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NSW GOVERNMENT

M1 Pacific Motorway extension to Raymond Terrace

Air Quality Working Paper

Transport for NSW | July 2021

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Executive summary

Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Performance outcomes

This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to air quality. In addition, the desired performance outcome for the project in relation to air quality as outlined in the SEARs (SSI 7319) is to:

- Minimise air quality impacts (including nuisance dust and odour) to reduce risks to human health and the environment to the greatest extent practicable through the design, construction and operation of the project.

Overview of air quality impacts

The key potential air quality issues for the project were identified as dust during construction, emissions from vehicles using the existing and modified road network during operation, and odour from asphalt batching.

A detailed review of the existing environment was carried out including an analysis of historically measured concentrations of key quality indicators (CO, NO_2, PM_{10} and $PM_{2.5}$). Data from historical monitoring at representative locations showed that measured CO and NO_2 concentrations in the past five years have been consistently below NSW Environmental Protection Authority (EPA) air quality impact assessment criteria. However, particle levels (as PM_{10} and $PM_{2.5}$) increased across the Hunter region from 2017 to 2019 due to dust from the widespread, intense drought and smoke from bushfires and hazard reduction burning. These events adversely influenced air quality with multiple days observed when PM_{10} and $PM_{2.5}$ concentrations exceeded NSW EPA criteria.

Potential air quality impacts of the project during construction were assessed using the semi-quantitative method developed by the Institute of Air Quality Management (IAQM). Computer-based dispersion modelling was used to predict the potential change in local and regional air quality as a result of the project operation.

The key outcomes of the air quality assessment are:

- Unmitigated construction of the project was determined to represent a 'high' risk of dust impacts according to the IAQM method. The application of the recommended mitigation measures would mean that adverse residual impacts from construction would not be anticipated
- Operation of the project would lead to a redistribution of vehicle emissions across the road network, generally from existing main roads to the proposed new roads. The highest concentrations of key air quality indicators (CO, NO_2, PM_{10} and $PM_{2.5}$) are expected to occur close to main roads under all 'with project' and 'without project' scenarios
- Increases in the concentrations of key air quality indicators, due to the project, are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River. In these locations there are generally few sensitive receivers

- Decreases in the concentrations of key air quality indicators, due to the redirection of traffic with the project, are expected to occur along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge
- The predicted maximum increases and decreases in concentrations of key air quality indicators, due to the project, are within the range of historically measured fluctuations in maximum concentrations for the region
- The project would lead to very little change to maximum and annual concentrations of key air quality indicators, relative to background levels, based on model predictions at selected sensitive receivers located near main roads along the proposed route
- The project is not expected to cause exceedances of the NSW EPA air quality impact assessment criteria for CO, NO_2, PM_{10}, $PM_{2.5}$ or key air toxics such as benzene and formaldehyde.

Management measures

Unmitigated construction of the project has been determined to represent a 'high' risk of dust impacts according to the IAQM method. All measures detailed in the IAQM are therefore recommended, including appropriate work practices and scheduling, equipment selection, monitoring and preventative controls. These measures would be incorporated into a relevant Air Quality Management Plan. Adverse residual impacts from construction are not anticipated with the application of the recommended mitigation measures. Other air quality impacts associated with odour from asphalt batching, and odour from the handling of potentially contaminated soils would be managed via procedures for identification, staging and handling.

Conclusion

Based on this assessment, during construction, adverse residual impacts are not anticipated with the application of the recommended mitigation measures. Operation of the project is not expected to cause adverse air quality impacts, based on dispersion modelling that showed that the project would not result in changes to air quality at local or regional scales that would cause exceedances of air quality criteria at sensitive receivers. These outcomes are consistent with the desired performance outcome for the project which, for air quality, is to minimise air quality impacts (including nuisance dust and odour) to reduce risks to human health and the environment to the greatest extent practicable through the design, construction and operation of the project.

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1. Introduction

1.1 Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The project would connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas. The project would provide regional benefits and substantial productivity benefits on a national scale. The project location is shown in **Figure 1-1** within its regional context.

1.2 Project description

The project would include the following key features:

- A 15 kilometre motorway comprised of a four lane divided road (two lanes in each direction)
- Motorway access from the existing road network via four new interchanges at:
  - Black Hill: connection to the M1 Pacific Motorway
  - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
  - Tomago: connection to the Pacific Highway and Old Punt Road
  - Raymond Terrace: connection to the Pacific Highway.
- A 2.6 kilometre viaduct over the Hunter River flood plain including new bridge crossings over the Hunter River, the Main North Rail Line, and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting
- Adjustment of waterways, including at Purgatory Creek at Tarro and tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including establishment and use of temporary ancillary facilities, temporary access tracks, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

A detailed project description is provided in Chapter 5 of the environmental impact statement (EIS). The locality of the project is shown in **Figure 1-1**, while an overview of the project is shown in **Figure 1-2**.

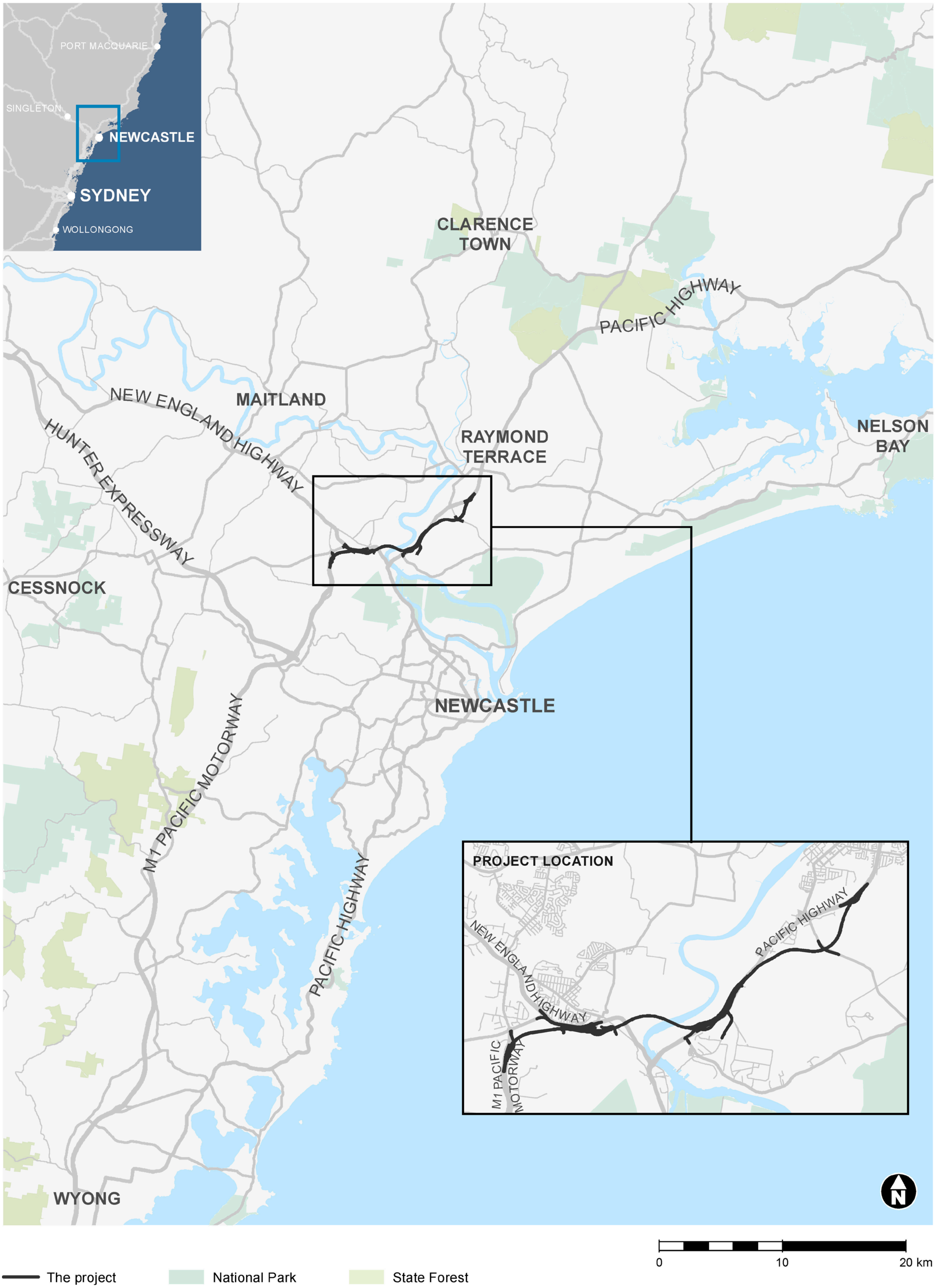

Figure 1-1 Regional context of the project

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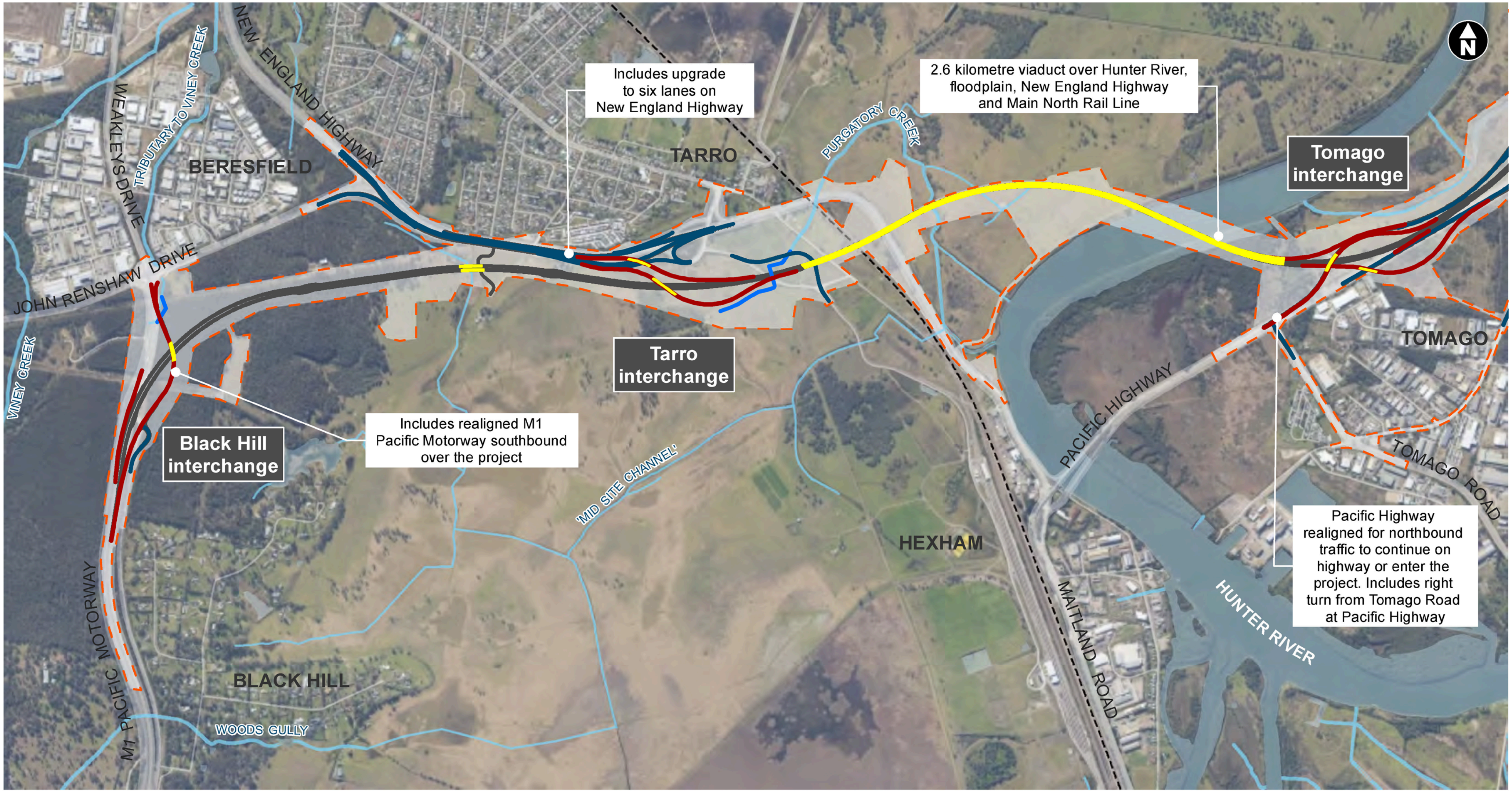

Main alignment
Adjustments to existing roads
New ramp
Creek realignment
Bridges/ Viaduct
Construction footprint
Waterways
Main North Rail Line

0 0.5 1 km

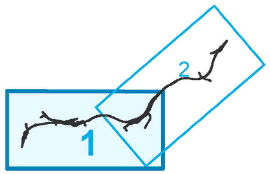

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Figure 1-2 Project key features (map 1 of 2)

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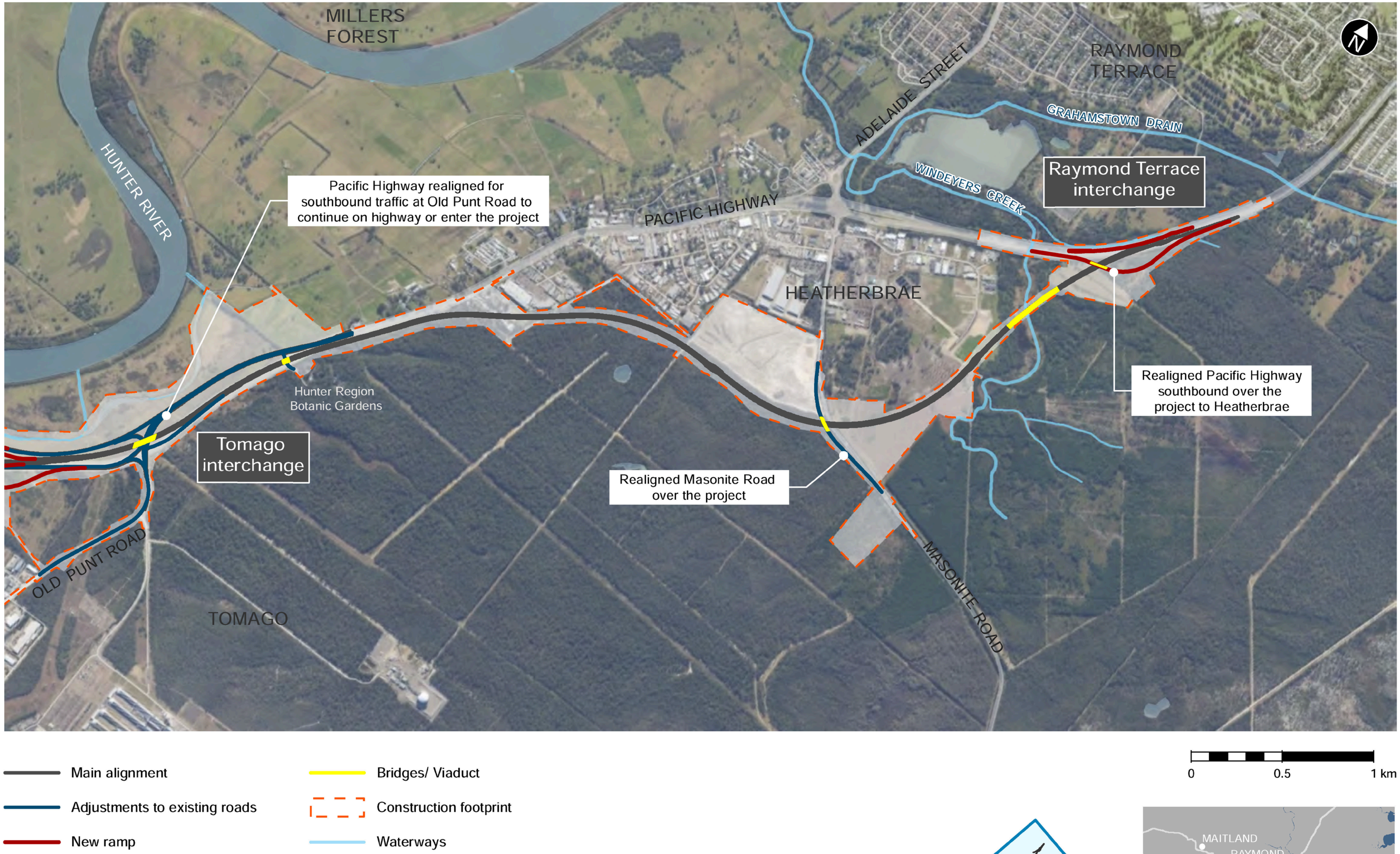

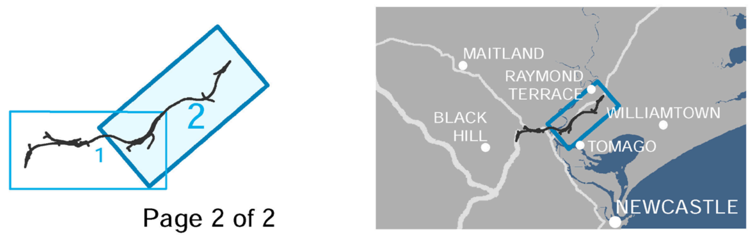

Figure 1-2 Project key features (map 2 of 2)

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1.3 Performance outcome

The desired performance outcome for the project relating to air quality is to:

- Minimise air quality impacts (including nuisance dust and odour) to reduce risks to human health and the environment to the greatest extent practicable through the design, construction and operation of the project (refer to **Chapter 5**).

1.4 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the project. The EIS has been prepared under Division 5.2 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to air quality and will assist the Minister for Planning and Public Spaces to make a determination on whether or not to approve the project. It provides an assessment of potential impacts of the project on air quality and outlines proposed management measures.

In 2019 revised SEARs were issued for the project, which included air quality as a key issue. **Table 1-1** outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to air quality

Secretary's requirement	Where addressed in this report
14. Air quality	
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	This document
2. The Proponent must ensure the AQIA also includes the following:	
(a) demonstrated ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the *Protection of the Environment Operations (Clean Air) Regulation 2010*;	The regulatory framework relevant to the *Protection of the Environment Operations Act 1997* and the *Protection of the Environment Operations (Clean Air) Regulation 2010* is discussed in **Section 2.2**. The compliance of the project with the regulatory framework is discussed in **Chapter 5**.
(b) an assessment of the impacts of the construction and operation of the project on sensitive receivers and the local community, including risks to human health;	The location of existing sensitive receivers is provided in **Section 4.1**. Assessment of construction impacts is provided in **Section 5.1**. Assessment of operation impacts is provided in **Section 5.2**.
(c) details of the proposed mitigation measures to minimise the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the project, particularly in relation to the operation of ancillary facilities (such as concrete and asphalt batching, treatment of acid sulfate soils and stockpiling of mulch), the use of mobile plant and machinery, stockpiles and the processing and movement of spoil, and construction vehicle movement along the alignment; and	Specific environmental management measures, including for dust and odour from these activities, are outlined in **Chapter 6**.
(d) a cumulative assessment of the local and regional air quality.	Potential cumulative impacts are discussed in **Section 5.2** and **Section 5.3**.

1.5 Report structure

The report is structured as follows:

- Chapter 1 – Introduces the project with a summary of the project background, project description, performance outcomes and SEARs
- Chapter 2 – Outlines the key legislative and policy assessment requirements for air quality
- Chapter 3 – Provides an overview of the methods used to assess the potential for air quality impacts
- Chapter 4 – Discusses key features of the existing environment including surrounding land uses, sensitive receivers, and local meteorological and air quality conditions
- Chapter 5 – Provides an assessment of the potential construction and operational air quality impacts including potential cumulative impacts
- Chapter 6 – Outlines the measures to mitigate or otherwise effectively manage potential air quality impacts
- Chapter 7 – Provides the conclusions of the assessment
- References
- Terms and Acronyms
- Appendix A – Provides information on the emission factors that were used for the operational assessment.

2. Policy and planning setting

2.1 Overview

There are several statutes and guidelines that apply to the regulation of emissions to air from developments including:

- *NSW Protection of the Environment Operations Act 1997* (POEO Act)
- NSW Protection of the Environment Operations (Clean Air) Regulation 2010 (POEO Clean Air Regulation)
- National Environment Protection Measure for Ambient Air Quality (AAQ NEPM) (National Environment Protection Council [NEPC], 2016)
- National Environment Protection Measure for Air Toxics (Air Toxics NEPM) (NEPC, 2011)
- Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (NSW EPA, 2016)
- Approved Methods for Sampling and Analysis of Air Pollutants in NSW (NSW Department of Environment and Conservation [DEC], 2005)
- Air Emissions Inventory for the Greater Metropolitan Region in New South Wales (NSW EPA, 2019a)
- Guidance on the assessment of dust from demolition and construction Version 1.1 (UK IAQM, 2014)
- Assessment and Management of Odour from Stationary Sources in NSW (DEC, 2006).

Requirements relevant to the project from each of these documents are outlined below. It is noted that there are other standards which regulate emissions from new and in-service vehicles and fuel quality, although these are not relevant to how air quality impacts have been assessed from the project.

2.2 State legislation

2.2.1 Protection of the Environment Operations Act 1997

The POEO Act is the primary piece of legislation for the regulation of potential pollution impacts associated with Scheduled operations or activities in NSW. Scheduled activities are those defined in Schedule 1 of the POEO Act. These include road construction where the activity results in the existence of four or more traffic lanes (other than bicycle lanes or lanes used for entry or exit) for at least:

- Roads classified under the NSW *Roads Act 1993* as a ‘freeway' or' tollway':
  - One kilometre of their length in the metropolitan area, or five kilometres of their length in any other area.
- Roads classified as a main road:
  - Three kilometres of their length in the metropolitan area, or five kilometres of their length in any other area.

The project comprises about 15 kilometres of new roadway and its construction would constitute the Scheduled activity of ‘Road construction' as defined under the POEO Act. As such, project construction activities would need to comply with the requirements of Chapter 5, Part 5.4 – Air Pollution of the POEO Act. In general, these requirements seek to ensure that emissions from a project do not result in unacceptable air quality beyond the project, including at surrounding sensitive receivers.

2.2.2 Protection of the Environment Operations (Clean Air) Regulation 2010

The NSW Protection of the Environment Operations (Clean Air) Regulation 2010 (POEO Clean Air Regulation) contains provisions for the regulation of emissions to air from wood heaters, open burning, motor vehicles and fuels and industry. The Protection of the Environment Operations (Clean Air) Regulation 2010 contains provisions for the regulation of emissions to air from motor vehicles, fuels and industry and specifies criteria for the assessment of the obligations imposed by Part 5.4 – Air Pollution of the POEO Act. The requirements of this Regulation have been incorporated into the air quality assessment for the project.

2.3 Commonwealth legislation

2.3.1 National Environment Protection (Ambient Air Quality) Measure

The National Environment Protection (Ambient Air Quality) Measure (NEPM) sets national ambient air standards that allow for the adequate protection of human health and well-being. The NEPM entered into force in 1998 and established national ambient air standards for six key pollutants:

- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Lead (Pb)
- Photochemical oxidants as ozone (O_3)
- Particulate matter with an aerodynamic diameter less than 10 microns (PM_{10}).

The NEPM was expanded in 2003 to include advisory reporting standards for particulate matter with an equivalent aerodynamic diameter less than 2.5 microns ($PM_{2.5}$). On 25 February 2016, NEPM entered into force and introduced the following changes:

- $PM_{2.5}$ advisory reporting standards were changed to formal standards consistent with the other six pollutants
- The annually averaged PM_{10} standard was revised from 30 µg/m^3 to 25 µg/m^3
- The introduction of an aim to reduce the 24-hour and annually averaged $PM_{2.5}$ standards from 8 µg/m^3 and 25 µg/m^3 to 7 µg/m^3 and 20 µg/m^3 by 2025
- Initiating a nationally consistent approach to reporting population exposure to $PM_{2.5}$
- Replacing the five-day exceedance form of the 24-hour $PM_{2.5}$ and PM_{10} standards with an exceptional event rule.

Further, on 7 December 2018, the National Government notified of their intent to vary the NEPM again to strengthen standards applicable to O_3, SO_2 and NO_2. This update would reflect current scientific understanding to provide a higher level of health protection from air pollution impacts associated with these pollutants for the Australian population.

The ambient air standards presented in the NEPM apply to urban ambient air quality monitoring stations, which broadly represent levels of exposure to urban populations. The standards are not intended to be used as criteria for assessing air quality impacts associated with projects and developments. These criteria are set by individual states and territories.

2.3.2 National Environment Protection Measure for Air Toxics

Recognising the health effects associated with exposure to air toxics, the Air Toxics NEPM was developed to improve the information base regarding ambient air toxics within the Australian environment to facilitate the development of ambient air quality standards for these substances.

Five priority pollutants are covered in the Air Toxics NEPM; these are benzene, formaldehyde, toluene, xylenes and benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons (PAHs). The Air Toxics NEPM includes monitoring investigation levels for these pollutants which are for use in assessing the significance of monitored concentrations with respect to provisions for the protection of human health. These monitoring investigation levels are not intended for assessing compliance from projects and developments but aim to improve the information base regarding ambient air toxics with the Australian environment in order to facilitate the development of standards.

Vehicles on the existing and proposed road network would be the main source of air toxics. Asphalt plants may also be a source of PAHs leading to potential odour.

2.4 Relevant guidelines

2.4.1 Approved Methods for the Modelling and Assessment of Air Pollutants in NSW

The Approved Methods (EPA, 2016) was published by the NSW EPA and outlines the approach to be applied for the modelling and assessment of air pollutants from stationary sources in NSW. Although the document relates to stationary sources of air pollutants, the impact assessment criteria have been considered to provide an indication of the significance of the project's effect on air quality, given that the criteria set out in the Approved Methods are a summary of criteria from other relevant guidelines and policies. Criteria relevant to the key pollutants related to the project are listed in **Table 2-1**.

Table 2-1 NSW EPA air quality impact assessment criteria

Pollutant	Averaging time	Criterion	Source
Criteria pollutants			
Carbon monoxide (CO)	1-hour	30,000 µg/m^3	NSW EPA, 2016
	8-hours	10,000 µg/m^3	NSW EPA, 2016
Nitrogen dioxide (NO_2)	1-hour	246 µg/m^3	NSW EPA, 2016
	Annual	62 µg/m^3	NSW EPA, 2016
Particulate matter (as PM_{10})	24-hour	50 µg/m^3	NSW EPA, 2016
	Annual	25 µg/m^3	NSW EPA, 2016
Particulate matter (as $PM_{2.5}$)	24-hour	25 µg/m^3	NSW EPA, 2016
	Annual	8 µg/m^3	NSW EPA, 2016
Particulate matter (as TSP)	Annual	90 µg/m^3	NSW EPA, 2016

Pollutant	Averaging time	Criterion	Source
Air toxics			
Benzene	1-hour	29 µg/m^3	NSW EPA, 2016
Formaldehyde	1-hour	20 µg/m^3	NSW EPA, 2016
Toluene	1-hour	360 µg/m^3	NSW EPA, 2016
Xylenes	1-hour	190 µg/m^3	NSW EPA, 2016
PAHs as benzo(a)pyrene	1-hour	0.4 µg/m^3	NSW EPA, 2016

The intent of each of these criteria has been summarised below:

- Carbon monoxide (CO) – The criteria for CO adopted from the 'WHO Air Quality Guidelines for Europe, 2nd Edition', (World Health Organisation, 2000) are intended to preserve a COHb (Carbon monoxide haemoglobin oxygen carrying capacity of the blood) safe level of 2.5 per cent for a 'normal subject' engaging in light or moderate exercise. Exposures to concentrations above these levels for the periods specified were stated to result in adverse health effects
- Nitrogen dioxide (NO_2) – The same objective is stated for NO_2 in the Ambient Air – National Environment Protection Measure for Ambient Air Quality, (National Environment Protection Council, 1998); namely to provide 'adequate protection of human health and well-being'. Guidance regarding NO_2 exposure is detailed in the World Health Organisation (2000) guideline which indicates that a one-hour averaged criteria of 200 µg/m^3 includes a 50 per cent 'safety margin' and that it was only when short-term exposure was greater than 400 µg/m^3 that there was 'evidence to suggest possible small effects in function of asthmatics'
- Particulate matter (PM_{10} and $PM_{2.5}$) – Part 2, Clause 5 of the NEPM states that the desired outcome of the measure is 'ambient air quality that allows for the adequate protection of human health and well-being'
- Total suspended particulates (TSP) – The now rescinded 'Ambient Air Quality Goals Recommended by the National Health and Medical Research Council', (National Health and Medical Research Council, 1996) states that 'at these levels (criterion in **Table 2-1** above) there still may be some people who would experience respiratory symptoms' but that the intent of this criteria is the protection of human health for the broader majority of the population
- Volatile organic compounds (VOCs) – This criterion is adopted from guidance presented in State Environment Protection Policy (Air Quality Management) No. S 240, (Government of Victoria, 2001). Part II Schedule A of the guideline describes how this criterion includes a factor of safety of 40, given the high toxicity and potential health effects arising from exposure to such substances.

The criteria for CO, NO_2, PM_{10}, $PM_{2.5}$, and TSP relate to the total concentration in the ambient air. For an air quality impact assessment this comprises of the maximum incremental concentration from the project or activity plus background levels due to influences of all other surrounding natural and anthropogenic sources. Further details of the background levels applied in the assessment are discussed below in **Chapter 4**. These criteria apply to the nearest existing or likely future sensitive receiver areas in relation to the project.

As noted in **Section 2.3.2**, the NEPM identifies 'investigation levels' for five priority air toxics: benzene, formaldehyde, toluene, xylenes and benzo(a)pyrene as a marker for PAHs. The 'investigation levels' levels are not compliance standards but are used for assessing the significance of monitored levels of air toxics with respect to the protection of human health. Although these criteria were developed for stationary sources of air pollutants, rather than moving sources such as vehicles, they have been used to provide an indication of the significance of the project's effect on air quality during operations.

2.4.2 Approved Methods for Sampling and Analysis of Air Pollutants in NSW

The Approved Methods for Sampling and Analysis of Air Pollutants in NSW (DEC, 2005) provides guidance for the monitoring and analysis of air pollutants in NSW. Ambient air quality data collected from stations being operated by the NSW Department of Planning, Industry and Environment (DPIE) in accordance with this guideline were adopted for this assessment (see **Section 4.3**).

2.4.3 Air Emissions Inventory for the Greater Metropolitan Region in New South Wales

The Air Emissions Inventory for the Greater Metropolitan Region in New South Wales (NSW EPA, 2019a) provides the outcomes of a study into the anthropogenic (i.e. human-made), and natural sources of emissions to air in the Greater Metropolitan Region comprising of Sydney, Newcastle and Wollongong. The investigation quantifies emissions from all sources of air pollution, including on-road transportation. The study and subsequent updates established vehicle emission databases for the base year of assessment (2008), and projections for 2011, 2016, 2021, 2026, 2031 and 2036. These emission factors are incorporated into Transport's Tool for Roadside Air Quality (TRAQ), a tool commonly used in NSW to quantify the potential operational air quality impacts of vehicles using an existing or new road.

2.4.4 Guidance on the assessment of dust from demolition and construction

In the absence of a NSW guideline for the assessment of dust from construction activities, a suitable alternative was used. The United Kingdom (UK) Institute of Air Quality Management (IAQM) developed the guideline, 'Guidance on the assessment of dust from demolition and construction Version 1.1', (UK IAQM, 2014). The document provides an approach for assessing the potential for dust-related impacts during construction, taking into consideration the sensitivity of the local environment and the expected magnitude of different construction activities. Further details of the IAQM assessment methodology are provided in **Section 3.2**, and its application to the project in **Section 5.1**.

2.4.5 Assessment and Management of Odour from Stationary Sources in NSW (DEC, 2006)

The document, 'Assessment and Management of Odour from Stationary Sources in NSW', (DEC, 2006) provides guidance for the assessment and management of odours arising from stationary sources in NSW. Given the nature of the project involving a new roadway, this guideline is not strictly applicable. However, recommendations for the management of potential odours during construction were considered with reference to the guidance presented.

3. Assessment methodology

3.1 Air quality issues

Air quality issues can arise when emissions from an industry or activity lead to a deterioration in the ambient air quality. Construction of the project could lead to emissions to air from a variety of activities including land clearing, earthworks, material handling, and material transport. Emissions may also arise from wind erosion of exposed areas. These construction-related emissions would mainly comprise of particulate matter in the form of:

- TSP, typically where particles are less than 30 microns in equivalent aerodynamic diameter
- PM_{10}, representing particulate matter with equivalent aerodynamic diameter of 10 microns or less
- $PM_{2.5}$, representing particulate matter with equivalent aerodynamic diameter of 2.5 microns or less.

There are relatively minor emissions (i.e. smaller quantities) from construction machinery exhausts such as CO, oxides of nitrogen (NO_x), PM_{10}, $PM_{2.5}$, some hydrocarbons, and to a lesser extent sulphur dioxide (SO_2). Odour and other volatile organic compounds also have the potential to be generated from asphalt batching, and the handling of potentially contaminated soils associated with historical land uses.

Operation of the project would lead to emissions to air from vehicles using both the existing and modified road network. There are a variety of air pollutants associated with road vehicles with the most significant pollutants, in terms of potential impacts to health, being:

- CO
- NO_x, representing the total of nitric oxide (NO) and NO_2
- Particulate matter as PM_{10} and $PM_{2.5}$
- Hydrocarbons (HC).

These pollutants are generated from the combustion of fuel and emitted via the exhaust system. Particulate matter emissions are also generated from brake and tyre wear, as well as re-suspended road dust.

In summary, the key potential air quality issues for the project include:

- Dust from construction activities
- Odour from asphalt batching during the construction phase
- Odour from the handling of potentially contaminated materials during the construction phase
- Odour from the stockpiling of mulch during the construction phase
- Emissions from vehicles using the existing and modified road network during operation.

The issues outlined above are the focus of this assessment. Due to the relatively minor emissions anticipated (compared with operational traffic emissions), exhaust emissions from plant and equipment, and stockpiled mulch are not identified as a key issue. In addition, the UK IAQM notes that these emissions are unlikely to have a significant impact on air quality.

A key objective was to identify the potential change in local and regional air quality that may occur as a result of the project.

3.2 Construction

Potential impacts to human health, annoyance and ecology (e.g. impacts to plant health) from dust generation represents the primary air quality-related risk during construction. The assessment has followed guidance presented in ‘Guidance on the assessment of dust from demolition and construction Version 1.1’ (UK IAQM, 2014) to identify the potential for dust impacts during the project. The IAQM aims to identify the overall unmitigated risks of the whole project and recommends appropriate management measures. Four primary activities are defined by the IAQM, as follows:

- ‘Demolition’
- ‘Earthworks’
- ‘Construction’
- ‘Trackout’, or the transport-related handling of construction materials.

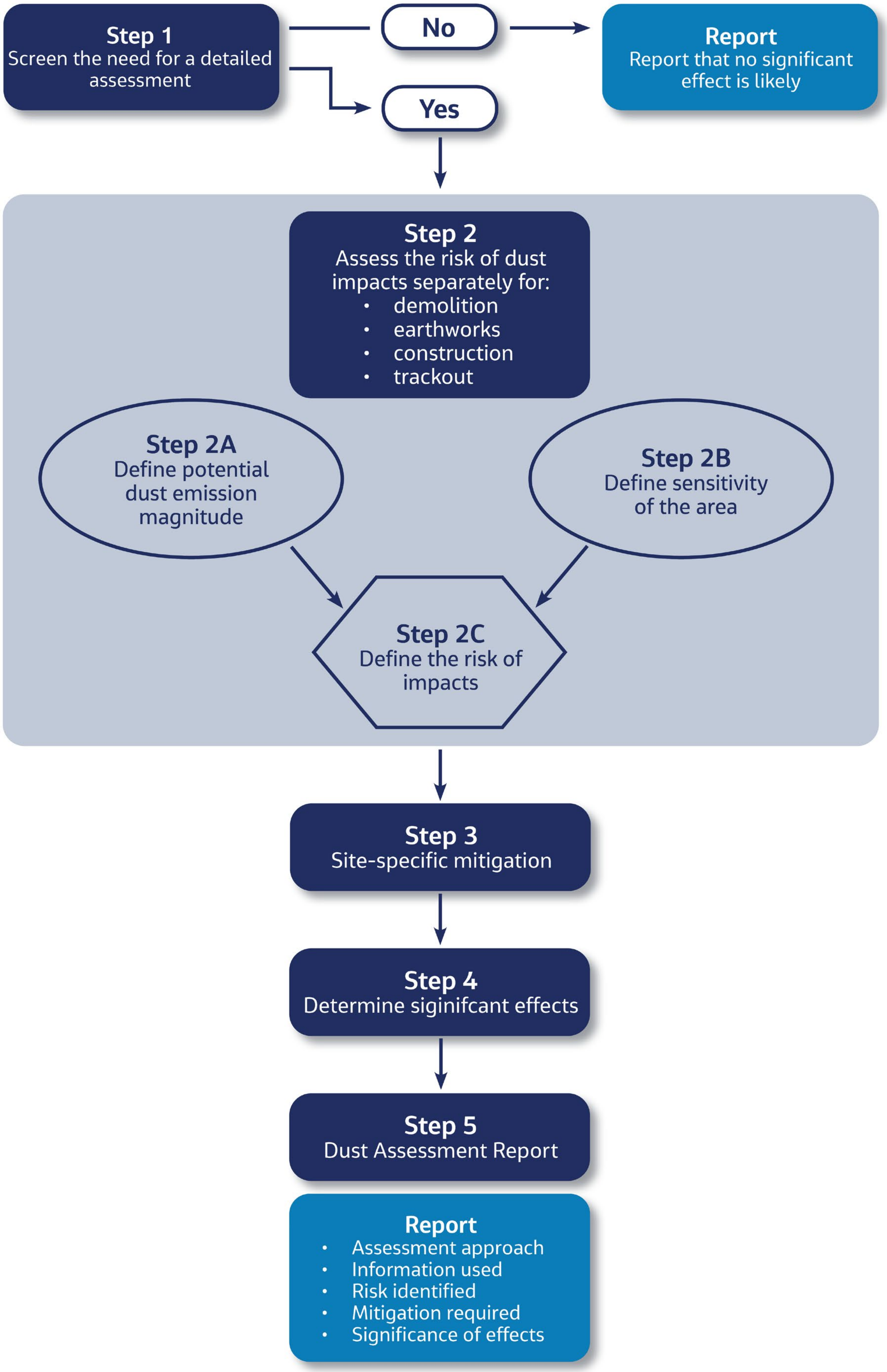
Application of this semi-quantitative, risk-based assessment approach is consistent with the approach used to assess construction related impacts on other recent large-scale Australian road transport projects. The approach is preferred as it can be difficult to reliably predict potential impacts using modelling approaches which have high levels of uncertainty about when, where and how intensively specific activities would be completed, and the corresponding weather conditions. The IAQM provides robust mitigation and management measures which are aligned to the assessed levels of unmitigated risk.

The assessment procedure involves four steps of assessment with the intended outcome of developing suitable mitigation measures to avoid any potential nuisance, human health and ecological impacts (such as impacts to vegetation health) from dust generated during the four primary activities. These steps are presented in **Figure 3-1** and involve:

- Step 1, a screening review to establish a study area for and identify nearby human and ecological receivers which have the potential to be impacted by the intended works
- Step 2, an evaluation of the potential magnitude (Step 2A) and sensitivity of the surrounding receiving environment to dust impacts (Step 2B). Step 2A and 2B were combined in Step 2C to estimate the risk of dust impacts if no mitigation measures were applied. Step 2 was completed for different work areas across the project so that changes in risk profiles could be identified and assessed across the entire project
- Step 3, the development of mitigation for each work location, commensurate to the level of risk determined in Step 2
- Step 4, an evaluation of any residual dust-related risks following the application of the control measures developed during Step 3 to verify that a suitable level of mitigation has been developed to reduce the impacts to the extent practicable.

The assessment methodology is intrinsically linked to the process and full details of how the assessment was completed and its outcomes are presented in **Section 5.1**.

As noted in **Section 3.1**, there are other air quality risks that have the potential to result in impacts to sensitive receivers during construction. These included exhaust emissions from construction plant and equipment, odour, and cumulative effects. Potential impacts of exhaust emissions from construction plant and equipment are incorporated into the activities defined by the IAQM. Odour from asphalt plants has been quantified by modelling in order determine suitable separation distances to minimise impacts. These issues are discussed in **Section 5.1**, with mitigation and management measures provided in **Chapter 6**. Odour from the handling of potentially contaminated materials and the generation and stockpiling of mulch was also considered by qualitative review to determine if there would be any odour impacts during construction.



Source: UK IAQM, 2014

Figure 3-1 Construction air quality assessment procedure

3.3 Operation

3.3.1 Overview

Changes to local air quality as a result of the project were quantified and assessed. The following sections outline the operational scenarios that were assessed, how emissions were calculated, and how an air dispersion model was used to predict changes in air quality as a result of the project.

The Approved Methods specifies how assessments based on the use of air dispersion models should be carried out. Although the Approved Methods is intended for stationary sources, not projects such as roadways, it includes relevant information related to the preparation of meteorological data, reporting requirements and air quality assessment criteria that are used to assess the significance of dispersion model predictions.

Emissions from vehicles on the local road network have been estimated using information on traffic volumes, traffic mix, and link locations, combined with emission factors from the NSW EPA. The computer-based dispersion model known as GRAL ('Graz Lagrangian') has then been used to predict key air pollutant concentrations due to these emissions under a range of operational scenarios, taking into account the local meteorological conditions. Details are outlined below.

As noted in **Section 3.1** the main objective of the operational assessment was to identify the potential change in air quality as a result of the project. These changes would be primarily influenced by changes in traffic volumes, mix, speed, and locations.

3.3.2 Emissions

Emissions have been calculated for each link in the traffic model (Jacobs, 2020a) using the hourly traffic volumes, mix and speed data in combination with emission factors from the NSW EPA Motor Vehicle Emissions Inventory (MVEI). The MVEI is fully described by the NSW EPA (2019a) and has been specifically designed for use in the NSW Greater Metropolitan Region (GMR).

The MVEI has been selected for the emission calculations for the following reasons:

- The model takes into account the operation of vehicles on surface roads and characteristics of vehicle fleets in the GMR
- The emission factors have been derived using an extensive database of Australian measurements
- The emission factors allow for the deterioration in emissions performance with mileage, the effects of tampering or failures in emission-control systems, and the use of ethanol in petrol
- The emission factors are defined for five specific road types and nine vehicle classes
- The emission factors are available for future years, taking into account the technological changes in the vehicle fleet
- Cold start and speed corrections are incorporated.

Five operational scenarios were developed in order to quantify and assess the potential change in air quality. **Table 3-1** lists these scenarios as well as the number of links used for the emission calculations.

Table 3-1 Assessment scenarios and number of links for emission calculations

Identification	Description	Number of links for emission calculations
2017 Base	Representing base case traffic conditions	231
2028 DN	2028 Do Nothing. Traffic conditions in the planned opening year, **without the project**.	243
2028 WP	2028 With Project. Traffic conditions in the planned opening year, **with the project**.	265
2038 DN	2038 Do Nothing. Traffic conditions 10 years after the planned opening year, **without the project**.	235
2038 WP	2038 With Project. Traffic conditions 10 years after the planned opening year, **with the project**.	255

Emissions of CO, NO_x, PM_{10}, and HC have been calculated for every road link in the traffic model, for each assessment scenario. The emission calculations involved:

- Extracting volumes, mix, and speed forecasts from the traffic model for between 200 and 300 links across the road network, as hourly breakdowns, for each assessment scenario
- Matching the traffic model road types to the NSW EPA road types
- Categorising the traffic into nine vehicle types (CP, CD, LCV-P, LCV-D, HDV-P, RT, AT, BusD and MC) for each hour of the day. The traffic mix data by road type and year were derived from the Western Harbour Tunnel air quality assessment (ERM, 2020)
- Calculating emissions of CO, NO_x, PM_{10} and HC in kilograms per hour (kg/h) for each hour of the day, for each vehicle type, for every road link by multiplying the vehicle numbers for each type by the respective NSW EPA emission factors
- Applying cold start effects (i.e. up-scaling of emissions to account for combustion inefficiencies during cold conditions)
- Correcting NO_x emission factors. The NSW EPA NO_x emissions are reported as NO_2. NO_x emission correction factors have therefore been derived from fleet weighted NO_2 to NO_x percentages, by vehicle type, from the NSW EPA
- Applying NSW EPA speed correction factors for each vehicle type, based on the road type
- Adding non-exhaust emissions, in the case of PM_{10}, for each vehicle type
- Preparing the emission estimates into a format for use in the dispersion models.

Figure 3-2 shows the road links for which emissions were calculated and that were used in the air dispersion modelling. These links represent those roads that are expected to undergo the most change as a result of the project.

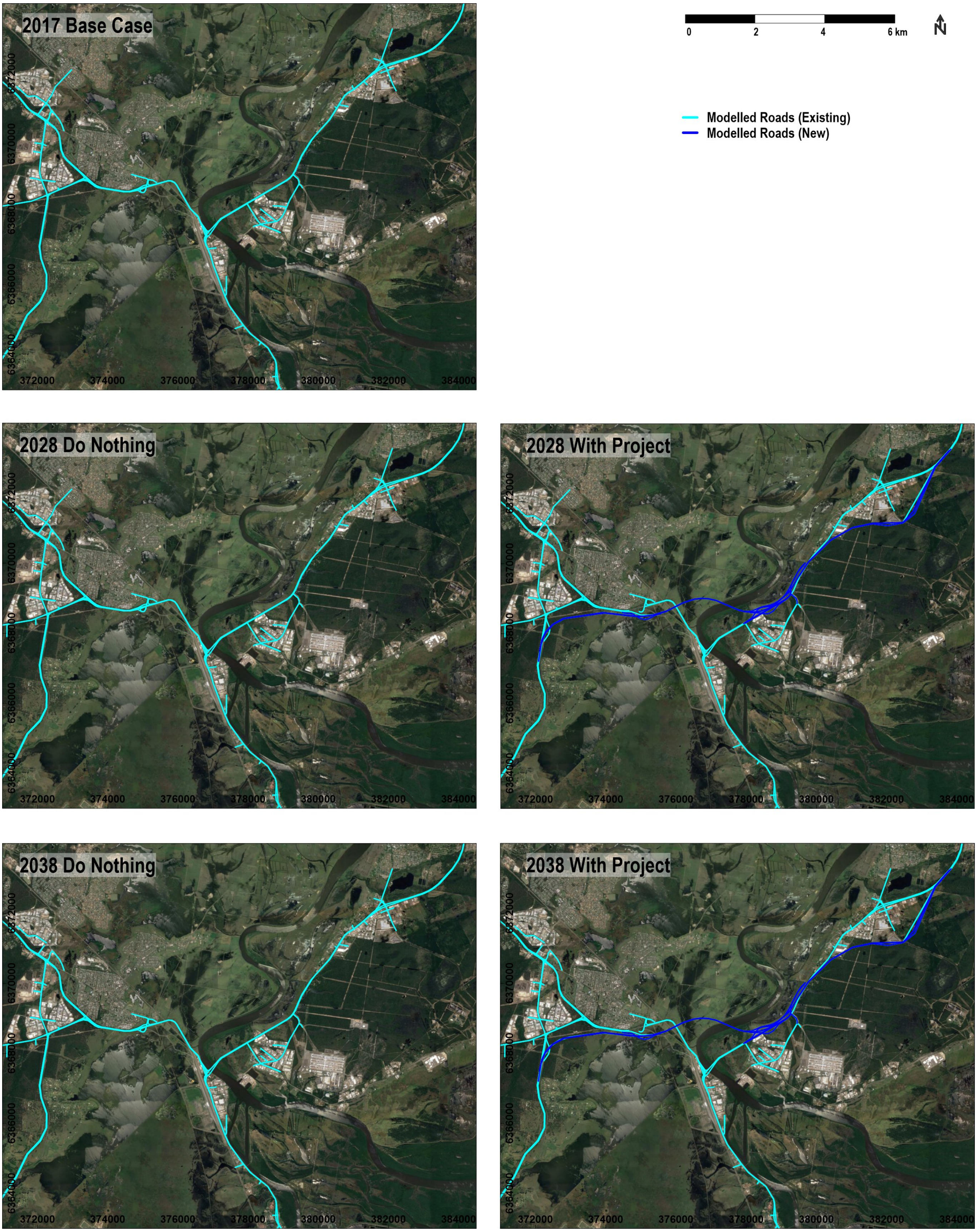


Figure 3-2 Road links for the air dispersion modelling

As an example of the emission outputs, **Figure 3-3** shows the forecast traffic data and the calculated hourly emissions of CO, NO_x and PM_{10} in 2028 for the westbound and eastbound directions of link 246 and 247; the 2.6 kilometre section of the proposed motorway that crosses the Hunter River. These hourly emissions data have been calculated for every link shown in **Figure 3-2** and used as input to the dispersion model.

It can be seen from **Figure 3-3** that the total traffic volume is expected to peak between 5 pm and 6 pm for both the eastbound and westbound directions. The emissions follow a similar profile although these calculations also reflect the influence of road type, traffic mix and traffic speed.

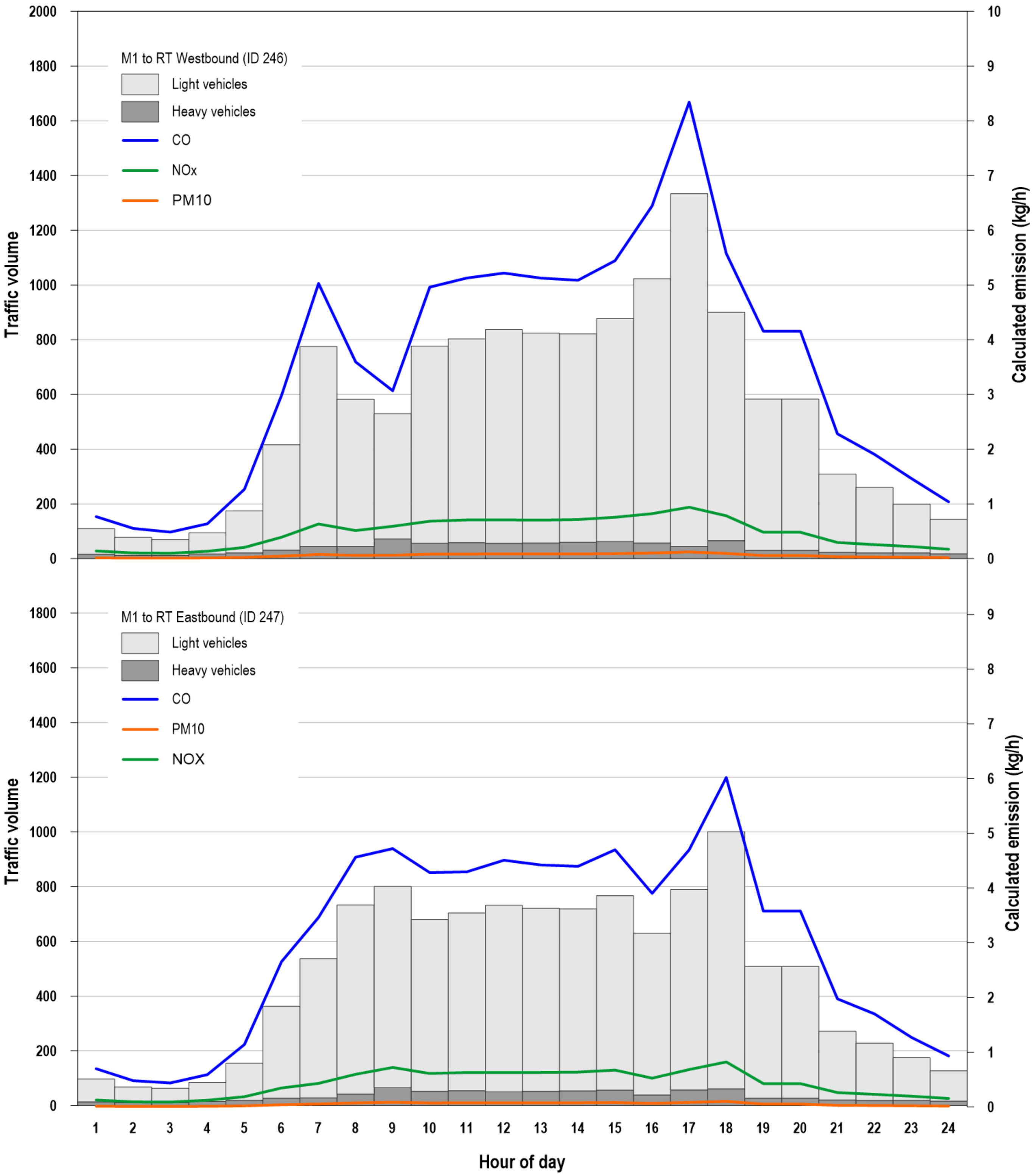


Figure 3-3 Traffic volumes and calculated emissions in 2026 for link ID 246 and 247

Table 3-2 provides a summary of the calculated total emissions from all modelled roads in the model domain. Total emissions in the model domain are expected to increase across the network with the project, relative to the do minimum case, largely due to the projected additional vehicle movements per day.

Table 3-2 Calculated emissions in the model domain

Scenario	Vehicles per day	Total emissions (kg/d)			
		CO	NO_x	PM_{10}	HC
2017 Base	1,542,663	2,244	792	80	128
2028 DN	2,605,260	2,648	648	112	102
2028 WP	2,608,523	3,339	717	118	108
2038 DN	2,905,844	2,059	639	121	92
2038 WP	2,958,411	3,011	700	132	97

Appendix A provides details of the emission calculations including the key inputs and assumptions.

3.3.3 Meteorological modelling

The air dispersion model used for this assessment, GRAL, requires information on the meteorological conditions in the modelled region. This information can be generated by the prognostic, meso-scale wind field model GRAMM ('Graz Mesoscale Model'), using surface observation data from local weather stations. The result of a GRAMM simulation is a compilation of classified meteorological conditions that can be used as input to GRAL.

Key model settings for GRAMM are shown below in **Table 3-3**.

Table 3-3 Model input settings for GRAMM

Parameter	Value
Model version	20.01
Model domain (MGA Zone 56)	Easting 370000-385000, Northing 6360000-6375000 (15km x 15km)
Horizontal grid resolution (m)	300
Vertical thickness of first layer (m)	10
Number of vertical layers	15
Vertical stretching factor	1.4
Relative layer height (m)	3874
Maximum time step (s)	10
Modelling time (s)	3600
Terrain option	Flat terrain
Land use	CORINE land-use categories, digitized from aerial imagery (**Figure 3-4**)
Wind speed classes	7
Wind direction sectors	36 sectors x 10 degree sector size

Terrain across the 15 kilometre by 15 kilometre domain varies from sea level to approximately 40 metres above sea level. There would be very little topographical influence on meteorological conditions in this area so model terrain was therefore assumed to be flat. Spatially varying land use data were extracted from aerial imagery and prescribed to the GRAMM using the CORINE (Coordination of Information on the Environment) categories. **Figure 3-4** shows the model domain, model grid, and land use information, as used by GRAMM.

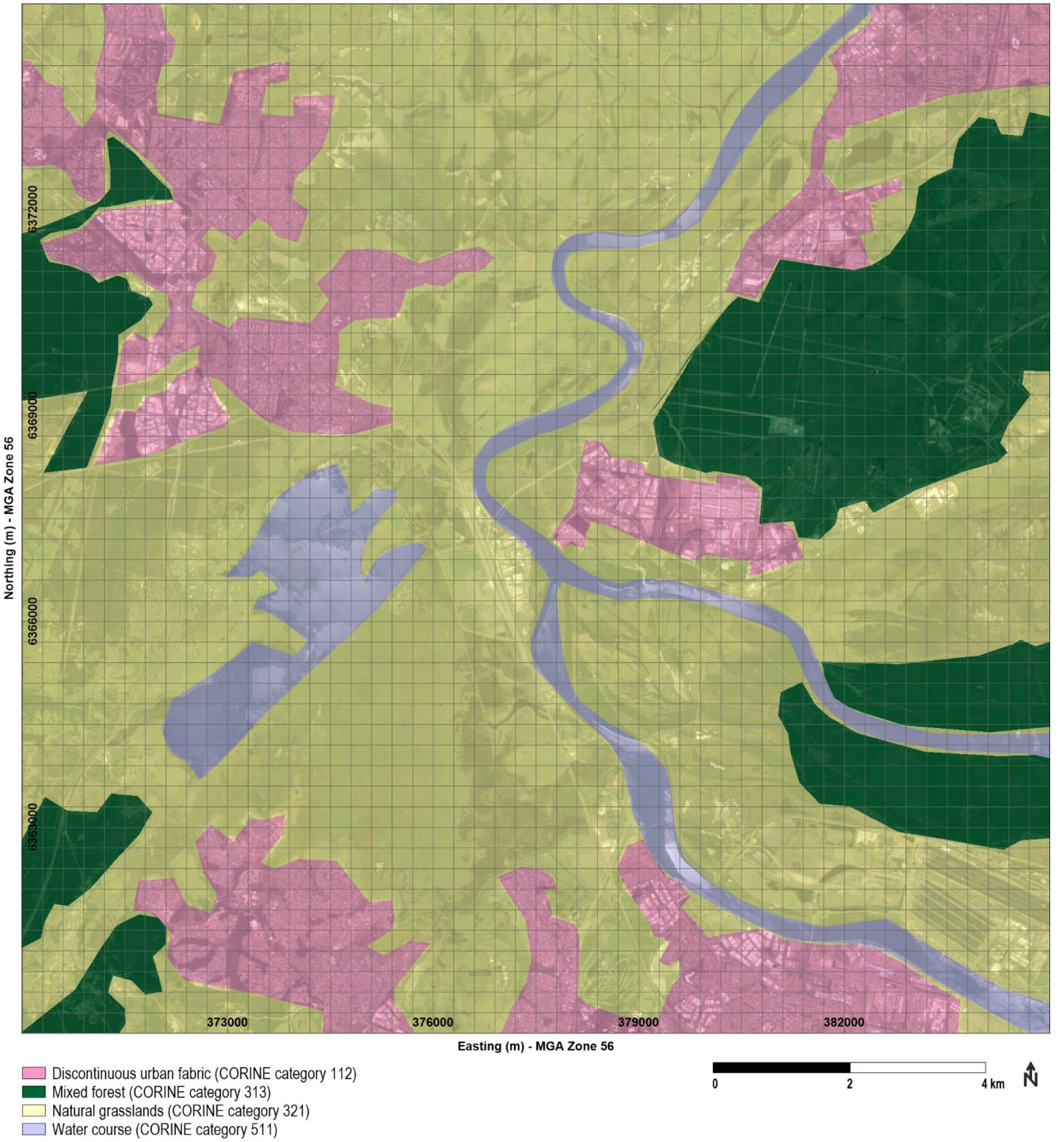


Figure 3-4 GRAMM model domain, grid resolution and land use setup

GRAMM has been used to develop a range of wind fields for the model domain based on the setup described above and informed by data from a representative meteorological station. The resultant wind fields, often referred to as ‘meteorological situations’, have then been used as input to the dispersion model, GRAL.

The DPIE operates a meteorological station in the grounds of Francis Greenway High School, Beresfield, located about 1.5 kilometres north of the project. This station is central to the project and well positioned to collect data that are representative of conditions across the proposed road alignment.

GRAMM requires hourly records of wind speed, wind direction, and atmospheric stability. Wind speed and wind direction are measured directly while atmospheric stability is a derived parameter. In this case, atmospheric stability was derived using sigma-theta and the method described by the United Stated Environmental Protection Agency (US EPA, 2000). Meteorological data collected at the DPIE Beresfield station in 2016 were used for GRAMM.

The GRAMM Match-to-Observation function was used to refine the order of the simulated wind fields to provide a better match to the observations at the DPIE Beresfield station. Weighting factors of 1 were used for both the overall weighting and wind direction weighting.

Further details regarding the meteorological conditions near the project are provided in **Chapter 4**.

3.3.4 Dispersion modelling

The changes in the air pollutant concentrations for each assessment scenario have been predicted over a 15 kilometre by 15 kilometre region using GRAL (Version 20.01). GRAL is a Lagrangian particle model that was developed at the Graz University of Technology, Austria. It is most commonly used for predicting air quality across road networks. Pollutant concentrations are predicted by simulating the movement of individual particles in a three-dimensional wind field. The trajectory of each of the particles is determined by mean and random velocity components.

GRAL simulates dispersion for all prescribed meteorological situations. Typically between 500 and 600 different meteorological situations are sufficient to characterise the dispersion conditions in an area during all 8760 hours of a year. The model is fully described in the user manual (Öttl and Kutner, 2020).

The modelling was performed using the emission estimates from **Section 3.3.2** and using the meteorological information provided by the GRAMM model, described in **Section 3.3.3**. The model has been used in this study to predict air pollutant concentrations across a region of 15 kilometres by 15 kilometres. Model predictions were made at regular spaced (20 metres) grid points across the entire model domain.

Key model settings for GRAL are shown below in **Table 3-4**.

Table 3-4 Model input settings for GRAL

Parameter	Value
Model version	20.01
Model domain (MGA Zone 56)	Easting 370000-385000, Northing 6360000-6375000
Dispersion time (s)	3600
Particles per second	400
Surface roughness (m)	0.4 (overridden by two-dimensional land use data provided to GRAMM)
Latitude (degrees)	32.80 S
Horizontal grid resolution (m)	20
Number of horizontal slices	1
Height above ground (m)	3.0
Source groups	96 (one per hour of the day and four pollutants)

Parameter	Value
Meteorological data	DPIE Beresfield station, 2016
Number of links	231 to 265 (refer **Table 3-1**)
Number of classified weather situations	513

Model predictions were then compared with the air quality design criteria, previously discussed in **Section 2.4**. Results have been tabulated for key sensitive receiver locations and contour plots have also been created to show the spatial distribution of model predictions. A low pass Gaussian filter has been applied to contour plots for averaging times of 24 hours or less to smooth some of the artefacts that arise from particle models that use random components.

Dispersion modelling has inherent uncertainties. The key sources of uncertainty in this assessment relate to the input traffic data, emission factors and the ability of the model to reproduce atmospheric conditions. In practice, this uncertainty cannot be reliably calculated for air quality modelling due to the nature of the key sources. However the uncertainty has been managed by adopting conservative approaches where possible. These approaches have included the selection of maximum or near maximum background levels, season maximum emission factors and, in the case of hydrocarbons, maximum assumed speciation percentages. In addition, five assessment scenarios have been considered in order to identify the variability of model predictions.

The existing environment has first been characterised (**Chapter 4**) and then an assessment of the project has been made (**Chapter 5**).

4. Existing environment

4.1 Local setting

A diverse range of land uses are located around the project including rural and agricultural uses, environmental and water resources, manufacturing and industrial uses, services and utilities, and residential uses of varying densities. The proximity and density of sensitive land uses such as residential, educational and medical vary along the project. Potential impacts to ecological receptors in both construction and operational phases have been assessed. During operation, changes in air quality at both ecological locations and identified sensitive receivers were assessed. As it was determined that impacts at the identified sensitive receivers would represent potential worst case outcomes, they have been further considered as representative receptors in this assessment.

The local communities and key sensitive receivers near the project have been identified as follows:

- Black Hill local community: Sensitive receiver (R1) located along Lenaghans Drive
- Beresfield local community: Sensitive receiver (R2) located north of the New England Highway around the John Renshaw Drive Interchange
- Tarro local community: Sensitive receivers (R3 and R4) located north of the New England Highway
- Hexham local community. Sensitive receiver (R5 and R6) located near the intersection of Maitland Road and the Pacific Highway, and on Old Maitland Road
- Tomago local community: Sensitive receiver (R7) located along Tomago Road
- Heatherbrae local community: Sensitive receiver (R8) located off the Pacific Highway
- Raymond Terrace local community: Sensitive receiver (R9) located south east of the Pacific Highway
- Various vegetation communities (i.e. ecological receivers), primarily around Hexham Swamp, north of the Hunter River and south and east of Heatherbrae.

The receivers listed above and shown in **Figure 4-1** have been selected to represent a range of residential, occupational, educational, medical and other potentially sensitive locations. The proximity of these receivers to the project also means that these locations would be expected to experience the highest potential air quality impacts. These locations have been used as the basis for summarising worst case potential impacts during the operational phase of the project.

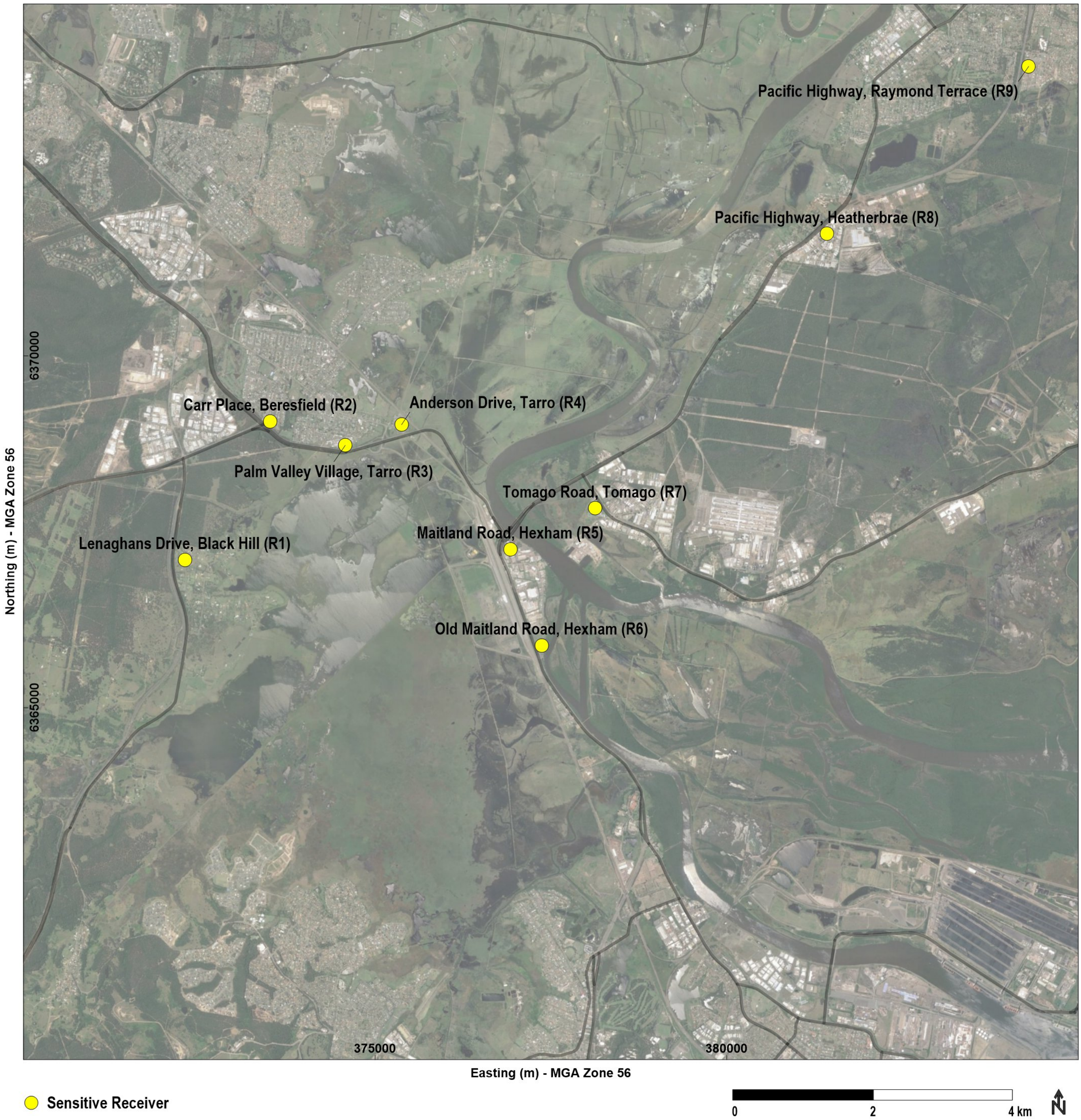


Figure 4-1 Sensitive receiver locations

4.2 Meteorological conditions

Meteorological conditions are important for determining the direction and rate at which emissions from a source would disperse. The key meteorological requirements of air dispersion models are, typically, hourly records of wind speed, wind direction, temperature and atmospheric stability. For air quality assessments, a minimum of one year of hourly data is usually required, which means that almost all possible meteorological conditions, including seasonal variations, are considered in the model simulations.

The NSW EPA has prescribed the minimum requirements for meteorological data that are to be used in dispersion modelling. These requirements are outlined in the 'Approved Methods for the Modelling and Assessment of Air Pollutants in NSW' (NSW EPA, 2016) and state that at least one year of 'site-specific' data should be used. If 'site-specific' data are not available then 'site-representative' data, correlated against at least five years of data, are acceptable. The meteorological data must also be at least 90 per cent complete. Although the Approved Methods were developed for stationary sources of air pollutants, rather than moving sources such as vehicles, this guidance was appropriate to use for this assessment to establish representative meteorological data suitable for air dispersion modelling.

Meteorological data collected over five recent years (2015 to 2019 inclusive) from the DPIE Beresfield station have been analysed in order to identify a representative year for the assessment. Hourly records of wind speed and wind direction were examined. The process for identifying a representative meteorological year involved comparing statistics and wind patterns for each calendar year for the period of 2015 to 2019, the most recent five years of data available at the time of writing.

Table 4-1 shows a range of statistics from the data collected at the DPIE Beresfield station from 2015 to 2019. These data show that the wind speed statistics do not vary significantly from year to year.

Table 4-1 Annual statistics from meteorological data collected at Beresfield between 2015 and 2019

Statistic	2015	2016	2017	2018	2019
Per cent complete (%)	99	98	85	100	99
Mean wind speed (m/s)	2.5	2.8	2.3	2.4	2.4
99^{th} percentile wind speed (m/s)	9.6	11.2	8.9	9.8	10.2
Percentage of calms (%)	4.0	4.2	4.0	4.9	4.7
Percentage of winds >6 m/s (%)	5.9	9.9	3.8	5.1	6.5

Figure 4-2 shows the annual wind patterns for each year from 2015 to 2019, based on data collected at the DPIE Beresfield station. Wind at a location can be summarised in data plots known as wind roses. Wind roses show the strength, direction and frequency of winds at a nominated location. The wind roses in **Figure 4-2** have been constructed in the following way:

- Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Eight directions are used
- The branches are divided into segments of different thickness and colour, which represent wind speed ranges from that direction. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

It can be seen from these wind roses that the most common winds in the area are from the west-northwest. This pattern of winds is common for the Lower Hunter Valley and reflects the influence of the northwest to southeast alignment of the Hunter Valley. It is also clear from **Figure 4-2** that wind patterns were similar in all five years of data presented. This suggests that wind patterns do not vary significantly from year to year, and potentially the data from any of the years presented could be used as a representative year for modelling purposes.

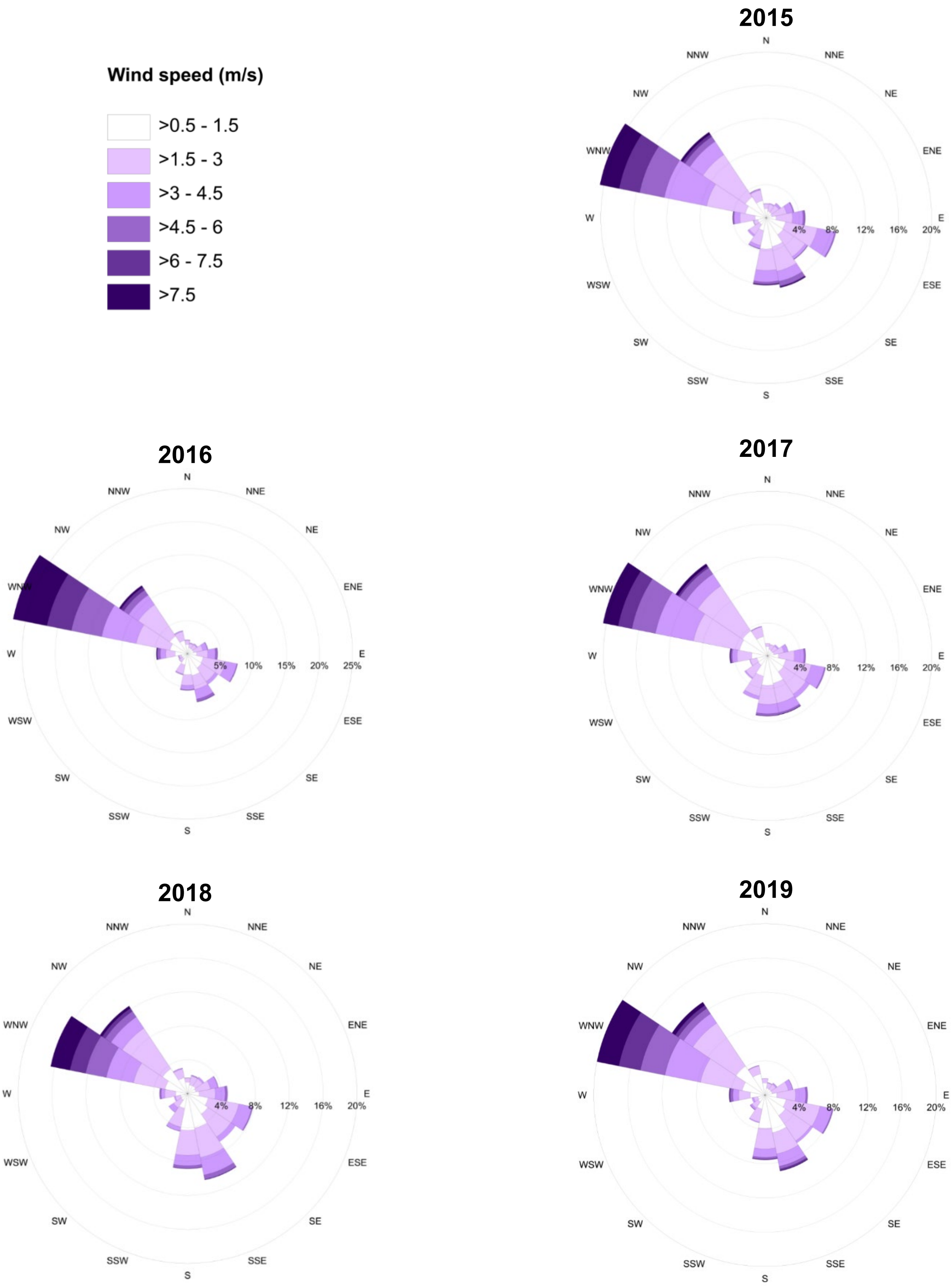


Figure 4-2 Annual wind-roses for data collected at the DPIE Beresfield station

4.3 Air quality conditions

4.3.1 Overview

The DPIE has established a network of monitoring stations across NSW to understand current air quality conditions and impacts, and to help identify programs to improve air quality. The closest air quality monitoring station to the area of interest is located at the DPIE Beresfield station. Data from this station have been examined and compared to relevant impact assessment criteria in order to understand the existing air quality conditions for the key pollutants that are relevant to the project.

Table 4-2 identifies the parameters that are measured at the DPIE Beresfield station. Carbon monoxide is not measured at the DPIE Beresfield station, so these records were obtained from the next nearest station, the DPIE Newcastle station, located approximately 14 kilometres to the southeast of the project.

Table 4-2 Measured parameters at nearby DPIE monitoring stations

Statistic	Distance from project	Measured parameters
Beresfield	2km	Meteorology, NO_2, PM_{10}, $PM_{2.5}$
Newcastle	14km	Meteorology, CO, NO_2, PM_{10}, $PM_{2.5}$

As for meteorological data, data completeness is important for ambient air quality records with 90 per cent completeness preferred. **Table 4-3** shows the data capture rates based on hourly records for the pollutants listed in **Table 4-2**. Data capture was more than 90 per cent in all cases except for CO in 2015.

Table 4-3 Summary of air quality monitoring data completeness

Parameter	Per cent of hourly records complete (%)				
	2015	2016	2017	2018	2019
CO (Newcastle)	89	94	93	92	91
NO_2 (Beresfield)	94	94	94	93	90
PM_{10} (Beresfield)	98	99	99	99	99
$PM_{2.5}$ (Beresfield)	93	94	94	91	91

Measurement data by pollutant are discussed further in the following sections.

4.3.2 Carbon monoxide (CO)

As noted above, the nearest monitoring station that measures CO is the DPIE Newcastle station. **Table 4-4** below provides a summary of CO concentrations measured at the DPIE Newcastle station from 2015 to 2019. These data show that CO concentrations have been consistently below the relevant NSW EPA impact assessment criteria for each year.

Table 4-4 Summary of measured CO concentrations at Newcastle

Statistic	Criterion	2015	2016	2017	2018	2019
Maximum 1-hour average in $\mu g/m^3$	30,000	2,000	2,400	1,600	1,400	2,200
Maximum 8-hour average in $\mu g/m^3$	10,000	1,700	1,600	1,300	1,200	1,700

4.3.3 Nitrogen dioxide (NO_2)

Table 4-5 below provides a summary of the measured NO_2 concentrations from the DPIE Beresfield station for the past five years. These data show that NO_2 concentrations have been consistently below the relevant NSW EPA impact assessment criteria for each year.

Table 4-5 Summary of measured NO_2 concentrations at Beresfield

Statistic	Criterion	2015	2016	2017	2018	2019
Maximum 1-hour average in µg/m^3	246	92	77	75	75	105
Annual average in µg/m^3	62	17	15	16	17	15

The assessment has been based on the modelling of NO_x emissions however NO_2 is the pollutant of interest for comparison with the air quality criteria. It is therefore important to distinguish between total NO_x and NO_2 and it is useful to assess the likely fraction of NO_x that is converted to NO_2 at locations where maximum impacts may be expected to occur. The monitoring data provide some insight into this conversion.

Oxides of nitrogen are produced in most combustion processes. During high-temperature processes there will be a variety of NO_x formed including NO and NO_2. In general, at the point of emission, NO will comprise the greatest proportion of the total emission. Typically this is approximately 90% by volume of the NO_x. The remaining 10 per cent will comprise mostly NO_2. It is the NO_2 which has been linked to adverse health effects. Over time, in the presence of ozone and sunlight, most of the NO_x converts to NO_2, but in general by the time this has occurred the NO_2 has been well dispersed to lower, less harmful concentrations.

At the point of maximum NO_x impacts from motor vehicle exhausts the time interval may be such that only a small fraction of the NO_x would be oxidised to NO_2. In many ambient NO_x monitoring programs the percentage of NO_2 in the NO_x is (as a rule) inversely proportional to the total NO_x concentration, and when NO_x concentrations as detected at monitoring stations are at their highest, the percentage of NO_2 in the NO_x is typically of the order of 20 per cent.

Data from the DPIE Beresfield station show that the NO_2 to NO_x ratio decreases with increasing NO_x concentration. **Figure 4-3** plots the ratio of NO_2 to NO_x against total NO_x concentrations measured at the DPIE Beresfield station between 2015 and 2019, including the exponential fit. The average NO_2 to NO_x percentage from all data is 68 per cent. This percentage decreases with increasing NO_x concentrations and for the very highest NO_x concentrations (i.e. above 300 µg/m^3) the NO_2 concentration is less than 20 per cent. Since the operations modelling aims to predict maximum NO_x concentrations it has therefore been assumed that 20 per cent of the NO_x is NO_2 when assessing the maximum 1-hour average predictions. This method of determining NO_2 from NO_x predictions is referred to as the ambient air quality method.

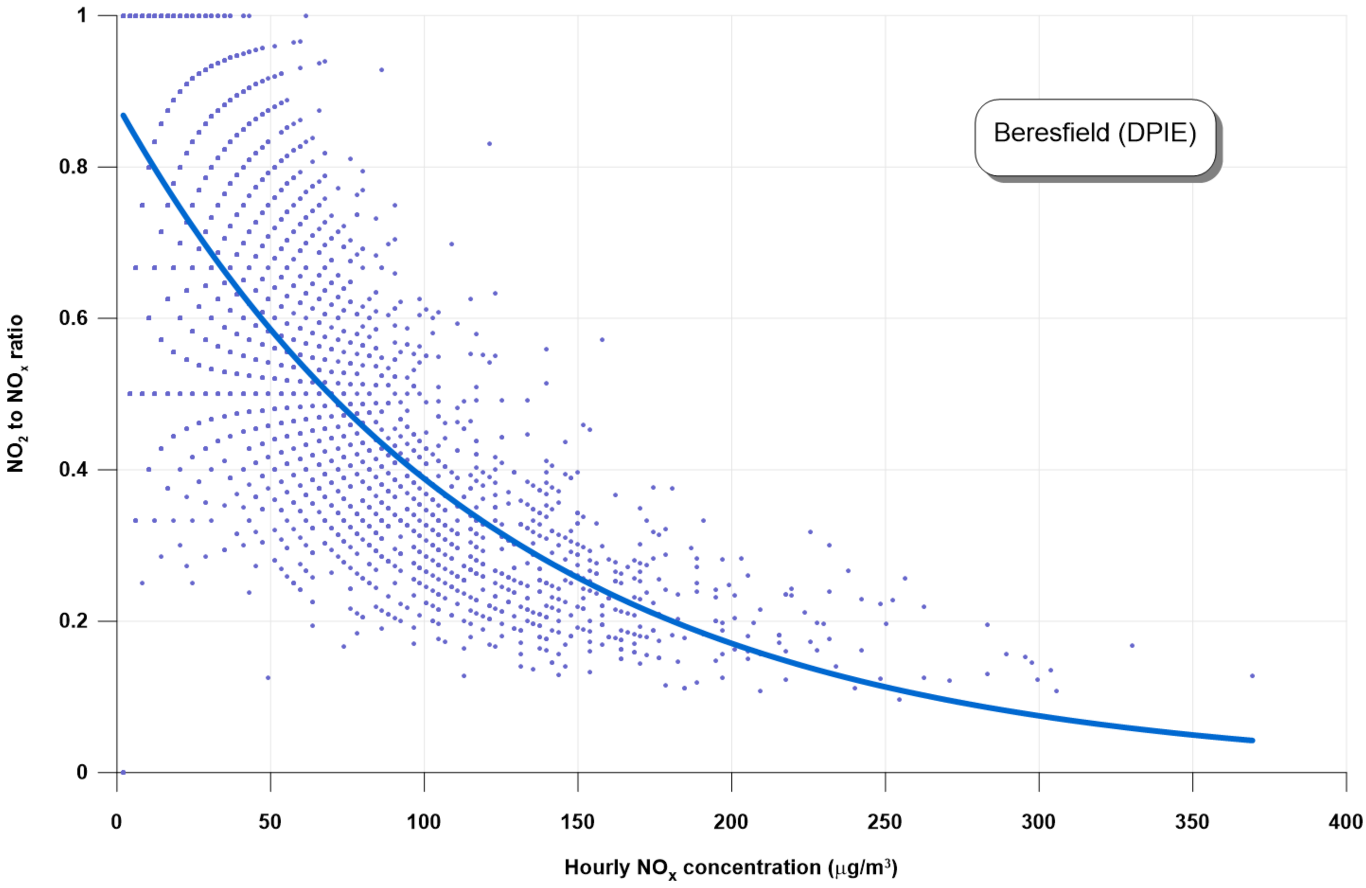


Figure 4-3 Measured NO_2 to NO_x ratios from hourly data collected at Beresfield (2015 to 2019)

4.3.4 Particulate matter (PM_{10})

A time-series of 24-hour average PM_{10} concentrations data collected from the DPIE Beresfield station between 2015 and 2019 is displayed below in **Figure 4-4**. For reference, the NSW EPA's daily impact assessment criterion of 50 µg/m^3 is also displayed (red-dashed line).

The measurement data represent the contributions from all sources that have at some stage been upwind of the monitor. For example, the measured concentrations may contain emissions from many sources such as from mining activities, construction works, bushfires and 'burning off', industry, vehicles, roads, wind-blown dust from nearby and remote areas, fragments of pollens, moulds, domestic wood fires and so on.

From 2015 to 2019 there were multiple instances when the 24-hour average PM_{10} concentrations exceeded 50 µg/m^3. In their 'Annual Air Quality Statement 2018' the Office of Environment and Heritage (now DPIE) concluded that particle levels increased across NSW due to dust from the widespread, intense drought and smoke from bushfires and hazard reduction burning (OEH, 2019). Air quality conditions in the Lower Hunter region were clearly influenced by the drought conditions in 2017 and 2018 and lower than average rainfall. In addition, late 2019 coincided with a period of unprecedented bushfires in Australia, predominantly across southeast Australia. The bushfires adversely affected air quality across many parts of NSW including the Lower Hunter and these events are reflected in the data presented in **Figure 4-4** and in the summary statistics (**Table 4-6**).

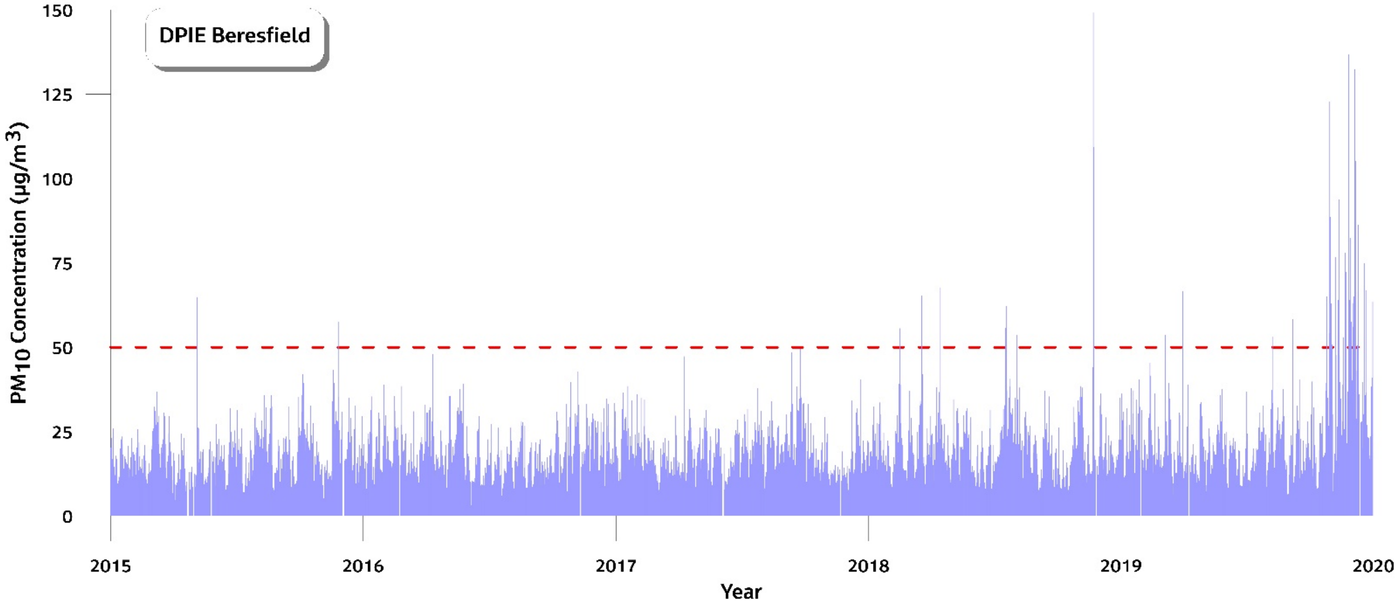


Figure 4-4 Measured 24-hour average PM_{10} concentrations at Beresfield

Table 4-6 Summary of measured PM_{10} concentrations at Beresfield

Statistic	Criterion	2015	2016	2017	2018	2019
Maximum 24-hour average in µg/m^3	50	65	48	49	149	137
Number of days above 50 µg/m^3	N/A	2	0	0	8	30
Annual average in µg/m^3	25*	19	19	20	22	26

NA = Not applicable (no criterion)
* Introduced by the NSW EPA from January 2017 onwards

4.3.5 Particulate matter ($PM_{2.5}$)

A time-series of 24-hour average $PM_{2.5}$ concentrations data collected from the DPIE Beresfield station between 2015 and 2019 is displayed below in **Figure 4-5**. The NSW EPA's 24-hour average $PM_{2.5}$ assessment criterion of 25 µg/m^3 is also displayed (red-dashed line).

There were multiple days from 2015 to 2019 when $PM_{2.5}$ concentrations exceeded the NSW EPA's impact assessment criterion (in this case 25 µg/m^3) with a higher frequency of exceedances also occurring in 2019 as a result of the bushfires. These outcomes are exhibited in the summary statistics (**Table 4-7**).

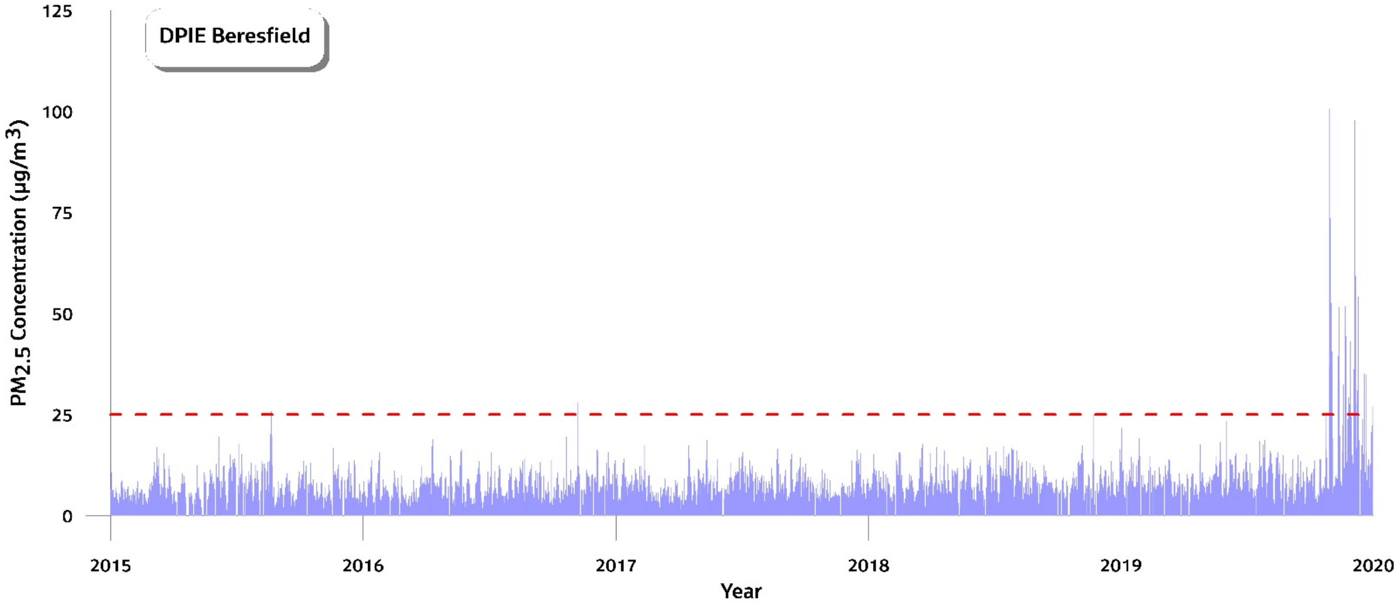


Figure 4-5 Measured 24-hour average $PM_{2.5}$ concentrations at Beresfield

Table 4-7 Summary of measured $PM_{2.5}$ concentrations at Beresfield

Statistic	Criterion	2015	2016	2017	2018	2019
Maximum 24-hour average in µg/m^3	25*	26	28	19	25	101
Number of days above 25 µg/m^3	NA	1	1	0	0	23
Annual average in µg/m^3	8*	7.4	7.4	7.6	8.7	12.2

NA = Not applicable (no criterion)
* Introduced by the NSW EPA from January 2017 onwards

4.4 Summary of existing environment

The following conclusions have been made from the review of local meteorological and ambient air quality monitoring data:

- Wind patterns in the vicinity of the project are characteristic of the Lower Hunter Valley, with the prevailing winds being from the west-northwest
- Measured CO and NO_2 concentrations have been consistently below NSW EPA air quality impact assessment criteria
- NO_2 concentrations are typically 68 per cent of the total NO_x concentrations, on average. However, the NO_2 percentage decreases with increasing NO_x concentrations and for the very highest NO_x concentrations the NO_2 concentration is less than 20 per cent
- Particle levels (as PM_{10} and $PM_{2.5}$) will be influenced by many sources including mining activities, construction works, bushfires and ‘burning off’, industry, vehicles, roads, wind-blown dust from nearby and remote areas, fragments of pollens, moulds, and domestic wood fires. Concentrations increased across NSW from 2017 to 2019 due to dust from the widespread, intense drought and smoke from bushfires and hazard reduction burning (OEH 2019). These events adversely influenced air quality with multiple days observed when PM_{10} and $PM_{2.5}$ concentrations exceeded NSW EPA criteria.

Meteorological data from the 2016 calendar year were used for the modelling, based on data completeness, a representative year that was not adversely impacted by bushfires and dust storms, and a year that was close to the baseline traffic year (2017).

Background air quality measurement data for relevant key pollutants were also reviewed. All years met the 90 per cent target for data completeness, except CO in 2015. The review highlighted that drought and bushfires had adversely influenced air quality between 2017 and 2019 but particularly in late 2019. The 2019 calendar year was an extraordinary year with regards to background air quality and cannot be considered as representative.

One of the objectives for reviewing the air quality monitoring data was to determine appropriate background levels to be added to model predictions for the assessment of potential cumulative impacts, that is, due to all existing and potentially modified sources of air pollutants. For this objective, it was necessary to estimate background levels that apply at sensitive receivers.

Table 4-8 shows the assumed background levels that apply in the vicinity of the project. The justification for these background levels is also provided, with conservative approaches adopted in most instances.

Table 4-8 Assumed background levels that apply in the vicinity of the project

Pollutant	Averaging time	Assumed background level	Notes
CO	1-hour	2,400 µg/m^3	Maximum 1-hour concentration from Newcastle (2015 to 2019)
	8-hour	1,700 µg/m^3	Maximum 8-hour concentration from Newcastle (2015 to 2019)
NO_2	1-hour	105 µg/m^3	Maximum 1-hour concentration from Beresfield (2015 to 2019)
	Annual	17 µg/m^3	Highest annual concentration from Beresfield (2015 to 2019)
PM_{10}	24-hour	48 µg/m^3	Maximum 24-hour average in 2016 (2017 to 2019 were excluded due to drought, dust storms and bushfires)
	Annual	22 µg/m^3	Highest annual concentration from Beresfield (2015 to 2018)
$PM_{2.5}$	24-hour	28 µg/m^3	Maximum 24-hour average in 2016 (2017 to 2019 were excluded due to drought, dust storms and bushfires)
	Annual	8.7 µg/m^3	Highest annual concentration from Beresfield (2015 to 2018)

5. Assessment of potential impacts

5.1 Construction impacts

The key air quality issue during construction would be dust. Dust emissions from construction works have the potential to cause nuisance impacts if not properly managed. Air quality impacts during construction would largely result from vegetation clearing, topsoil stripping, lime stabilisation of soils and lime neutralisation of acid sulfate soils, demolition of redundant assets, stockpiling of soil, operation of batch plants, and general material handling.

The project would be constructed as follows:

- Early works including preparation of utilities, construction of temporary pavement, establishment of ancillary sites, salvage works, ground contamination remediation, construction of access tracks, modifications to intersections and surcharge loading of areas identified as soft soil
- Construction of 12 bridge structures including over existing roads, the rail line and the Hunter River
- Development of interfaces, tie-ins and interchanges with existing roadways
- Provision of drainage and utility services
- Development of 21 ancillary sites to support the construction works
- Development of ancillary sites construction access tracks.

The total amount of dust generated would depend on the quantities of material handled, silt and moisture content of the soil, the types of operations being carried out, exposed areas, frequency of water spraying and speed of vehicles and machinery operating on unpaved roads and areas. The detailed approach to construction would depend on decisions made by the successful contractor(s), and changes to the construction methods and sequences that are expected to take place during the construction phase.

During construction, various materials would need to be handled including topsoil, mulch, cut and fill, pavement, and concrete. The handling of these materials has the potential to generate dust. Equipment is anticipated to include excavators and backhoes, concrete trucks, tipper trucks, cranes, compressors for pneumatic equipment, generators, staff vehicles, fuel for equipment, machinery and vehicles, asphalt paver and profilers, and water carts. The number and type of equipment would vary depending on the development activity being carried out.

Construction would typically occur between 6 am and 7 pm Monday to Friday and between 8 am and 1 pm on Saturday. In areas where work would be carried out away from sensitive received (for example, north of Tarro) the construction may also occur on Saturday, Sunday and public holidays between 7 am and 5 pm. Construction is anticipated to occur over approximately a three year period.

In practice, it is not possible to realistically quantify impacts using dispersion modelling. To do so would require knowledge of weather conditions for the period in which work would be taking place in each location on the site. However, it would be important that exposed areas be stabilised as quickly as possible and that appropriate dust measures are implemented to keep dust impacts to a minimum.

The semi-quantitative method developed by the IAQM was used to assess the potential for dust impacts during the construction phase of the project. This method aims to identify a dust risk for the entire project and, as shown in **Figure 3-1**, involves the following steps:

- Step 1 Screening review: a screening review to identify whether there are receivers nearby which have the potential to be impacted by the intended works, and whether a more detailed assessment is required

- Step 2 Risk assessment including:
  - 2A: evaluating the potential magnitude of the works
  - 2B: determining receiver sensitivities to dust soiling, human health and ecological dust impacts
  - 2C: estimating the risk of dust soiling, human health and ecological dust impact impacts if no mitigation measures are applied.
- Step 3 Mitigation and management: developing mitigation measures for each work location depending on the level of risk determined in Step 2
- Step 4 Residual risks: evaluating any residual dust related risks following the application of the mitigation measures in Step 3 to verify that a suitable level of mitigation has been applied to reduce the impact to the extent practicable.

The findings of each step are presented in the following sections.

5.1.1 Step 1 (screening review)

Step 1 of the IAQM assessment method involves a screening review to confirm the presence of human and ecological receptors within the vicinity of a project. The IAQM considers human receivers as any location where people spend some period of time and where property may be impacted by dust, and ecological receivers as any ecological areas that might be sensitive to dust impacts. This definition is considered to include threatened ecological communities, as well as ecologically sensitive commercial developments. The intent of this step is to identify whether there are human and ecological receivers nearby which have the potential to be impacted by the proposed work. The IAQM advises a study area of 350 metres from the boundary of the site or within 500 metres of site egress points for human receivers, and 50 metres from the boundary of the site or within 500 metres of site egress points for ecological receivers.

As described in **Section 4.1**, there are many human and ecological receivers located within the setback distances above from the construction footprint of the project. As such, it was determined that the next stages of the assessment would be required.

5.1.2 Step 2 (risk assessment)

The second step in the IAQM methodology involves evaluating the risk of dust impacts during construction. This step is further divided into three steps which are described in the following sections.

Step 2A (potential for dust emissions)

Step 2A involves the estimation of the magnitude of potential dust emissions associated with the project construction activities. The method for evaluating the magnitude of potential emissions considers the scale and nature of the anticipated activities. The objectives used to classify the magnitude of dust emissions arising from demolition, earthworks, construction and trackout activities from the IAQM method have been reproduced in **Table 5-1**. Colour-coding was added in **Table 5-1** as well as subsequent tables for ease of interpretation of the results. ‘Orange’ shading was added for large or high classifications or ratings, with ‘yellow’ and ‘green’ shading applied for medium and low or small classifications and ratings respectively.

Table 5-1 IAQM Step 2A (objectives for classifying the magnitude of potential dust emissions)

Activity	**Potential dust emission magnitude classification**		
	'Large'	**'Medium'**	**'Small'**
Demolition	Large – Total building volume greater than 50,000 m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities greater than 20 metres above ground level	Medium – Total building volume 20,000 to 50,000 m^3, potentially dusty construction material, demolition activities 10 to 20 metres above ground.	Small – Total building volume less than 20,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber), demolition activities less than 10 metres above ground, demolition during wetter months.
Earthworks	Large – Total site area greater than 10,000 m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), more than 10 heavy earth moving materials active at any one time, formation of bunds greater than eight metres in height, total materials moved exceeding 100,000 tonnes.	Medium – Total site area between 2500 and 10,000 m^2, moderately dusty soil type (e.g. silt), five to 10 heavy earth moving vehicles active at any one time, formation of bunds four to eight metres in height, total material moved between 20,000 and 100,000 tonnes.	Small – Total site area less than 2500 m^2, soil type with large grain size (e.g. sand), less than five heavy earth moving vehicles active at any one time, formation of bunds less than four metres in height, total materials moved less than 20,000 tonnes, earthworks during wetter months.
Construction	Large – Total building volume greater than 100,000 m^3, on-site concrete batching, sandblasting	Medium – Total building volume between 25,000 and 100,000 m^3, potentially dusty construction material (e.g. concrete), on-site concrete batching plant.	Small – Total building volume less than 25,000 m^3, construction material with a low potential for dust release (e.g. metal cladding or timber).
Trackout	Large – More than 50 heavy vehicle movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road lengths greater than 100 metres.	Medium – 10 to 50 heavy vehicle movements in any one day, moderately dusty surface (e.g. high clay content), unpaved road length between 50 and 100 metres.	Small – Less than 10 heavy vehicle movements in any one day, surface material with low potential for dust release, unpaved road length less than 50 metres.

Source: UK IAQM, 2014

Using the descriptions of proposed construction activities for the project outlined in Chapter 5 of the EIS, potential dust emission magnitude classifications were developed for the project. These are listed in **Table 5-2**.

Table 5-2 Dust emission magnitude classifications determined for the project

Activity	**Potential dust emission magnitude classification**
Demolition	Medium
Earthworks	Large
Construction	Large
Trackout	Large

Step 2B (sensitivity of surrounding local environment)

Step 2B involves the evaluation of the sensitivity of the receiving environment around the construction footprint. Classification of the sensitivity of these receiver areas considered:

- The specific sensitivities of receptors in the area
- The proximity and number of nearby receivers
- Local background air quality conditions characterised based on PM_{10} concentrations
- Site-specific factors such as whether there are natural shelters, to reduce the risk of wind-blown dust (UK IAQM, 2014).

The IAQM method considers how sensitive surrounding receiver areas may be to the effects of dust soiling, human health, and ecosystem impacts. Guidance on how the sensitivity of the receiving environment to these different dust effects were classified is listed in **Table 5-3**.

Table 5-3 IAQM receiver sensitivity classifications

Receiver sensitivity	Classification		
	'High'	'Medium'	'Low'
Sensitivity to dust soiling	High – Surrounding land where: • Users can reasonably expect enjoyment of a high level of amenity • The appearance, aesthetics or value of a property would be diminished by soiling • The people or property would reasonably be expected to be present continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land. Indicative examples include dwellings, museums and other culturally important collections, medium and long-term car parks and car show rooms.	Medium – Surrounding land where: • Users would expect to enjoy a reasonable level of amenity, but would not reasonably expect to enjoy the same level of amenity as in their home • The appearance, aesthetics or value of a property could be diminished by soiling • The people or property wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land. Indicative examples include parks and places of worship.	Low – Surrounding land where: • The enjoyment of amenity would not reasonably be expected • Property would not reasonably be expected to be diminished in appearance, aesthetics or value by soiling • There is transient exposure, where the people or property would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land. Indicative examples include playing fields, farmland (unless commercially-sensitive horticultural), footpaths, short-term car parks and roads.
Sensitivity to human health impacts	High: Locations where members of the public are exposed over a time period relevant to the air quality criteria for PM_{10}. Indicative examples include residential properties. Hospitals, schools and residential care homes should also be considered as having equal sensitivity to residential areas for the purpose of this assessment.	Medium: Locations where the people exposed are workers, and exposure is over a time period relevant to the air quality criteria for PM_{10}. Indicative examples include office and shop workers but will generally not include workers occupationally exposed to PM_{10}, as protection is covered by relevant Health and Safety legislation.	Low: Locations where human exposure is transient. Indicative examples include public footpaths, playing fields, parks and shopping streets.

Receiver sensitivity	Classification		
	'High'	'Medium'	'Low'
Sensitivity to ecological effects	High: Locations with an international or national designation and the designated features may be affected by dust soiling. Locations where there is a community of particularly dust sensitive species	Medium: Locations where there is particularly important plant species, where dust sensitivity is uncertain or unknown. Locations with a national or state designation where the features may be affected by dust deposition.	Low: Locations with a local designation where the features may be affected by dust deposition.

Source: UK IAQM, 2014

The techniques used to determine the respective sensitivities of nearby receivers to these effects have been reproduced in **Table 5-4**, **Table 5-5** and **Table 5-6**. In **Table 5-5** it is noted that the annual PM_{10} background concentration adopted for the assessment was 22 µg/m^3, as was determined from monitoring data for the local environment around the project (**Section 4.3**).

Table 5-4 IAQM Step 2B (method for determining sensitivity of receiving area to dust soiling effects)

Receiver sensitivity	Approximate number of receivers	Distance of receivers from the source (m)			
		Less than 20m	20 to 50m	50 to 100m	100 to 350m
High	More than 100	High	High	Medium	Low
	10 to 100	High	Medium	Low	Low
	1 to 10	Medium	Low	Low	Low
Medium	More than 1	Medium	Low	Low	Low
Low	More than 1	Low	Low	Low	Low

Source: UK IAQM, 2014

Table 5-5 IAQM Step 2B (method for determining sensitivity of receiving area to human health impacts)

Receiver sensitivity	Average PM_{10} concentration [a]	Approximate number of receivers	Distance of receivers from the source (m)				
			< 20	20 to 50	50 to 100	100 to 200	200 to 350
High	> 20 µg/m^3	More than 100	High	High	High	Medium	Low
		10 to 100	High	High	Medium	Low	Low
		1 to 10	High	Medium	Low	Low	Low
	17.5 to 20 µg/m^3	More than 100	High	High	Medium	Low	Low
		10 to 100	High	Medium	Low	Low	Low
		1 to 10	High	Medium	Low	Low	Low
	15 to 17.5 µg/m^3	More than 100	High	Medium	Low	Low	Low
		10 to 100	High	Medium	Low	Low	Low
		1 to 10	Medium	Low	Low	Low	Low
	< 15 µg/m^3	More than 100	Medium	Low	Low	Low	Low
		10 to 100	Low	Low	Low	Low	Low

Receiver sensitivity	Average PM_{10} concentration [a]	Approximate number of receivers	Distance of receivers from the source (m)				
			< 20	20 to 50	50 to 100	100 to 200	200 to 350
		1 to 10	Low	Low	Low	Low	Low
Medium	> 21 µg/m³	More than 10	High	Medium	Low	Low	Low
		1 to 10	Medium	Low	Low	Low	Low
	17.5 to 20 µg/m³	More than 10	Medium	Low	Low	Low	Low
		1 to 10	Low	Low	Low	Low	Low
	15 to 17.5 µg/m³	More than 10	Low	Low	Low	Low	Low
		1 to 10	Low	Low	Low	Low	Low
	< 15 µg/m³	More than 10	Low	Low	Low	Low	Low
		1 to 10	Low	Low	Low	Low	Low
Low	-	More than 1	Low	Low	Low	Low	Low

Source: UK IAQM, 2014.
[a] scaled for project, according to the ratio of NSW and UK annual average PM_{10} standards (25 µg/m³ and 40 µg/m³ respectively)

Table 5-6 IAQM Step 2B (method for determining sensitivity of receiving area to ecological impacts)

Receiver sensitivity	Distance of receivers from the source (m)	
	< 20	20 to 50
High	High	Medium
Medium	Medium	Low
Low	Low	Low

Source: UK IAQM, 2014.

The following dust soiling, human health, and ecological area sensitivity classifications were developed from application of the method outlined above and land use mapping around the project.

Sensitivity to dust soiling impacts

Potentially sensitive receivers and land uses would include residential, commercial, educational, medical, place of worship, sporting venues. The 'receiver sensitivity' to dust soiling near all construction areas was therefore determined to be high based on the definitions in **Table 5-3**. The number of high sensitivity human receiver locations were counted by mapping and, using the guidance in **Table 5-4**, the following dust soiling sensitivity ratings were determined (**Table 5-7**).

Table 5-7 Results for sensitivity of areas to dust soiling effects

Activity	Receiver sensitivity	Number of receivers by distance from the source (m)				Sensitivity to dust soiling impacts of area
		< 20	20 to 50	50 to 100	100 to 350	
Demolition	High	10 to 100	More than 100	More than 100	More than 100	High
Earthworks	High	10 to 100	More than 100	More than 100	More than 100	High
Construction	High	10 to 100	More than 100	More than 100	More than 100	High

Activity	Receiver sensitivity	Number of receivers by distance from the source (m)				Sensitivity to dust soiling impacts of area
		< 20	20 to 50	50 to 100	100 to 350	
Trackout	High	10 to 100	More than 100	More than 100	More than 100	High

Source: UK IAQM, 2014.

Given the density of receivers within 20 and 50 metres of the project, receiver sensitivity to dust soiling from construction activities was determined to be 'high'.

Sensitivity to human health impacts

For human health impacts, 'receiver sensitivity' was estimated based on the proximity and density of different types of receivers as outlined in **Table 5-3.** Using mapping, the number of high sensitivity human receiver locations were counted and using the guidance from **Table 5-5**, the human health sensitivity ratings in **Table 5-8** were determined.

Table 5-8 Results for sensitivity of areas to human health effects

Activity	Receiver sensitivity	Number of receivers by distance from the source (m)					Sensitivity to dust soiling impacts of area
		< 20	20 to 50	50 to 100	100 to 200	200 to 350	
Demolition	High	10 to 100	More than 100	More than 100	More than 100	More than 100	High
Earthworks	High	10 to 100	More than 100	More than 100	More than 100	More than 100	High
Construction	High	10 to 100	More than 100	More than 100	More than 100	More than 100	High
Trackout	High	10 to 100	More than 100	More than 100	More than 100	More than 100	High

Source: UK IAQM, 2014.

As listed, the sensitivity of the surrounding environment to human health effects was also determined to be high given the density of receivers in closer proximity to the construction footprint.

Sensitivity to ecological impacts

Sensitivity of the receiving environment to ecological impacts was classified by reviewing the presence of any ecologically sensitive areas within 50 metres of construction areas, consistent with **Table 5-6**. A number of ecologically sensitive habitat areas are located within 20 metres of the project. On this basis, as displayed in **Table 5-9**, the ecological sensitivity around each construction area was determined to be 'high'.

Table 5-9 Results for sensitivity of areas to ecological impacts

Activity	Receptor sensitivity	Distance from the source (m)	Ecological sensitivity of area
Demolition	High	<20 m	High
Earthworks	High	<20 m	High
Construction	High	<20 m	High
Trackout	High	<20 m	High

Source: UK IAQM, 2014.

Summary

Table 5-10 summarises the receiver sensitivity ratings determined for dust soiling, human health effects and ecological impacts. It should be noted that the IAQM aims to identify the overall unmitigated risks of the whole project. That is, the outcomes presented below represent the worst case, unmitigated outcome.

Table 5-10 Surrounding receiver sensitivity classifications determined for the project

Sensitivity to potential impact	Surrounding receiver sensitivity rating
Dust soiling	High
Human health impacts	High
Ecological effects	High

Source: UK IAQM, 2014.

Step 2C – Evaluation of the risk of dust impacts

Potential dust emission magnitude ratings determined in Step 2A (**Table 5-2**) and the surrounding area sensitivity classifications determined in Step 2B (**Table 5-10**) were combined in Step 2C using the guidance below in **Table 5-11** to 'determine the risk of impacts with no mitigation applied' (UK IAQM, 2014).The highest unmitigated risk values determined for each dust-related risk (i.e. dust soiling, human health and ecological impacts) for each of the four types of construction activities are summarised in **Table 5-12**.

Table 5-11 IAQM Step 2C (method for determining unmitigated dust impact risks)

Sensitivity of area (from Step 2B)	Dust emission potential (from Step 2A)		
	Large	Medium	Small
Demolition			
High	High risk	Medium risk	Medium risk
Medium	High risk	Medium risk	Low risk
Low	Medium risk	Low risk	Negligible
Earthworks			
High	High risk	Medium risk	Low risk
Medium	Medium risk	Medium risk	Low risk
Low	Low risk	Low risk	Negligible
Construction			
High	High risk	Medium risk	Low risk
Medium	Medium risk	Medium risk	Low risk
Low	Low risk	Low risk	Negligible
Trackout			
High	High risk	Medium risk	Low risk
Medium	Medium risk	Medium risk	Negligible
Low	Low risk	Low risk	Negligible

Source: UK IAQM, 2014.

Table 5-12 Unmitigated construction dust risk values for the project

Activity	Potential impact		
	Dust soiling	Human health impacts	Ecological effects
Demolition	Medium risk	Medium risk	Medium risk
Earthworks	High risk	High risk	High risk
Construction	High risk	High risk	High risk
Trackout	High risk	High risk	High risk

Source: UK IAQM, 2014.

As presented in **Table 5-12**, the highest unmitigated risk rating determined for the project was 'high risk'. This was determined for dust soiling, human health and ecological effects during earthworks, construction and trackout activities. This outcome represents the worst case, unmitigated outcome across the whole project.

5.1.3 Step 3 (mitigation and management)

As shown in **Table 5-12** a 'high' potential risk was the highest unmitigated level determined from the review of potential dust deposition, human health and ecological impacts from demolition, earthworks, construction and trackout activities during the project. Based on this result, the project was determined to present a 'high' risk of dust impacts during construction and measures commensurate to this level of risk have been recommended from guidance in the IAQM method. These are presented in **Chapter 6**.

5.1.4 Step 4 (residual risks)

It is anticipated that, with the application of the measures detailed in **Chapter 6**, residual risks from key activities during construction would be reduced to the extent where impacts could be effectively managed. Adverse residual impacts are therefore not anticipated.

5.1.5 Odour

In addition to construction dust, odour has the potential to impact on sensitive receivers and local communities during construction, including:

- Odour from asphalt batching
- Odour from the handling of potentially contaminated materials, including acid sulfate soils.

Existing asphalt batching plants may meet the needs of the project however there is a possibility that temporary, project-specific asphalt plants would be required. The most likely locations for these asphalt plants would be the ancillary sites (see Jacobs, 2020c) as follows:

- Black Hill (referred to as AS3)
- Tarro (referred to as AS7)
- Tomago (referred to as AS10)
- Tomago (referred to as AS11)
- Heatherbrae (referred to as AS16)
- Heatherbrae (referred to as AS17)
- Heatherbrae (referred to as AS19).

The number of asphalt plants would be dependent on the construction needs for the project once the procurement strategy and contractor(s) is engaged. Each necessary plant would occupy an area of approximately one hectare. This area would accommodate the stockpiling of various aggregates, vertical bins, drying drum and horizontal tanks. Jacobs (2020c) has estimated that the project would require in the order of 41,000 cubic metres of asphalt.

Odour is one of the key air quality issues for asphalt batch plants with the most significant emissions arising from the dryer, storage tanks and loadout areas. The indicative odour impacts of an asphalt plant have been quantified by dispersion modelling. This involved:

- Estimating odour emissions from a typical asphalt plant based on data presented by Jacobs (2018)
- Running the NSW EPA approved dispersion model, AUSPLUME, to predict odour levels at various distances from an asphalt plant, using meteorological data from the DPIE Beresfield station.

Table 5-13 shows the assumed model input data for a typical asphalt plant. These data have been derived from information presented by Jacobs (2018) and based on measurements from a plant producing 100 tonnes per hour (tph) of asphalt, a conservative estimate of the production rate for the project.

Table 5-13 Model input data for prediction of odour levels due to a typical asphalt plant

Parameter	Dryer / baghouse stack	Storage tank	Loadout
Assumed source type	Point	Volume	Volume
Assumed height (m)	6	2.5	2.5
Assumed stack tip diameter (m)	0.1	NA	NA
Assumed stack exhaust temperature (C)	64	NA	NA
Assumed stack exhaust velocity (m/s)	21	NA	NA
Assumed odour mass emission rates (OU/s)	33,333	204	222

Figure 5-1 shows the predicted 99^{th} percentile (i.e. near maximum) odour levels as a function of distance from a plant producing 100 tph of asphalt, based on all simulated meteorological conditions. These results reflect an assumed production and anticipated operating arrangements of a typical plant and are therefore indicative of the expected odour levels.

The modelling represents a guide on the potential separation distances required to minimise odour impacts from the asphalt plants since the locations and operations of each plant would not be defined until the procurement strategy for the project has been completed. The results from **Figure 5-1** indicate that a distance of 500 metres or more would be required to make sure that odour impacts at sensitive receivers are minimised and maintained below all relevant NSW EPA criteria under all conditions. Given the conservative nature of the modelling, the results have been interpreted to suggest that a distance in the order of 300 metres or more would be appropriate to manage odour impacts under most conditions. Therefore, if a temporary project-specific asphalt batching plant is required, then the recommended separation from nearest residences should be in the order of 300 metres or more.

Odour from the handling of potentially contaminated materials has also been investigated. Areas of potential contamination risk identified within the project construction footprint (Jacobs, 2020b) were reviewed to determine activities that may result in odour impacts during construction.

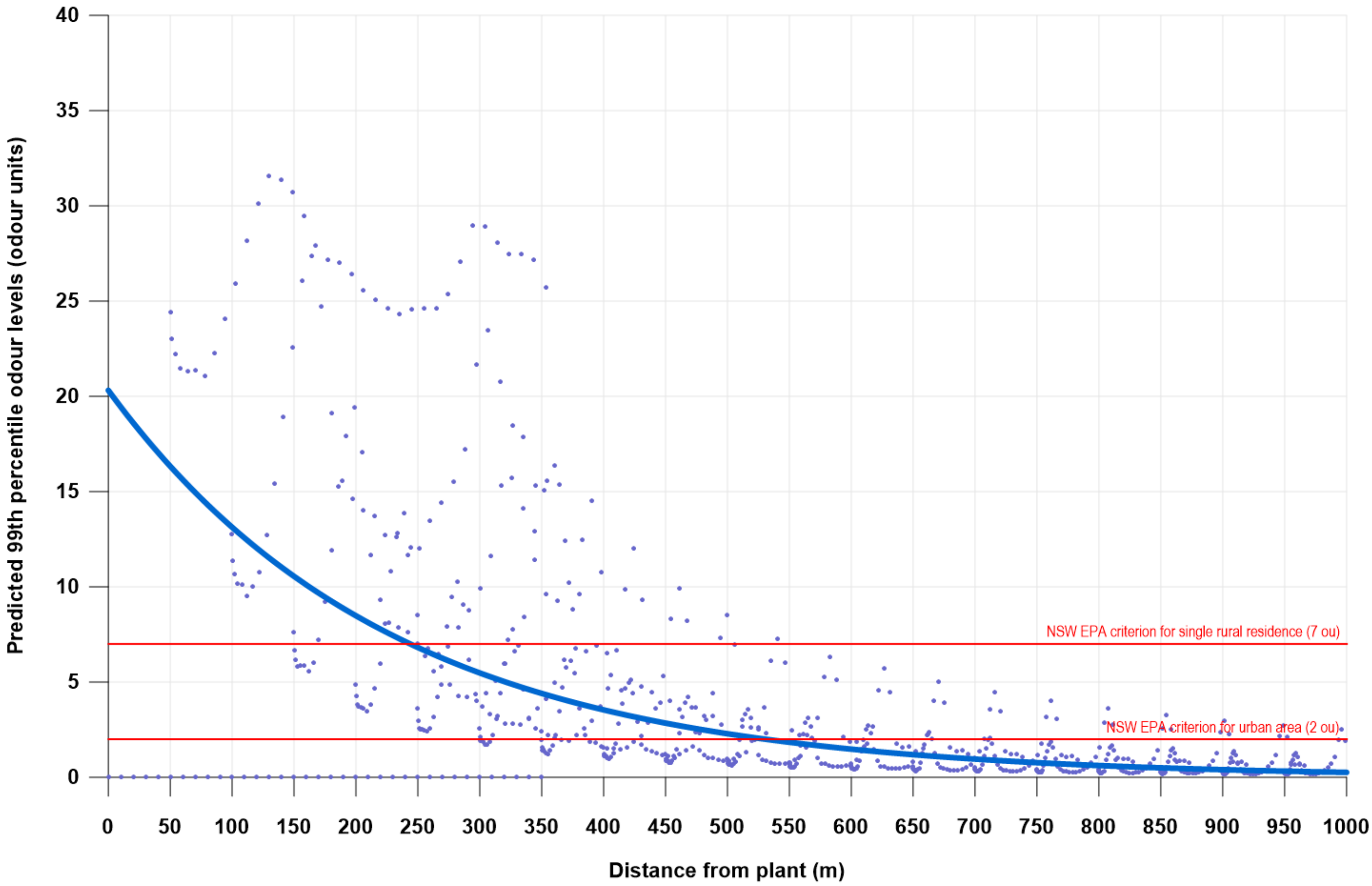


Figure 5-1 Predicted 99th percentile odour levels with distance from a 100 tph asphalt plant

The following contaminated materials have been identified as potentially resulting in odour impacts during construction:

- Acid sulphate soils
- Buried waste and asbestos waste at Tarro and Tomago
- Illegally dumped waste at various locations
- Hunter River sediments.

Jacobs (2020b) has conducted an extensive desktop review of publicly available information, historical land use information, aerial imagery, government registers and historical reports. This review concluded that contamination impacts, such as mobilisation of existing contamination and potential groundwater contamination, would likely be associated with construction of the project but odour associated with the above contaminated materials were not identified as a high project risk. Nevertheless, further investigation would be required to confirm specific remediation, treatment and management requirements for areas of potential contamination risk prior to construction (refer to the Soils and Contamination Working Paper [Appendix P of the EIS]).

Mulch would be generated by clearing of vegetation. Construction of the project is estimated to generate about 75,000 cubic metres of mulch, about half of which would be stockpiled within ancillary facilities for landscape planting and site rehabilitation. While odour from the generation and stockpiling of mulch would generally be of a fresh cut wood or soil nature, mulch stockpiles have potential to cause offensive odours due to the accumulation of toxins. Mulch would be turned regularly to precent accumulation of toxins and minimise odour impacts.

Measures to effectively manage these odour risks are included in **Chapter 6**. Provided the effective implementation of these measures, adverse odour impacts are not anticipated.

5.2 Operational impacts

The potential operational impacts of the project have been quantified using dispersion modelling as described in **Section 3.3.4**. Traffic network changes assumed for modelled scenarios are described in Traffic and Transport Working Paper for the project (Appendix G of the EIS). Results from the modelling have been assessed by examining the spatial differences between the with and without project scenarios, and also in terms of the potential for the project to cause exceedances of NSW EPA air quality impact assessment criteria at sensitive receivers. In this context, changes in air quality represent the difference between future scenarios with and without the project. This approach aimed to identify the overall effect on air quality as a result of introducing the project into the road network, including improved, more efficient traffic flow. Where the project would result in a decrease in the concentrations of key air quality indicators, due to the redirection of traffic that would result from the project, this has been identified within this section.

Air quality has been assessed at both a local scale (i.e. within a few hundred metres of the proposed route and other roads) and at a regional scale (i.e. across an area of 15 kilometres by 15 kilometres). Operation of the project would lead to a redistribution of vehicle emissions across the road network, generally from existing main roads to the proposed new roads. The highest concentrations of key air quality indicators are expected to occur close to main roads under all 'with project' and 'without project' scenarios. Increases in the concentrations of key air quality indicators, due to the project, are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River. In these locations there are generally few sensitive receivers. Decreases are expected to occur along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge. Specific assessment of each key air quality indicator is provided below.

5.2.1 Carbon monoxide (CO)

Model predictions of CO concentrations within the study area for each scenario are presented in **Figure 5-2** to **Figure 5-5**. These results represent the contribution of emissions from those roads that are expected to undergo the most change as a result of the project, as shown previously in **Figure 3-2**. Background levels are not included in the contour plots but are discussed below with reference to **Table 5-14**.

The model results in **Figure 5-2** to **Figure 5-5** indicate the following outcomes in terms of the spatial variations in CO:

- The highest 1-hour and 8-hour average CO concentrations are expected to occur close to existing and, where applicable, proposed main roads, under all scenarios, as this is where traffic would be concentrated
- The highest maximum 1-hour average CO concentrations are predicted to be in the order of 2 to 5 mg/m^3, under all scenarios (**Figure 5-2**)
- Increases in the maximum 1-hour average CO concentrations are expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-3**). Some decreases in maximum 1-hour average CO concentrations are expected along the New England Highway, east of Quarter Sessions Road. The lack of a visible reduction in **Figure 5-3** is due to the low concentrations and selected contour level
- The highest maximum 8-hour average CO concentrations are predicted to be in the order of 1 to 2 mg/m^3, under all scenarios (**Figure 5-4**)
- Increases in maximum 8-hour average CO concentrations are only expected in areas where there are no existing main roads (**Figure 5-5**). Some decreases in maximum 8-hour average CO concentrations are expected along the M1 Pacific Motorway, south of John Renshaw Drive, along the New England Highway, east of Quarter Sessions Road, and in the vicinity of the existing Hexham Bridge.

The predicted changes in CO concentrations due to the project (both increases and decreases) represent less than five per cent of the NSW EPA air quality assessment criteria. These changes are also within the range of historically measured fluctuations in CO concentrations for the region (**Section 4.3**).

Table 5-14 provides a summary of the model results for key sensitive receivers, where maximum impacts may be expected. These data show the contribution of modelled sources, the background levels, and the cumulative CO concentrations. The cumulative concentrations represent the background level plus the increment of the project relative to the scenario without the project.

The results in **Table 5-14** show that, at the selected sensitive receivers and local communities located near main roads along the proposed route, the project would lead to very little change to maximum CO concentrations. The changes in CO concentrations are predicted to be less than one per cent of the NSW EPA criteria. In addition, the project is not expected to cause exceedances of the NSW EPA air quality impact assessment criteria.

Table 5-14 Predicted CO concentrations at selected sensitive receivers

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
Maximum 1-hour average CO (µg/m³)									
R1 (Lenaghans Drive, Black Hill)	30000	266	465	464	432	459	2400	2399	2427
R2 (Carr Place, Beresfield)	30000	402	344	451	292	355	2400	2507	2463
R3 (Palm Valley Village, Tarro)	30000	585	479	651	348	588	2400	2572	2641
R4 (Anderson Drive, Tarro)	30000	811	725	851	520	665	2400	2526	2545
R5 (Maitland Road, Hexham)	30000	1087	778	791	690	735	2400	2413	2445
R6 (Old Maitland Road, Hexham)	30000	817	716	663	495	542	2400	2347	2448
R7 (Tomago Road, Tomago)	30000	157	162	212	129	176	2400	2450	2447
R8 (Pacific Hwy, Heatherbrae)	30000	167	224	228	198	221	2400	2404	2423
R9 (Pacific Hwy, Raymond Ter.)	30000	163	299	397	253	333	2400	2498	2480
Maximum 8-hour average CO (µg/m³)									
R1 (Lenaghans Drive, Black Hill)	10000	135	244	221	197	215	1700	1676	1717
R2 (Carr Place, Beresfield)	10000	214	193	238	155	208	1700	1745	1753
R3 (Palm Valley Village, Tarro)	10000	287	221	330	163	328	1700	1809	1865
R4 (Anderson Drive, Tarro)	10000	449	345	431	264	383	1700	1786	1819

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
R5 (Maitland Road, Hexham)	10000	575	449	444	374	408	1700	1696	1735
R6 (Old Maitland Road, Hexham)	10000	383	345	366	272	297	1700	1721	1725
R7 (Tomago Road, Tomago)	10000	93	88	107	70	94	1700	1719	1724
R8 (Pacific Hwy, Heatherbrae)	10000	96	120	127	101	122	1700	1706	1721
R9 (Pacific Hwy, Raymond Ter.)	10000	93	160	216	145	192	1700	1756	1747

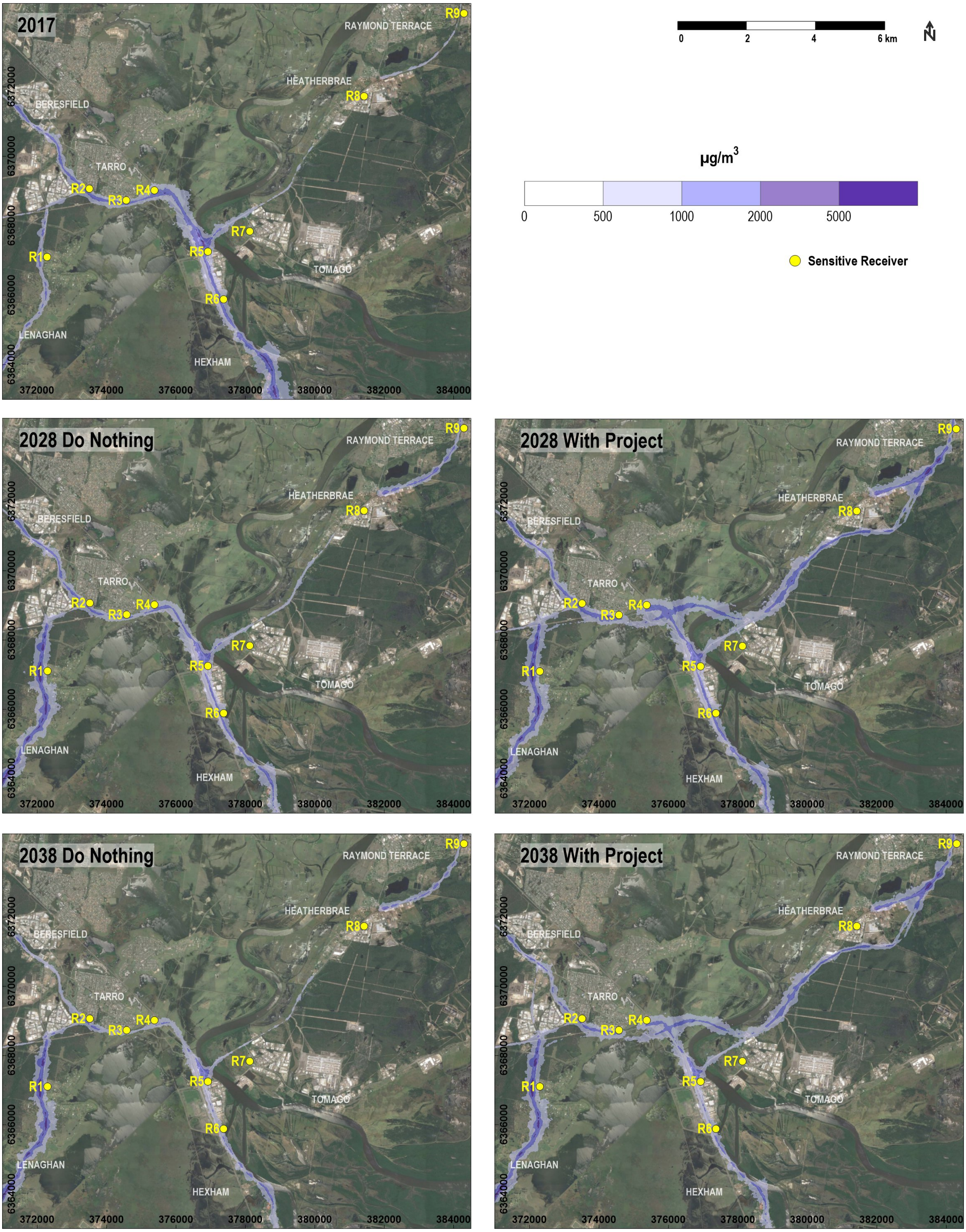


Figure 5-2 Predicted maximum 1-hour average CO due to modelled sources

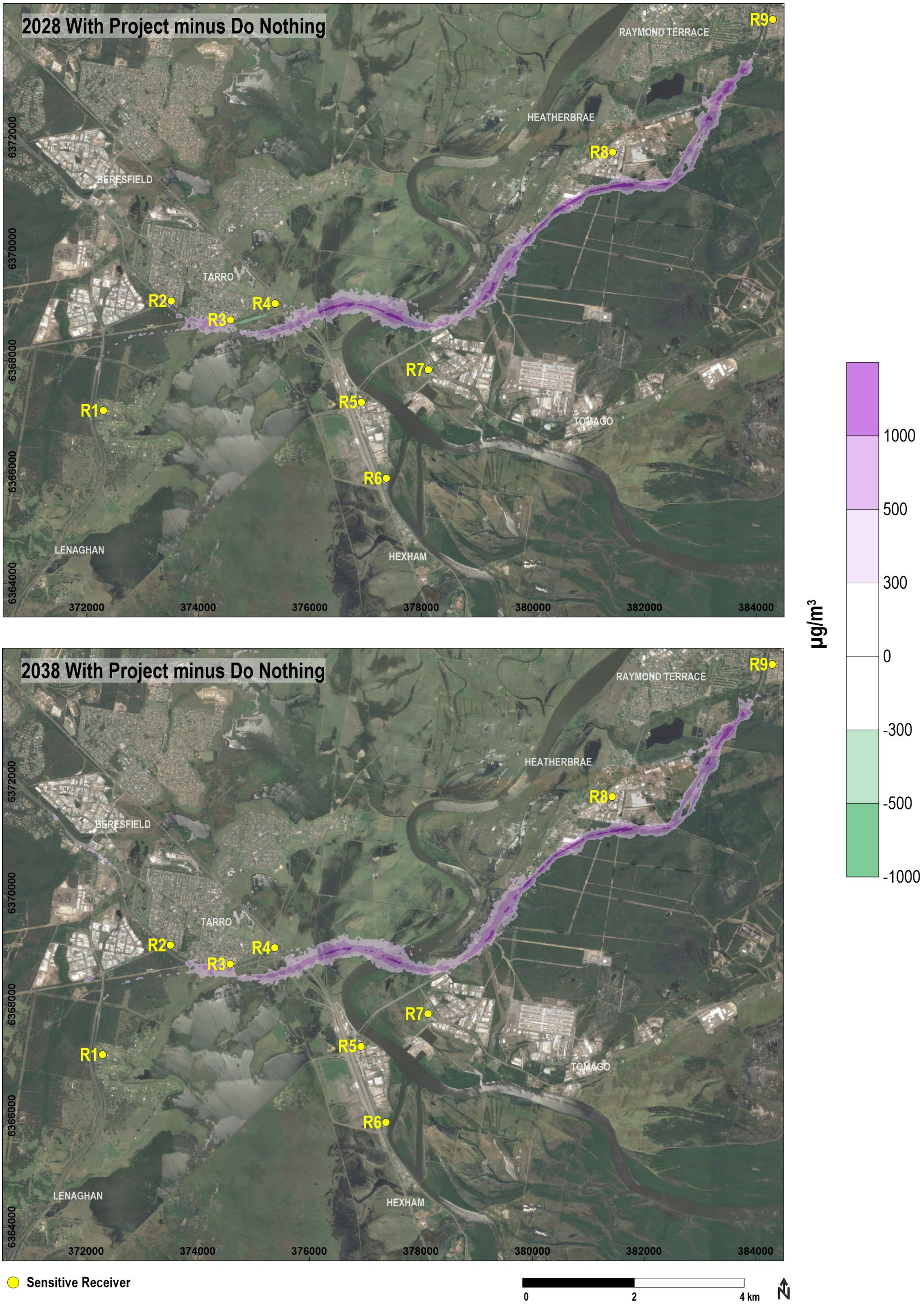


Figure 5-3 Predicted change in maximum 1-hour average CO due to modelled sources

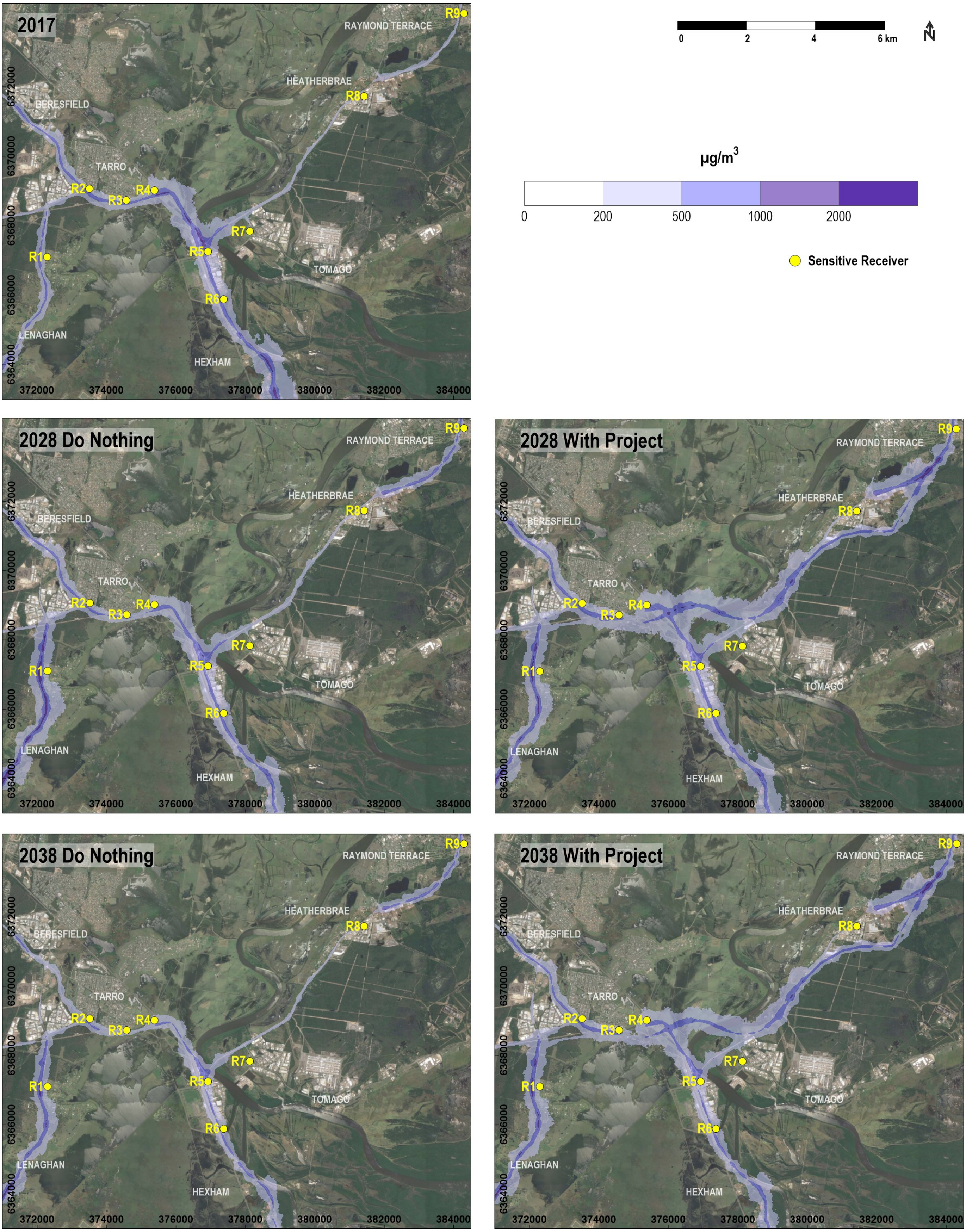


Figure 5-4 Predicted maximum 8-hour average CO due to modelled sources

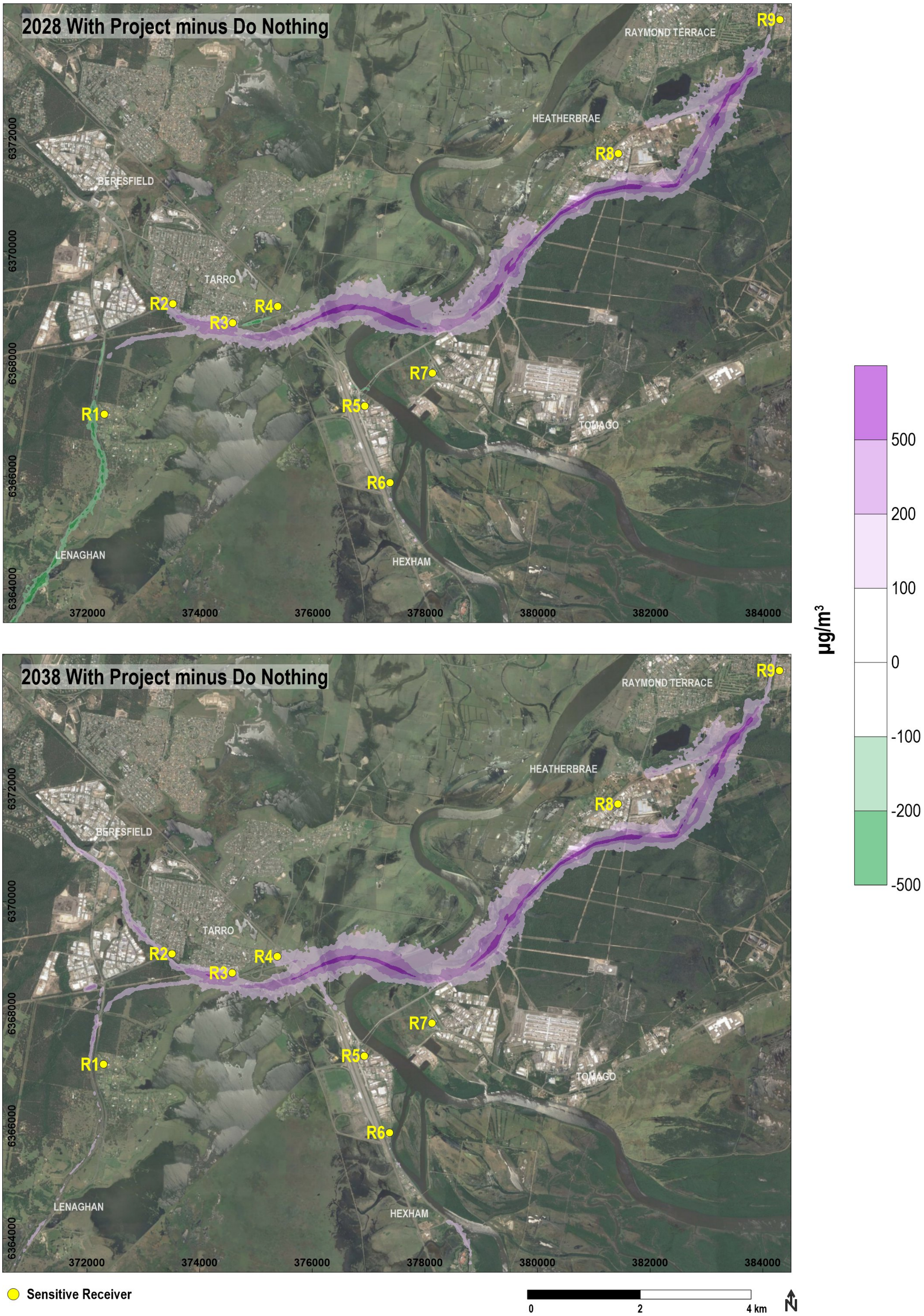


Figure 5-5 Predicted change in maximum 8-hour average CO due to modelled sources

5.2.2 Nitrogen dioxide (NO_2)

Model predictions of NO_2 concentrations within the study area for each scenario are presented in **Figure 5-6** to **Figure 5-9**. These results represent the contribution of emissions from those roads that are expected to undergo the most change as a result of the project. Background levels are not included in the contour plots but are discussed below with reference to **Table 5-15**. As discussed in **Section 4.3.3**, the maximum 1-hour average NO_2 concentrations have been derived from the NO_x predictions by assuming that 20 per cent of the NO_x is NO_2 at the point of maximum concentrations. Annual average NO_2 concentrations have been derived by assuming the 100 per cent of the NO_x has converted to NO_2. This is a conservative approach since air quality monitoring data showed that 68 per cent of the NO_x is NO_2, on average (**Section 4.3.3**).

The model results in **Figure 5-6** to **Figure 5-9** indicate the following outcomes in terms of the spatial variations in NO_2:

- The highest 1-hour and annual average NO_2 concentrations are expected to occur close to existing and, where applicable, proposed main roads, under all scenarios, as this is where traffic would be concentrated
- The highest maximum 1-hour average NO_2 concentrations are predicted to be in the order of 100 to 200 µg/m^3, under all scenarios (**Figure 5-6**)
- Increases in the maximum 1-hour average NO_2 concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-7**). Decreases in maximum 1-hour average NO_2 concentrations are expected along the New England Highway, east of Quarter Sessions Road, and on the Pacific Highway around the Hexham Bridge. The pattern of contours on **Figure 5-7** highlights some artefacts that can result from particle models for short averaging times. This pattern can be smoothed by various model settings, such as the number of particles simulated per second, however the same general trends in NO_2 concentration changes would be anticipated
- The highest annual average NO_2 concentrations are predicted to be in the order of 20 to 50 µg/m^3, under all scenarios (**Figure 5-8**)
- Increases in annual average NO_2 concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-9**). Decreases in annual average NO_2 concentrations are expected along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge.

The predicted maximum changes in NO_2 concentrations due to the project (both increases and decreases in one hour averages) are within the range of historically measured fluctuations in maximum NO_2 concentrations for the region (**Section 4.3**).

Table 5-15 provides a summary of the model results for sensitive receivers, where maximum impacts may be expected. These data show the contribution of modelled sources, the background levels, and the cumulative NO_2 concentrations. The cumulative concentrations represent the background level plus the difference between the 'with project' and 'without project' scenarios.

The results in **Table 5-15** show that, at the selected sensitive receivers and local communities located near main roads along the proposed route, the project would lead to very little change to maximum and annual NO_2 concentrations, relative to background levels. In addition, the project is not expected to cause exceedances of the NSW EPA air quality impact assessment criteria.

Table 5-15 Predicted NO_2 concentrations at selected sensitive receivers

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
Maximum 1-hour average NO_2 (µg/m^3)									
R1 (Lenaghans Drive, Black Hill)	246	25	30	33	30	38	105	108	113
R2 (Carr Place, Beresfield)	246	36	32	37	39	36	105	111	102
R3 (Palm Valley Village, Tarro)	246	50	36	43	36	39	105	112	108
R4 (Anderson Drive, Tarro)	246	84	78	47	53	54	105	74	107
R5 (Maitland Road, Hexham)	246	112	74	84	70	61	105	115	96
R6 (Old Maitland Road, Hexham)	246	75	52	50	42	47	105	103	109
R7 (Tomago Road, Tomago)	246	20	18	17	18	18	105	104	105
R8 (Pacific Hwy, Heatherbrae)	246	21	25	24	24	19	105	104	100
R9 (Pacific Highway, Raymond Terrace)	246	14	18	27	19	21	105	114	107
Annual average NO_2 (µg/m^3)									
R1 (Lenaghans Drive, Black Hill)	62	3	4	4	4	4	17	17	17
R2 (Carr Place, Beresfield)	62	8	5	6	6	5	17	17	17
R3 (Palm Valley Village, Tarro)	62	9	6	5	6	5	17	16	16
R4 (Anderson Drive, Tarro)	62	12	7	6	7	6	17	16	16
R5 (Maitland Road, Hexham)	62	18	12	12	12	11	17	17	16
R6 (Old Maitland Road, Hexham)	62	13	8	9	8	8	17	18	17
R7 (Tomago Road, Tomago)	62	3	3	2	2	2	17	17	17
R8 (Pacific Hwy, Heatherbrae)	62	3	3	2	3	2	17	16	16
R9 (Pacific Highway, Raymond Terrace)	62	2	2	3	2	3	17	18	17

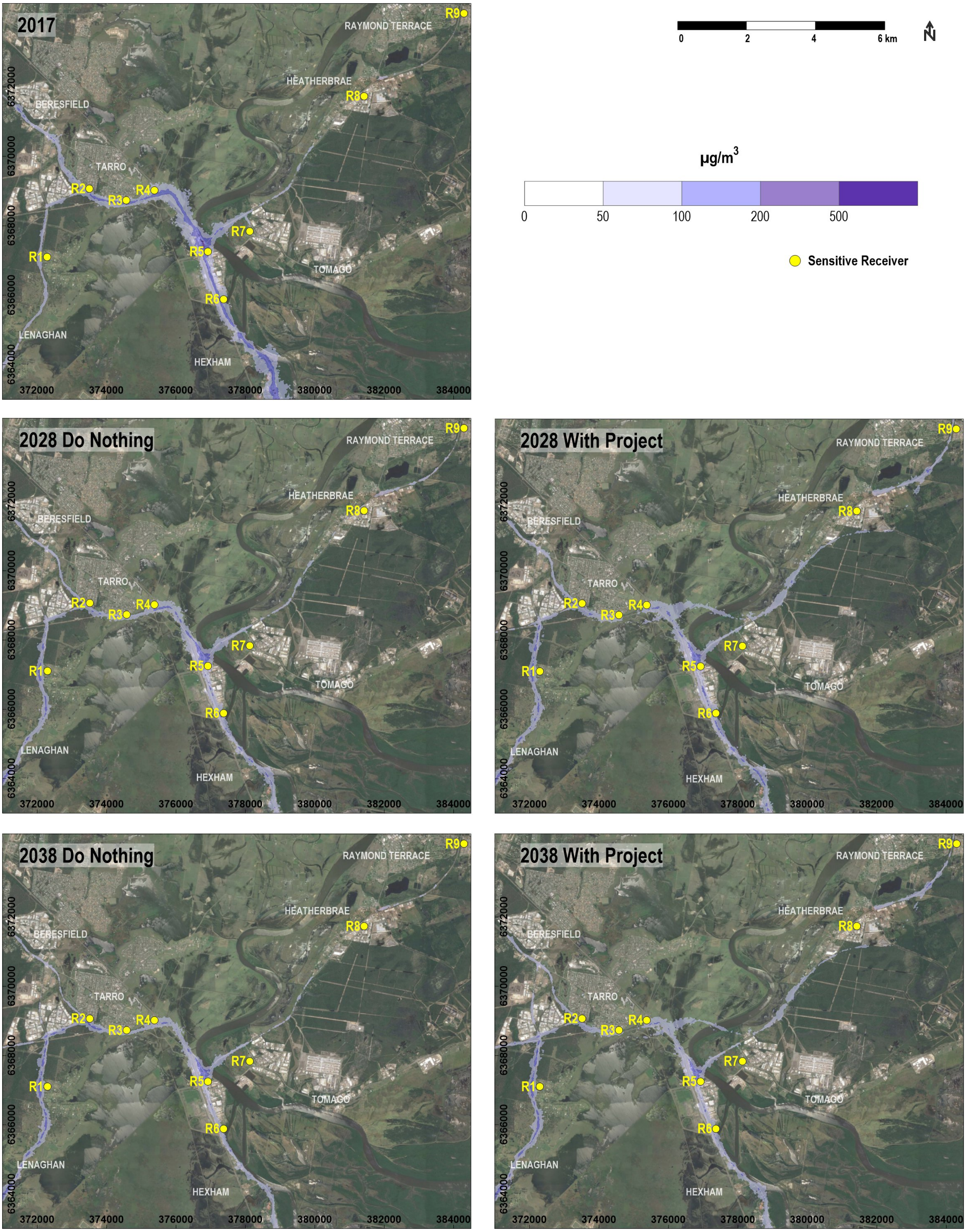


Figure 5-6 Predicted maximum 1-hour average NO_2 due to modelled sources

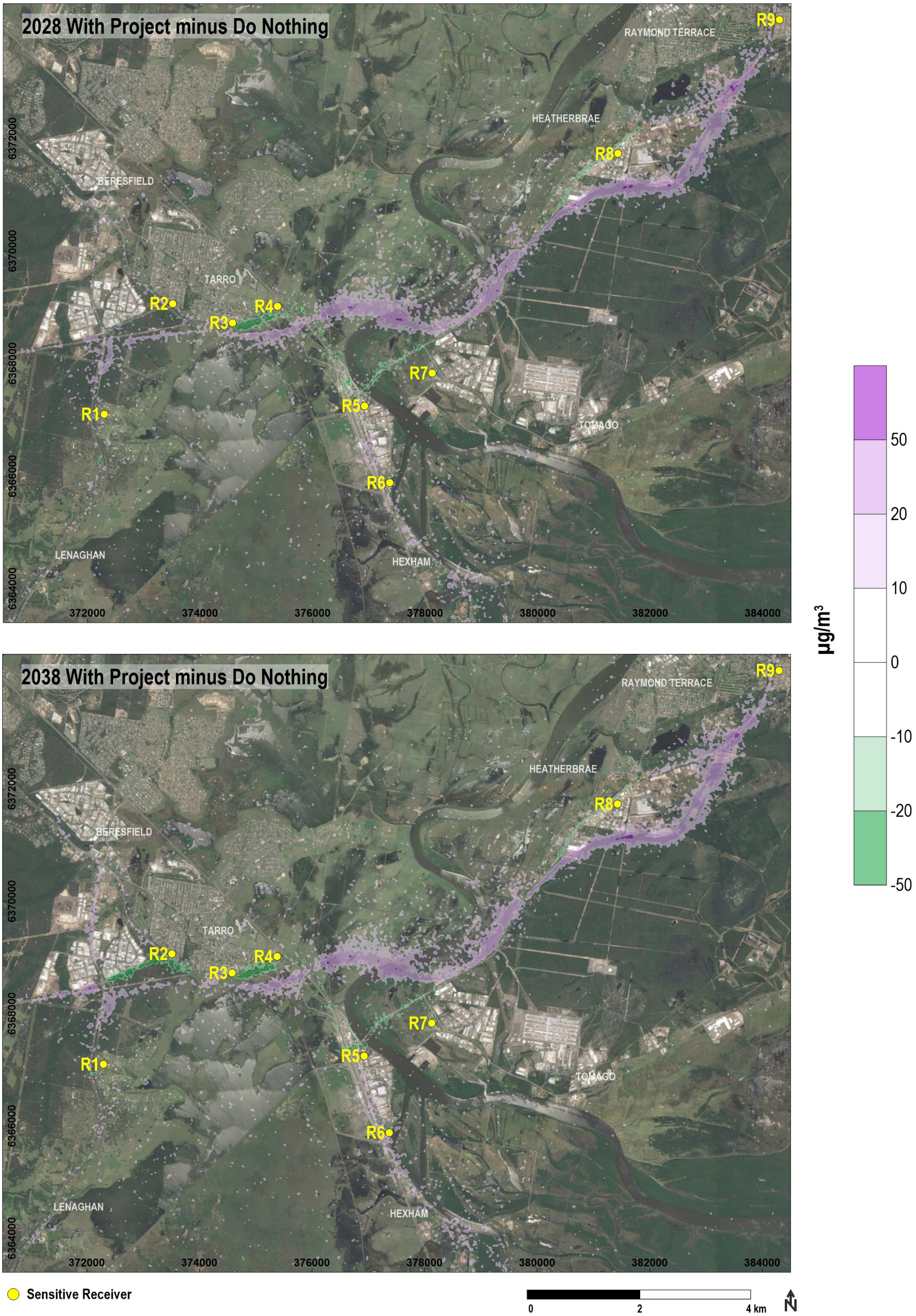


Figure 5-7 Predicted change in maximum 1-hour average NO_2 due to modelled sources

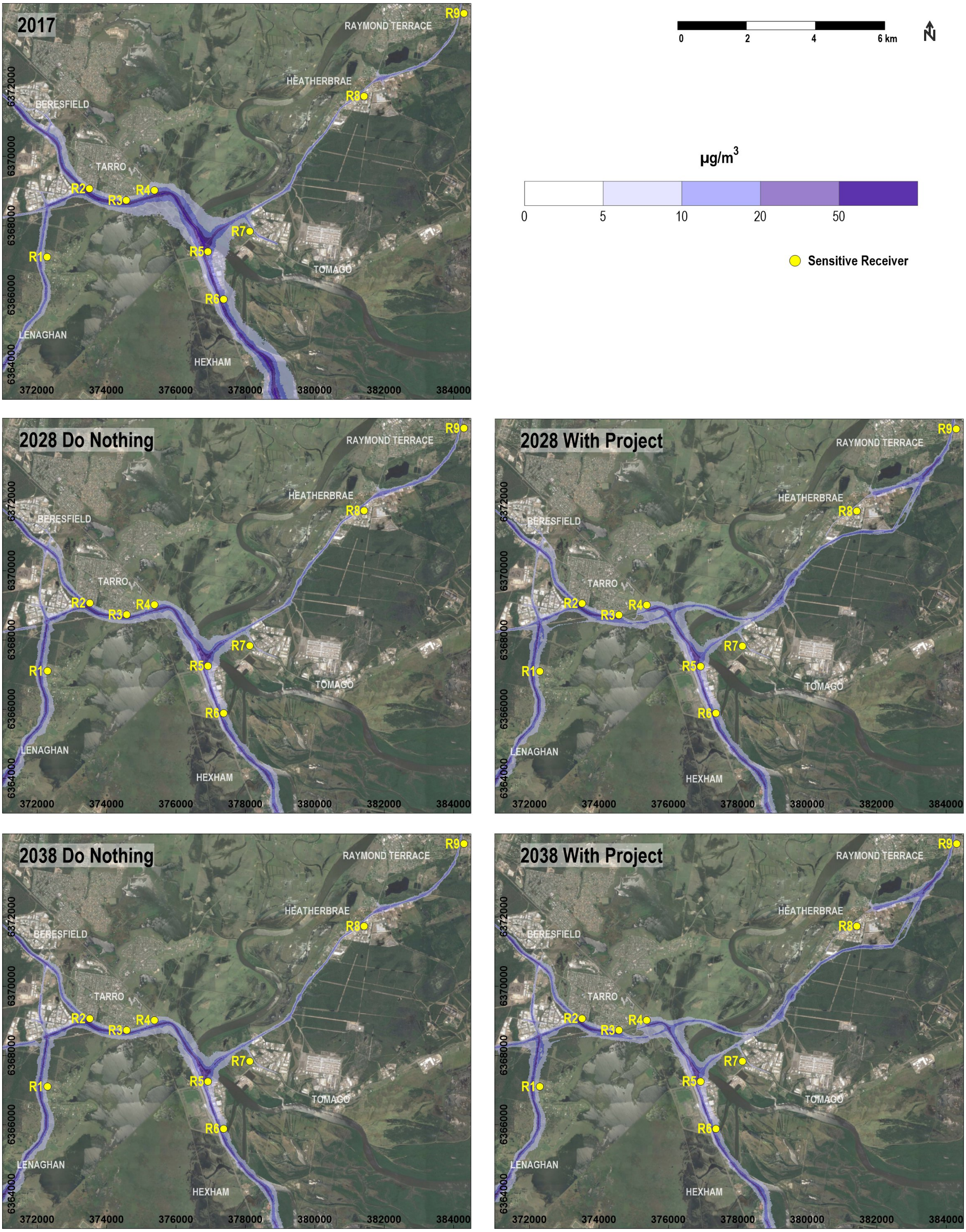


Figure 5-8 Predicted annual average NO_2 due to modelled sources

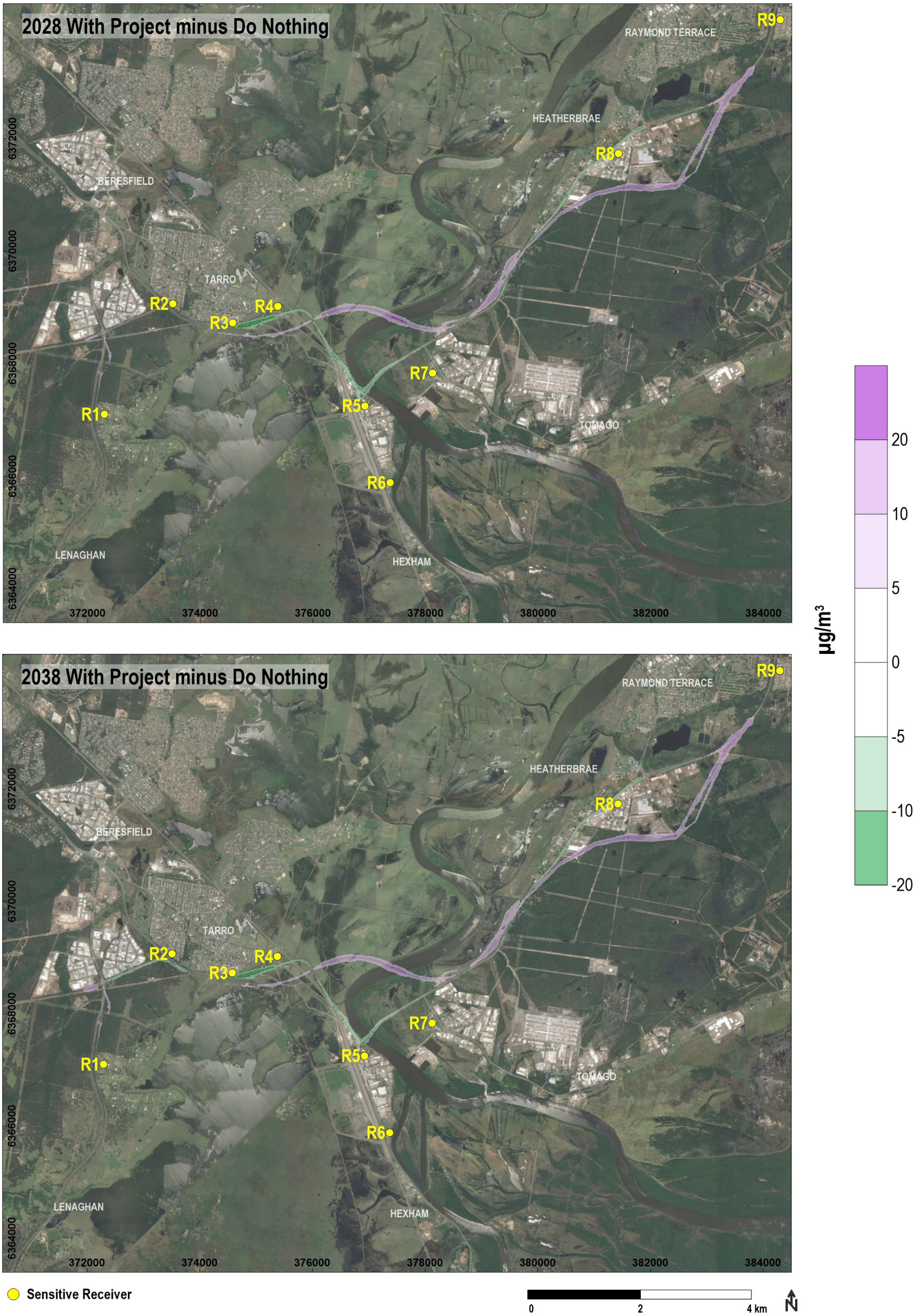


Figure 5-9 Predicted change in annual average NO_2 due to modelled sources

5.2.3 Particulate matter (PM_{10})

Model predictions of PM_{10} concentrations within the study area for each scenario are presented in **Figure 5-10** to **Figure 5-13**. These results represent the contribution of emissions from those roads that are expected to undergo the most change as a result of the project. Background levels are not included in the contour plots but are discussed below with reference to **Table 5-16**.

The model results in **Figure 5-10** to **Figure 5-13** indicate the following outcomes in terms of the spatial variations in PM_{10}:

- The highest 24-hour and annual average PM_{10} concentrations are expected to occur close to existing and, where applicable, proposed main roads, under all scenarios, as this is where traffic would be concentrated
- The highest maximum 24-hour average PM_{10} concentrations are predicted to be in the order of 20 µg/m^3, under all scenarios (**Figure 5-10**). Changes in concentrations are predicted most significantly on the main roads around the existing Hexham Bridge (that is, Maitland Road and Pacific Highway)
- Increases in the maximum 24-hour average PM_{10} concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-11**). Decreases in maximum 24-hour average PM_{10} concentrations are expected along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge
- The highest annual average PM_{10} concentrations are predicted to be in the order of 5 to 10 µg/m^3, under all scenarios (**Figure 5-12**). Again, changes in concentrations are predicted most significantly on the main roads around the existing Hexham Bridge
- Increases in annual average PM_{10} concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-13**). Decreases in annual average PM_{10} concentrations are expected along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge.

The predicted maximum changes in PM_{10} concentrations due to the project (both increases and decreases in one hour averages) are within the range of historically measured fluctuations in maximum PM_{10} concentrations for the region (**Section 4.3**).

Table 5-16 provides a summary of the model results for key sensitive receivers, where maximum impacts may be expected. These data show the contribution of modelled sources, the background levels, and the cumulative PM_{10} concentrations. The cumulative concentrations represent the background level plus the increment of the project relative to the scenario without the project.

The results in **Table 5-16** show that, at the selected sensitive receivers and local communities located near main roads along the proposed route, the project would lead to very little change to maximum and annual PM_{10} concentrations, relative to background levels. In addition, the project is not expected to cause exceedances of the NSW EPA air quality impact assessment criteria.

Table 5-16 Predicted PM_{10} concentrations at selected sensitive receivers

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
Maximum 24-hour average PM_{10} ($\mu g/m^3$)									
R1 (Lenaghans Drive, Black Hill)	50	2	3	3	3	3	48	48	48
R2 (Carr Place, Beresfield)	50	3	4	5	4	4	48	48	48
R3 (Palm Valley Village, Tarro)	50	4	4	4	4	5	48	48	49
R4 (Anderson Drive, Tarro)	50	8	9	7	8	8	48	47	48
R5 (Maitland Road, Hexham)	50	9	11	11	10	11	48	48	48
R6 (Old Maitland Road, Hexham)	50	6	7	8	7	8	48	48	49
R7 (Tomago Road, Tomago)	50	2	2	2	3	3	48	48	48
R8 (Pacific Highway, Heatherbrae)	50	2	4	3	4	3	48	47	47
R9 (Pacific Highway, Raymond Terrace)	50	1	2	3	2	3	48	49	49
Annual average PM_{10} ($\mu g/m^3$)									
R1 (Lenaghans Drive, Black Hill)	25	0.2	0.6	0.5	0.6	0.5	22	22	22
R2 (Carr Place, Beresfield)	25	0.7	1.0	0.9	1.0	0.9	22	22	22
R3 (Palm Valley Village, Tarro)	25	0.8	0.9	0.8	1.0	1.0	22	22	22
R4 (Anderson Drive, Tarro)	25	1.3	1.3	1.1	1.5	1.3	22	22	22
R5 (Maitland Road, Hexham)	25	2.0	2.4	2.2	2.7	2.6	22	22	22
R6 (Old Maitland Road, Hexham)	25	1.4	1.6	2.0	2.0	2.0	22	22	22
R7 (Tomago Road, Tomago)	25	0.4	0.5	0.4	0.5	0.5	22	22	22
R8 (Pacific Highway, Heatherbrae)	25	0.3	0.6	0.4	0.6	0.4	22	22	22
R9 (Pacific Highway, Raymond Terrace)	25	0.1	0.3	0.4	0.3	0.4	22	22	22

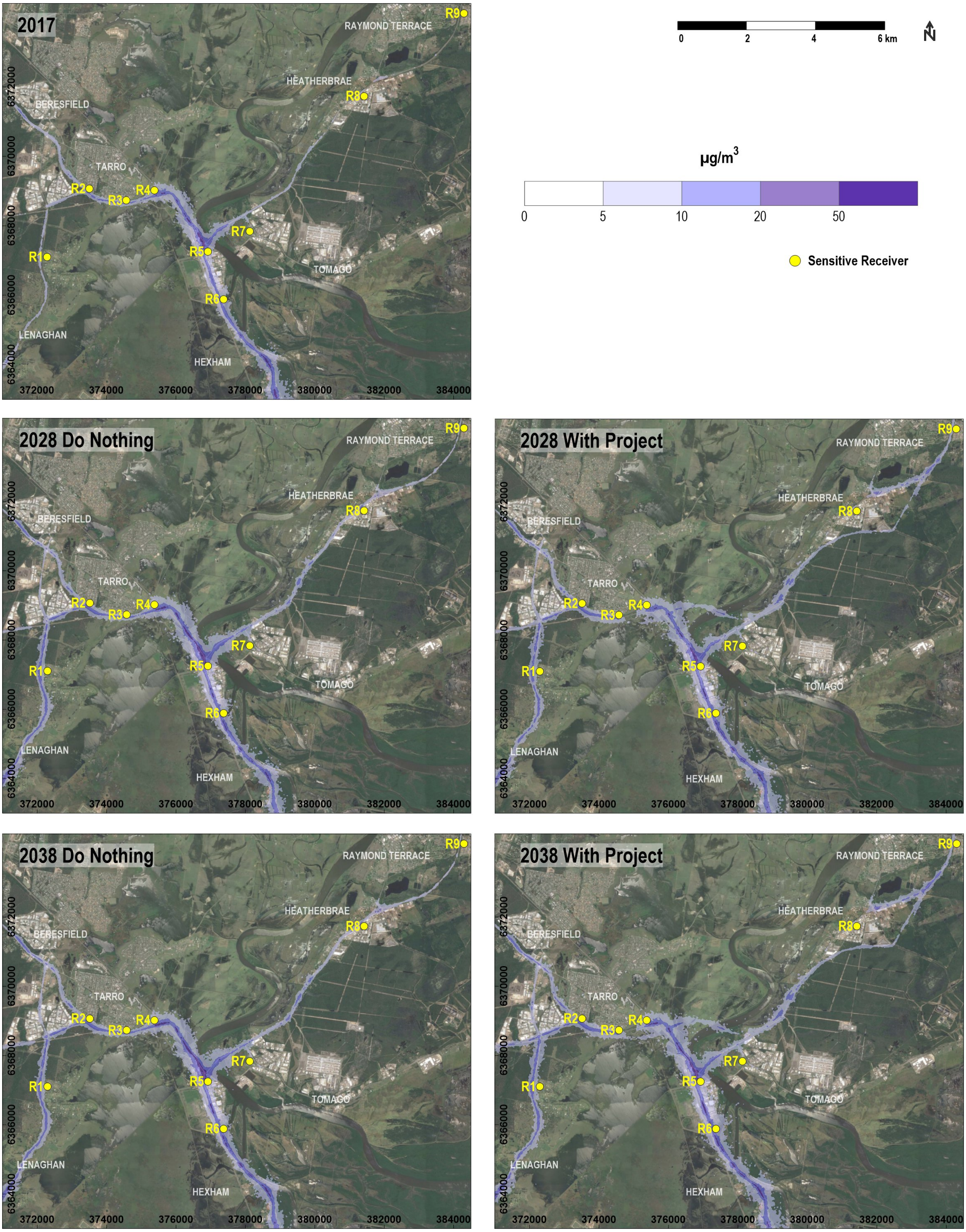


Figure 5-10 Predicted maximum 24-hour average PM_{10} due to modelled sources

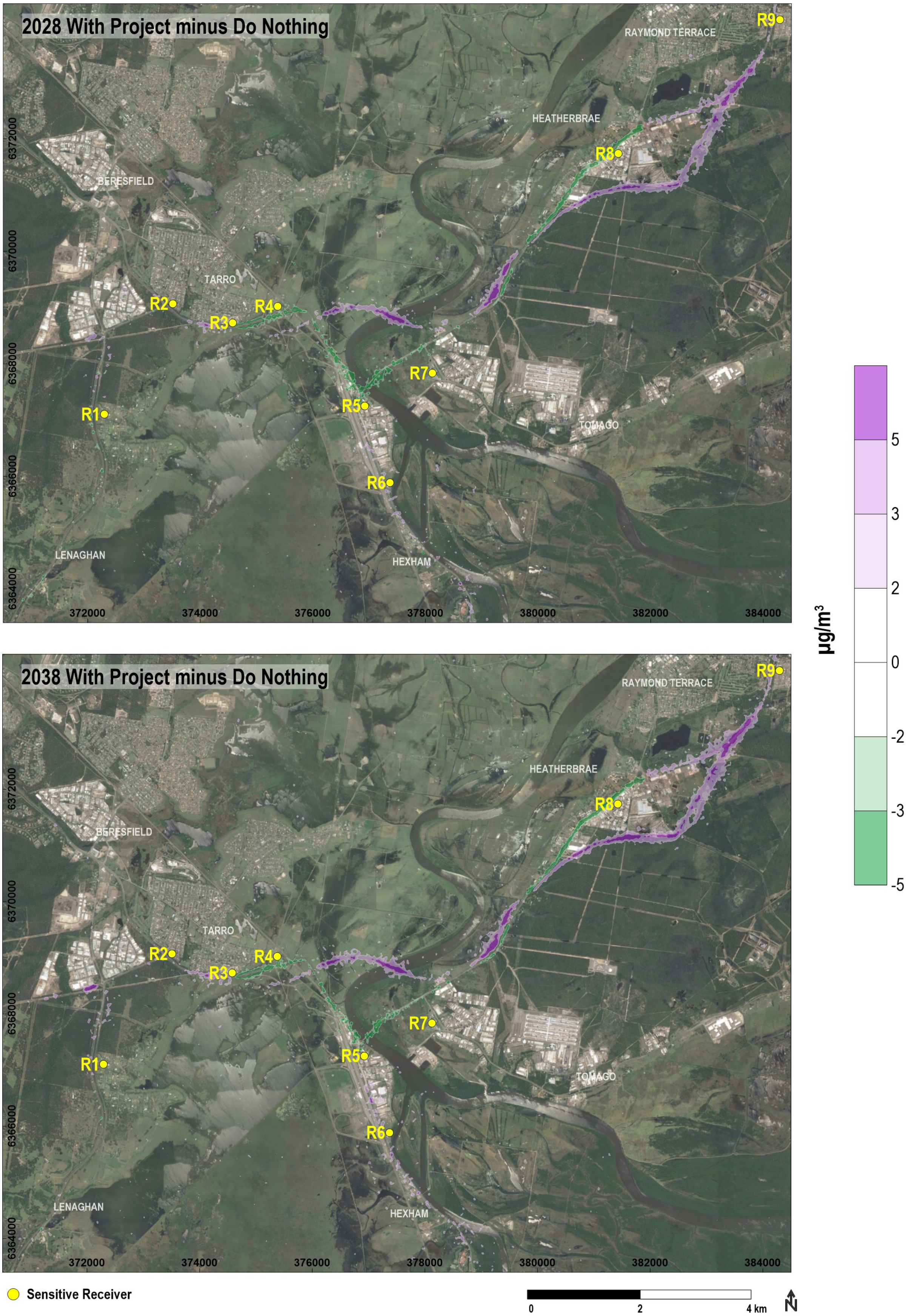


Figure 5-11 Predicted change in maximum 24-hour average PM_{10} due to modelled sources

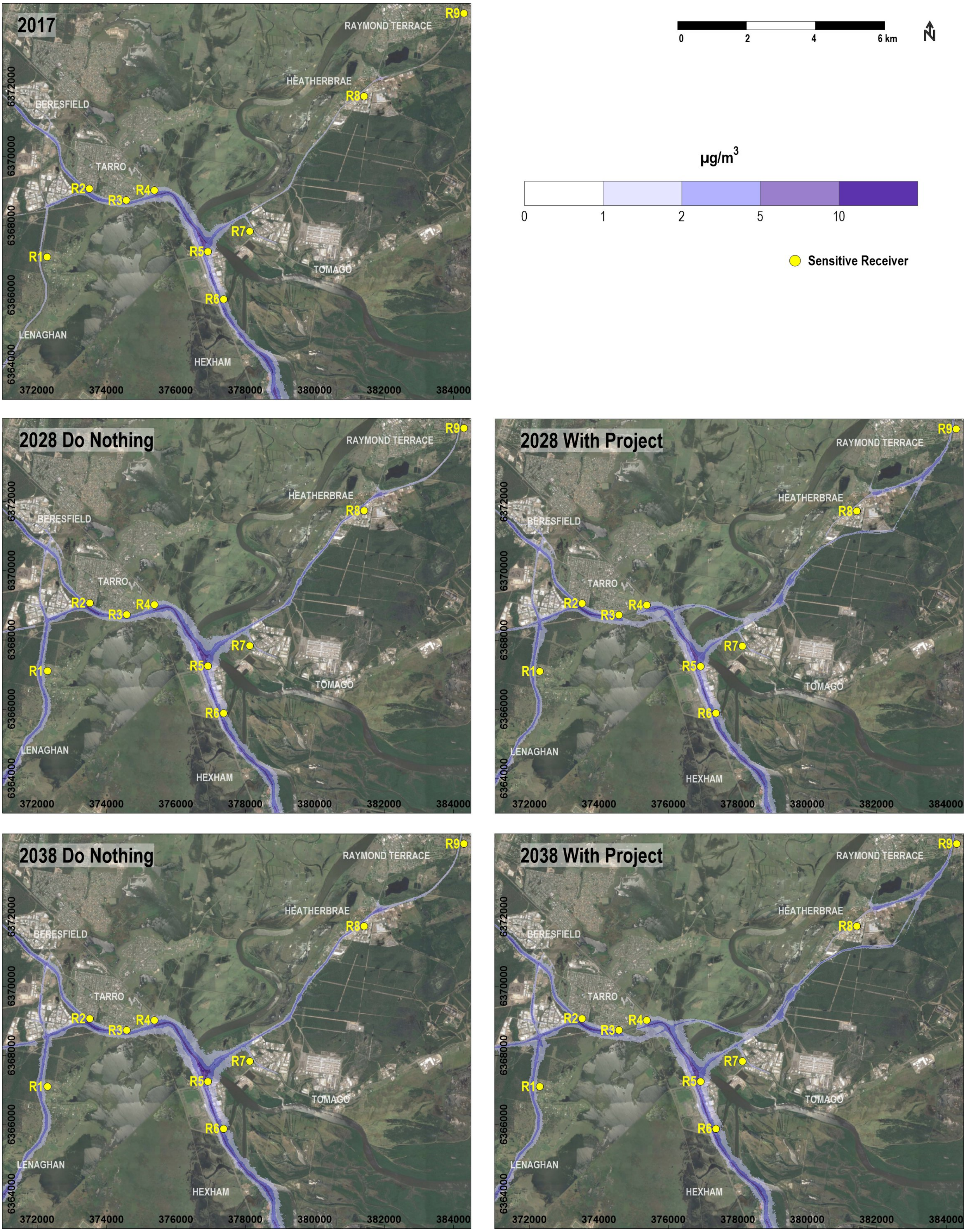


Figure 5-12 Predicted annual average PM_{10} due to modelled sources

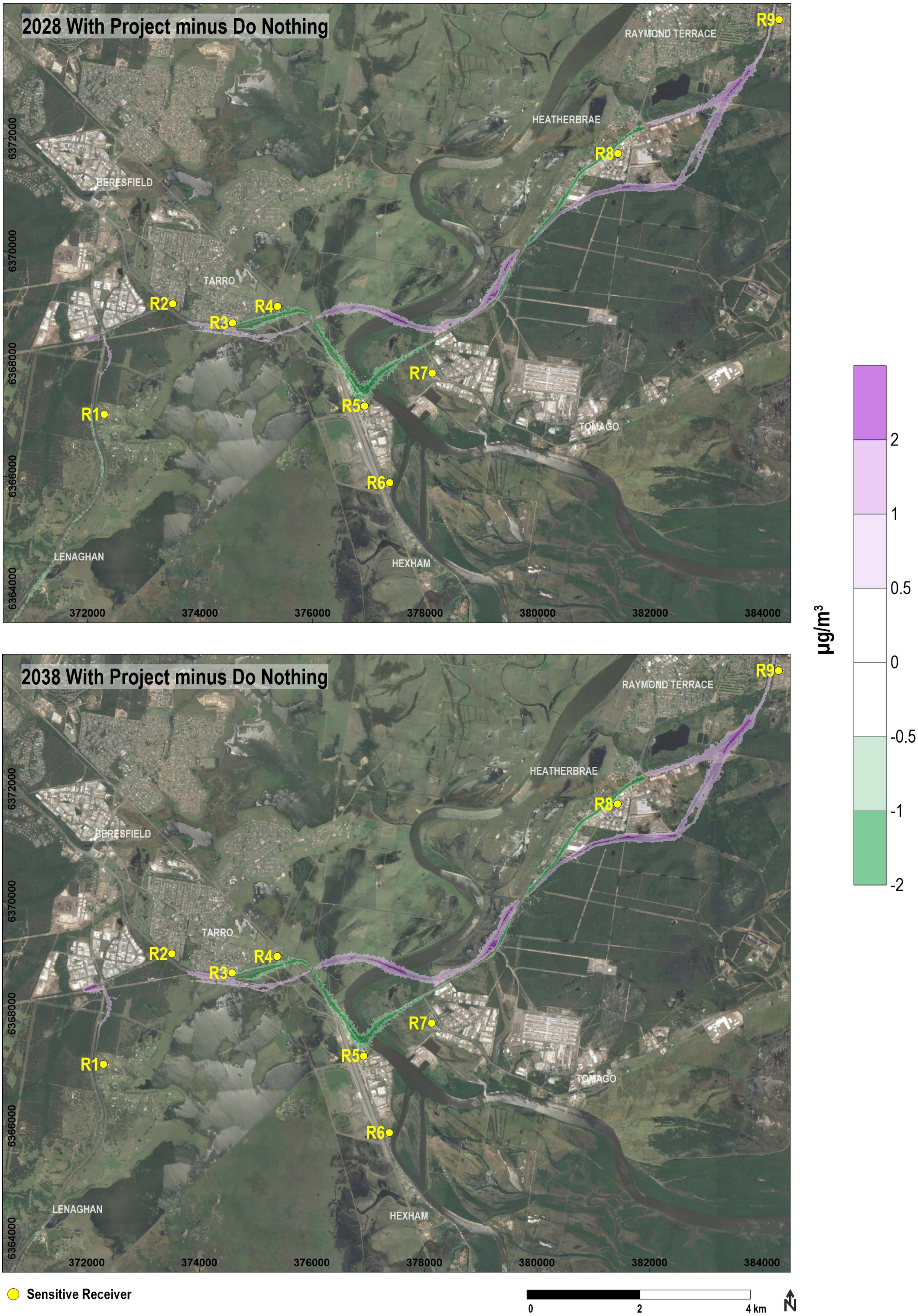


Figure 5-13 Predicted change in annual average PM_{10} due to modelled sources

5.2.4 Particulate matter ($PM_{2.5}$)

Emissions of $PM_{2.5}$ have not been explicitly modelled however the potential for $PM_{2.5}$ impacts has been assessed by assuming that 100 per cent of the PM_{10} is $PM_{2.5}$. This is a conservative assumption as not all the PM_{10} would be $PM_{2.5}$. Emissions of PM_{10} are anticipated to be higher than $PM_{2.5}$ as a greater fraction of the PM_{10} is related to non-exhaust components than for $PM_{2.5}$, for example, due to brake and tyre wear. The NSW EPA estimated that $PM_{2.5}$ emissions were 69 per cent of the PM_{10} emissions for on-road mobile sources in the Newcastle region (NSW EPA, 2019b).

Model predictions of PM_{10} concentrations were presented for each scenario in **Figure 5-10** to **Figure 5-13**. On the assumption that all PM_{10} is $PM_{2.5}$ the model results indicate the following outcomes in terms of the spatial variations in $PM_{2.5}$:

- The highest 24-hour and annual average $PM_{2.5}$ concentrations are expected to occur close to existing and, where applicable, proposed main roads, under all scenarios, as this is where traffic would be concentrated
- The highest maximum 24-hour average $PM_{2.5}$ concentrations are predicted to be in the order of 20 µg/m^3, under all scenarios (**Figure 5-10**). Changes in concentrations are predicted most significantly on the main roads around the existing Hexham Bridge
- Increases in the maximum 24-hour average $PM_{2.5}$ concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-11**). Decreases in maximum 24-hour average $PM_{2.5}$ concentrations are expected along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge
- The highest annual average $PM_{2.5}$ concentrations are predicted to be in the order of 5 to 10 µg/m^3, under all scenarios (**Figure 5-12**). Again, changes in concentrations are predicted most significantly on the main roads around the existing Hexham Bridge
- Increases in annual average $PM_{2.5}$ concentrations are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River where there are few sensitive receivers (**Figure 5-13**). Decreases in annual average $PM_{2.5}$ concentrations are expected along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge.

Table 5-17 provides a summary of the model results for key sensitive receivers, where maximum impacts may be expected. These data show the contribution of modelled sources, the background levels, and the cumulative $PM_{2.5}$ concentrations. The cumulative concentrations represent the background level plus the increment of the project relative to the scenario without the project.

A comparison of existing background levels to the predicted cumulative with-project concentrations shows that the predicted changes in $PM_{2.5}$ concentrations due to the project (both increases and decreases) represent less than five per cent of the NSW EPA air quality assessment criteria. These changes are also within the range of historically measured fluctuations in $PM_{2.5}$ concentrations for the region (**Section 4.3**).

The results in **Table 5-17** show that, at the selected sensitive receivers located near main roads along the proposed route, the project would lead to very little change to maximum 24-hour and annual average $PM_{2.5}$ concentrations, relative to background levels. As noted in **Section 4.3**, air quality monitoring has shown that particle levels (as $PM_{2.5}$) have historically exceeded the NSW EPA criteria, particularly in recent years due to the widespread, intense drought and smoke from bushfires and hazard reduction burning (OEH, 2019). The project is not predicted to cause additional exceedances of the NSW EPA air quality impact assessment criteria.

The change in annual average $PM_{2.5}$ concentration is a key metric for assessing the risk to human health. An increment change in annual average $PM_{2.5}$ of 1.7 µg/m^3 has recently been determined as the criterion to manage the risk of all-cause mortality below one in 10,000 (ERM, 2020). None of the sensitive receivers and local communities identified in **Table 5-17** are expected to experience increases in $PM_{2.5}$

concentrations above 1.7 µg/m³ due to the project, relative to either the 2017 or the future without project scenarios.

Table 5-17 Predicted $PM_{2.5}$ concentrations at selected sensitive receivers

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
Maximum 24-hour average $PM_{2.5}$ (µg/m³)									
R1 (Lenaghans Drive, Black Hill)	25	2.0	3.5	3.1	3.2	3.2	28	28	28
R2 (Carr Place, Beresfield)	25	3.5	4.4	4.7	3.6	4.0	28	28	28
R3 (Palm Valley Village, Tarro)	25	3.8	4.2	3.8	4.2	5.0	28	28	29
R4 (Anderson Drive, Tarro)	25	8.2	8.6	7.4	8.0	8.2	28	27	28
R5 (Maitland Road, Hexham)	25	9.0	10.7	10.6	10.5	11.0	28	28	28
R6 (Old Maitland Road, Hexham)	25	5.7	7.5	8.0	6.7	7.9	28	28	29
R7 (Tomago Road, Tomago)	25	2.2	2.5	2.5	2.5	2.9	28	28	28
R8 (Pacific Highway, Heatherbrae)	25	2.4	3.5	2.8	3.6	2.7	28	27	27
R9 (Pacific Highway, Raymond Terrace)	25	1.2	1.7	2.9	2.0	2.9	28	29	29
Annual average $PM_{2.5}$ (µg/m³)									
R1 (Lenaghans Drive, Black Hill)	8	0.2	0.6	0.5	0.6	0.5	8.7	8.6	8.7
R2 (Carr Place, Beresfield)	8	0.7	1.0	0.9	1.0	0.9	8.7	8.6	8.6
R3 (Palm Valley Village, Tarro)	8	0.8	0.9	0.8	1.0	1.0	8.7	8.6	8.7
R4 (Anderson Drive, Tarro)	8	1.3	1.3	1.1	1.5	1.3	8.7	8.5	8.5
R5 (Maitland Road, Hexham)	8	2.0	2.4	2.2	2.7	2.6	8.7	8.5	8.6
R6 (Old Maitland Road, Hexham)	8	1.4	1.6	2.0	2.0	2.0	8.7	9.1	8.7
R7 (Tomago Road, Tomago)	8	0.4	0.5	0.4	0.5	0.5	8.7	8.6	8.7

Location	Criterion	Concentration due to modelled sources					Background level	Cumulative due to change with the project	
		2017	2028DN	2028WP	2038DN	2038WP		2028	2038
R8 (Pacific Highway, Heatherbrae)	8	0.3	0.6	0.4	0.6	0.4	8.7	8.4	8.5
R9 (Pacific Highway, Raymond Terrace)	8	0.1	0.3	0.4	0.3	0.4	8.7	8.8	8.9

5.2.5 Air toxics

An assessment of the five priority air toxics identified by the NEPM has been made. These air toxics include benzene, formaldehyde, toluene, xylenes and PAHs as benzo(a)pyrene. Model predictions of these air toxics have been derived from the hydrocarbon results using the speciation factors shown in **Table 5-18** below.

Table 5-18 Speciation of selected air toxics from hydrocarbon predictions

Air toxic	Assumed percentage of total hydrocarbons (%) *
Benzene	5
Formaldehyde	1.4
Toluene	4.7
Xylenes	3.5
PAHs as benzo(a)pyrene	0.4

* From data published by the NSW EPA (2019a)

Table 5-19 provides the predicted air toxics concentrations for key sensitive receivers, where maximum impacts may be expected. These results show that, at the selected sensitive receivers and local communities located near main roads along the proposed route, the concentrations would not exceed NSW EPA air quality impact assessment criteria. Lower concentrations would be expected at locations further from main roads. It is therefore concluded that the project would not lead to adverse air quality impacts with regards to air toxics.

Table 5-19 Predicted air toxics concentrations at selected sensitive receivers

Location	Criterion	Concentration due to modelled sources				
		2017	2028DN	2028WP	2038DN	2038WP
Maximum 1-hour average benzene (µg/m^3)						
R1 (Lenaghans Drive, Black Hill)	29	2	3	3	2	3
R2 (Carr Place, Beresfield)	29	4	4	3	3	3
R3 (Palm Valley Village, Tarro)	29	4	3	3	3	3
R4 (Anderson Drive, Tarro)	29	7	6	6	5	5
R5 (Maitland Road, Hexham)	29	8	5	6	5	6

Location	Criterion	Concentration due to modelled sources				
		2017	2028DN	2028WP	2038DN	2038WP
R6 (Old Maitland Road, Hexham)	29	7	5	6	4	5
R7 (Tomago Road, Tomago)	29	3	2	3	2	2
R8 (Pacific Highway, Heatherbrae)	29	2	3	2	2	2
R9 (Pacific Highway, Raymond Terrace)	29	2	2	2	2	2
Maximum 1-hour average formaldehyde (µg/m^3)						
R1 (Lenaghans Drive, Black Hill)	20	0.6	0.9	0.9	0.6	0.8
R2 (Carr Place, Beresfield)	20	1.0	1.0	0.7	0.8	0.9
R3 (Palm Valley Village, Tarro)	20	1.0	0.8	0.8	0.8	0.9
R4 (Anderson Drive, Tarro)	20	2.0	1.5	1.7	1.3	1.5
R5 (Maitland Road, Hexham)	20	2.1	1.4	1.7	1.4	1.6
R6 (Old Maitland Road, Hexham)	20	1.8	1.2	1.6	1.2	1.4
R7 (Tomago Road, Tomago)	20	0.7	0.7	0.7	0.6	0.5
R8 (Pacific Highway, Heatherbrae)	20	0.7	0.9	0.6	0.6	0.5
R9 (Pacific Highway, Raymond Terrace)	20	0.6	0.4	0.6	0.5	0.6
Maximum 1-hour average toluene (µg/m^3)						
R1 (Lenaghans Drive, Black Hill)	360	2.0	3.2	3.3	2.0	2.9
R2 (Carr Place, Beresfield)	360	3.6	3.6	2.5	2.8	3.0
R3 (Palm Valley Village, Tarro)	360	3.3	2.8	2.8	2.9	3.1
R4 (Anderson Drive, Tarro)	360	6.9	5.2	5.8	4.6	5.2
R5 (Maitland Road, Hexham)	360	7.2	5.0	6.1	4.8	5.8
R6 (Old Maitland Road, Hexham)	360	6.2	4.4	5.7	4.1	4.9
R7 (Tomago Road, Tomago)	360	2.5	2.3	2.6	2.1	1.7
R8 (Pacific Highway, Heatherbrae)	360	2.3	3.0	2.1	2.2	1.6
R9 (Pacific Highway, Raymond Terrace)	360	2.0	1.5	2.1	1.7	2.2
Maximum 1-hour average xylene (µg/m^3)						
R1 (Lenaghans Drive, Black Hill)	190	1.5	2.4	2.4	1.5	2.1
R2 (Carr Place, Beresfield)	190	2.6	2.7	1.8	2.0	2.2
R3 (Palm Valley Village, Tarro)	190	2.4	2.1	2.1	2.2	2.3
R4 (Anderson Drive, Tarro)	190	5.0	3.8	4.2	3.4	3.8
R5 (Maitland Road, Hexham)	190	5.2	3.7	4.5	3.5	4.2
R6 (Old Maitland Road, Hexham)	190	4.5	3.2	4.2	3.0	3.6
R7 (Tomago Road, Tomago)	190	1.8	1.7	1.9	1.5	1.2
R8 (Pacific Highway, Heatherbrae)	190	1.7	2.2	1.5	1.6	1.2

Location	Criterion	Concentration due to modelled sources				
		2017	2028DN	2028WP	2038DN	2038WP
R9 (Pacific Highway, Raymond Terrace)	190	1.5	1.1	1.5	1.3	1.6
Maximum 1-hour average xylene (µg/m^3)						
R1 (Lenaghans Drive, Black Hill)	0.4	0.05	0.08	0.08	0.05	0.07
R2 (Carr Place, Beresfield)	0.4	0.09	0.09	0.06	0.07	0.07
R3 (Palm Valley Village, Tarro)	0.4	0.08	0.07	0.07	0.07	0.08
R4 (Anderson Drive, Tarro)	0.4	0.17	0.13	0.14	0.11	0.12
R5 (Maitland Road, Hexham)	0.4	0.17	0.12	0.15	0.12	0.14
R6 (Old Maitland Road, Hexham)	0.4	0.15	0.11	0.14	0.10	0.12
R7 (Tomago Road, Tomago)	0.4	0.06	0.05	0.06	0.05	0.04
R8 (Pacific Highway, Heatherbrae)	0.4	0.06	0.07	0.05	0.05	0.04
R9 (Pacific Highway, Raymond Terrace)	0.4	0.05	0.04	0.05	0.04	0.05

5.3 Cumulative impacts

Cumulative air quality impacts may arise from the interaction of construction and operation activities of the project, and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may, however, be more substantial, when the impact of multiple projects on the same receivers is considered.

The projects detailed in **Table 5-20** are in varying stages of delivery and planning. This section provides an assessment of cumulative air quality impacts based on the most current and publicly available information for these projects. In many instances this is a high-level qualitative assessment.

In summary, the contributions of these projects to local air quality in areas where the M1 Pacific Motorway Extension to Raymond Terrace project has the potential to influence air quality is unlikely to be significant enough to influence the outcomes of this assessment.

Table 5-20 Assessment of potential cumulative impacts for relevant identified projects

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Kinross Industrial / Weathertex, Heatherbrae (Approved)	• Located within the project's construction footprint (AS16) on Masonite Road, Heatherbrae. • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	The industrial development is proposed within the construction footprint and on land identified for AS16. If the Kinross Industrial development is developed prior to or during construction, this ancillary site would be unavailable to the project for use. Construction of the project and the Kinross Industrial development has potential to contribute to local air quality. Once operational, the project would support access to the motorway for industrial uses within the development via the Tomago interchange. The contribution of this project to local air quality is not significant enough to influence the assumed background levels or outcomes of this assessment.

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Hunter Gas Pipeline (Approved)	• Located within the construction footprint at Tomago	The project involves construction of an underground gas pipeline from the Wallumbilla Gas Supply Hub in Queensland to Newcastle to connect to the NSW gas transmission network. The program for construction is not yet available however it is anticipated that construction would occur between 2022 and 2023. There is a potential for work associated with the construction of the Hunter Gas Pipeline to coincide with work associated with the construction of the M1 Pacific Motorway Extension to Raymond Terrace project. It is not possible to realistically identify air quality impacts as the timing, nature of location of all works in not known. However, all construction work would be expected to be carried out in accordance with a management plan for minimise air quality impacts.
Black Hill Hunter Business Park (In planning)	• Located south of John Renshaw Drive and west of the M1 Pacific Motorway. • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	This development is currently in planning and is anticipated to be similar to the Northern Estates development. Due to the differing time frames involved, it is not expected there would be any cumulative impacts during construction. Once operational, the project would support future industrial development in the area through improved access and connectivity for freight and commercial vehicles. The traffic data used for the air quality assessment included the effect of this project.
Newcastle Power Station (In planning)	• Located within the project's construction footprint at Tomago near Old Punt Road. • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	AGL propose to construct a 250 Mega Watt (MW) gas fired power station at Tomago, with gas pipelines and electricity transmission lines. Construction of the power station is due to commence in 2021 with the power station expected to be operational in 2022. The site for the proposed power station is located between the Pacific Highway and Old Punt Road, north of the Tomago industrial area (AGL, 2019). The power station would be located next to AS12 and AS13. Consideration of the project has been given in the siting and layout of the power station. Potential cumulative impacts on air quality may arise from the combination of emissions from the power station with emissions from vehicles using the road network. The contribution of this project to local air quality in areas where the M1 Pacific Motorway Extension to Raymond Terrace project has the potential to influence air quality is not significant enough to influence the outcomes of this assessment.
Lower Hunter Freight Corridor (in planning)	Investigation area includes Hexham.	The Transport Lower Hunter Freight Corridor (LHFC) website (TfNSW, July 2018) indicates that in 2018 preliminary investigations were being carried out to assess options for a dedicated freight rail line between Fassifern and Hexham. No options were available on the website to review. An investigation areas figure between Fassifern and Hexham was available. As corridor options and environmental assessment are not available for the LHFC, the level of impact on land use and property generated by this project is

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
		currently unknown. Consequently, cumulative impacts associated with the construction or operation of the project is unknown. Contributions to air quality from freight trains are most significantly observed near the rail line. The contribution of this project to local air quality in areas where the M1 Pacific Motorway Extension to Raymond Terrace project has the potential to influence air quality is not significant enough to influence the outcomes of this assessment.
Richmond Vale Rail Trail to Shortland, including Shortland to Tarro cycleway (In planning)	Intersects the project at Tarro	This project is not expected to result in cumulative impacts with the project. The Richmond Vale Rail Trail to Shortland would encourage additional active transport use within the study area. Therefore this project is more likely to result in lower traffic movements than assumed for the M1 Pacific Motorway Extension to Raymond Terrace project. Consequently no adverse cumulative impacts are expected.

6. Environmental management measures

Unmitigated project construction has been determined to represent a 'high' risk of dust impacts according to the IAQM method (**Section 5.1**). This outcome represented the worst case, unmitigated outcome across the whole project, although these risks are not present where major earthworks activities, such as bridge construction, are not occurring. Operation of the project is not expected to cause adverse air quality impacts based on dispersion modelling which showed that the project would not cause exceedances of air quality criteria at sensitive receivers (**Section 5.2**). These outcomes indicated the environmental management measures would need to be targeted to the construction phase of the project. The following management measures (refer to **Table 6-1**) have been developed to specifically manage potential impacts which have been predicted as a result of the proposed work and informed by outcomes of the IAQM methodology. These measures should be incorporated into a relevant Air Quality Management Plan (AQMP) as described below.

Table 6-1 Environmental management measures

Impact	Reference	Management measure	Responsibility	Timing
Adverse air quality during construction	AQ01	Preparation and implementation of an Air Quality Management Plan (AQMP) to minimise risks to air quality. The AQMP will identify: • Potential sources of air pollution (including odours and dust) during construction • Air quality management objectives consistent with relevant published guidelines • Identification of all dust and odour sensitive receivers • Measures to manage dust • Requirements to separate temporary project specific asphalt batching plants, if feasible, from the nearest residences by at least 300m • Community notification and complaint handling procedures.	Contractor	Detailed design/ Prior to construction

7. Conclusions

This report has provided an assessment of the potential air quality impacts of the project. A key objective of the assessment was to determine the potential change in local and regional air quality that may occur as a result of the project.

The key potential air quality issues were identified as dust during construction, emissions from vehicles using the existing and modified road network during operation, and odour from asphalt batching.

A detailed review of the existing environment was carried out including an analysis of historically measured concentrations of key quality indicators (CO, NO_2, PM_{10} and $PM_{2.5}$) from representative monitoring stations. The following conclusions were made in relation to the existing air quality and meteorological conditions:

- Wind patterns in the vicinity of the project are characteristic of the Lower Hunter Valley, with the prevailing winds being from the west-northwest
- Measured CO and NO_2 concentrations in the past five years have been consistently below NSW EPA air quality impact assessment criteria
- Particle levels (as PM_{10} and $PM_{2.5}$) increased across NSW and the Hunter region from 2017 to 2019 due to dust from the widespread, intense drought and smoke from bushfires and hazard reduction burning (OEH 2019). These events adversely influenced air quality with multiple days observed when PM_{10} and $PM_{2.5}$ concentrations exceeded NSW EPA criteria.

Potential air quality impacts of the project during construction were assessed using the semi-quantitative method developed by the IAQM. Computer-based dispersion modelling was used to predict the potential change in local and regional air quality as a result of the project operation.

The key outcomes of the air quality assessment are:

- Unmitigated construction of the project was determined to represent a ‘high’ risk of dust impacts according to the IAQM method. The application of the recommended mitigation measures would mean that adverse residual impacts from construction would not be anticipated
- Operation of the project would lead to a redistribution of vehicle emissions across the road network, generally from existing main roads to the proposed new roads. The highest concentrations of key air quality indicators (CO, NO_2, PM_{10} and $PM_{2.5}$) are expected to occur close to main roads under all ‘with project’ and ‘without project’ scenarios
- Increases in the concentrations of key air quality indicators, due to the project, are generally expected in areas where there are no existing main roads such as east of Tarro, north of the Hunter River. In these locations there are generally few sensitive receivers
- Decreases in the concentrations of key air quality indicators, due to the redirection of traffic with the project, are expected to occur along the existing main connection from the M1 Pacific Motorway to Heatherbrae, and most significantly from Tarro to the Hexham Bridge
- The predicted maximum increases and decreases in concentrations of key air quality indicators, due to the project, are within the range of historically measured fluctuations in maximum concentrations for the region
- The project would lead to very little change to maximum and annual concentrations of key air quality indicators, relative to background levels, based on model predictions at selected sensitive receivers located near main roads along the proposed route, which are representative of nearby local communities
- The project is not expected to cause exceedances of the NSW EPA air quality impact assessment criteria for CO, NO_2, PM_{10}, $PM_{2.5}$ or key air toxics such as benzene and formaldehyde.

Based on this assessment, during construction, adverse residual impacts are not anticipated with the application of the recommended mitigation measures. Operation of the project is not expected to cause adverse air quality impacts, based on dispersion modelling which showed that the project would not result in changes to air quality at local or regional scales that would cause exceedances of air quality criteria at sensitive receivers. Specific measures for odour minimisation have been identified.

These outcomes are consistent with the desired performance outcome for the project which, for air quality, is to minimise air quality impacts (including nuisance dust and odour) to reduce risks to human health and the environment to the greatest extent practicable through the design, construction and operation of the project.

8. References

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Terms and acronyms

Term / Acronym	Description
AQMP	Air Quality Management Plan
BaP	Benzo(a)pyrene
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CO	Carbon monoxide
DEC	Department of Environment and Conservation
DPIE	Department of Planning, Industry and Environment
EPL	Environmental Protection Licence
GMR	Greater Metropolitan Region
GRAL	Graz Lagrangian Model
GRAMM	Graz Mesoscale Model
IAQM	Institute of Air Quality Management
Jacobs	Jacobs Group (Australia) Pty Limited
MVEI	Motor Vehicle Emissions Inventory
NEPM	National Environment Protection Measure
NEPC	National Environmental Protection Council of Australia
NSW EPA	New South Wales Environment Protection Authority
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
OEH	Office of Environment and Heritage, now part of the Department of Planning, Industry and Environment
PAHs	Polycyclic aromatic hydrocarbons
$PM_{2.5}$	Particulate matter with equivalent aerodynamic diameters less than 2.5 microns
PM_{10}	Particulate matter with equivalent aerodynamic diameters less than 10 microns
POEO Act	*Protection of the Environment Operations (POEO) Act 1997*
SEARs	Secretary's Environmental Assessment Requirements
SO_2	Sulfur dioxide
THC	Total hydrocarbons
TRAQ	Tool for Roadside Air Quality, an air pollution screening tool developed by Roads and Maritime
TSP	Total suspended particulates
VOCs	Volatile organic compounds
$\mu g/m^3$	Micrograms per cubic metre

Appendix A Emission factors

Emission factors for 2016 were used for 2017 scenarios. Emission factors for 2026 were used for 2028 scenarios. Emission factors for 2036 were used for 2038 scenarios.

Table A-1: Descriptions of NSW EPA vehicle types

Code	Description	Initial category
CP	Cars (petrol)	Light
CD	Cars (diesel)	Light
LDC-P	Light duty commercial (petrol)	Light
LDC-D	Light duty commercial (diesel)	Light
HDC-P	Heavy duty commercial (petrol)	Heavy
RT	Rigid trucks	Heavy
AT	Articulated trucks	Heavy
BusD	Buses (diesel)	Heavy
MC	Motorcycles	Light

Table A-2: Approach to matching road types to NSW EPA road types

Road type	Assumed NSW EPA road type
motorway, ramp	Highway / freeway
arterial, sub-arterial	Arterial
collector, minor road	Residential
regional_arterial (speed less than or equal to 70km/h)	Commercial arterial
regional_arterial (speed greater than 70km/h)	Commercial highway

Table A-3 Traffic mix by road type and year

Road type	Year	Proportion of traffic (%)								
		CP	CD	LCV-P	LCV-D	HDV-P	RT	AT	BusD	MC
Residential	2016	70.4	9.7	6.3	8.9	0.0	2.8	0.8	0.6	0.5
Residential	2026	59.2	20.0	2.5	13.0	0.0	3.2	1.0	0.6	0.5
Residential	2036	48.0	30.8	0.7	14.9	0.0	3.5	1.0	0.6	0.5
Arterial	2016	67.5	9.3	7.2	10.1	0.0	3.8	1.2	0.5	0.5
Arterial	2026	56.8	19.2	2.8	14.7	0.0	4.3	1.3	0.5	0.5
Arterial	2036	46.0	29.4	0.8	16.8	0.0	4.6	1.4	0.5	0.5
Commercial arterial	2016	65.3	9.0	7.7	10.7	0.0	4.8	1.7	0.4	0.5
Commercial arterial	2026	54.8	18.5	3.0	15.6	0.0	5.4	1.9	0.4	0.5
Commercial arterial	2036	44.2	28.3	0.8	18.0	0.0	5.8	2.0	0.4	0.5
Commercial highway	2016	65.3	9.0	7.7	10.7	0.0	4.8	1.7	0.4	0.5
Commercial highway	2026	54.8	18.5	3.0	15.6	0.0	5.4	1.9	0.4	0.5
Commercial highway	2036	44.2	28.3	0.8	18.0	0.0	5.8	2.0	0.4	0.5
Highway / freeway	2016	57.9	8.0	6.9	9.7	0.0	10.6	6.3	0.3	0.4
Highway / freeway	2026	47.8	16.2	2.7	14.1	0.0	11.9	6.8	0.3	0.4
Highway / freeway	2036	37.9	24.3	0.8	16.0	0.0	13.0	7.3	0.2	0.4

Table A-4 Average speed relating to emission factors

Road type	Average speed (km/h)		
	2016	2026	2036
Residential	23.7	23.7	23.6
Arterial	36.3	36	35.5
Commercial arterial	34.2	33.9	33.6
Commercial highway	55	54.6	54.1
Highway / freeway	65.7	65.1	64.8

Table A-5 Base composite emission factors for 2026 (hot running)

Road type	CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC
CO (season maximum) (g/km)									
Residential	0.486	0.077	1.57	0.228	20.9	0.201	0.74	0.582	8.855
Arterial	0.325	0.046	1.105	0.176	12.58	0.147	0.439	0.427	7.557
Commercial arterial	0.611	0.056	1.806	0.217	13.81	0.16	0.295	0.504	7.685
Commercial highway	0.538	0.074	1.444	0.166	8.789	0.111	0.229	0.314	7.654
Highway / freeway	0.711	0.069	1.653	0.136	8.225	0.103	0.213	0.22	8.152
NO_x (season maximum) (g/km)									
Residential	0.068	0.432	0.257	0.599	2.188	2.09	6.527	7.385	0.126
Arterial	0.074	0.385	0.231	0.444	2.362	1.779	5.621	5.659	0.127
Commercial arterial	0.102	0.434	0.28	0.498	2.325	1.864	6.207	6.268	0.125
Commercial highway	0.064	0.367	0.215	0.45	2.601	1.579	4.709	4.693	0.161
Highway / freeway	0.047	0.357	0.203	0.447	2.715	1.544	4.309	3.783	0.189
PM_{10} (season maximum) (g/km)									
Residential	0.001	0.009	0.004	0.02	0.005	0.046	0.106	0.102	0.014
Arterial	0.001	0.008	0.004	0.015	0.005	0.039	0.071	0.074	0.014
Commercial arterial	0.001	0.008	0.003	0.017	0.005	0.047	0.072	0.085	0.014
Commercial highway	0.001	0.008	0.004	0.011	0.006	0.032	0.051	0.061	0.014
Highway / freeway	0.002	0.008	0.004	0.009	0.006	0.028	0.047	0.054	0.014
HC (season maximum) (g/km)									
Residential	0.036	0.031	0.161	0.06	1.604	0.04	0.083	0.12	1.551
Arterial	0.041	0.022	0.137	0.039	0.887	0.027	0.053	0.085	1.066
Commercial arterial	0.057	0.023	0.19	0.04	0.995	0.029	0.054	0.093	1.134
Commercial highway	0.029	0.017	0.086	0.027	0.522	0.019	0.039	0.066	0.795
Highway / freeway	0.024	0.016	0.071	0.023	0.443	0.017	0.036	0.052	0.732

Table A-6 Base composite emission factors for 2036 (hot running)

Road type	CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC
CO (season maximum) (g/km)									
Residential	0.394	0.074	0.814	0.219	20.55	0.125	0.576	0.389	8.532
Arterial	0.255	0.045	0.532	0.169	12.37	0.088	0.336	0.272	7.295
Commercial arterial	0.517	0.054	1.106	0.21	13.58	0.093	0.222	0.316	7.416
Commercial highway	0.461	0.072	0.955	0.159	8.64	0.066	0.171	0.188	7.408
Highway / freeway	0.676	0.067	1.339	0.13	8.085	0.061	0.158	0.132	7.903
NO_x (season maximum) (g/km)									
Residential	0.039	0.293	0.082	0.407	2.174	1.897	6.224	6.143	0.124
Arterial	0.045	0.262	0.083	0.301	2.348	1.609	5.278	4.511	0.125
Commercial arterial	0.064	0.295	0.105	0.337	2.31	1.688	5.825	5.054	0.123
Commercial highway	0.031	0.249	0.062	0.305	2.585	1.42	4.278	3.647	0.158
Highway / freeway	0.015	0.242	0.044	0.303	2.698	1.387	3.861	2.782	0.187
PM_{10} (season maximum) (g/km)									
Residential	0.001	0.005	0.003	0.012	0.005	0.036	0.096	0.083	0.014
Arterial	0.001	0.005	0.003	0.009	0.004	0.03	0.064	0.054	0.014
Commercial arterial	0.001	0.005	0.003	0.01	0.004	0.037	0.065	0.062	0.014
Commercial highway	0.001	0.005	0.003	0.006	0.005	0.024	0.046	0.037	0.014
Highway / freeway	0.001	0.005	0.004	0.005	0.005	0.021	0.042	0.029	0.014
HC (season maximum) (g/km)									
Residential	0.024	0.03	0.077	0.058	1.583	0.02	0.06	0.04	1.487
Arterial	0.032	0.022	0.079	0.037	0.875	0.013	0.038	0.027	1.022
Commercial arterial	0.047	0.023	0.125	0.038	0.982	0.014	0.039	0.03	1.087
Commercial highway	0.024	0.017	0.06	0.026	0.516	0.009	0.027	0.019	0.764
Highway / freeway	0.019	0.015	0.051	0.022	0.437	0.008	0.024	0.015	0.705

Table A-7 Sixth order polynomial coefficients for speed correction (2026)

Road type	CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC
CO									
A	7E-12	4E-10	1E-11	8E-11	1E-11	3E-11	1E-10	6E-11	0
B	-3E-09	-2E-07	-5E-09	-3E-08	-5E-09	-9E-09	-4E-08	-2E-08	0
C	6E-07	3E-05	9E-07	5E-06	9E-07	1E-06	5E-06	4E-06	0
D	-6E-05	-0.003	-1E-04	-5E-04	-1E-04	-1E-04	-4E-04	-3E-04	0
E	0.005	0.124	0.008	0.021	0.008	0.005	0.013	0.013	0
F	-0.283	-3.011	-0.311	-0.524	-0.311	-0.136	-0.253	-0.347	0
G	5.548	30.16	5.494	6.24	5.494	2.569	3.298	4.938	1
NO_x									
A	6E-11	5E-11	7E-11	1E-10	7E-11	3E-11	2E-11	5E-11	0
B	-2E-08	-2E-08	-3E-08	-5E-08	-3E-08	-1E-08	-6E-09	-2E-08	0
C	4E-06	4E-06	5E-06	8E-06	5E-06	2E-06	9E-07	3E-06	0
D	-3E-04	-3E-04	-4E-04	-7E-04	-4E-04	-1E-04	-7E-05	-3E-04	0
E	0.017	0.014	0.021	0.033	0.021	0.006	0.003	0.014	0
F	-0.408	-0.353	-0.533	-0.833	-0.533	-0.136	-0.09	-0.339	0
G	5.013	4.494	6.353	9.39	6.353	2.356	2.181	4.591	1
PM_{10}									
A	4E-11	7E-11	4E-11	9E-11	4E-11	-1E-11	1E-10	-3E-11	0
B	-1E-08	-3E-08	-2E-08	-4E-08	-2E-08	5E-09	-4E-08	1E-08	0
C	2E-06	4E-06	2E-06	6E-06	2E-06	-8E-07	6E-06	-9E-07	0
D	-2E-04	-4E-04	-2E-04	-5E-04	-2E-04	6E-05	-4E-04	2E-05	0
E	0.01	0.018	0.01	0.022	0.01	-0.002	0.019	0.003	0
F	-0.235	-0.427	-0.238	-0.523	-0.238	0.011	-0.458	-0.166	0
G	3.288	5.202	3.317	6.227	3.317	1.293	5.751	3.803	1
HC									
A	-3E-12	5E-11	6E-11	9E-11	6E-11	5E-11	8E-11	4E-11	0
B	1E-09	-2E-08	-2E-08	-4E-08	-2E-08	-2E-08	-3E-08	-2E-08	0
C	-2E-07	3E-06	4E-06	6E-06	4E-06	3E-06	5E-06	3E-06	0
D	8E-06	-2E-04	-4E-04	-5E-04	-4E-04	-3E-04	-4E-04	-2E-04	0
E	2E-04	0.011	0.017	0.024	0.017	0.012	0.019	0.011	0
F	-0.032	-0.273	-0.451	-0.583	-0.451	-0.304	-0.469	-0.303	0
G	1.607	3.816	5.818	6.87	5.818	4.149	6.106	4.604	1

Table A-8 Sixth order polynomial coefficients for speed correction (2036)

Road type	CP	CD	LDCP	LDCD	HDCP	RT	AT	BusD	MC
CO									
A	3E-13	4E-10	1E-12	8E-11	1E-12	3E-11	1E-10	7E-11	0
B	-1E-10	-2E-07	-6E-10	-3E-08	-6E-10	-1E-08	-4E-08	-3E-08	0
C	3E-08	3E-05	1E-07	5E-06	1E-07	2E-06	5E-06	4E-06	0
D	-3E-06	-0.003	-2E-05	-5E-04	-2E-05	-1E-04	-4E-04	-3E-04	0
E	0.003	0.124	0.004	0.021	0.004	0.006	0.013	0.014	0
F	-0.241	-3.024	-0.248	-0.517	-0.248	-0.175	-0.254	-0.368	0
G	5.396	30.29	5.338	6.177	5.338	2.951	3.339	5.168	1
NO_x									
A	3E-11	5E-11	5E-11	1E-10	5E-11	4E-11	2E-11	7E-11	0
B	-1E-08	-2E-08	-2E-08	-5E-08	-2E-08	-1E-08	-6E-09	-3E-08	0
C	2E-06	4E-06	3E-06	8E-06	3E-06	2E-06	9E-07	4E-06	0
D	-2E-04	-3E-04	-3E-04	-7E-04	-3E-04	-1E-04	-7E-05	-4E-04	0
E	0.008	0.014	0.014	0.033	0.014	0.006	0.003	0.017	0
F	-0.204	-0.353	-0.348	-0.84	-0.348	-0.141	-0.084	-0.416	0
G	3.032	4.494	4.495	9.454	4.495	2.397	2.144	5.297	1
PM_{10}									
A	4E-11	7E-11	4E-11	9E-11	4E-11	-1E-11	1E-10	-2E-11	0
B	-1E-08	-3E-08	-1E-08	-4E-08	-1E-08	5E-09	-4E-08	5E-09	0
C	2E-06	4E-06	2E-06	6E-06	2E-06	-9E-07	6E-06	-3E-07	0
D	-2E-04	-4E-04	-2E-04	-5E-04	-2E-04	7E-05	-5E-04	-3E-05	0
E	0.01	0.017	0.01	0.021	0.01	-0.002	0.02	0.004	0
F	-0.234	-0.412	-0.234	-0.498	-0.234	0.016	-0.484	-0.207	0
G	3.279	5.055	3.279	5.973	3.279	1.264	6	4.369	1
HC									
A	-4E-13	5E-11	1E-10	9E-11	1E-10	6E-11	9E-11	5E-11	0
B	1E-10	-2E-08	-4E-08	-4E-08	-4E-08	-2E-08	-3E-08	-2E-08	0
C	-2E-08	3E-06	7E-06	6E-06	7E-06	3E-06	5E-06	3E-06	0
D	1E-06	-2E-04	-6E-04	-5E-04	-6E-04	-3E-04	-4E-04	-3E-04	0
E	2E-04	0.011	0.028	0.024	0.028	0.013	0.019	0.012	0
F	-0.011	-0.271	-0.693	-0.592	-0.693	-0.326	-0.487	-0.332	0
G	1.179	3.8	7.826	6.962	7.826	4.355	6.3	4.928	1