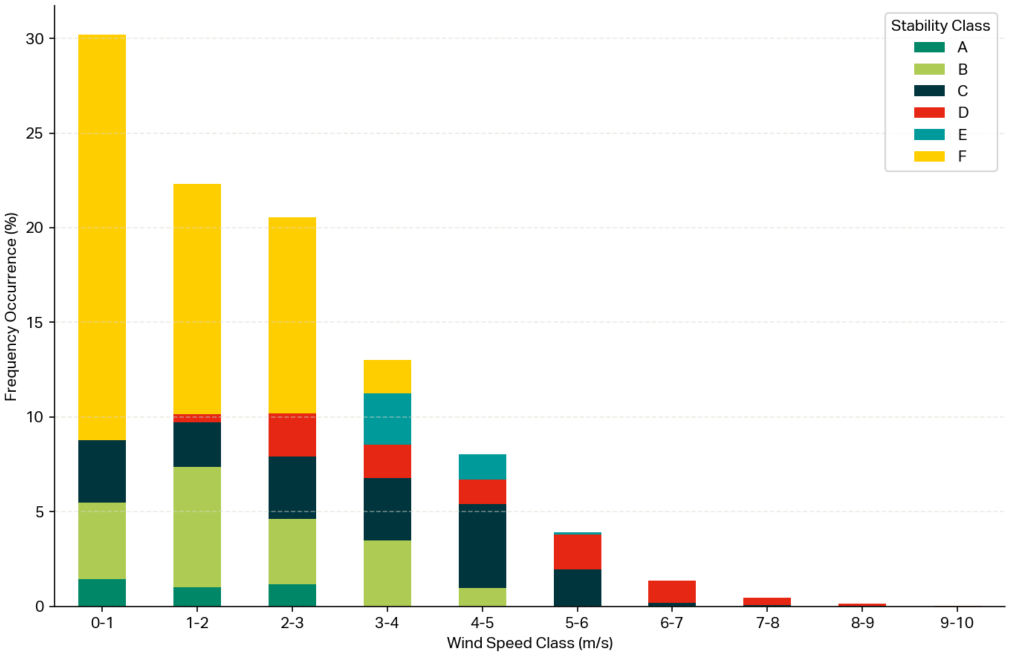


Figure D-21 CALMET stability class frequency by wind speed at Horsley Park BoM station location

Appendix E

Interpolation of background data

Appendix E Interpolation of background data

Regional availability of DPE data

The proposal is located in between two NSW DPE operated air quality monitoring stations, St Marys and Bringelly, as shown in **Figure E-22**. The broader air environment in the areas surrounding the proposal and the two stations are similar, with the major difference being the WSA development near the proposal. Data was used from the 2017 calendar year to match the modelled meteorology, so any air emissions associated with the airport construction work is not included in the data. Data from the two stations were interpolated spatially to estimate hourly background concentrations at a single point (shown as a blue circle at centre in **Figure E-22**). Interpolated concentrations at this point were summed with predicted concentrations at each receptor to estimate cumulative air quality impacts for the proposal.

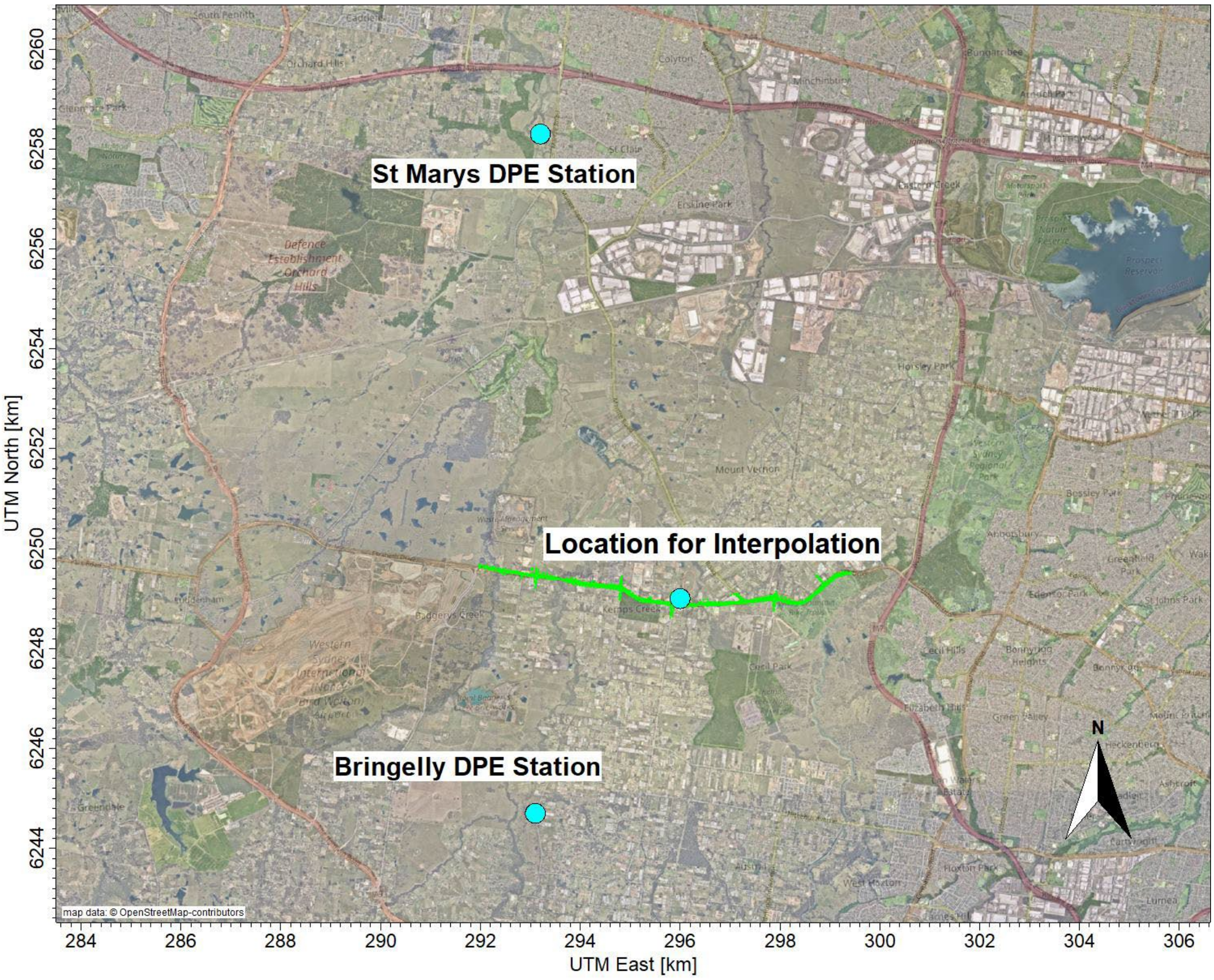


Figure E-22 **Location of background stations included in the interpolation process**

Data interpolation

Hourly recorded monitoring data at each identified monitoring station was interpolated into a grid covering the extent of the monitoring stations using the Python programming language. MGA 56 easting and northing coordinates in metres for each DPE Station were assigned x and y values respectively and hourly background concentrations are assigned z values.

Hourly data was gridded using radial basis function (RBF) interpolation method to create a spatially varying gridded data from the formerly unstructured background air quality data. A multiquadric basis kernel function was used for interpolating grid nodes.

A 500m grid resolution was used for the RBF interpolation. The RBF-interpolated grid was then used to interpolate a concentration at each of the modelled sensitive receptors. This step was carried out using a simple linear interpolation.

An overview of the interpolation process is presented in **Figure E-23**.

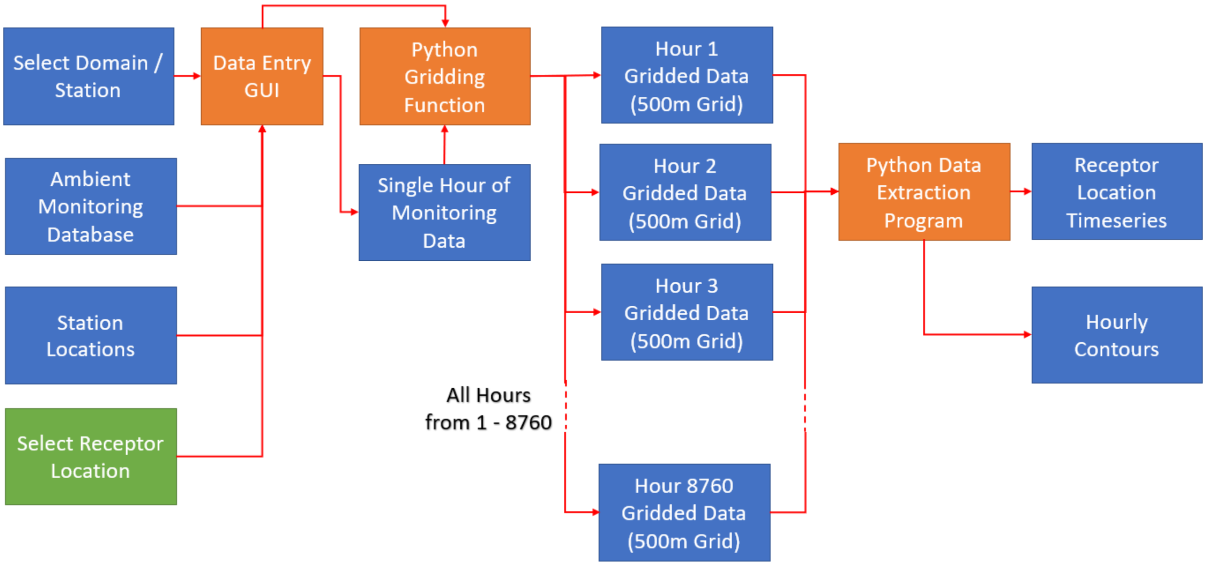


Figure E-23 Background Air Quality Interpolation methodology flow chart.

A timeseries covering each hour in the modelled year for each pollutant (NO_2, PM_{10} and $PM_{2.5}$) was generated from the interpolated data. The timeseries data was combined with hourly predicted concentrations from the GRAL model to generate a contemporaneous data set of cumulative pollutant concentrations (proposal plus background).

A sample of the interpolated grid data is presented in **Table E-10-10**. This represents interpolated PM_{10} concentrations for the first eight hours of the background data (January 1st 2017 00:00- 07:00). Note that with just two stations included in the spatial interpolation, the interpolated values always sit in between the two measured values.

Table E-10-10 Sample of interpolated $PM_{2.5}$ concentrations (µg/m³)

Date	$PM_{2.5}$ concentration (µg/m³)		
	St Marys	Bringelly	Interpolation at construction footprint
1/01/2017 0:00	10.3	7.1	8.1
1/01/2017 1:00	9.5	7.6	8.2
1/01/2017 2:00	9	7.6	8.0
1/01/2017 3:00	9	5.1	6.3
1/01/2017 4:00	11.4	4.7	6.8
1/01/2017 5:00	15.5	6.1	9.1
1/01/2017 6:00	15.5	9.4	11.3
1/01/2017 7:00	16.3	7.8	10.5

Appendix F

Sensitive receptors

Appendix F Sensitive receptors

The coordinates for all sensitive receptors used in the modelling are provided in **Table F-10-11** and are shown on a map in **Figure F-24** and **Figure F-25**.

Table F-10-11 Sensitive receptor locations for southern and northern modelling domains

Southern Domain Receptor ID	MGA 56 (m)	
	Easting	Northing
1	291408	6250198
2	292415	6249637
3	292749	6249454
4	292728	6249380
5	292673	6249327
6	292791	6249264
7	292776	6249218
8	292769	6249647
9	292771	6249715
10	292905	6249429
11	293003	6249424
12	293182	6249338
13	293198	6249111
14	293353	6249303
15	293249	6249711
16	293420	6249321
17	293476	6249286
18	293965	6249232
19	294039	6249361
20	294155	6249358
21	294329	6249355
22	294394	6249210
23	294460	6249302
24	294543	6249200
25	294431	6249197
26	294615	6249175
27	294961	6249193
28	295286	6249018
29	295586	6248991
30	295741	6248964
31	295624	6248871
32	295755	6248852

Southern Domain Receptor ID	MGA 56 (m)	
	Easting	Northing
33	295881	6248761
34	296036	6248818
35	296129	6248915
36	296135	6248825
37	296204	6248826
38	296280	6248734
39	296655	6248944
40	296705	6248943
41	296565	6248842
42	296627	6248843
43	297031	6248821
44	297286	6248995
45	297358	6248988
46	297521	6249053
47	297615	6249095
48	297663	6249108
49	297742	6249136
50	297806	6249136
51	297857	6249251
52	297901	6249264
53	298044	6249293
54	298132	6249169
55	298173	6249243
56	298227	6249172
57	298341	6249008
58	298429	6249017
59	298482	6249139
60	298587	6249235
61	298625	6249372
62	298703	6249440
63	298749	6249412
64	298889	6249363
65	299021	6249445
66	299070	6249488
67	299117	6249547
68	299153	6249592

Southern Domain Receptor ID	MGA 56 (m)	
	Easting	Northing
69	299477	6249582
70	299147	6249707

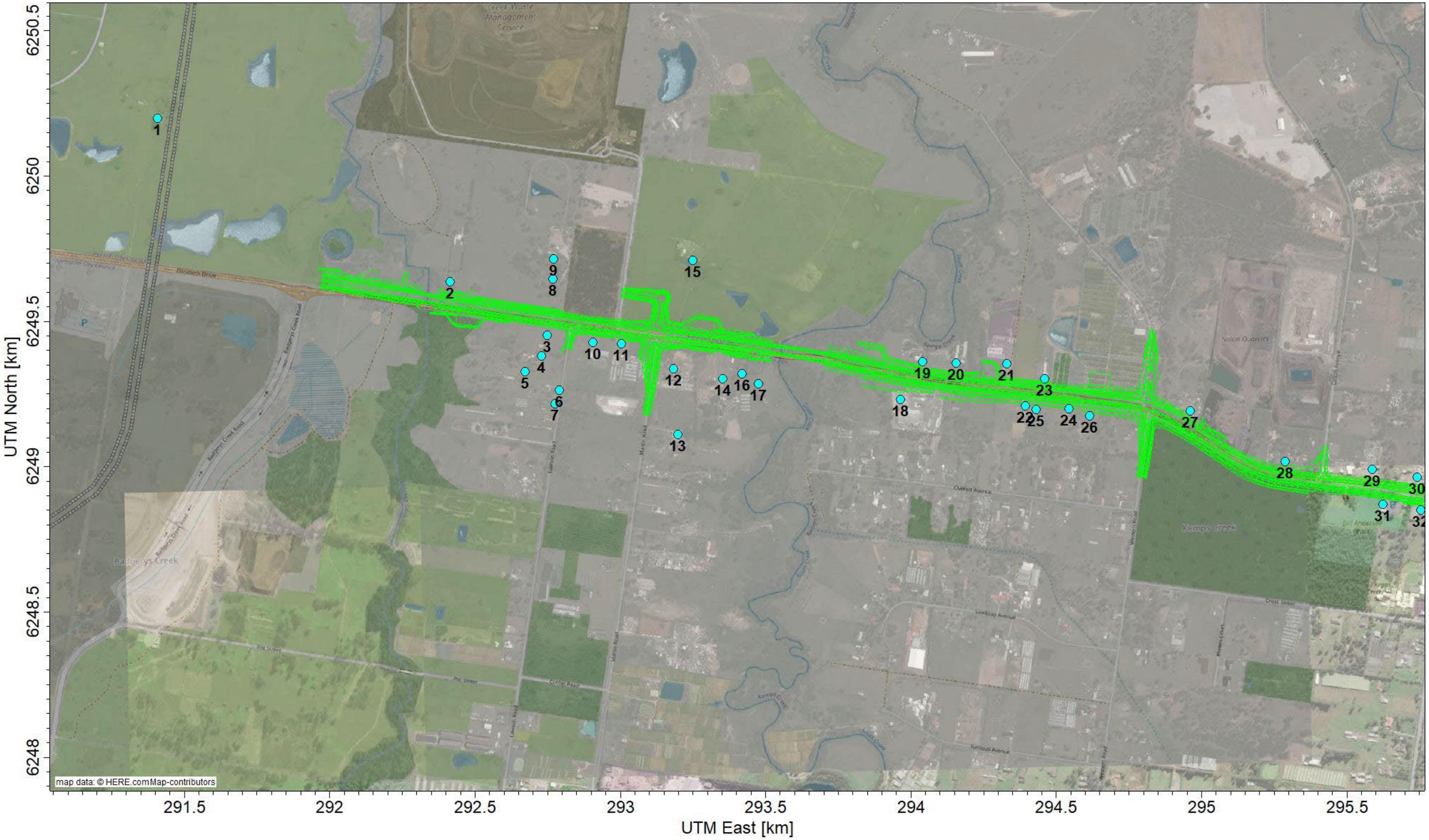


Figure F-24 Location of modelled sensitive receptors – 1 of 2

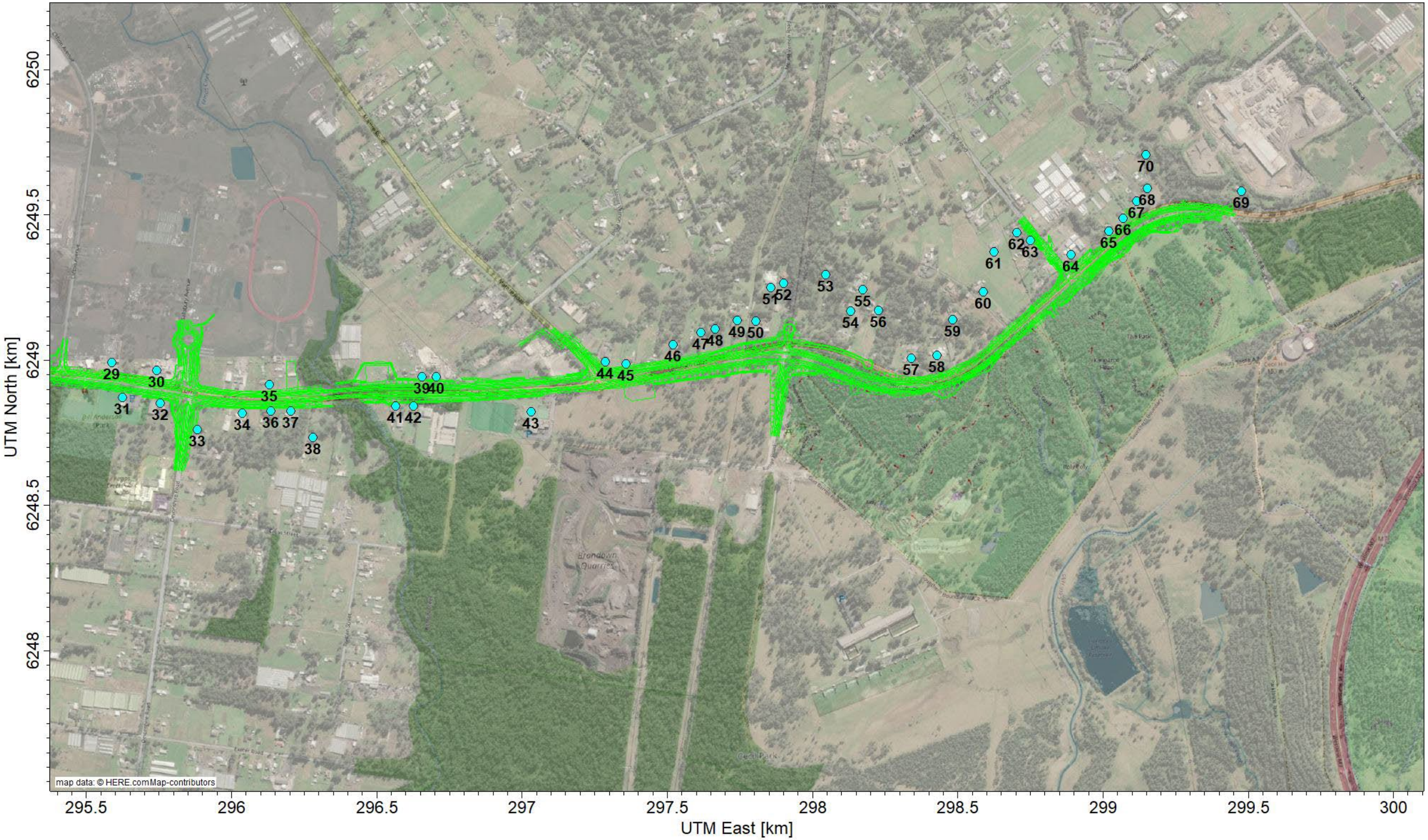


Figure F-25 Location of modelled sensitive receptors – 2 of 2

Appendix G

Emissions inventory

Appendix G Emissions inventory

Base hot running emission factors used in the assessment for each vehicle type and road type are presented in **Table G-10-12**. These factors were sourced from NSW EPA Air Emissions Inventory for the Greater Metropolitan Region in NSW – On Road Mobile Emissions model for the 2013 calendar year.

Road grade factors used in the assessment are presented in **Table G-10-13**. The grade factors are derived from *Road Tunnels: Vehicle Emissions and Air Demand for Ventilation* report (PIARC (2019)), as have other recent road proposals in NSW.

Table G-10-12 Base hot running emission factor by vehicle and road type

Year	2021 (2016 emission factors)					2030 (2026 emission factors)					2040 (2036 emission factors)				
Veh Class	Centroid Conn.[9]	Local/Coll.[10]	Sub Arterial[11]	Arterial[12]	MW/FW[13]	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW
1 – HC (g/km)															
PPV	0.075	0.081	0.081	0.069	0.051	0.020	0.023	0.024	0.018	0.015	0.015	0.017	0.017	0.011	0.010
DPV	0.056	0.055	0.054	0.049	0.036	0.009	0.009	0.009	0.008	0.005	0.003	0.003	0.002	0.002	0.002
PLCV	0.414	0.446	0.451	0.374	0.270	0.171	0.191	0.196	0.139	0.107	0.069	0.080	0.083	0.055	0.044
DLCV	0.077	0.076	0.075	0.071	0.060	0.010	0.010	0.010	0.010	0.008	0.003	0.003	0.003	0.003	0.002
RIG	0.300	0.291	0.284	0.244	0.196	0.065	0.063	0.062	0.053	0.042	0.030	0.030	0.029	0.025	0.020
ART	0.511	0.489	0.476	0.436	0.337	0.138	0.133	0.129	0.117	0.089	0.092	0.088	0.086	0.077	0.058
BUSD	0.317	0.310	0.303	0.270	0.211	0.071	0.070	0.069	0.062	0.049	0.040	0.040	0.039	0.036	0.029
2 – CO (g/km)															
PPV	0.929	1.150	1.220	1.090	0.913	0.366	0.531	0.592	0.532	0.483	0.365	0.459	0.494	0.438	0.392
DPV	0.281	0.277	0.271	0.274	0.188	0.103	0.101	0.099	0.103	0.064	0.053	0.053	0.052	0.056	0.038
PLCV	4.852	5.634	5.833	5.439	4.898	1.897	2.513	2.698	2.919	2.750	0.859	1.157	1.253	1.322	1.204
DLCV	0.369	0.364	0.358	0.361	0.276	0.083	0.082	0.080	0.083	0.064	0.022	0.021	0.021	0.022	0.017
RIG	1.525	1.488	1.458	1.231	0.993	1.088	1.074	1.059	0.952	0.830	0.499	0.493	0.487	0.437	0.379
ART	6.601	5.660	5.250	4.123	2.307	6.503	5.487	5.065	4.082	2.213	2.481	2.089	1.927	1.552	0.827
BUSD	1.747	1.787	1.775	1.527	1.087	1.482	1.491	1.471	1.240	0.824	1.105	1.112	1.097	0.926	0.614

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[9] Secondary roads with prime purpose of access to property
[10] Connection roads from local to arterial
[11] Major roads for purpose of regional or inter-regional traffic movement – speed limits 60-80 km/h
[12] Major roads for purpose of regional or inter-regional traffic movement – speed limits 70-90 km/h
[13] Motorway/freeway

Year	2021 (2016 emission factors)					2030 (2026 emission factors)					2040 (2036 emission factors)				
Veh Class	Centroid Conn.[9]	Local/Coll.[10]	Sub Arterial[11]	Arterial[12]	MW/FW[13]	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW
3 – NO_x (g/km)															
PPV	0.194	0.229	0.240	0.231	0.248	0.048	0.060	0.065	0.059	0.052	0.034	0.041	0.043	0.036	0.027
DPV	0.863	0.893	0.896	0.908	0.964	0.716	0.745	0.749	0.834	1.029	0.390	0.405	0.408	0.473	0.618
PLCV	0.792	0.893	0.925	0.874	0.932	0.321	0.377	0.395	0.367	0.375	0.141	0.168	0.177	0.161	0.158
DLCV	1.241	1.292	1.301	1.266	1.199	1.159	1.163	1.161	1.128	1.090	0.628	0.628	0.625	0.609	0.591
RIG	4.488	4.433	4.370	3.835	3.197	3.786	3.705	3.615	2.836	1.849	1.698	1.660	1.617	1.245	0.770
ART	12.379	12.545	12.499	11.640	9.828	9.409	9.769	9.812	8.274	5.143	3.380	3.502	3.509	2.945	1.766
BUSD	10.506	10.526	10.389	9.156	6.783	7.478	7.455	7.304	6.056	3.680	5.301	5.279	5.167	4.244	2.487
4 – Exhaust PM_{10} (g/km)															
PPV	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
DPV	0.031	0.031	0.031	0.029	0.025	0.010	0.010	0.010	0.010	0.008	0.004	0.004	0.004	0.003	0.003
PLCV	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.002
DLCV	0.180	0.179	0.178	0.172	0.169	0.009	0.009	0.008	0.008	0.006	0.003	0.003	0.003	0.003	0.002
RIG	0.183	0.182	0.180	0.172	0.174	0.051	0.051	0.050	0.047	0.044	0.018	0.017	0.017	0.016	0.014
ART	0.295	0.284	0.276	0.247	0.204	0.141	0.136	0.132	0.119	0.095	0.048	0.046	0.045	0.041	0.032
BUSD	0.147	0.151	0.151	0.147	0.140	0.069	0.073	0.073	0.068	0.059	0.045	0.047	0.047	0.044	0.038
5 – Non-Exhaust PM_{10} (g/km)															
PPV	0.034	0.034	0.034	0.026	0.022	0.034	0.034	0.034	0.026	0.022	0.034	0.034	0.034	0.026	0.022
DPV	0.034	0.034	0.034	0.026	0.022	0.034	0.034	0.034	0.026	0.022	0.034	0.034	0.034	0.026	0.022
PLCV	0.046	0.046	0.046	0.035	0.030	0.046	0.046	0.046	0.035	0.030	0.046	0.046	0.046	0.035	0.030
DLCV	0.046	0.046	0.046	0.035	0.030	0.046	0.046	0.046	0.035	0.030	0.046	0.046	0.046	0.035	0.030
RIG	0.141	0.141	0.141	0.106	0.087	0.141	0.141	0.141	0.106	0.087	0.141	0.141	0.141	0.106	0.087

Year	2021 (2016 emission factors)					2030 (2026 emission factors)					2040 (2036 emission factors)				
Veh Class	Centroid Conn.[9]	Local/Coll.[10]	Sub Arterial[11]	Arterial[12]	MW/FW[13]	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW	Centroid Conn.	Local/Coll.	Sub Arterial	Arterial	MW/FW
ART	0.182	0.182	0.182	0.143	0.120	0.182	0.182	0.182	0.143	0.120	0.182	0.182	0.182	0.143	0.120
BUSD	0.139	0.139	0.139	0.104	0.085	0.139	0.139	0.139	0.104	0.085	0.139	0.139	0.139	0.104	0.085

Table G-10-13 PIARC 2019 derived grade factors

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
PPV	PC	P	CO	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PPV	PC	P	CO	10	0.70	0.80	0.88	1.00	1.09	1.28	1.51
PPV	PC	P	CO	20	0.54	0.66	0.81	1.00	1.47	2.29	3.24
PPV	PC	P	CO	30	0.56	0.68	0.81	1.00	1.26	1.67	2.27
PPV	PC	P	CO	40	0.50	0.63	0.79	1.00	1.36	2.02	2.98
PPV	PC	P	CO	50	0.49	0.65	0.77	1.00	1.30	1.81	2.56
PPV	PC	P	CO	60	0.47	0.63	0.73	1.00	1.39	2.08	3.26
PPV	PC	P	CO	70	0.39	0.52	0.70	1.00	1.42	2.36	4.26
PPV	PC	P	CO	80	0.40	0.52	0.68	1.00	1.61	2.88	5.37
PPV	PC	P	CO	90	0.33	0.44	0.64	1.00	1.89	4.10	7.42
PPV	PC	P	CO	100	0.31	0.42	0.63	1.00	1.71	4.16	8.25
PPV	PC	P	CO	110	0.34	0.43	0.61	1.00	1.90	4.18	10.13
PPV	PC	P	CO	120	0.36	0.42	0.57	1.00	1.99	4.62	11.52
PPV	PC	P	CO	130	0.36	0.45	0.60	1.00	2.13	5.57	10.86
PPV	PC	P	NOx	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
PPV	PC	P	NOx	10	0.65	0.73	0.86	1.00	1.12	1.23	1.39
PPV	PC	P	NOx	20	0.56	0.65	0.82	1.00	1.20	1.41	1.74
PPV	PC	P	NOx	30	0.48	0.61	0.78	1.00	1.26	1.59	1.99
PPV	PC	P	NOx	40	0.45	0.57	0.76	1.00	1.33	1.62	1.99
PPV	PC	P	NOx	50	0.40	0.52	0.72	1.00	1.34	1.71	2.18
PPV	PC	P	NOx	60	0.36	0.50	0.70	1.00	1.42	1.92	2.38
PPV	PC	P	NOx	70	0.33	0.48	0.68	1.00	1.48	2.09	2.55
PPV	PC	P	NOx	80	0.27	0.40	0.62	1.00	1.43	1.90	2.38
PPV	PC	P	NOx	90	0.24	0.37	0.57	1.00	1.54	1.83	2.27
PPV	PC	P	NOx	100	0.25	0.39	0.57	1.00	1.57	1.99	2.32
PPV	PC	P	NOx	110	0.28	0.41	0.65	1.00	1.51	1.99	2.44
PPV	PC	P	NOx	120	0.28	0.41	0.67	1.00	1.34	1.78	2.17
PPV	PC	P	NOx	130	0.25	0.40	0.73	1.00	1.11	1.38	1.66
PPV	PC	P	PM	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PPV	PC	P	PM	10	0.96	0.97	0.98	1.00	1.01	1.03	1.07
PPV	PC	P	PM	20	0.97	0.98	0.99	1.00	1.02	1.05	1.10
PPV	PC	P	PM	30	0.98	0.98	0.99	1.00	1.02	1.06	1.11
PPV	PC	P	PM	40	0.99	0.99	0.99	1.00	1.02	1.06	1.11
PPV	PC	P	PM	50	0.99	0.99	0.99	1.00	1.02	1.06	1.10
PPV	PC	P	PM	60	0.98	0.98	0.98	1.00	1.03	1.08	1.16
PPV	PC	P	PM	70	0.98	0.98	0.98	1.00	1.04	1.11	1.23
PPV	PC	P	PM	80	0.96	0.97	0.97	1.00	1.06	1.14	1.34

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
PPV	PC	P	PM	90	0.96	0.96	0.96	1.00	1.09	1.23	1.50
PPV	PC	P	PM	100	0.97	0.95	0.96	1.00	1.10	1.30	1.58
PPV	PC	P	PM	110	0.95	0.94	0.95	1.00	1.11	1.31	1.61
PPV	PC	P	PM	120	0.89	0.89	0.93	1.00	1.13	1.31	1.60
PPV	PC	P	PM	130	0.80	0.83	0.89	1.00	1.18	1.35	1.55
DPV	PC	D	CO	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DPV	PC	D	CO	10	0.61	0.70	0.83	1.00	1.18	1.40	1.54
DPV	PC	D	CO	20	0.32	0.38	0.46	1.00	1.19	1.30	1.50
DPV	PC	D	CO	30	0.39	0.49	0.60	1.00	1.26	1.47	1.63
DPV	PC	D	CO	40	0.47	0.58	0.69	1.00	1.34	1.59	1.81
DPV	PC	D	CO	50	0.55	0.62	0.74	1.00	1.40	1.71	1.97
DPV	PC	D	CO	60	0.63	0.68	0.75	1.00	1.47	1.86	2.17
DPV	PC	D	CO	70	0.60	0.67	0.75	1.00	1.29	1.73	2.11
DPV	PC	D	CO	80	0.57	0.66	0.74	1.00	1.28	1.46	1.97
DPV	PC	D	CO	90	0.62	0.71	0.81	1.00	1.29	1.45	1.99
DPV	PC	D	CO	100	0.75	0.83	0.91	1.00	1.19	1.42	2.02
DPV	PC	D	CO	110	0.88	0.89	0.91	1.00	1.11	1.28	1.87
DPV	PC	D	CO	120	0.93	0.96	0.87	1.00	1.28	1.42	2.01
DPV	PC	D	CO	130	1.00	1.02	0.88	1.00	1.48	1.76	2.09
DPV	PC	D	NOx	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DPV	PC	D	NOx	10	0.64	0.74	0.85	1.00	1.19	1.39	1.63
DPV	PC	D	NOx	20	0.53	0.65	0.79	1.00	1.25	1.57	1.93

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
DPV	PC	D	NOx	30	0.46	0.58	0.74	1.00	1.29	1.70	2.13
DPV	PC	D	NOx	40	0.42	0.54	0.71	1.00	1.36	1.83	2.42
DPV	PC	D	NOx	50	0.39	0.50	0.69	1.00	1.41	1.95	2.65
DPV	PC	D	NOx	60	0.35	0.47	0.68	1.00	1.47	2.13	2.99
DPV	PC	D	NOx	70	0.30	0.43	0.65	1.00	1.51	2.18	3.04
DPV	PC	D	NOx	80	0.22	0.35	0.59	1.00	1.67	2.61	3.72
DPV	PC	D	NOx	90	0.19	0.30	0.56	1.00	1.59	2.47	3.91
DPV	PC	D	NOx	100	0.19	0.30	0.53	1.00	1.70	2.58	4.01
DPV	PC	D	NOx	110	0.19	0.32	0.55	1.00	1.67	2.61	3.61
DPV	PC	D	NOx	120	0.22	0.38	0.62	1.00	1.66	2.78	3.67
DPV	PC	D	NOx	130	0.21	0.40	0.64	1.00	1.58	2.41	3.09
DPV	PC	D	PM	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DPV	PC	D	PM	10	0.82	0.88	0.93	1.00	1.08	1.16	1.26
DPV	PC	D	PM	20	0.79	0.85	0.92	1.00	1.09	1.19	1.30
DPV	PC	D	PM	30	0.79	0.84	0.92	1.00	1.08	1.18	1.29
DPV	PC	D	PM	40	0.77	0.82	0.90	1.00	1.10	1.22	1.33
DPV	PC	D	PM	50	0.76	0.81	0.90	1.00	1.12	1.25	1.36
DPV	PC	D	PM	60	0.77	0.82	0.90	1.00	1.14	1.30	1.46
DPV	PC	D	PM	70	0.75	0.81	0.90	1.00	1.13	1.27	1.49
DPV	PC	D	PM	80	0.72	0.79	0.88	1.00	1.17	1.30	1.53
DPV	PC	D	PM	90	0.71	0.78	0.87	1.00	1.19	1.35	1.49
DPV	PC	D	PM	100	0.70	0.75	0.85	1.00	1.16	1.31	1.41

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
DPV	PC	D	PM	110	0.72	0.78	0.86	1.00	1.17	1.28	1.37
DPV	PC	D	PM	120	0.72	0.79	0.89	1.00	1.11	1.21	1.29
DPV	PC	D	PM	130	0.70	0.80	0.91	1.00	1.07	1.15	1.23
PLCV	LCV	P	CO	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PLCV	LCV	P	CO	10	0.78	0.84	0.92	1.00	1.10	1.23	1.36
PLCV	LCV	P	CO	20	0.69	0.78	0.91	1.00	1.13	1.31	1.61
PLCV	LCV	P	CO	30	0.63	0.73	0.90	1.00	1.15	1.38	1.81
PLCV	LCV	P	CO	40	0.56	0.64	0.85	1.00	1.27	1.72	1.82
PLCV	LCV	P	CO	50	0.56	0.63	0.82	1.00	1.29	1.77	2.02
PLCV	LCV	P	CO	60	0.59	0.68	0.88	1.00	1.35	1.90	2.95
PLCV	LCV	P	CO	70	0.48	0.57	0.79	1.00	1.39	2.13	4.20
PLCV	LCV	P	CO	80	0.53	0.63	0.83	1.00	1.67	2.77	6.57
PLCV	LCV	P	CO	90	0.44	0.57	0.84	1.00	2.00	4.91	11.65
PLCV	LCV	P	CO	100	0.46	0.64	0.93	1.00	2.23	6.44	14.83
PLCV	LCV	P	CO	110	0.46	0.63	0.85	1.00	2.56	7.18	14.61
PLCV	LCV	P	CO	120	0.37	0.51	0.69	1.00	2.49	5.79	9.25
PLCV	LCV	P	CO	130	0.23	0.31	0.48	1.00	2.24	3.69	4.32
PLCV	LCV	P	NOx	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PLCV	LCV	P	NOx	10	0.48	0.62	0.79	1.00	1.25	1.56	1.86
PLCV	LCV	P	NOx	20	0.39	0.47	0.65	1.00	1.34	1.90	2.23
PLCV	LCV	P	NOx	30	0.34	0.36	0.54	1.00	1.39	1.86	2.27
PLCV	LCV	P	NOx	40	0.30	0.33	0.55	1.00	1.53	2.13	2.69

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
PLCV	LCV	P	NOx	50	0.22	0.27	0.59	1.00	1.65	2.35	3.10
PLCV	LCV	P	NOx	60	0.12	0.22	0.52	1.00	1.64	1.96	2.83
PLCV	LCV	P	NOx	70	0.09	0.21	0.52	1.00	1.62	2.00	2.69
PLCV	LCV	P	NOx	80	0.06	0.16	0.46	1.00	1.56	1.76	2.08
PLCV	LCV	P	NOx	90	0.07	0.18	0.51	1.00	1.55	1.62	1.76
PLCV	LCV	P	NOx	100	0.11	0.21	0.53	1.00	1.45	1.45	1.46
PLCV	LCV	P	NOx	110	0.13	0.25	0.57	1.00	1.23	1.15	1.08
PLCV	LCV	P	NOx	120	0.13	0.29	0.64	1.00	1.07	0.95	0.88
PLCV	LCV	P	NOx	130	0.16	0.37	0.73	1.00	1.01	0.90	0.85
PLCV	LCV	P	PM	0	0.65	0.75	0.87	1.00	1.34	1.86	2.77
PLCV	LCV	P	PM	10	0.96	0.97	0.98	1.00	1.04	1.10	1.21
PLCV	LCV	P	PM	20	0.96	0.97	0.98	1.00	1.05	1.14	1.29
PLCV	LCV	P	PM	30	0.96	0.96	0.98	1.00	1.05	1.15	1.32
PLCV	LCV	P	PM	40	0.94	0.95	0.96	1.00	1.07	1.24	1.32
PLCV	LCV	P	PM	50	0.96	0.96	0.98	1.00	1.05	1.16	1.35
PLCV	LCV	P	PM	60	0.96	0.97	0.98	1.00	1.07	1.22	1.51
PLCV	LCV	P	PM	70	0.91	0.92	0.95	1.00	1.11	1.35	1.85
PLCV	LCV	P	PM	80	0.93	0.94	0.96	1.00	1.18	1.55	2.40
PLCV	LCV	P	PM	90	0.94	0.95	0.97	1.00	1.27	1.82	2.74
PLCV	LCV	P	PM	100	0.90	0.91	0.92	1.00	1.37	1.87	2.95
PLCV	LCV	P	PM	110	0.78	0.81	0.84	1.00	1.30	1.95	2.98
PLCV	LCV	P	PM	120	0.73	0.78	0.83	1.00	1.31	2.28	3.09

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
PLCV	LCV	P	PM	130	0.72	0.76	0.83	1.00	1.49	2.58	3.25
DLCV	LCV	D	CO	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DLCV	LCV	D	CO	10	0.63	0.72	0.86	1.00	1.11	1.26	1.42
DLCV	LCV	D	CO	20	0.57	0.67	0.84	1.00	1.09	1.18	1.29
DLCV	LCV	D	CO	30	0.53	0.66	0.83	1.00	1.12	1.22	1.31
DLCV	LCV	D	CO	40	0.52	0.66	0.82	1.00	1.15	1.25	1.43
DLCV	LCV	D	CO	50	0.51	0.68	0.81	1.00	1.19	1.35	1.47
DLCV	LCV	D	CO	60	0.49	0.67	0.78	1.00	1.26	1.42	1.59
DLCV	LCV	D	CO	70	0.46	0.69	0.77	1.00	1.30	1.44	1.65
DLCV	LCV	D	CO	80	0.55	0.71	0.79	1.00	1.33	1.46	1.70
DLCV	LCV	D	CO	90	0.68	0.77	0.79	1.00	1.37	1.50	1.96
DLCV	LCV	D	CO	100	0.74	0.83	0.80	1.00	1.42	1.67	2.06
DLCV	LCV	D	CO	110	0.80	0.86	0.84	1.00	1.45	1.77	2.05
DLCV	LCV	D	CO	120	0.67	0.72	0.82	1.00	1.28	1.42	1.57
DLCV	LCV	D	CO	130	0.56	0.70	0.82	1.00	1.18	1.25	1.33
DLCV	LCV	D	NOx	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DLCV	LCV	D	NOx	10	0.58	0.67	0.81	1.00	1.26	1.53	1.78
DLCV	LCV	D	NOx	20	0.45	0.57	0.74	1.00	1.36	2.37	2.99
DLCV	LCV	D	NOx	30	0.37	0.50	0.70	1.00	1.41	2.36	3.10
DLCV	LCV	D	NOx	40	0.31	0.44	0.65	1.00	1.51	2.55	3.45
DLCV	LCV	D	NOx	50	0.26	0.38	0.61	1.00	1.59	2.42	3.43
DLCV	LCV	D	NOx	60	0.22	0.42	0.58	1.00	2.05	3.11	4.41

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
DLCV	LCV	D	NOx	70	0.15	0.30	0.56	1.00	1.64	2.49	3.53
DLCV	LCV	D	NOx	80	0.11	0.22	0.46	1.00	1.75	2.51	3.38
DLCV	LCV	D	NOx	90	0.15	0.27	0.52	1.00	1.77	2.50	3.14
DLCV	LCV	D	NOx	100	0.16	0.31	0.57	1.00	1.60	2.22	2.76
DLCV	LCV	D	NOx	110	0.18	0.36	0.62	1.00	1.41	1.81	2.13
DLCV	LCV	D	NOx	120	0.22	0.42	0.69	1.00	1.31	1.55	1.72
DLCV	LCV	D	NOx	130	0.30	0.50	0.75	1.00	1.22	1.34	1.41
DLCV	LCV	D	PM	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DLCV	LCV	D	PM	10	0.78	0.82	0.90	1.00	1.12	1.24	1.32
DLCV	LCV	D	PM	20	0.72	0.79	0.89	1.00	1.11	1.28	1.48
DLCV	LCV	D	PM	30	0.73	0.78	0.88	1.00	1.21	1.44	1.63
DLCV	LCV	D	PM	40	0.69	0.79	0.87	1.00	1.18	1.44	1.65
DLCV	LCV	D	PM	50	0.66	0.74	0.87	1.00	1.16	1.50	1.58
DLCV	LCV	D	PM	60	0.63	0.71	0.83	1.00	1.14	1.47	1.61
DLCV	LCV	D	PM	70	0.62	0.68	0.80	1.00	1.24	1.45	1.64
DLCV	LCV	D	PM	80	0.64	0.69	0.81	1.00	1.22	1.40	1.57
DLCV	LCV	D	PM	90	0.67	0.74	0.83	1.00	1.19	1.36	1.53
DLCV	LCV	D	PM	100	0.72	0.79	0.88	1.00	1.16	1.33	1.47
DLCV	LCV	D	PM	110	0.71	0.79	0.88	1.00	1.13	1.27	1.40
DLCV	LCV	D	PM	120	0.72	0.81	0.90	1.00	1.14	1.26	1.35
DLCV	LCV	D	PM	130	0.71	0.80	0.89	1.00	1.12	1.21	1.24
BUSD	HGV	D	CO	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
BUSD	HGV	D	CO	10	0.55	0.67	0.82	1.00	1.15	1.33	1.49
BUSD	HGV	D	CO	20	0.45	0.51	0.80	1.00	1.18	1.37	1.58
BUSD	HGV	D	CO	30	0.37	0.42	0.77	1.00	1.28	1.58	1.77
BUSD	HGV	D	CO	40	0.22	0.32	0.70	1.00	1.39	1.79	2.05
BUSD	HGV	D	CO	50	0.14	0.21	0.66	1.00	1.47	1.93	2.20
BUSD	HGV	D	CO	60	0.10	0.18	0.57	1.00	1.53	1.79	1.94
BUSD	HGV	D	CO	70	0.09	0.15	0.50	1.00	1.57	1.68	1.75
BUSD	HGV	D	CO	80	0.08	0.13	0.45	1.00	1.60	1.68	1.67
BUSD	HGV	D	CO	90	0.08	0.13	0.47	1.00	1.61	1.77	1.75
BUSD	HGV	D	CO	100	0.07	0.12	0.45	1.00	1.58	1.79	1.78
BUSD	HGV	D	NOx	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUSD	HGV	D	NOx	10	0.63	0.76	0.89	1.00	1.07	1.14	1.20
BUSD	HGV	D	NOx	20	0.46	0.62	0.86	1.00	1.11	1.17	1.26
BUSD	HGV	D	NOx	30	0.35	0.52	0.81	1.00	1.11	1.20	1.38
BUSD	HGV	D	NOx	40	0.23	0.40	0.66	1.00	1.13	1.34	1.66
BUSD	HGV	D	NOx	50	0.18	0.30	0.57	1.00	1.16	1.50	1.89
BUSD	HGV	D	NOx	60	0.13	0.20	0.51	1.00	1.48	2.01	2.46
BUSD	HGV	D	NOx	70	0.09	0.12	0.43	1.00	1.75	2.45	2.93
BUSD	HGV	D	NOx	80	0.08	0.11	0.40	1.00	1.97	2.81	3.32
BUSD	HGV	D	NOx	90	0.08	0.11	0.39	1.00	2.01	2.86	3.31
BUSD	HGV	D	NOx	100	0.08	0.11	0.38	1.00	2.01	2.83	3.22
BUSD	HGV	D	PM	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NSW EPA Vehicle Class	PIARC Vehicle Class	Fuel	Pollutant	Speed	6%	4%	2%	0%	2%	4%	6%
BUSD	HGV	D	PM	10	0.82	0.86	0.93	1.00	1.07	1.14	1.21
BUSD	HGV	D	PM	20	0.82	0.86	0.95	1.00	1.06	1.13	1.21
BUSD	HGV	D	PM	30	0.84	0.87	0.94	1.00	1.08	1.16	1.22
BUSD	HGV	D	PM	40	0.82	0.84	0.91	1.00	1.10	1.19	1.27
BUSD	HGV	D	PM	50	0.82	0.84	0.91	1.00	1.11	1.21	1.29
BUSD	HGV	D	PM	60	0.83	0.84	0.91	1.00	1.14	1.28	1.37
BUSD	HGV	D	PM	70	0.83	0.85	0.91	1.00	1.16	1.33	1.43
BUSD	HGV	D	PM	80	0.81	0.82	0.88	1.00	1.15	1.33	1.43
BUSD	HGV	D	PM	90	0.80	0.80	0.86	1.00	1.13	1.26	1.34
BUSD	HGV	D	PM	100	0.81	0.81	0.86	1.00	1.14	1.24	1.31

Appendix H

Modelled road links

Appendix H– Modelled road links

The links digitized in the model are presented in the following figures; existing road in **Figure H-26** and proposal in **Figure H-27**.

Figure H-26 Links modelled for the existing and 'do nothing' scenarios (red lines)

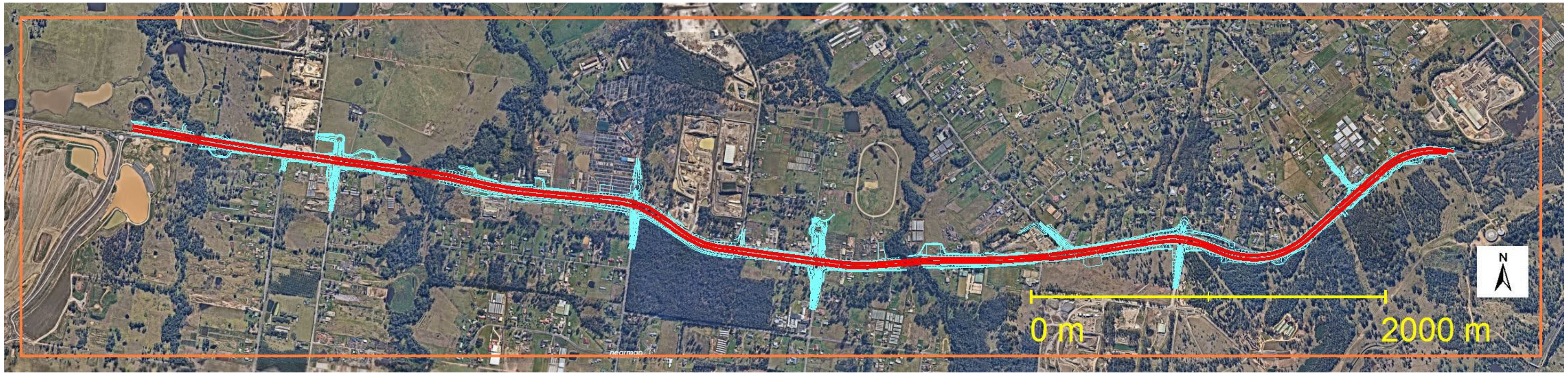

Figure H-27 Links modelled for the proposal scenarios (red lines) ()

Appendix I

Predicted incremental and cumulative air quality impacts

Appendix I Predicted incremental and cumulative air quality impacts

This Appendix provides a detailed assessment of predicted incremental and cumulative air quality impacts from the proposal. Predicted ground level concentrations are presented in the context of:

- Road contributions (or incremental contributions) from road traffic in isolation for all pollutants for the worst affected receptors in each modelling domain. Road contributions for all sensitive receptors have also been presented graphically for each modelled scenario.
- Cumulative concentrations for the worst affected receptor where the road contribution is added to the background concertation and assessed against relevant EPA criteria for pollutants NO_2, CO, PM_{10} and $PM_{2.5}$.
    - Background data used to estimate predicted cumulative impacts for NO_2 and particulates have utilised the background data interpolation methodology as described in **Section 5.7.8** of this report and **Appendix E**.
    - Background data used to estimate predicted cumulative impacts for 1-hour and 8-hour maximum CO have been based on the maximum recorded values at Liverpool monitoring station between 2016 and 2020 as discussed in **Section 4.2.2.2** of this report.

Nitrogen dioxide

The following section provides a discussion on predicted incremental (road contributions) and cumulative maximum 1-hour and annual average NO_2 ground level concentrations at sensitive receptors. Predicted NO_2 ground level concentrations are discussed for each modelled scenario.

NO_2 concentrations were based on the concentration of NO_X and the conversion ratio outlined in **Section 5.7.9**. Background data used to estimate predicted cumulative impacts for NO_2 and utilise the background data interpolation methodology as described in **Section 5.7.8** and **Appendix E**.

Road contributions

Predicted incremental maximum 1-hour NO_2 concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-14**. Predicted incremental maximum 1-hour NO_2 at all sensitive receptors are provided in **Figure I-28**.

All receptors were predicted to have maximum concentrations above the EPA criterion for 1-hour NO_2 of 164 µg/m³ for all scenarios except the 2040 'do nothing'. As discussed in **Section 7.3**, the 'do nothing' scenarios did not model queuing, which would be expected in both the 2030 and 2040 'do nothing' scenarios. The values presented here for the 'do nothing' scenarios are, therefore, likely to be an underestimate of actual potential NO_2 concentrations.

Table I-10-14 Predicted incremental maximum 1-hour NO_2 concentrations for all modelled scenarios

Statistic	Predicted Incremental Maximum 1 hour NO2 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	180	179	202	157	183
Criteria (µg/m³)	164				

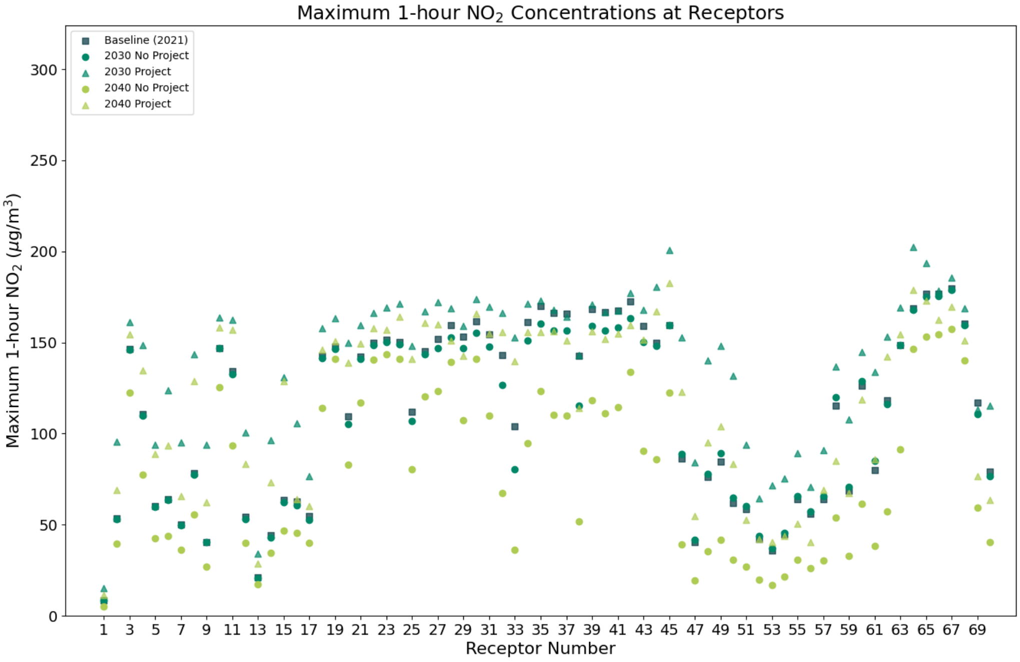

Figure I-28 Predicted maximum 1-hour NO_2 incremental concentration at sensitive receptors

Predicted incremental annual average NO_2 concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-15** and predicted incremental annual average NO_2 at all sensitive receptors are provided in **Figure I-29**.

Concentrations at all receptors for the proposal in 2030 were predicted to be above the EPA criterion for annual average NO_2 of 31 µg/m^3. All other scenarios were below the criterion.

Table I-10-15 Predicted incremental maximum annual average NO_2 concentrations for all modelled scenarios.

Statistic	Predicted Incremental Maximum Annual Average NO_2 Concentration (µg/m^3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	15.0	12.6	42.0	5.9	30.7
Criteria (µg/m^3)	31				

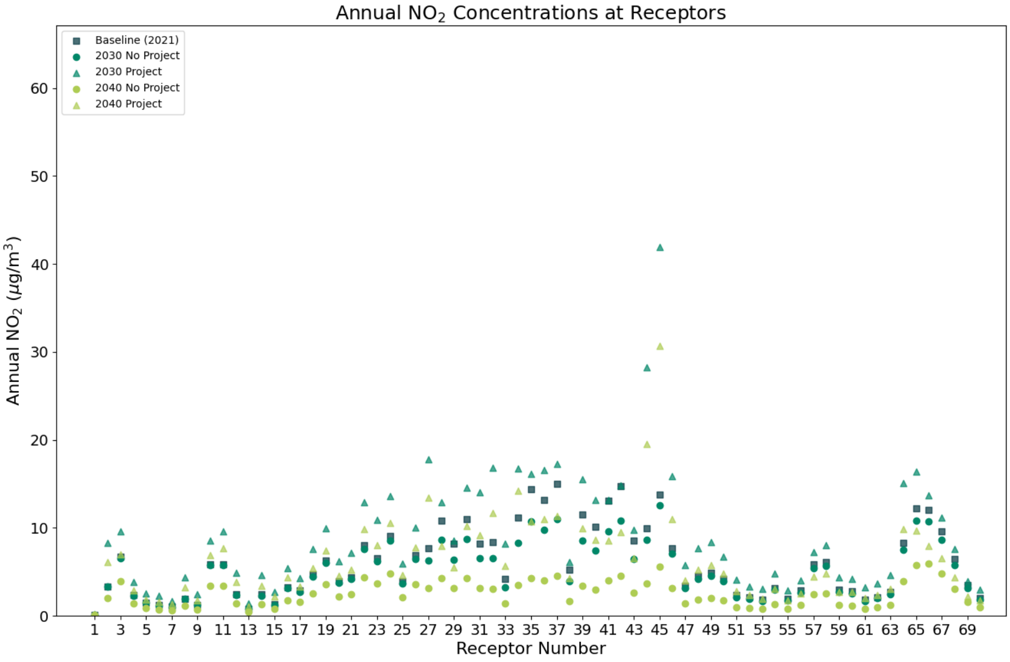

Figure I-29 **Predicted annual average NO$_2$ incremental concentration at sensitive receptors**

Cumulative concentrations

Cumulative concentrations of maximum 1-hour NO$_2$ are presented in **Table I-10-16**. Concentrations at the worst affected receptor above the EPA criterion of 164 µg/m^3 for all scenarios.

Table I-10-16 **Predicted cumulative maximum 1-hour NO$_2$ concentrations for all modelled scenarios.**

Statistic	Predicted Cumulative Maximum 1 hour NO2 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	204	203	225	182	207
Criteria (µg/m^3)	164				

Cumulative concentrations of maximum annual average NO$_2$ are presented in **Table I-10-17**. Concentrations at the worst affected receptor were above the EPA criterion of 31 µg/m^3 for both future proposal scenarios.

Table I-10-17 **Predicted cumulative maximum annual average NO$_2$ concentrations for all modelled scenarios.**

Statistic	Predicted Cumulative Maximum Annual Average NO2 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	23.4	21.0	50.4	14.3	39.1
Criteria (µg/m^3)	31				

Carbon monoxide

The following section provides a discussion on predicted incremental (road contributions) and cumulative maximum 1-hour and 8-hour CO ground level concentrations at sensitive receptors. Predicted CO ground level concentrations are discussed for each modelled scenario.

Background data used to estimate predicted cumulative impacts for 1-hour and 8-hour maximum CO have been based on the maximum recorded values at Liverpool monitoring station between 2016 and 2021 as discussed in **Section 4.2.2.2** of this report.

Road contributions

Predicted incremental 1-hour maximum CO concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-18** and predicted incremental 1-hour maximum CO concentrations at all sensitive receptors are provided in **Figure I-30**.

Concentrations were predicted to become lower in the future scenarios (2026 and 2036) compared with the existing baseline. Concentrations were well below the EPA criterion for all scenarios.

Table I-10-18 Predicted incremental maximum 1-hour CO concentrations for all modelled scenarios.

Statistic	Predicted Incremental Maximum 1 hour CO Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	546	394	607	233	424
Criteria (µg/m^3)	30,000				

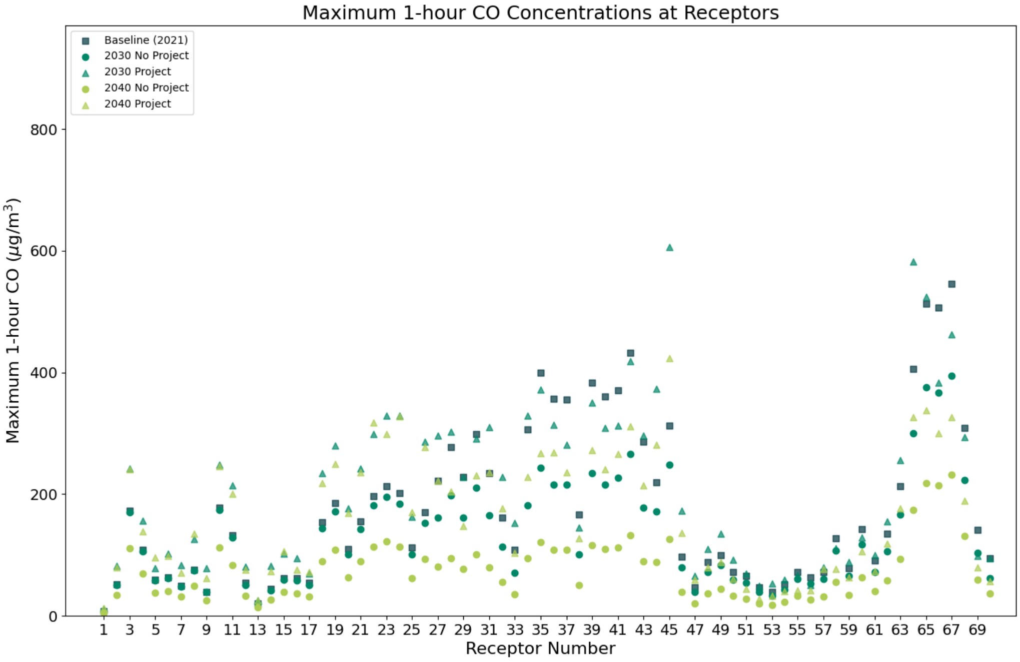

Figure I-30 Predicted maximum 1-hour CO incremental concentration at sensitive receptors

Predicted incremental 8-hour maximum CO concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-19**. Predicted incremental 8-hour maximum CO concentrations at all sensitive receptors are provided in **Figure I-31**.

Concentrations were well below the EPA criterion for all scenarios.

Table I-10-19 Predicted incremental maximum 8-hour CO concentrations for all modelled scenarios.

Statistic	Predicted Incremental Maximum 8 hour CO Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	143	88	182	49	145
Criteria (µg/m^3)	10,000				

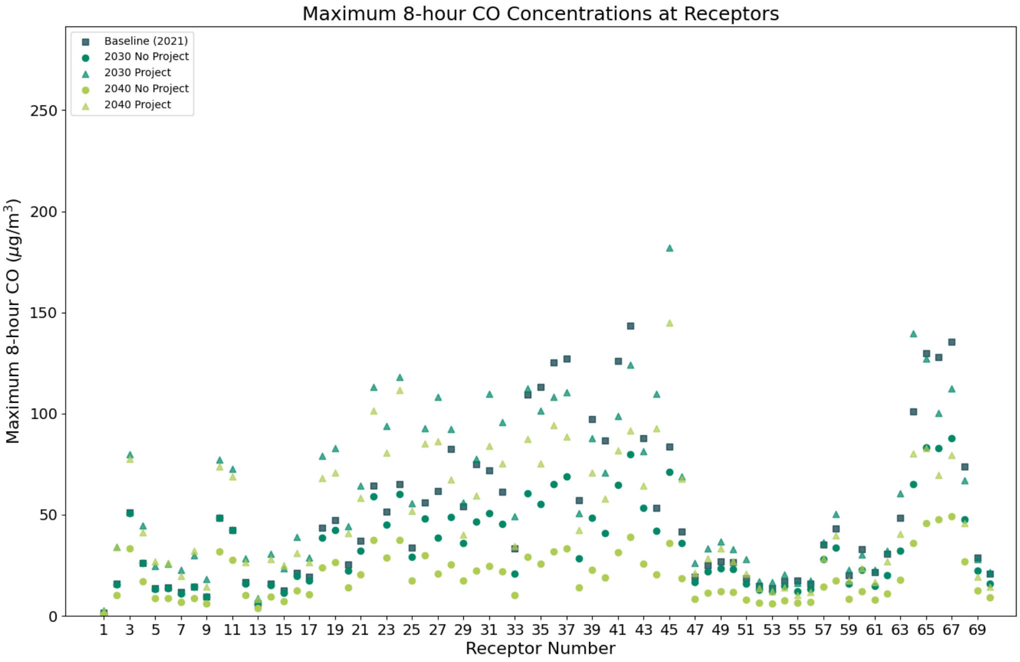

Figure I-31 Predicted maximum 8-hour CO incremental concentration at sensitive receptors

Cumulative concentrations

Cumulative 1-hour CO concentrations are presented in **Table I-10-20**. Existing background values of 4,625 µg/m^3 was adopted from Liverpool monitoring station. Cumulative concentrations were well below the EPA criterion at all receptors for all scenarios.

Table I-10-20 Predicted Cumulative Maximum 1-hour CO_2 Concentrations for all Modelled Scenarios.

Statistic	Predicted Cumulative Maximum 1 hour CO Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	5,171	5,019	5,232	4,858	5,049
Criteria (µg/m^3)	30,000				

Cumulative 8-hour CO concentrations are presented in **Table I-10-21**. Existing background values of 2,140 µg/m^3 was adopted from data measured at Liverpool monitoring station. Cumulative concentrations were well below the EPA criterion at all receptors for all scenarios.

Table I-10-21 Predicted cumulative Maximum 8-hour CO_2 concentrations for all modelled scenarios.

Statistic	Predicted Cumulative Maximum 8 hour CO Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	2,283	2,228	2,322	2,189	2,285
Criteria (µg/m^3)	10,000				

Particulate matter (PM_{10})

The following section provides a discussion on predicted incremental (road contributions) and cumulative maximum 24-hour and annual average PM_{10} ground level concentrations at sensitive receptors. Predicted PM_{10} ground level concentrations are discussed for each modelled scenario.

Background data used to estimate predicted cumulative impacts for PM_{10} and utilise the background data interpolation methodology as described in **Section 5.7.8** and **Appendix E**.

Road contributions

Predicted incremental 24-hour maximum PM_{10} concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-22**. Predicted incremental 24-hour maximum PM_{10} concentrations at all sensitive receptors are provided in **Figure 10-32**.

Concentrations were predicted to be well below the EPA criterion.

Table I-10-22 Predicted incremental maximum 24-hour PM_{10} concentrations for all modelled scenarios.

Statistic	Predicted Incremental Maximum 24 hour PM_{10} Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	6.2	4.2	6.4	3.2	6.6
Criteria (µg/m^3)	50				

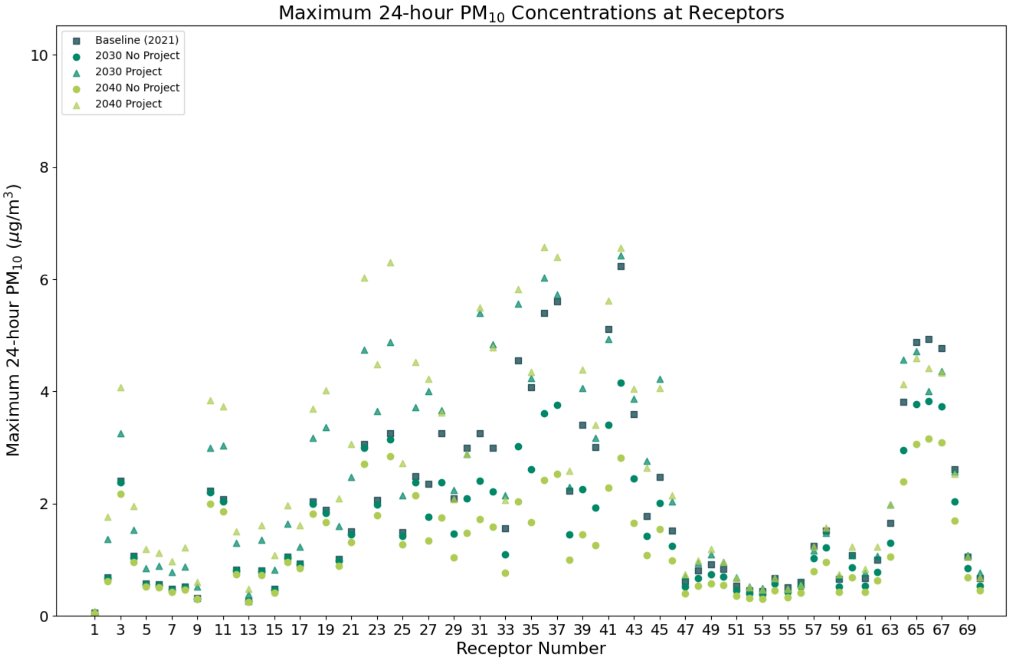

Figure 10-32 **Predicted maximum 24-hour PM_{10} incremental concentration at sensitive receptors**

Predicted incremental annual average PM_{10} concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-23.**

Predicted incremental annual average PM_{10} concentrations at all sensitive receptors are provided in **Figure I-33**. Annual concentrations were predicted to be well below the EPA criterion.

Table I-10-23 **Predicted incremental maximum annual average PM_{10} concentrations for all modelled scenarios.**

Statistic	Predicted Incremental Maximum Annual Average PM_{10} Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	1.3	0.9	1.8	0.7	1.7
Criteria (µg/m^3)	25				

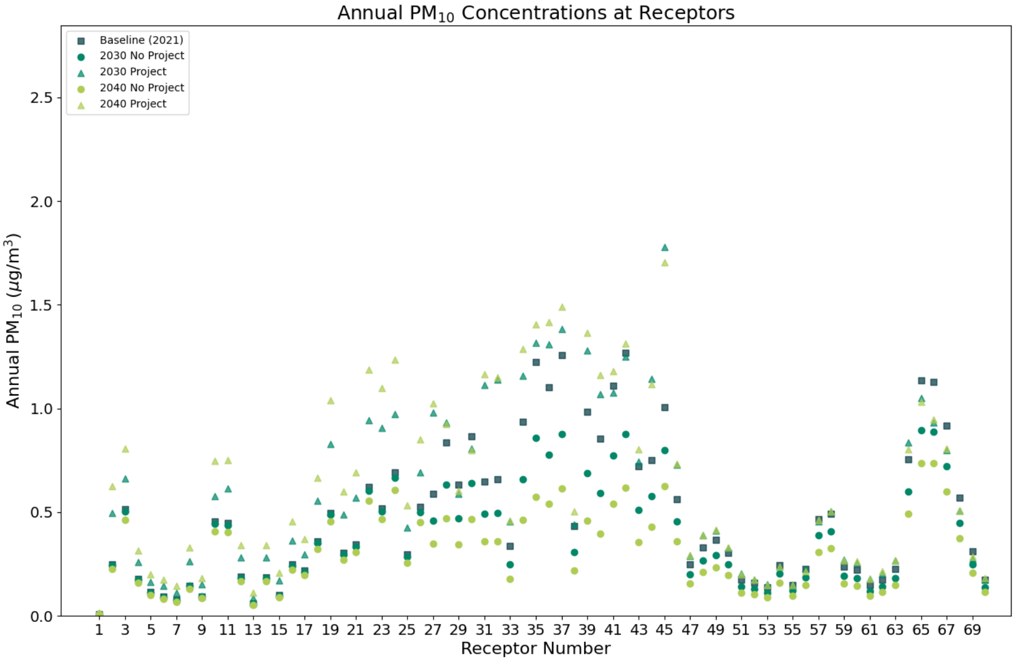

Figure I-33 **Predicted annual average PM_{10} incremental concentration at sensitive receptors**

Cumulative concentrations

Cumulative 24-hour PM_{10} concentrations are presented in **Table I-10-24**. Interpolated background 1-hour PM_{10} concentrations were combined with model predicted 1-hour PM_{10} concentrations at each receptor and then averaged to 24-hour values.

The highest cumulative concentrations were above the EPA criterion for all scenarios, both with and without the proposal. This is not unexpected, however, due to concentrations above the criterion observed in the background data (see **Section 4.2.2.3** of this report). Overall, there was little difference in the predicted maximum cumulative concentrations between scenarios, suggesting that they are likely mostly due to existing background concentrations.

Table I-10-24 **Predicted cumulative maximum 24-hour PM_{10} concentrations for all modelled scenarios.**

Statistic	Predicted Cumulative Maximum 24 hour PM10 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	67.1	65.9	67.4	65.1	67.7
Criteria ($\mu g/m^3$)	50				

Predicted annual average PM_{10} concentrations for the worst affect receptor are presented in **Table I-10-25**. Predicted concentrations were predicted to be below the EPA criterion at all receptors for all scenarios.

Table I-10-25 Predicted cumulative maximum annual average PM_{10} concentrations for all modelled scenarios.

Statistic	Predicted Cumulative Maximum Annual Average PM10 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	19.4	19.1	19.9	18.9	19.9
Criteria ($\mu g/m^3$)	25				

Particulate matter ($PM_{2.5}$)

The following section provides a discussion on predicted incremental (road contributions) and cumulative maximum 24-hour and annual average $PM_{2.5}$ ground level concentrations at sensitive receptors. Predicted $PM_{2.5}$ ground level concentrations are discussed for each modelled scenario.

Background data used to estimate predicted cumulative impacts for $PM_{2.5}$ and utilise the background data interpolation methodology as described in **Section 5.7.8** of this report and **Appendix E**.

Road contributions

Predicted incremental 24-hour maximum $PM_{2.5}$ concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-26**. Predicted incremental 24-hour maximum $PM_{2.5}$ concentrations at all sensitive receptors are provided in **Figure I-34**.

Predicted concentrations were well below the EPA criterion at all receptors for all scenarios.

Table I-10-26 Predicted incremental maximum 24-hour $PM_{2.5}$ concentrations for all modelled scenarios.

Statistic	Predicted Incremental Maximum 24 hour PM2.5 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	4.7	2.6	4.0	1.8	3.8
Criteria ($\mu g/m^3$)	25				

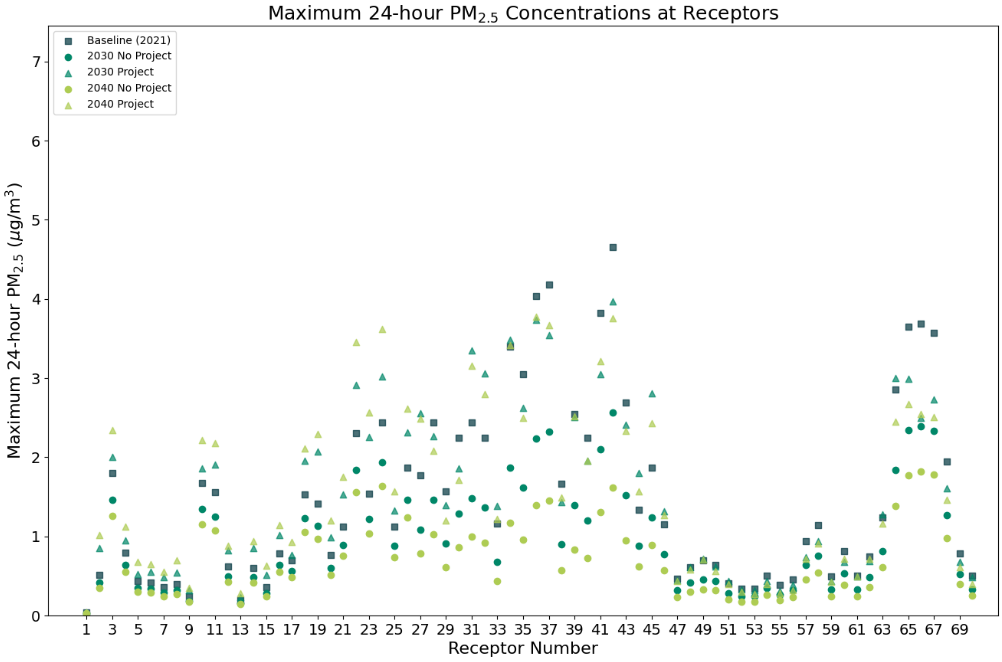

Figure I-34 **Predicted maximum 24-hour $PM_{2.5}$ incremental concentration at sensitive receptors**

Predicted incremental annual average $PM_{2.5}$ concentrations at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-27** and predicted incremental annual average $PM_{2.5}$ concentrations at all sensitive receptors are provided in **Figure I-35**.

Predicted concentrations were well below the EPA criterion at all receptors for all scenarios.

Table I-10-27 **Predicted incremental maximum annual average $PM_{2.5}$ concentrations for all modelled scenarios.**

Statistic	Predicted Incremental Maximum Annual Average PM2.5 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	0.9	0.6	1.2	0.4	1.0
Criteria (µg/m^3)	8				

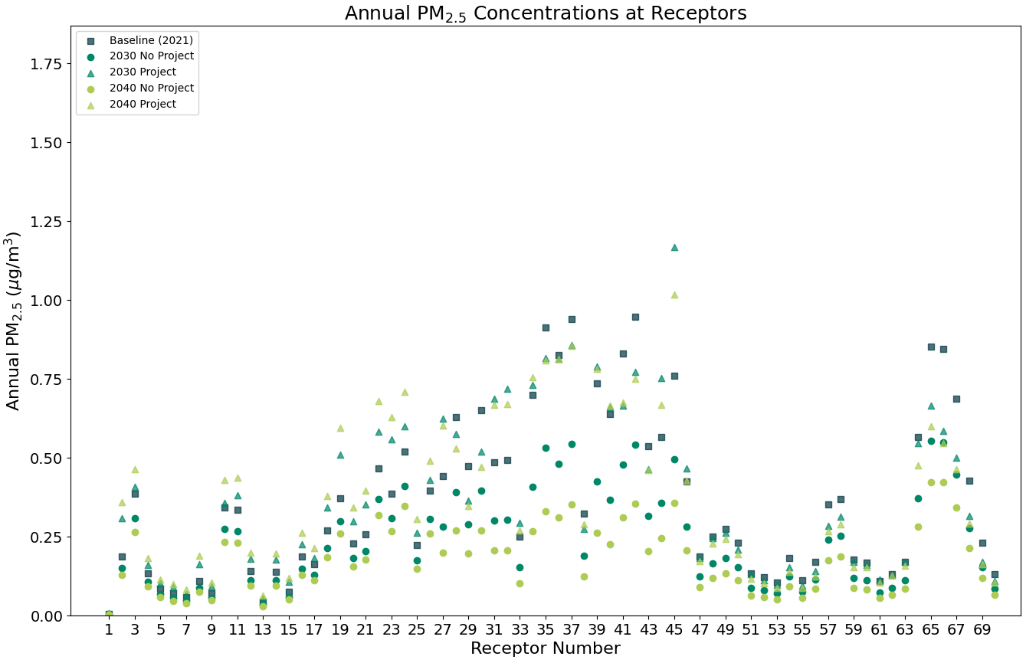

Figure I-35 **Predicted annual average $PM_{2.5}$ incremental concentration at sensitive receptors**

Cumulative Concentrations

Cumulative concentrations of 24-hour $PM_{2.5}$ are presented in **Table I-10-28**. Existing background concentrations (see **Section 4.2.2.4**) had maximum concentrations above the criterion so all cumulative concentrations were also predicted to be above the criterion.

Table I-10-28 **Predicted cumulative maximum 24-hour $PM_{2.5}$ concentrations for all modelled scenarios.**

Statistic	Predicted Cumulative Maximum 24 hour PM2.5 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	44.0	42.7	43.7	42.2	43.7
Criteria (µg/m^3)	25				

The highest cumulative annual average $PM_{2.5}$ concentrations predicted at the modelled receptors are presented in **Table I-10-29**. Predicted concentrations were slightly below the criterion for all scenarios, primarily driven by background concentrations which were already approaching the criterion.

Table I-10-29 **Predicted cumulative maximum annual average $PM_{2.5}$ concentrations for all modelled scenarios.**

Statistic	Predicted Cumulative Maximum Annual Average PM2.5 Concentration (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	7.8	7.4	8.0	7.3	7.8
Criteria (µg/m^3)	8				

Volatile organic compounds (VOCs)

The following section provides a discussion on predicted incremental (road contributions) 1-hour 99.9th percentile ground level concentrations at sensitive receptors for VOCs. Predicted benzene and formaldehyde ground level concentrations are discussed for each modelled scenario.

Road contributions from benzene

Predicted incremental 1-hour 99.9th percentile concentrations for benzene at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-30**.Predicted incremental 1-hour 99.9th percentile concentrations for benzene at all sensitive receptors are provided in **Figure I-36**. Concentrations of benzene are well below the EPA criterion for all scenarios.

Table I-10-30 Predicted incremental 1-hour 99.th percentile concentrations for benzene for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for Benzene (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	0.8	0.3	0.5	0.2	0.3
Criteria (µg/m^3)	29				

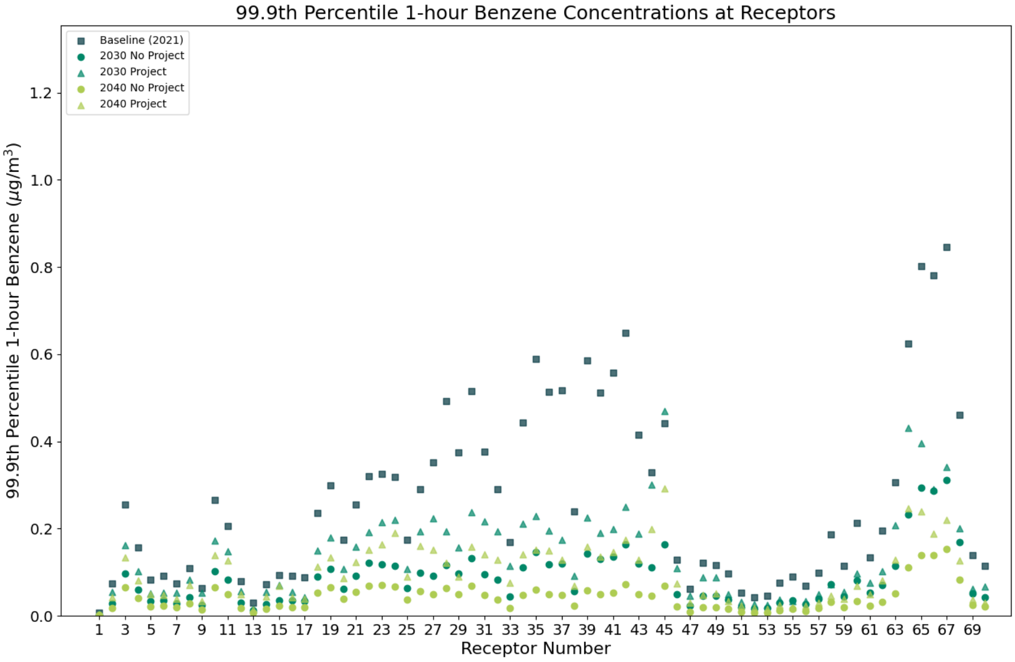

Figure I-36 Predicted 1-hour 99.9th %ile benzene incremental concentration at sensitive receptors

Road contributions from formaldehyde

Predicted incremental 1-hour 99.9th percentile concentrations for formaldehyde at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-31**. Predicted incremental 1-hour 99.9th percentile concentrations for formaldehyde at all sensitive receptors are provided in **Figure I-37**. Concentrations were well below the EPA criterion for all scenarios.

Table I-10-31 Predicted incremental 1-hour 99.th percentile concentrations for formaldehyde for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for Formaldehyde (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	0.5	0.2	0.3	0.1	0.2
Criteria (µg/m^3)	20				

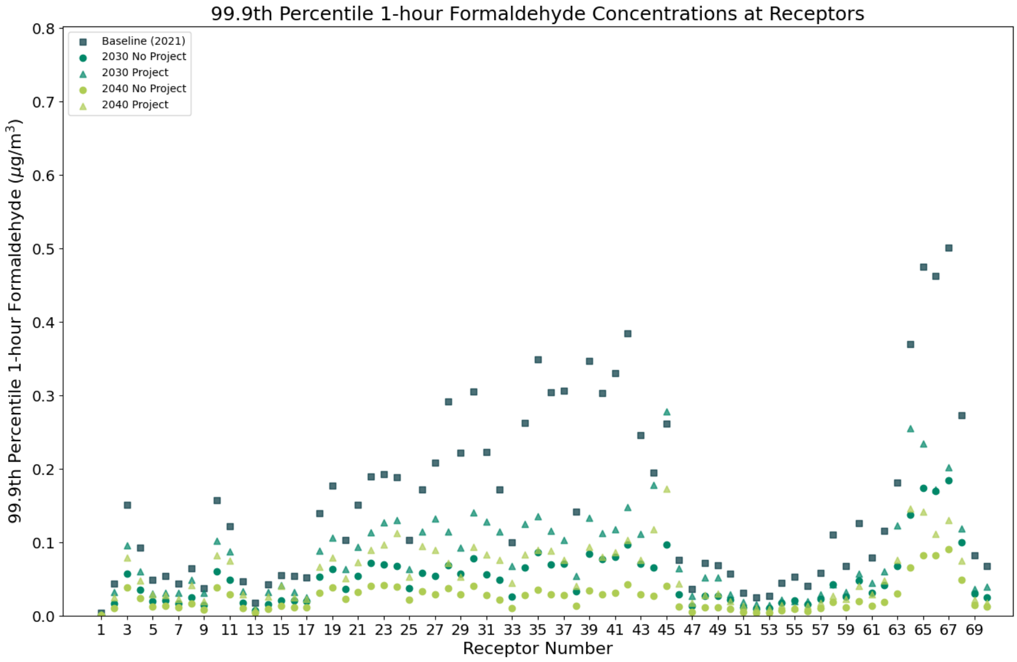

Figure I-37 Predicted 1-hour 99.9th %ile formaldehyde incremental concentration at sensitive receptors

Predicted concentrations for other VOCs 1,3 butadiene, acetaldehyde, toluene and xylene are presented in **Table I-10-32** to **Table I-10-35**. These tables represent the maximum 99.9th percentile concentrations at the worst affected receptors for each domain. The predicted concentrations are well below the respective criterion for each pollutant.

Table I-10-32 Predicted incremental 1-hour 99.th percentile concentrations for 1,3 butadiene for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for 1,3 Butadiene (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	0.20	0.07	0.11	0.04	0.07
Criteria (µg/m^3)	40				

Table I-10-33 Predicted incremental 1-hour 99.th percentile concentrations for acetaldehyde for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for Acetaldehyde (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	0.20	0.07	0.11	0.04	0.07
Criteria (µg/m^3)	42				

Table I-10-34 Predicted incremental 1-hour 99.th percentile concentrations for toluene for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for Toluene (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	1.8	0.6	1.0	0.3	0.6
Criteria (µg/m^3)	360				

Table I-10-35 Predicted incremental 1-hour 99.th percentile concentrations for xylene for all modelled scenarios.

Statistic	Predicted Highest 1 hour 99.9%ile Concentrations for Xylene (µg/m3)				
	Existing 2021	2030		2040	
		Do Nothing	Proposal	Do Nothing	Proposal
Highest value at a receptor	1.3	0.5	0.7	0.2	0.5
Criteria (µg/m^3)	190				

Polycyclic aromatic hydrocarbons (PAHs)

The following section provides a discussion on predicted incremental (road contributions) 1-hour 99.9th percentile ground level concentrations at sensitive receptors for total PAHs expressed as BaP equivalent. Predicted benzene and formaldehyde ground level concentrations are discussed for each modelled scenario.

Road contributions

Predicted incremental 1-hour 99.9th percentile concentrations for total PAHs (as BaP) at the worst affected sensitive receptors for all modelled scenarios reported against the EPA criterion are shown in **Table I-10-36**. Predicted incremental 1-hour 99.9th percentile concentrations for total PAHs at all sensitive receptors are provided in **Figure I-38**.

Concentrations of PAS (as BaP) were predicted to be well below the EPA criterion for all scenarios.

Table I-10-36 Predicted incremental 1-hour 99.th percentile concentrations for total PAHs (BaP) for all modelled scenarios.

Modelling Domain	**Predicted Highest 1 hour 99.9%ile Concentrations for PAH (µg/m3)**				
	Existing 2021	**2030**		**2040**	
		Do Nothing	**Proposal**	**Do Nothing**	**Proposal**
South Domain	0.0008	0.0003	0.0005	0.0001	0.0003
Criteria (µg/m^3)	0.04				

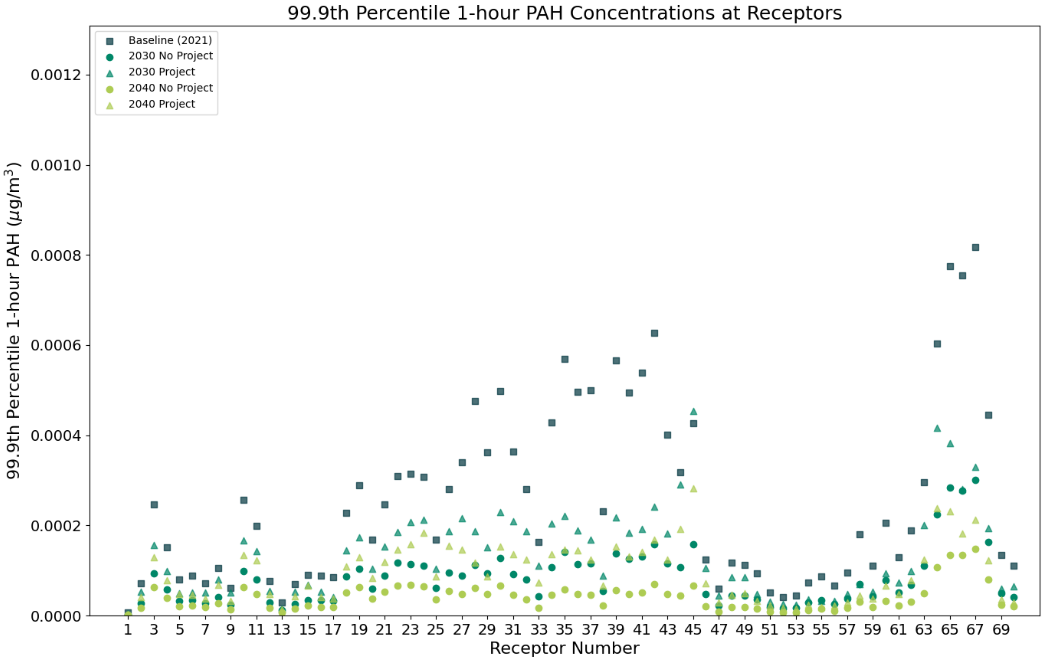

Figure I-38 Predicted 1-hour 99.9th %ile PAHs (as BaP) incremental concentration at sensitive receptors