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Hornsby Quarry

Road Construction Spoil Management project

Environmental Impact Statement
Volume 2: Appendices A to F

August 2015

Volume 2 – Appendices A to F

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Appendix A

Secretary's Environmental Assessment Requirements

Appendix A – Secretary's Environmental Assessment Requirements

Table A-1 Secretary's environmental assessment requirements

SEARs	Where addressed
The Environmental Impact Statement (EIS) must meet the minimum form and content requirements in clauses 6 and 7 of Schedule 2 the *Environmental Planning and Assessment Regulation 2000*.	The requirements of the *Environmental Planning and Assessment Regulation 2000* are addressed throughout the EIS and in **Appendix B**.
Notwithstanding the key issues specified below, the EIS must include an environmental risk analysis to identify the potential environmental impacts associated with the infrastructure. Where relevant, the assessment of the key issues below, and any other significant issues identified in the risk assessment, must include: • adequate baseline data; • consideration of potential cumulative impacts due to other development in the vicinity; and • measures to avoid, minimise and if necessary, offset the predicted impacts, including detailed contingency plans for managing any significant risks to the environment.	An environmental risk analysis has been undertaken and is described in **Chapter 9**.
The EIS must also address the following specific matters:	
Statutory and strategic context	
• A statement of the objectives of the proposal, including a description of the strategic need, justification, objectives and outcomes for the proposal, its relationship to NorthConnex and the Hornsby Shire Council's plans for the Hornsby Quarry site, and as relevant the outcomes and objectives of relevant strategic planning and transport policies, including, but not limited to, *NSW 2021, NSW Government State Infrastructure Strategy, NSW Long Term Transport Master Plan* (December 2012), *A Plan for Growing Sydney* (December 2014) and any other relevant plans.	Objectives of the project are identified in **Section 3.2**. The strategic need, justification, outcomes and relationship to NorthConnex and Hornsby Shire Council's plans for the quarry site is addressed in **Section 3.2**. Consideration of the project against the outcome and objectives of strategic planning and transport policies is provided in **Section 3.1**.
• An analysis of feasible alternatives to the carrying out of the proposal and proposal justification, including:	An analysis of feasible alternatives and a justification of the proposal are outlined in **Section 3.3**.
– An analysis of alternatives/options considered having regard to the proposal's objectives (including an assessment of the environmental costs and benefits of the proposal relative to alternatives and the consequences of not carrying out the proposal), and the provision of a clear discussion of the route development and selection process, the suitability of the chosen alignment and whether or not the proposal is in the public interest.	Analysis of the options and alternatives considered for the proposal is presented in **Section 3.3** along with consideration of environmental costs and benefits of the project relative to the alternatives. The consequence of not carrying out the Project is provided in **Section 3.3.4**. A discussion of haulage route development and selection process is provided in **Section 3.3.2**. Justification of the project considering the suitability of the site and public interest is provided in **Section 3.2**.

SEARs	Where addressed
– Justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979.*	Justification for the proposal having regard to the objectives of the EP&A Act is included in **Section 10.2**.
• An analysis of the proposal, including an identification of how relevant planning, land use and development matters (including relevant strategic and statutory matters) have been considered in the impact assessment (direct, indirect and cumulative impacts) and/or in developing management/ mitigation measures.	Planning, land use and development matters have been given consideration in the development of the proposal (including relevant strategic and statutory matters) and are detailed in **Chapter 2**, **Chapter 3** and **Chapter 8**.
• Relationship between the proposal and existing approvals and licences applying to the site, including the existing groundwater discharge licence.	Relationship between the proposal and existing approvals and licences applying to the site, including the existing groundwater discharge licence is provided in **Section 2.5**.
• A detailed description of the proposal and its relationship and/or interaction with the NorthConnex spoil management strategy.	A detailed description of the proposal and the interaction with the NorthConnex spoil management strategy is described in **Section 3.2.1**.
• A detailed analysis of the proposal and its consistency with the *Old Mans Valley - Community Land - Plan Of Management: Adopted 21 March 2012* (Hornsby Shire Council).	Consistency of the project with the *Old Mans Valley - Community Land - Plan of Management* is described in **Section 3.1.6**.
• Details of how the principles of ecologically sustainable development will be incorporated in the design, construction and ongoing operation phases of the proposal.	The principles of ecologically sustainable development have been incorporated into the design and construction of the project and are described in **Section 10.2**.
• Justification for final form of proposal (that is, the proposed landform at the completion of spoil emplacement works), with reference to stabilisation and rehabilitation requirements.	Justification for the proposal is described in **Section 3.2**. Information on the final landform proposed and stabilisation and rehabilitation requirements are described in **Section 4.8**.
Traffic and transport	
• An assessment of the traffic impacts of required preparatory works.	Traffic related impacts of preparatory works are assessed in **Section 6.1.4** and in **Appendix C**.
• An assessment (including modelling) of the traffic impacts of spoil emplacement works, including impacts (number, frequency and type/size of construction related vehicles volumes; speeds; intersection performance; etc.) on Pennant Hills Road, Pacific Highway, Peats Ferry Road, Bridge Road, and the surrounding local, regional and state road network.	Traffic impacts of the project on Pennant Hills Road, Pacific Highway, Peats Ferry Road, Bridge Road, and the surrounding local, regional and state road network are assessed in **Section 6.1.4** and in **Appendix C**.
• Designation of haulage routes between the proposal and the spoil extraction sites, and delineation of site access points; description of any road network upgrades or alterations required to facilitate the proposal.	Haulage routes, site access points and descriptions of required road network upgrades or alterations are described in **Section 6.1.4** and in **Appendix C**.
• A strategy for managing traffic impacts, including parking impacts, with a particular focus placed on those activities identified as having the greatest potential for adverse traffic flow, capacity or safety implications, and a broader, more generic approach developed for day-to-day	Mitigation measures to be included in the project Traffic Management Plan are described in **Section 6.1.6** and a framework strategy is provided in **Appendix C**.

SEARs	Where addressed
traffic management.	
• Consideration of the cumulative construction impacts on residents/businesses taking into account other projects that have either commenced construction, are preparing for construction or have recently been completed.	Cumulative impacts on residents/ businesses that take into account other projects have been assessed in **Section 6.1.4** and in **Appendix C**.
Noise and vibration	
• An assessment of the noise impacts of the proposal, consistent with the *Interim Construction Noise Guideline* (DECCW, 2009), *Assessing Vibration: a technical guideline* (DEC, 2006), and any other relevant guidelines or policies. The assessment must have regard to the nature of construction activities (including transport, tonal or impulsive noise generating works and the removal of operational noise barriers, as relevant), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially affected receivers, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management), and mitigation and management measures. The assessment should present, as relevant, an indication of potential for works outside standard working hours, including predicted levels and exceedances, justification for the activity and discussion of available mitigation.	An assessment of the noise and vibration impacts of the proposal and associated management and mitigation measures is included in **Section 6.2** and in **Appendix D**.
Soil, water and waste	
• A commitment to receiving and handling material generated solely from tunnelling activities required for delivery of NorthConnex.	A commitment to receiving only material generated from tunnelling activities required for the delivery of NorthConnex is included in **Section 4.1**.
• Identification, classification and quantification of likely waste streams that would be managed at the proposal.	Potential waste streams have been assessed and are described in **Section 7.9.1**. Management and mitigation measures are outlined in **Section 7.9.2**.
• Assessment of construction and operational erosion and sediment impacts, and details of proposed controls.	An assessment of erosion and sedimentation impacts associated with the project has been completed and is described in **Section 6.4.3**. Management and mitigation measures are outlined in **Section 6.4.4**.
• Assessment of surface water impacts, including details of proposed stormwater management systems, having consideration to impacts on Old Mans Creek and all other watercourses and riparian corridors potentially affected by the proposal. The assessment of water quality impacts is to have reference to relevant public health and environmental water quality criteria, including those specified in the *Australian and New Zealand Guidelines for Fresh and Marine*	Potential surface water impacts, having regard to relevant public health and environmental water quality criteria, have been assessed and are described in **Section 6.4.3**.

SEARs	Where addressed
Water Quality (ANZECC/ARMCANZ 2000), and any applicable regional, local or site specific guidelines.	
• An assessment of groundwater flows at the proposal site, appropriate management measures for dewatering during site establishment, and ongoing dewatering and site management processes during spoil emplacement works. • The assessment must consider: extent of drawdown; impacts to groundwater quality; volume of inflows and water licence requirements; discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater-dependent ecological communities, and groundwater users. The assessment should be prepared having consideration to the requirements of the *NSW Aquifer Interference Policy.*	An assessment of groundwater impacts as a result of the project including consideration of the requirements of the NSW Aquifer Interference Policy is included in **Section 6.3.3** and **Appendix M**. Consideration of appropriate management and mitigation measures is included in **Section 6.3.4**.
Hazards and risk	
A Preliminary Hazard Analysis in accordance with the requirements of State Environmental Planning Policy No 33—Hazardous and Offensive Development and the Department's Hazardous Industry Planning and Assessment Guidelines.	A preliminary hazard analysis has been undertaken in accordance with SEPP 33 and the department's Hazardous Industry Planning and Assessment Guidelines and is included in **Section 6.5.1**.
• Detailed construction methodology having consideration of geotechnical stability of the Hornsby Quarry site, walls and access tracks, prior to, during and after completion of the proposal;	Hazards and risks associated with the geotechnical stability of the Hornsby Quarry site have been assessed in **Section 6.5.1** and in **Section 6.3.3** of the Hydrogeology and soils assessment.
• Processes for identification, management, treatment and disposal of contaminated spoil; and	A process for identifying and management contaminated spoil is outlined in **Section 6.3.4** and would also be detailed in the CEMP to be prepared for the project.
• An assessment of potential bushfire risks.	An assessment of potential bushfire risks is included in **Section 6.5.1**.
Air quality	
• An assessment of activities that have the potential to impact on local and regional air quality; and	Activities that the potential to impact on local and regional air quality have been assessed in **Section 7.1** and in **Appendix E**.
• Details of the proposed methods to minimise adverse impacts on air quality, particularly in relation to spoil haulage and emplacement, and mobile plant.	Management and mitigation measures are described in **Section 7.1.6** and in **Appendix E**.
Health	
• An assessment of human health impacts with particular consideration of:	Human health impacts have been assessed in **Section 7.2** and in **Appendix F**.
– How the design of the proposal minimises adverse health impacts.	An assessment of the way in which the design minimises adverse health impacts is described in **Section 7.2** and in **Appendix F**.
– Human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts, during the construction and	Human health risks and costs associated with the proposal relating to air quality are assessed in **Section 7.1** (Air quality) and in **Appendix E**. Human health risks and costs

SEARs	Where addressed
operation of the proposal.	associated with the proposal relating to noise and vibration are assessed in **Section 6.2** and in **Appendix D**. The social impacts are assessed in **Section 7.4** and in **Appendix H**.
– The *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth, 2012) and Air Quality in and Around Traffic Tunnels* (NHMRC, 2008).	Relevant guidelines have been given regard in **Section 7.2** and in **Appendix F**.
Land use, property and socio-economic	
• Impacts on directly affected properties and land uses, including impacts related to access, land use, and amenity related changes.	Impacts on properties and land uses are described in **Section 7.5.2**.
• Effects on existing mountain bike trails and recreation areas within Old Mans Valley, including, where applicable, details of rerouted trails and access paths.	Potential impacts of the project on existing mountain bike trails and recreation areas have been assessed in **Section 7.5.2**, in **Section 7.4.3** and within the technical working paper: socio-economic in **Appendix H**.
• Social and economic impacts to businesses along Pennant Hills Road and the Pacific Highway, and the community associated with traffic, access, property, public domain and amenity related changes.	Social and economic impacts have been assessed and are described in **Section 7.4.3** and in the technical working paper: socio-economic impact assessment in **Appendix H**.
Urban design and visual amenity	
• A consideration of the urban design and visual amenity implications of the proposal, including supporting infrastructure, during construction and operation.	Urban design and visual amenity impacts have been assessed and are described in **Section 7.8.3**.
• A consideration of impacts on views and vistas, streetscapes, key sites and buildings.	Urban design and visual amenity impacts have been assessed and are described in **Section 7.8.3**.
• Measures to manage lighting impacts both during construction and operation.	Management and mitigation measures including measures relating to lighting are outlined in **Section 7.8.3**.
Non-Aboriginal heritage	
• Impacts to State and local historic heritage (including conservation areas, built heritage, landscapes and archaeology) should be assessed, including—in particular—the Hornsby Diatreme and surrounding vegetation, Hornsby Heritage steps, the Old Mans Valley Cemetery, street trees on Dural Street, and the TAFE college. Where impacts to State or locally significant historic heritage are identified, the assessment shall:	Impacts to State and local historic heritage have been assessed in **Section 7.6.4** and in **Appendix I**.
– Outline the proposed mitigation and management measures (including measures to avoid significant impacts and an evaluation of the effectiveness of the mitigation measures) generally consistent with the guidelines in the NSW Heritage Manual (Heritage Office and DUAP 1996).	Mitigation and management measures are described in **Section 7.6.6** and in **Appendix I**.

SEARs	Where addressed
– Be undertaken by a suitably qualified heritage consultant(s) with relevant heritage expertise (note: where archaeological excavations are proposed the relevant consultant must meet the NSW Heritage Council's Excavation Director criteria).	The technical working paper: non-Aboriginal heritage has been prepared by a suitable qualified heritage consultant(s). Refer to **Appendix I**.
– Include a statement of heritage impact for all heritage items/conservation areas to be impacted (including significance assessment). This should include detailed mapping of all heritage items and how they are affected by the proposal,.	A statement of heritage impact is included in **Section 7.6.5** and in the technical working paper at **Appendix I**.
– Include details of any proposed mitigation measures (architectural and landscape).	Mitigation and management measures are described in **Section 7.6.6** and in **Appendix I**.
– Consider impacts from, including but not limited to, vibration, demolition, archaeological disturbance, altered historical arrangements and access, landscape and vistas, and architectural noise treatment (as relevant).	Impacts to State and local historic heritage have been assessed in **Section 7.6.4** and in **Appendix I**.
– Where physical archaeological test excavations are proposed, develop an appropriate archaeological assessment methodology, including research design, in consultation with the Heritage Council of New South Wales (for items of State significance) and the Department, to guide the test excavations, and include the results of these excavations.	Not relevant to this project.
– Provision of future mitigation strategies for all identified archaeological impacts that would arise from the proposal.	Mitigation and management measures are described in **Section 7.6.6** and in **Appendix I**.
Aboriginal heritage	
• Impacts to Aboriginal heritage (including cultural and archaeological significance), in particular impacts to Aboriginal objects and potential archaeological deposits (PAD) should be assessed. Where impacts are identified, the assessment shall:	Impacts to Aboriginal heritage have been assessed in the technical working paper: Aboriginal heritage in **Appendix J** and in **Section 7.7**.
– Outline the proposed mitigation and management measures (including measures to avoid significant impacts and an evaluation of the effectiveness of the measures) generally consistent with the Draft Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation (DEC 2005) and other relevant guidelines and requirements.	Management and mitigation measures have been developed having regard to the Draft Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation (DEC 2005) and other relevant guidelines and requirements and are included in **Section 7.7.4** and in **Appendix J**.
– Be undertaken by a suitably qualified heritage consultant(s).	The technical working paper: Aboriginal heritage in **Appendix J** has been prepared by a suitably qualified heritage consultant(s).
– Demonstrate effective consultation with Aboriginal communities in determining and assessing impacts and developing and selecting options and mitigation measures	Consultation with Aboriginal communities is described in **Section 7.7.1** and in **Appendix J**.

SEARs	Where addressed
(including the final proposed measures).	
– Assess and document the archaeological and cultural significance of cultural heritage values of affected sites.	The cultural heritage values of the site are assessed and documented in **Appendix J**.
– Undertake appropriate archaeological investigations generally in accordance with the Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW (DECCW 2010), to establish the full spatial extent and significance of any archaeological evidence across each site/area of PAD, and include the results of these excavations. If an alternative excavation method is proposed, it shall be developed in consultation with Office of Environment and Heritage.	Archaeological investigations are described in **Section 7.7** and in **Appendix J**.
Biodiversity	
• An assessment in accordance with the Framework for Biodiversity Assessment, unless otherwise agreed by OEH, by a person accredited in accordance with s142B(1)(c) of the Threatened Species Conservation Act 1995. • *Note:* This includes a requirement for a Biodiversity Assessment Report and a Biodiversity Offset Strategy.	An assessment in accordance with the Framework for Biodiversity Assessment has been prepared for the project and is described in **Section 7.3** and in **Appendix G**. The Biodiversity Assessment Report assessed the type and quantum of credits as a result of the project using the Framework for Biodiversity Assessment (FBA) methodology to quantify the impacts of the proposal. An offset strategy consistent with the offset strategy for the NorthConnex project would be prepared to compensate for the loss of native vegetation, endangered ecological communities and threatened species habitat which cannot be avoided or mitigated.
Community liaison	
• A draft Community Involvement Plan for the works, identifying relevant stakeholders, procedures for distributing information and receiving/responding to feedback and procedures for resolving community complaints during construction. Key issues that should be addressed in the draft Plan should include (but not necessarily be limited to): – Traffic management (including property access and pedestrian access). – Noise and vibration mitigation and management, including work outside standard construction hours. – Pedestrian and bicycle access to Old Mans Valley.	A draft Community Involvement Plan is provided in **Appendix L** of the EIS.

SEARs	Where addressed
Environmental risk analysis	
Notwithstanding the above assessment requirements, the EIS must include an environmental risk analysis to identify potential environmental impacts associated with the proposal (construction and operation), proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures. Where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of this additional key environmental impact must be included in the EIS.	An environmental risk analysis has been undertaken and is described in **Section 9**.
Consultation	
During the preparation of the EIS, you must consult with the relevant local and State Government authorities, service providers, community groups and affected landowners. In particular you must consult with:	Information regarding consultation is provided in this **Section 5**.
• Local, State and Australian government authorities, including the: – Environment Protection Authority; – Office of Environment and Heritage (including Heritage Division); – Department of Primary Industries; – NSW Office of Water; – Hornsby Shire Council; and – Emergency services.	Consultation with government authorities and emergency services is described in **Section 5.2.3**. Issues raised by government agencies and emergency services are identified in **Section 5.3.1**. Issues raised by Hornsby Shire Council are identified in **Section 5.3.2**.
• Specialist interest groups, including local sporting groups, Aboriginal stakeholders, and pedestrian and bicycle user groups.	Consultation with Aboriginal stakeholders is described in **Section 5.2.2**. Further details are provided in **Section 7.7** and the technical working paper: Aboriginal heritage (**Appendix J**). Consultation with interest groups, including local sporting groups and pedestrian and bicycle user groups is provided in **Section 5.2.4**. Issues raised by these key stakeholders are identified in **Section 5.3.3**.
• Utilities and service providers.	Consultation with utility and service providers is described in **Section 5.2.4**.
• The public, including community groups, businesses, and adjoining and affected landowners.	Consultation with the public, including community groups, businesses and adjoining and affected landowners is described in **Sections 5.2.4** and **5.2.5**.
The EIS must describe the consultation process and the issues raised, and identify where the design of the infrastructure has been amended in response to these issues. Where amendments have not been made to address an issue, a short explanation should be provided.	The consultation process, stakeholders consulted and consultation activities have been addressed in **Section 5.1** and **Section 5.2**. Issues raised through the consultation process, and where in the EIS these issues have been addressed is provided in

SEARs	Where addressed
	Section 5.3. Amendments that have been made to the project in response to consultation with the community and stakeholders have been provided in **Section 5.4**.

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Appendix B

Environmental Planning and Assessment Regulation 2000 checklist

Appendix B – Environmental Planning and Assessment Regulation 2000 checklist

Table B-1 EP&A Regulation 2000 checklist

Requirement		Where addressed
6 Form of the environmental impact statement		
An environmental impact statement must contain the following information:		
the name, address and professional qualifications of the person by whom the statement is prepared,		Certification page
the name and address of the responsible person,		Certification page
the address of the land: i) in respect of which the development application is made, or ii) on which the activity or infrastructure to which the statement relates is to be carried out,		Certification page
a description of the development, activity or infrastructure to which the statement relates,		Certification page
an assessment by the person by whom the statement is prepared of the environmental impact of the development, activity or infrastructure to which the statement relates, dealing with the matters referred to in this Schedule, and		Certification page
a declaration by the person by whom the statement is prepared to the effect that: the statement has been prepared in accordance with this Schedule, and the statement contains all available information that is relevant to the environmental assessment of the development, activity or infrastructure to which the statement relates, and that the information contained in the statement is neither false nor misleading.		Certification page
7 Content of the environmental impact statement		
1)	An environmental impact statement must also include each of the following:	
a)	a summary of the environmental impact statement,	Executive summary
b)	a statement of the objectives of the development, activity or infrastructure,	**Chapter 3 –** Strategic justification and project need
c)	an analysis of any feasible alternatives to carrying out of the development, activity or infrastructure, having regard to the objectives, including the consequences of not carrying out the development, activity or infrastructure,	**Chapter 3 –** Strategic justification and project need
d)	an analysis of the development, activity or infrastructure, and	**Chapter 4** – Project description
i)	a full description of the development, activity or infrastructure,	**Chapter 4** – Project description
ii)	a general description of the environment likely to be affected by the development, activity or infrastructure, together with a detailed description of those aspects of the environment that are likely to be significantly affected, and	Executive Summary **Chapter 6** – Assessment of key issues **Chapter 7** - Assessment of other issues
iii)	the likely impact on the environment of the development, activity or infrastructure, and	**Chapter 6**– Assessment of key issues **Chapter 7** - Assessment of other issues

Requirement		Where addressed
iv)	a full description of the measures proposed to mitigate any adverse effects of the development, activity or infrastructure on the environment, and	**Chapter 6** – Assessment of key issues **Chapter 7** - Assessment of other issues
v)	a list of any approvals that must be obtained under any other Act or law before the development, activity or infrastructure may lawfully be carried out,	**Chapter 2** – Assessment process
e)	compilation (in a single section of the environmental impact statement) of the measures referred to in item (d)(iv),	**Chapter 8** – Summary of environmental management measures
f)	the reasons justifying the carrying out of the development, activity or infrastructure in the manner proposed, having regard to biophysical, economic and social considerations, including the principles of ecologically sustainable development set out in subclause (4) of Schedule 2 Part 3 Section 7.	**Chapter 10** – Project justification and conclusions
2)	Subclause (1) is subject to the environmental assessment requirements that relate to the environmental impact statement.	SEARs are addressed throughout the document. **Appendix A** addresses where SEARs have been addressed in EIS.
3)	Secretary has waived the need for SEARs.	Not applicable
4)	Principles of ecologically sustainable development.	**Chapter 10** – Project justification and conclusions

Appendix C

Technical working paper:
Traffic

Roads and Maritime Services

Hornsby Quarry Road Construction Spoil Management Project

Technical Working Paper: Traffic and Transport

July 2015

Prepared for

Roads and Maritime Services

Prepared by

AECOM Australia Pty Ltd

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Executive summary

Background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by the construction of NorthConnex.

The site would be used to receive up to 1.5 million cubic metres of excavated natural material and/or virgin excavated natural material from the approved NorthConnex construction sites. Only excavated natural material and/or virgin excavated natural material would be received and reused at the Hornsby Quarry site.

Construction of the project is anticipated to commence in late 2015 and is expected to take around 33 months to complete.

The purpose of the traffic and transport assessment is to address the SEARs by documenting the existing and future conditions structured around the following three elements:

- Existing traffic and transport conditions, including current traffic volumes, network and intersection performance, public transport and walking / cycling facilities.
- Forecast future conditions without the project. This will assess network and intersection performance based on current traffic conditions with background growth to represent future year scenarios.
- Forecast future conditions with the project. This element details performance testing of the roads that would be impacted by construction-related vehicles and project activities.

Existing traffic and transport conditions

The Pacific Highway and M1 Pacific Motorway form the central spine of the study area and provide key arterial / sub-arterial roles within the wider road network. The Pacific Highway connects the suburbs of Hornsby, Waitara and Asquith to the Hornsby Town Centre and M1 Pacific Motorway whilst the M1 Pacific Motorway provides inter-state connectivity to the Central Coast, Newcastle and beyond.

Private vehicles are the dominant mode of travel in the Hornsby Local Government Area (LGA) representing 50 per cent of overall mode share. This is higher than the Greater Sydney Metropolitan Area (GSMA) at 47 per cent. Due to resident’s proximity to rail stations such as Hornsby, Waitara and Asquith the percentage of rail as a mode share at nine per cent also exceeds that of the GSMA at five per cent. Despite bus usage in the area falling below the typical mode share of the GSMA (six per cent compared to four per cent) the Pacific Highway, in the vicinity of the Hornsby Town Centre, is of strategic importance to bus operation in the area as it provides access for bus services to the interchange located west of Hornsby Station. From a cyclist perspective the study area does not contain any dedicated or separated cycle facilities.

Analysis of traffic data at key intersections within the study area indicates that the proportion of heavy vehicles within the study area ranges from three to six per cent of total traffic in the AM peak hour and two to five per cent in the PM peak hour.

Under current operating conditions in the AM peak hour the intersection of Pacific Highway / Pennant Hills Road records a Level of Service (LoS) of E. All other intersections, in both the AM and PM peak period, record a LoS no worse than D. An explanation of LoS banding and terminology can be found in **Section 6.3.2**.

Impact Assessment

Basis for assessing future traffic conditions

A strategic transport model was used to forecast future traffic network volumes including anticipated land use changes and upgrades to the road network. Modelling was undertaken for the year of 2016 with the network assessed for both 'with' and 'without' project scenarios to determine the relative impacts.

Assessment

Intersection performance

A maximum of 385 vehicles per day, associated with spoil haulage, are anticipated to travel through the study area at the peak of site activity. On a per hour basis this equates to a maximum of 35 vehicles. The notion of maximum truck volumes is important given that they will only potentially be achievable for a total of 14 months based on the forecast rate of spoil generation from tunnelling and excavation for NorthConnex. Given the naturally fluctuating truck volumes across the period of construction this assessment has focused on a worst case scenario however, in reality, the relatively minor increase in average delay discussed in this report will not occur for the majority of the 28 month haulage period.

The majority of the proposed haulage route passes through intersections which, even with the worst case assessment of construction vehicle traffic under a 'with construction' scenario, will not result in the intersection's capacity being exceeded. The exception to this is in the south of the study area in proximity to the M1 Pacific Motorway / Pacific Highway interchange and Pacific Highway / Pennant Hills Road intersection. Analysis of these locations under a 'without construction' scenario indicates that with background growth alone these intersections will exceed capacity regardless of the addition of construction traffic. The 'with construction' scenario assessment indicated a negligible additional capacity impact on the operation of these intersections.

LoS parameters, whilst falling to a LoS of E or F in the locations stated above as well as the intersection of Pacific Highway / Bridge Road and Pacific Highway / Yirra Road, are considered acceptable given the localised area and short time frame in which they occur. The remainder of the study area is forecast to operate at LoS of D or better under the worst case construction haulage scenario ('with construction' scenario).

Predicted Impacts

Traffic crashes

As the volume of traffic generated by construction is expected to be low compared to existing traffic levels, the effects of this short-term increase on the existing road network is not expected to significantly impact road safety in the study area.

Public transport services

An increase in heavy vehicles on the existing road network during the project would potentially result in increased delays at intersections along the project corridor and in surrounding areas. Heavy vehicle volumes would be increased within the study area and surrounding major roads. While the increase in truck volumes, as a proportion of overall traffic, is anticipated to be minor, the following impacts to public transport services could potentially be experienced:

- Buses:

An increase in bus service travel times due to slower travel speeds and increased intersection delays.

Longer travel times to and from bus stops by supplementary travel modes (e.g. car passenger, walking to/from bus stop, etc) due to an increase in traffic volumes, slower travel speeds and increased intersection delays.

Reduced amenity for bus users waiting at stops; an increase in traffic would result in impacts including a reduction in pedestrian roadside safety.

- Rail services:

Rail services in the project corridor and surrounding areas are not expected to be affected by the project.

Walking and cycling

An increase in heavy vehicle volumes during the project along the project corridor and in surrounding areas would potentially impact on walking and cycling amenity, including:

- Walking:
  - Reduced overall amenity throughout the study area.
- Cycling:
  - Increased delays at intersections for on road cyclists due to an increase in traffic volumes travelling along the corridor.

Reduced overall amenity throughout the study area.

Project benefits

The temporary increase in traffic on the road network surrounding the Hornsby Quarry gives rise to substantial long term benefits for the environment and community following completion of the project. The project provides the platform for the following key opportunities:

- Facilitating Hornsby Shire Council's rehabilitation of the quarry void to provide a space for community use and recreation.
- Facilitating the construction of NorthConnex which provides increased transport accessibility for the Hornsby LGA and an extension of Sydney's orbital network to facilitate improved road safety, efficiency and freight transport outcomes.
- Addressing an ongoing safety risk to the community by stabilising the quarry site so it can be opened to the public by Hornsby Shire Council in the future.
- Recognition for implementing a safe and sustainable solution to a community concern (the quarry site).
- Removing an ongoing maintenance cost to Hornsby Shire Council and the community.

Mitigation measures

A traffic management plan (TMP) would be prepared as part of the construction environmental management plan (CEMP). The TMP would include the guidelines, general requirements and procedures to be used when construction activities would have a potential impact on existing traffic arrangements. Implementation of the measures in the TMP would ensure that delays and disruptions are managed with appropriate measures, and identify and respond to any changes in road safety as a result of construction works.

Overall, the TMP would set out the strategy and procedures to minimise, mitigate and communicate the impacts of the construction of the project on the capacity, performance and safety of the local road network and traffic systems. The TMP would also address the management of impacts on emergency services, cyclists, pedestrians, public transport and parking.

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1 Introduction

1.1 Project background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for NorthConnex identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

The Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Hornsby Shire Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 2 July 2015 and included a requirement to undertake an assessment of the project on traffic and transport conditions. This traffic and transport assessment has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management Project.

1.2 Project location

The Hornsby Quarry site is located around 21 kilometres north west of the Sydney Central Business District, in Old Mans Valley to the west of Hornsby town centre. The site covers about 35 hectares and is owned by Hornsby Shire Council (Council) (refer to **Figure 4-1**). The site is accessed via local Council roads, including Quarry Road (off Dural Street and other local roads) from the south east and Bridge Road (off the Pacific Highway/Peats Ferry Road) from the north east.

The site comprises a quarry void, internal access roads and a cleared area to the east, which was used as a processing area when the quarry was operational. Disused facilities associated with the previous quarrying operations remain on the site, including concrete office block buildings, a crushing and screening plant, a pipeline, security fencing and gates.

Whilst the site is zoned for public recreation (RE1) under the *Hornsby Local Environmental Plan 2013*, the quarry void itself is unsafe for public access given the steep sides and flooded nature of the void. Council currently maintains exclusion fencing around the void to prevent public access for public safety reasons. The areas outside of the void exclusion fencing are open to public access including mountain bike trails which have been established across the site by Council. However, until the quarry void is filled, full rehabilitation of the site for recreational purposes is not possible.

The site and surrounds are densely vegetated with some cleared areas comprising the void itself, internal access roads and the cleared area to the east. Dense bushland comprising the Berowra Valley National Park lies directly to the west. The Pacific Highway and Main North Railway Line are located to the east, approximately 300 metres and 500 metres respectively.

1.3 Purpose of this report

The SEARs for the project with respect to traffic and transport were issued on 2 July 2015. The SEARs have informed the preparation of the EIS for the project and include the following requirements specific to potential impacts on traffic and transport:

An assessment of the traffic impacts of required preparatory works;

- An assessment (including modelling) of the traffic impacts of spoil emplacement works, including impacts (number, frequency and type/size of construction related vehicles volumes; speeds; intersection performance; etc) on Pennant Hills Road, Pacific Highway, Peats Ferry Road, Bridge Road, and the surrounding local, regional and state road network;
- Designation of haulage routes between the proposal and the spoil extraction sites, and delineation of site access points;
- Description of any road network upgrades or alterations required to facilitate the proposal;
- A strategy for managing traffic impacts, including parking impacts, with a particular focus placed on those activities identified as having the greatest potential for adverse traffic flow, capacity or safety implications, and a broader, more generic approach developed for day-to-day traffic management; and
- Consideration of the cumulative construction impacts on residents/businesses taking into account other projects that have either commenced construction, are preparing for construction or have recently been completed.

The purpose of the traffic and transport assessment is to address the SEARs by documenting the existing and future conditions structured around the following three elements:

- Existing traffic and transport conditions, including current traffic volumes, network and intersection performance, public transport and walking / cycling facilities.
- Forecast future conditions without the project. This assesses network and intersection performance based on current traffic conditions with background growth to represent future year scenarios.
- Forecast future conditions with the project during construction. This element details performance testing of the roads that would be impacted by construction-related vehicles and construction activities.

1.4 Structure of this report

The report has the following structure:

- Section 1 introduces and provides an overview of the project, project location and purpose of the report.
- Section 2 provides an overview of the assessment methodology.
- Section 3 provides a description of the project incorporating an overview of construction site hours, traffic and haulage routes.
- Section 4 provides an overview of the existing traffic and transport conditions, including description of the route, details of public transport frequency and patronage, a review of relevant walking and cycling routes, and a summary of daily and peak period traffic patterns. A summary of the operational performance of the existing road network in terms of intersection level of service (LoS) and a review of historical crash data is also provided.

- Section 5 documents the traffic modelling approach adopted to predict future traffic volumes for the project and the surrounding road network and to test the construction and operational impacts.
- Section 6 documents the impact assessment undertaken for the construction scenarios of the project.
- Section 7 outlines management measures to be developed to mitigate any traffic and transport impacts.

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2 Assessment methodology

The assessment of the traffic and transport implications associated with the Hornsby Quarry Road Construction Spoil Management Project, is based on the following methodology:

- **Review existing traffic and transport conditions**, including current traffic volumes, network and intersection performance, public transport and walking / cycling facilities.
- **Forecast future conditions both with and without the project during the year of construction (2016)**. This element consists of performance testing of the roads that would be impacted under both 'with' and 'without' project scenarios. This will assist in providing a comparison between the two scenarios and identifying the magnitude of any impacts.
- To accurately model both the existing and future conditions on the road network specific to the study area, macro-simulation and strategic modelling packages, LinSig and Cube, were utilised. Full details of the methodology behind the project's modelling outputs can be found in **Section 5**.
- **Identify any management measures that would be required** to mitigate the impact of the project on the traffic and transport network within the study area.

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3 Description of the Project

3.1 The project

The Hornsby Quarry site would receive up to 1.5 million cubic metres of excavated natural material (ENM) and/or virgin excavated natural material (VENM) from the approved NorthConnex construction sites. Only ENM and/or VENM would be received and reused at the Hornsby Quarry site.

Key features of the project would include:

- Widening and sealing of the quarry access road (Bridge Road and track) to facilitate all weather access.
- Clearing and grubbing, and establishment of erosion and sediment controls.
- Establishment of a compound site, security fencing and signage around the construction area.
- Dewatering of the void (to be undertaken by Hornsby Council in accordance with its existing groundwater licence) to a suitable level that allows working within the void.
- Construction of a conveyor from the stockpile site to the rim of the quarry void.
- Spoil haulage by truck from the NorthConnex construction sites to the Hornsby Quarry site over a period of approximately 28 months.
- Stockpiling of spoil within the Hornsby Quarry site using dozers.
- Transport of the spoil via the conveyor from the stockpiles to the rim of the quarry void, where the spoil would fall directly into the void.
- Spreading and grading of the spoil on the quarry floor.
- Site demobilisation and rehabilitation of the compound site, stockpile areas and the conveyer corridor.

The project is anticipated to commence in late 2015 and is expected to take around 33 months to complete. An indicative project program is provided in **Table 3-1**.

Table 3-1 Indicative project program

Phase	Indicative timeframe 2015				2016				2017				2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Site establishment (including preparatory works)				■												
Establishment of conveyer					■											
Spoil haulage and stockpiling					■	■	■	■	■	■	■	■	■	■		
Spoil emplacement (operation of conveyor)						■	■	■	■	■	■	■	■	■	■	
Site clean-up and demobilisation														■	■	

Note: Traffic volumes would vary over the project timeframe as vehicle movements associated with each project phase increase and then decline based on the commencement and completion of various phases as well as the rate of spoil production by the NorthConnex project. Modelling of construction traffic volumes in this report has focused on the period which incorporates the highest project traffic volumes.

An overview of project activities is included in **Table 3-2**. Detailed descriptions of each activity can be found in Section 4.1 of the EIS for the project.

Table 3-2 Overview of works

Phase	Proposed activities
Site establishment	The following works would completed: • Dewatering of the void to a suitable working level • Clearing and grubbing, and establishment of erosion and sediment controls • Establishment of a compound site • Establishment of security fencing and signage around the construction site • Widening and sealing of the currently unsealed quarry access road (Bridge Road) to facilitate all weather access including access to the TAFE.
Establishment of conveyor	The construction of the conveyor works would include establishment of footings and the conveyor.
Spoil haulage and stockpiling	Trucks would enter and leave via Bridge Road during standard construction hours over a maximum period of 28 months. Spoil would be unloaded from the dump trucks and stockpiled using dozers. It is expected that haulage and stockpiling would commence whilst the conveyer is still being constructed.
Spoil emplacement (operation of conveyor)	Once the conveyer is constructed, these works would occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto the site. The activities include: • Placement of spoil from the stockpiles into the conveyor by front end loader • Transport of the spoil via overhead conveyor to the quarry void rim where the spoil would fall directly into the void. • Front-end loaders and articulated trucks would move the spoil along the quarry floor with dozers and rollers spreading the material. Periodic maintenance pumping of water from the void would be conducted during all phases.
Site demobilisation and rehabilitation	The construction compound and conveyor would be dismantled and removed from the site. Disturbed areas would be rehabilitated to a standard agreed with the Council. Security fencing would be removed, however would be retained around the quarry void if the void is deemed to remain an ongoing risk to public safety. Public access would then be reinstated to the areas outside the void exclusion zone.

3.2 Work hours, traffic and haulage routes

All works and haulage associated with spoil management at the Hornsby Quarry site would be confined to standard day time hours comprising:

- 7 am to 6 pm, Monday to Friday
- 8 am to 1 pm, Saturdays
- No work on Sundays or public holidays.

Traffic attributable to the project activities identified in **Section 3.1** is specific to spoil haulage and staff movements. The maximum number of trucks accessing Hornsby Quarry in an hour is 35. This equates to a maximum potential total of 385 trucks per weekday of operation. Initially truck volumes during peak hours were anticipated to be in the vicinity of 50 trucks accessing/egressing the site each hour. However, during design development and further sensitivity analysis undertaken for the project, the haulage volumes and internal site operations were optimised to reduce impacts to the surrounding community with regards to traffic, noise and air quality.

While the program for spoil haulage is anticipated to run for 28 months, the acceleration and deceleration of the NorthConnex construction program will mean that these maximums are not reached every month. The trip patterns of project site staff, whose shift is slated to commence at 6 am, will not impact on the peak period of traffic on the surrounding road network. Similarly, following completion of construction site activities at 6 pm, workers will leave the site after the PM peak period and are not anticipated to impact on the operation of the surrounding road network. Staff traffic generation is estimated to be approximately 20 light vehicles.

The routes between the NorthConnex spoil locations and Hornsby Quarry are different for the inbound and outbound trips to/from the quarry during peak times. Peak times have been defined as 7 am to 10 am during the AM peak hour and 3 pm to 6 pm for the PM peak hour on weekdays.

The haulage routes to/from Hornsby Quarry are shown in **Table 3-3** and **Table 3-4** respectively and **Figure 3-1** and **Figure 3-2.** The haulage routes to/from Hornsby Quarry are indicative only and will be developed further during detailed design and will be presented in the Traffic Management Plan as part of the Construction Environmental Management Plan (discussed in **Section 7**). Any alterations to the proposed routes will ensure that the impact on existing traffic and transport conditions is minimised.

Table 3-3 Access routes to Hornsby Quarry from NorthConnex sites south of the M1 Pacific Motorway / Pennant Hills Road intersection

Into Hornsby Quarry	Out of Hornsby Quarry
Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.	Non-peak hours: Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road. **Peak hours**: out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

Table 3-4 Access routes to Hornsby Quarry from NorthConnex sites north of the M1 Pacific Motorway / Pennant Hills Road intersection

Into Hornsby Quarry (M1 Compound Scenario)	Out of Hornsby Quarry (M1 Compound Scenario)
From the Mt Colah M1 Pacific Motorway exit, a U-turn via Ku-ring-gai Chase Road interchange back onto the M1 Pacific Motorway to travel south, then take exit onto the A1 (Pacific Highway), turn right and travel along Pacific Highway as per the southern haulage route (Pacific Highway, George Street and into Bridge Road).	**Non-peak hours:** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road and back on the M1 Pacific Motorway. **Peak hours**: out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

Modelling undertaken to assess the impacts of construction traffic on the local road network has focused on the access routes identified in the M1 compound scenario. This scenario provides for the distribution of 23 haulage vehicles which emanate from the M1 compound and travel northbound on the M1. Vehicles are proposed to utilise the M1 / Ku-ring-gai Chase Road interchange to undertake a u-turn before travelling southbound and accessing the Pacific Highway via the M1/ Pacific Highway interchange. The remaining 12 haulage vehicles originate from sites located to the south of the Pennant Hills Road / Pacific Highway intersection and travel north to the intersection of Pennant Hills Road / Pacific Highway via Pennant Hills Road. To the north of this location, regardless of the access route scenario, the distribution of construction haulage vehicles and their routes to and from Hornsby Quarry during peak times are identical.

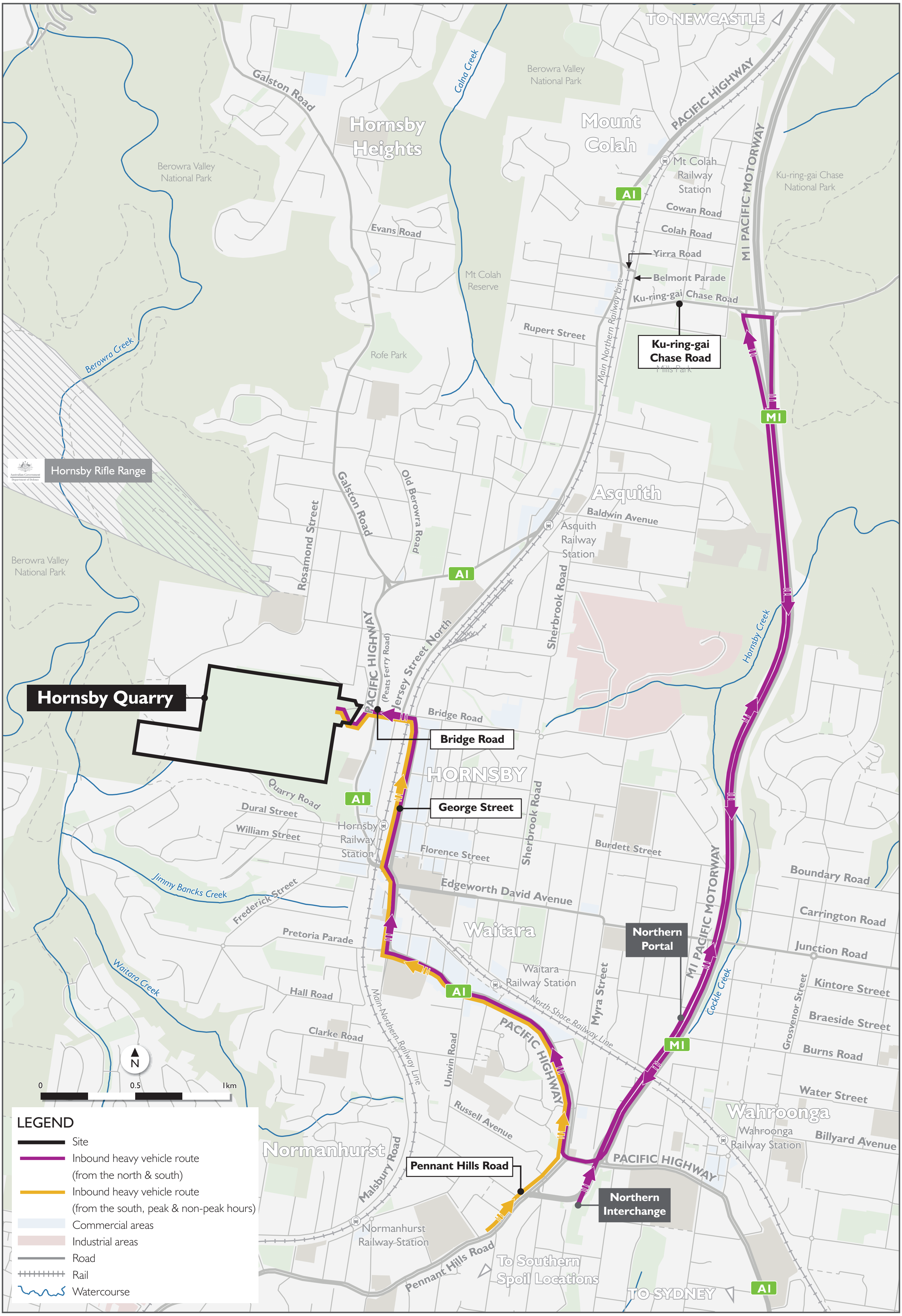

Figure 3-1 Inbound haulage routes

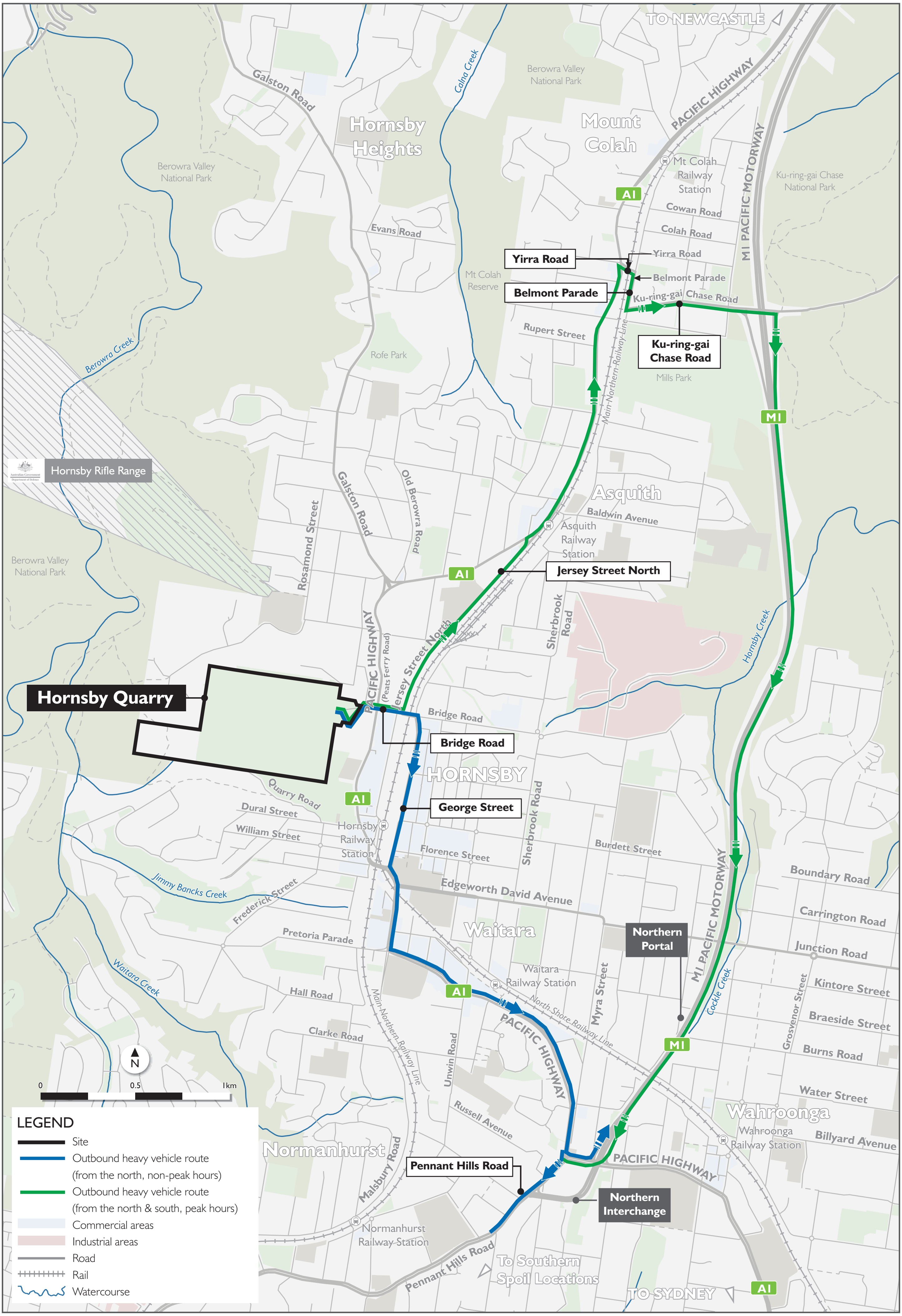

Figure 3-2 Outbound haulage routes

4 Existing Traffic and Transport Environment

4.1 Route description

Figure 4-1 provides an illustration of the study area under consideration for the project which stretches from the Pacific Highway between Pennant Hills Road and Ku-ring-gai Chase Road in the north to the M1 Pacific Motorway / Pacific Highway interchange in the south as well as encompassing the M1 Motorway.

4.1.1 Pacific Highway

The Pacific Highway north of the Pacific Highway / Pennant Hills Road intersection is a divided carriageway which has a speed limit of 60 kilometres per hour. Within the study area, the Pacific Highway provides access to the suburbs of Hornsby, Normanhurst, Waitara Mount Colah and Mount Ku-ring-gai. Parking is available in the kerbside lane through a number of sections. South of High Street, the Pacific Highway is three lanes in either direction. To the north of William Street until the intersection with Bridge Road, the Pacific Highway is primarily a single carriageway with a speed limit of 50 kilometres per hour. The stretch of the Pacific Highway between George Street and Bridge Road is also referred to as Peats Ferry Road.

4.1.2 M1 Pacific Motorway

Within the study area, the M1 Pacific Motorway extends between Pennant Hills Road and Ku-ring-gai Chase Road under dual carriageway conditions with separation between the northbound and southbound directions of travel. The speed limit ranges between 80 to 100 kilometres per hour and the cross section consists of three lanes in either direction (six lanes in total).

4.1.3 George Street

George Street facilitates a sub-arterial function within the Hornsby town centre. The route is designed to remove traffic from the Hornsby town centre located to the west of Hornsby Station. The southern section provides a narrow median with pedestrian fencing prohibiting pedestrians crossing the road. The posted speed limit is 60 kilometres per hour and parking is not permitted on either side of the road.

4.1.4 Jersey Street North

Jersey Street North serves a sub-arterial road linking Hornsby town centre with Mount Colah. The posted speed limit is 60 kilometres per hour.

4.1.5 Bridge Road

Bridge Road is mainly a local road; however, between Pacific Highway and George Street, the road performs a sub-arterial role in linking George Street and Jersey Street North. Bridge Road has two trafficable lanes in either direction between George Street and the Pacific Highway. West of the Pacific Highway, the lane arrangement transitions to one lane in either direction with an additional lane of parking. There are approximately 12 car parking spaces on the eastern side of Bridge Road, south of Roper Lane. The posted speed limit is 60 kilometres per hour where Bridge Road it is a sub-arterial, 50 kilometres per hour west of the Pacific Highway and drops to 30 kilometres per hour at the curve to access the quarry.

4.1.6 Ku-ring-gai Chase Road

Ku-ring-gai Chase Road is a sub-arterial road primarily consisting of a single carriageway with one lane in either direction. Ku-ring-gai Chase Road has access to the M1 Motorway through southern access ramps. The speed limit on Ku-ring-gai Chase Road is 60 kilometres per hour.

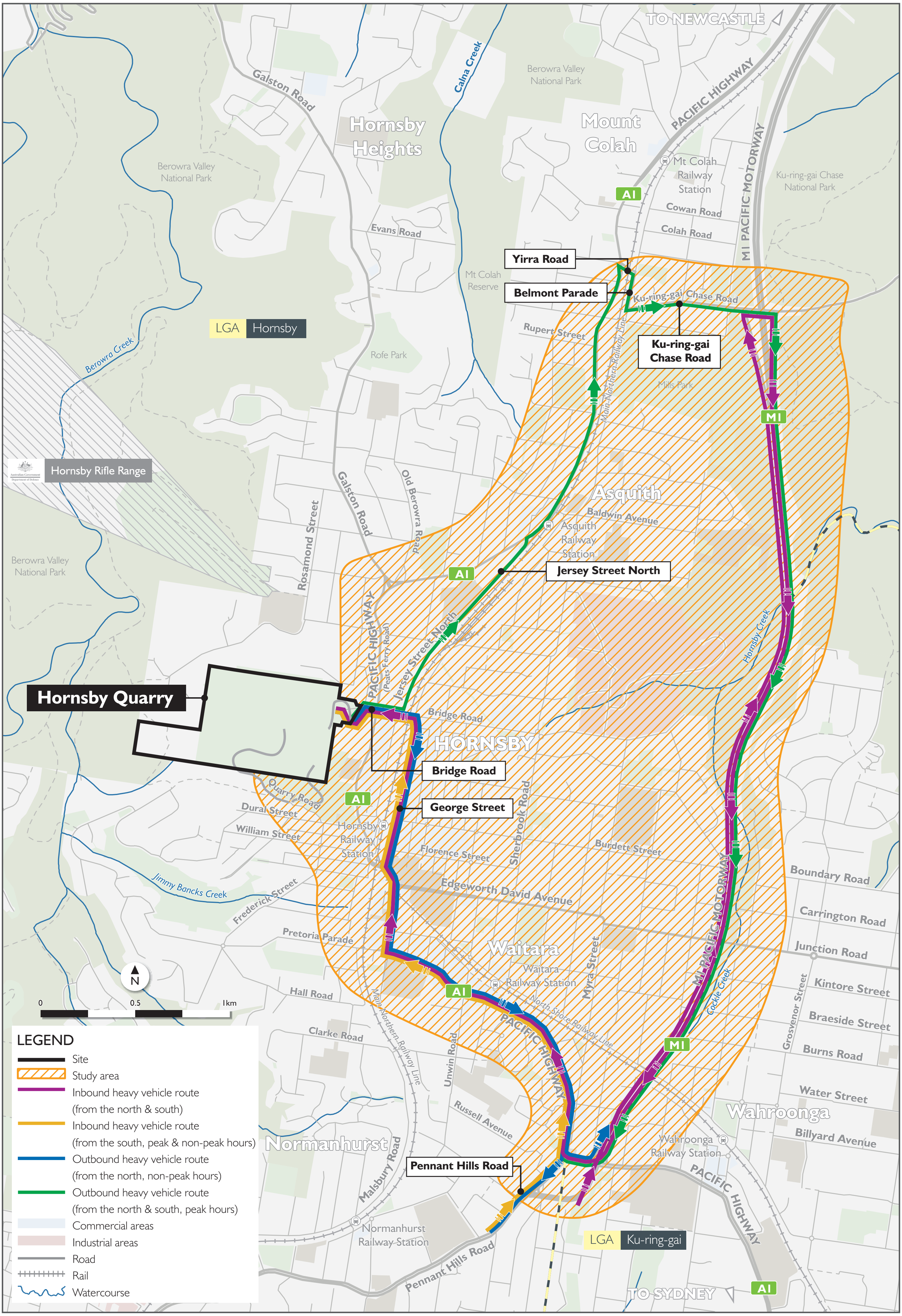

Figure 4-1 Study area

4.1.7 Modes of travel

Private vehicles are the predominant mode of transport in the study area, which is reflected by a higher than average vehicle ownership per household in the Hornsby local government area (LGA) of 1.7, compared to an average of 1.6 in the Sydney greater metropolitan area (GMA). The mode split for Hornsby compared to the Sydney GMA is shown in **Table 4-1**.

Table 4-1 Average weekday travel mode share for Hornsby LGA and Sydney GMA (2011/12)

Local Government Area	Private vehicle			Rail	Bus	Walk only	Other modes
	Driver	Passenger	Total				
Hornsby	50%	21%	71%	9%	4%	14%	2%
Sydney Greater Metropolitan Area	47%	21%	68%	5%	6%	18%	3%

(Source: NSW BTS, Household Travel Survey 2011/12 Summary Report, 2013 Release)

4.1.8 Public transport services

Public transport services are a key method of transport for journeys to work in the area, particularly to the Sydney central business district (CBD). **Figure 4-2** shows the public transport services in the study area.

Rail services

Hornsby Station is located to the east of the Pacific Highway opposite Dural Lane. There are two other stations either side of Hornsby Station which are in the study area, namely Waitara and Asquith. The North Shore, Northern and Central Coast and Newcastle lines stop at Hornsby Station. Peak train services operating on the Northern and North Shore lines are shown in **Table 4-2** with the location of the stations displayed in **Figure 4-2**.

Table 4-2 Sydney Trains services

Line	Major destinations	AM peak services 7 am-9 am	Frequency	PM peak services 4 pm-6 pm	Frequency
Northern and North Shore	Epping, Chatswood, Sydney CBD	30	4 mins	28	4.5 mins

(Source: Sydney Trains, March 2014)

Sydney Trains publishes annual NSW station entry and exit statistics of which the latest data (2013) was released in March 2015. Station entry and exit barrier counts for the five stations in the study area are summarised in **Table 4-3**. Entry and exit statistics are for 6 am to 6.30 pm and over the corresponding 24 hour period. Hornsby encounters a high passenger volume due to its status as a key retail and residential hub on the Sydney Trains network. Waitara and Asquith handle a smaller volume of passengers compared to Hornsby. Waitara has tidal passenger flows in the AM and PM peak periods when compared to the remainder of the daily profile. Asquith has even flows in the AM peak but reverts to a tidal profile between the inter peak and PM Peak.

Table 4-3 Station entry and exit barrier counts (2013)

Station	AM peak 6 am-9.30 am		Inter peak 9.30 am-3 pm		PM peak 3 pm-6.30 pm		24 hours	
	In	Out	In	Out	In	Out	In	Out
Hornsby	5,230	2,200	2,350	2,320	3,120	4,680	11,560	11,560
Waitara	1,680	830	430	360	810	1,240	3,000	3,000
Asquith	810	690	550	30	40	460	1,460	1,460

(Source: NSW BTS, Electronic Publication No. E2014-09 Rail Barrier Counts Summary)

Bus services

There are a number of bus services operating in the study area, as shown in **Figure 4-2**. HillsBus operate a bus service which stops at the train station and travels south. Transdev operates nine bus routes that stop at Hornsby Station. The number and frequency of bus services operating vary, ranging from every 10 minutes to once an hour. All the bus routes that stop at Hornsby Station are shown in **Table 4-4**.

Table 4-4 Hornsby bus services

Route	AM peak services (7:00 9:00)	Frequency	PM peak services (16:00 18:00)	Frequency
M60 Hornsby to Parramatta	6	10 mins	12	10 mins
575 Macquarie University to Hornsby	5	24 mins	5	24 mins
588 Hornsby to Normanhurst West	2	60 mins	5	24 mins
596 Hornsby to Hornsby Heights	7	17 mins	7	17 mins
598 Hornsby to Asquith	4	30 mins	4	30 mins
587 Hornsby to Westleigh	2	60 mins	4	30 mins
589 Hornsby to Sydney Adventist Hospital	2	60 mins	2	60 mins
595 Hornsby to Mt Colah	3	40 mins	4	30 mins
597 Hornsby to Berowra	2	60 mins	2	60 mins
594H City Express	2	60 mins	3	40 mins

(Source: HillsBus and Transdev, 2015)

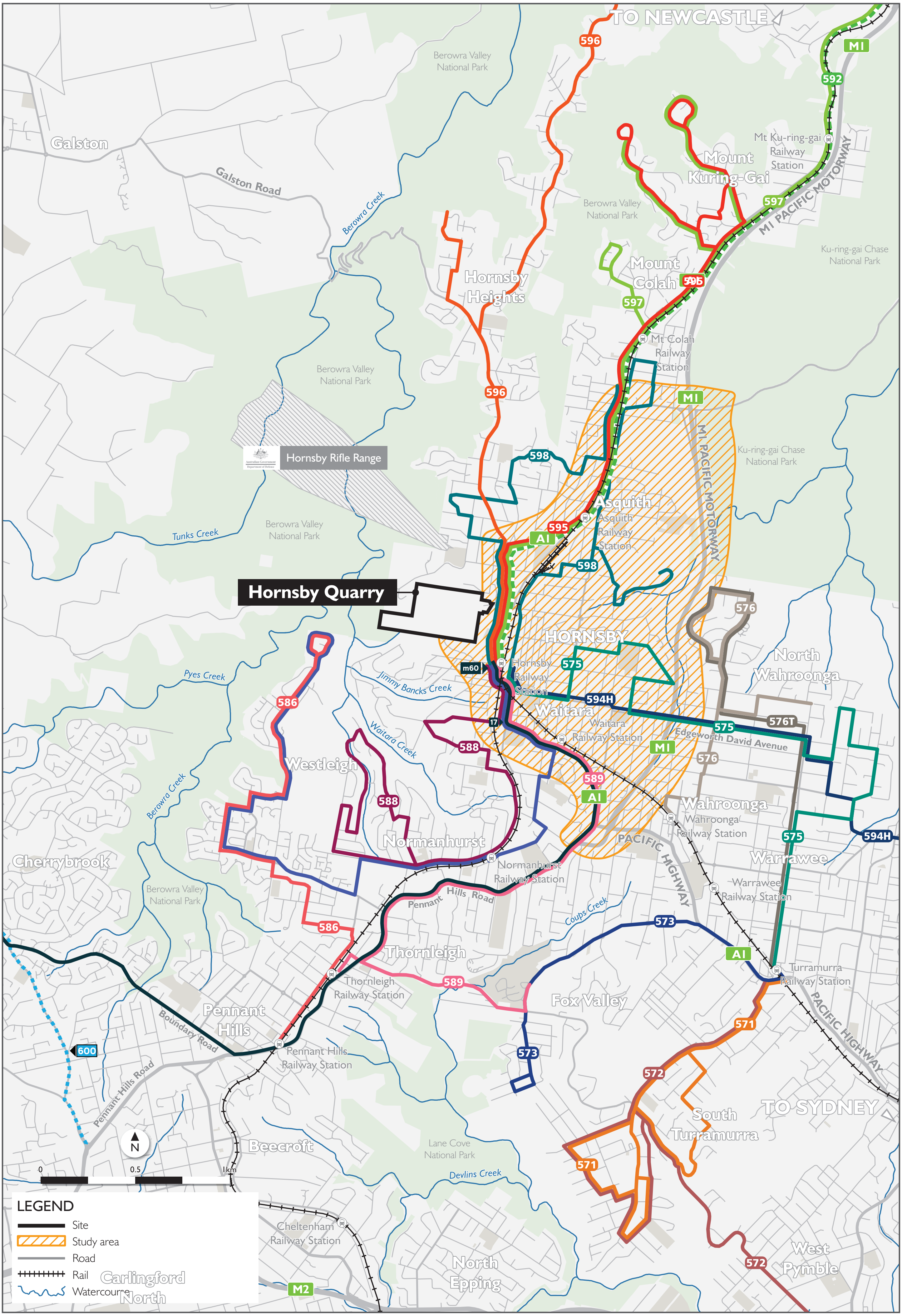

Figure 4-2 Public transport services

4.1.9 Walking and cycling

Walk only trips in the area represent 14 per cent of average weekday travel mode share in Hornsby. Cycle trips are not represented in the mode share data, although account for a proportion of the 'other' category which represents two per cent in the Hornsby LGA.

Pedestrian footpaths are provided along the sides of the roads, with regular crossings via signalised intersections as well as two pedestrian overpasses at Hornsby train station. There are no separated cyclist facilities within the Hornsby area and although roads within the study area are generally not an inviting cycle route, Hornsby Shire Councils promote sustainable travel and cycling as a means of travelling short distances. The Pacific Highway provides on-road cycle facilities, in the form of a widened road shoulder, between Galston Road and Ku-Ring-gai Chase Road.

The Hornsby Mountain Bike Trail is also located within the study area. It provides six kilometres of off-road trails which are accessed from Quarry Road.

4.2 Existing traffic volumes and patterns

4.2.1 Intersection traffic volumes

Intersection counts for a portion of the study area were obtained during the NorthConnex EIS assessment undertaken in 2013 which initially involved the potential for using Hornsby Quarry for spoil emplacement. This element of the project was later discontinued from the NorthConnex assessment but remained an option for further assessment. Following Hornsby Quarry's re-instatement as a potential spoil emplacement location, additional traffic counts were collected in November 2014 and February 2015 to account for intersections requiring assessment due to identified haulage routes. These are as follows:

- 2013
  - M1 Pacific Motorway / Pacific Highway Interchange.
  - Pennant Hills Road / Pacific Highway.
  - Pacific Highway / Edgeworth David Avenue.
  - Pacific Highway / Bridge Road.
  - Bridge Road / Jersey Street North.
  - Pacific Highway / George Street.
- 2014
  - Pacific Highway / College Crescent.
- 2015
  - Pacific Highway / Jersey Street North / Wattle Street.
  - Pacific Highway / Yirra Road.
  - Pacific Highway / Ku-ring-gai Chase Road.

Light and heavy volumes associated with the abovementioned intersection counts are presented in **Table 4-5**. The Pacific Motorway is subject to high traffic volumes, as well as a high proportion of heavy vehicles.

Table 4-5 Hourly intersection count summary (2013, 2014 & 2015) for peak periods

Intersection/Peak	Light Vehicles	Heavy Vehicles	Total	HV % (Peak Hour)
M1 Pacific Motorway / Pacific Highway Interchange				
AM Peak	4,450	240	4,690	5%
PM Peak	4,970	120	5,090	2%
Pennant Hills Road / Pacific Highway				
AM Peak	2,950	200	3,150	6%
PM Peak	3,330	110	3,440	3%
Pacific Highway / College Crescent / Pretoria Parade				
AM Peak	2,617	161	2,778	6%
PM Peak	2,786	153	2,939	5%
Pacific Highway / Edgeworth David Avenue				
AM Peak	2,966	183	3,149	6%
PM Peak	3,407	90	3,497	3%
Pacific Highway / George Street				
AM Peak	2,958	187	3,145	6%
PM Peak	3,405	90	3,495	3%
Pacific Highway / Bridge Road				
AM Peak	1,906	62	1,968	3%
PM Peak	2,104	48	2,152	2%
Bridge Road / Jersey Street North				
AM Peak	2,004	48	2,052	2%
PM Peak	2,107	34	2,141	2%
Pacific Highway / Jersey Street North / Wattle Street				
AM Peak	1,658	64	1,722	4%
PM Peak	2,023	58	2,081	3%
Pacific Highway / Yirra Road				
AM Peak	2,215	66	2,281	3%
PM Peak	2,595	52	2,647	2%
Pacific Highway / Ku-ring-gai Chase Road				
AM Peak	497	24	521	5%
PM Peak	639	12	651	2%

(Source: Austraffic, 2013; Skyhigh 2014, Skyhigh 2015)

4.3 Road network performance

4.3.1 Traffic crashes

In the study area, both the M1 Pacific Motorway and the Pacific Highway have a crash history, with respect to crash severity index statistics, which is broadly consistent with NSW averages. On both routes, no fatal crashes have occurred within the past six years, while injury crashes have occurred on a slightly higher than average frequency when compared to the NSW average. However, even minor crashes have an impact on congestion due to the high traffic flows and strategic importance of the M1 Pacific Motorway.

Table 4-6 summarises the crash history for this period, including the section where crashes occurred. A map highlighting crash locations within the study area can be found in **Figure 4-5**. In summary, between 1 July 2010 and 30 June 2015:

- On the M1 Pacific Motorway between Ku-Ring-Gai Chase Road and the Pacific Highway interchange:
  - A total of 104 crashes occurred, with no fatal crashes and 40 injury crashes.
  - Around 30 per cent of total crashes involved rear-end collisions.
  - Heavy vehicles accounted for around 17 per cent of all vehicles involved in crashes.
- On the Pacific Highway between Yirra Road and Pennant Hills Road:
  - A total of 149 crashes occurred, with no fatal crashes and 59 injury crashes.
  - Over 15 per cent of total crashes occurred as a result of one or more vehicles making a right turn across through traffic.
  - Around 22 per cent of total crashes involved rear-end collisions.
  - Heavy vehicles accounted for 11 per cent of all vehicles involved in crashes.
  - On Ku-Ring-Gai Chase Road between Yirra Road and the Pacific Motorway interchange:
  - A total of 13 crashes occurred, with no fatal crashes and 7 injury crashes.
  - Around 31 per cent of total crashes involved rear-end collisions.
  - Heavy vehicles accounted for around 11 per cent of all vehicles involved in crashes.
- Along Jersey Street North, Bridge Road and George Street, between the Wattle Street and the Pacific Highway interchange:
  - A total of 71 crashes occurred, with no fatal crashes and 34 injury crashes.
  - Over 18 per cent of total crashes occurred as a result of one or more vehicles making a right turn across through traffic.
  - Around 32 per cent of total crashes involved rear-end collisions.
  - Heavy vehicles accounted for around 17 per cent of all vehicles involved in crashes.

Table 4-6 Crash history (1 July 2010 to 30 June 2014)

Section from	Section to	Section length (km)	Crashes Total	Fatal	Injury	Tow away
M1 Pacific Motorway						
Total – Ku-Ring-Gai Chase Road to Pacific Highway		**4.6**	**104**	**0**	**40**	**64**
Pacific Highway						
Yirra Road	Bridge Road	3.0	38	0	14	24
George Street	Pacific Highway	2.1	98	0	38	60
Pacific Highway	Bundarra Avenue South	0.3	12	0	3	9
Pacific Highway	Pennant Hills Road	0.4	32	0	11	21
Total – Pennant Hills Road to Yirra Road		**6.2**	**180**	**0**	**66**	**114**
Ku-Ring-Gai Chase Road						
Total – Yirra Road to M1 Pacific Motorway		**1.2**	**13**	**0**	**7**	**6**
Jersey Street North – Bridge Road – George Street						
Pacific Highway	Bridge Road	1.2	14	0	5	9
Bridge Road	Wattle Street	0.9	57	0	29	28
Total – Pacific Highway to Wattle Street		**2.1**	**71**	**0**	**34**	**37**

(Source: AECOM, 2014 based on Roads and Maritime Crash Data, 2015)

Crash severity indices provide an assessment of road safety based on the type and number of crashes occurring on a route. Fatal, injury and tow-away crashes carry different weightings; they are determined independently of absolute traffic volumes, and calculated to establish the average level of severity of crashes that occur. **Table 4-7** shows crash severity indices and **Figure 4-3** illustrates the formula used to calculate these indices.

Crash Severity Index =

*[(No. of fatal crashes * 3.0) + (No. of injury crashes * 1.5) + (No. of non-injury crashes)] / Total no. of crashes*

Figure 4-3 Crash severity index calculation

(Source: Roads and Maritime Crash Data, 2013)

The average crash severity index on the M1 Pacific Motorway is 1.27, compared to an average of 1.22 for all crashes reported on public roads in the Sydney Metropolitan Area. This index indicates the M1 Pacific Motorway corridor has a lower than average proportion of fatal and injury crashes.

The slightly higher than average index could be due to the speed environment of the M1 Pacific Motorway. There is also a high proportion of traffic crashes in the corridor involving rear-end collisions suggesting traffic congestion is a significant contributing factor.

The average crash severity index of 1.18 for the Pacific Highway is lower than the Sydney Metropolitan Area average. However, on Ku-Ring-Gai Chase Road and the Jersey Street North – Bridge Road – George Street section, the average crash severity index is 1.27 and 1.24 respectively. Both sections are slightly higher than the Sydney Metropolitan Area average crash severity index.

Table 4-7 Crash severity indices (1 July 2010 to 30 June 2015)

Section from	Section to	Crash severity index
M1 Pacific Motorway		
Total – Ku-Ring-Gai Chase Road to Pacific Highway		**1.27**
Pacific Highway		
Yirra Road	Bridge Road	1.18
George Street	Pacific Highway	1.19
Pacific Highway	Bundarra Avenue South	1.13
Pacific Highway	Pennant Hills Road	1.17
Total – Pennant Hills Road to Yirra Road		**1.18**
Ku-Ring-Gai Chase Road		
Total – Yirra Road to M1 Pacific Motorway		**1.27**
Jersey Street North – Bridge Road – George Street		
Pacific Highway	Bridge Road	1.18
Bridge Road	Wattle Street	1.25
Total – Pacific Highway to Wattle Street		**1.24**
New South Wales | Sydney Metropolitan Area Averages – All roads		
New South Wales (1 Jan 2008 to 31 Dec 2012)		**1.24**
Sydney Metropolitan Area (1 Jan 2012 to 31 Dec 2012)		**1.22**

(Source: AECOM, based on Roads and Maritime Crash Data & TfNSW Centre for Road Safety Data)

Crash rates per 100 million vehicle kilometres travelled (100MVKT) are shown in **Table 4-8**. These crash rates are calculated using the volume of traffic and distance travelled along a route, therefore offering a measure of risk per kilometre travelled. The formula used to calculate this rate is shown in **Figure 4-4**.

Crash rate per 100 MVKT =

*(Total no. of crashes * 100,000,000) / (No. of years * 365 * Length (km) * AADT)*

Figure 4-4 Crash rate per 100 million vehicle kilometres calculation

(Source: Roads and Maritime Crash Data. 2013)

The latest available Roads and Maritime data (for the 12 month period ending December 2013) show average fatality and injury rates across the Sydney Metropolitan Area of 0.2 and 29.4 per 100MVKT respectively.

Table 4-8 shows the average fatality and injury rates on the M1 Pacific Motorway corridor are 0.0 and 6.6 per 100MVKT respectively. These statistics indicate that the occurrence of fatal crashes on the M1 Pacific Motorway is lower per kilometre travelled than the Sydney Metropolitan Area average, and crashes without injury also occur at a lower than average rate.

Similarly, on the Pacific Highway between Yirra Road and Pennant Hills Road, average fatality and injury rates are 0.0 and 24.1 per 100MVKT respectively. These statistics indicate that the occurrence of fatal and injury crashes is lower per kilometre travelled than the Sydney Metropolitan Area average.

Conversely, on the Ku-Ring-Gai Chase Road between Yirra Road and the M1 Pacific Motorway, the average fatality and injury rates are 0.0 and 39.6 respectively. Though the occurrence of fatal crashes is lower than the Sydney Metropolitan Area average, the injury rate indicates that the occurrence of crashes resulting in an injury is higher.

Along the Jersey Street North – Bridge Road – George Street section, the average fatality and injury rates are 0.0 and 51.8 respectively. Similar to Ku-Ring-Gai Chase Road, the occurrence of fatal crashes is lower than the Sydney Metropolitan Area average, with injury rates per 100 million vehicle kilometres higher than both the Sydney and NSW average.

Table 4-8 Crash rates per 100MVKT (2014)

Section from	Section to	Section length (km)	2014 ADT (veh)	Crash rate per 100MVKT			
				Total	Fatal	Injury	Tow away
M1 Pacific Motorway							
Total – Ku-Ring-Gai Chase Road to Pacific Highway		**4.6**	**72,400**	**17.1**	**0.0**	**6.6**	**10.5**
Pacific Highway							
Yirra Road	Bridge Road	3.0	22,770	30.8	0.0	11.3	19.4
George Street	Pennant Hills Road	2.1	24,565	104.1	0.0	40.4	63.7
Pacific Highway	Bundarra Avenue South	0.3	65,643	33.4	0.0	8.3	25.0
Pacific Highway	Pennant Hills Road	0.4	27,805	157.7	0.0	54.2	103.5
Total – Pennant Hills Road to Yirra Road		**5.8**	**-**	**65.7**	**0.0**	**24.1**	**41.6**
Section from	**Section to**	**Section length (km)**	**2014 ADT (veh)**	**Crash rate per 100MVKT**			
				Total	**Fatal**	**Injury**	**Tow away**

Section from	Section to	Section length (km)	2014 ADT (veh)	Crash rate per 100MVKT			
				Total	Fatal	Injury	Tow away
Ku-Ring-Gai Chase Road							
Total – Yirra Road to M1 Pacific Motorway		**1.2**	**7,835**	**73.5**	**0.0**	**39.6**	**33.9**
Jersey Street North – Bridge Road – George Street							
Pacific Highway	Bridge Road	1.2	11,701	56.7	0.0	20.2	36.4
Bridge Road	Wattle Street	0.9	24,948	139.1	0.0	70.8	68.3
Total – Pacific Highway to Wattle Street		**2.1**	**-**	**108.1**	**0.0**	**51.8**	**56.3**
Section from	**Section to**	**Section length (km)**	**2014 ADT (veh)**	**Crash rate per 100MVKT**			
New South Wales | Sydney Metropolitan Area Averages – All roads							
New South Wales (1 Jan 2013 to 31 Dec 2013)		-	-	-	**0.5**	**28.0**	-
Sydney Metropolitan Area (1 Jan 2012 to 31 Dec 2012)		-	-	**68.8**	**0.2**	**29.4**	**39.2**

(Source: AECOM, based on Roads and Maritime Crash Data; 2015; TfNSW Centre for Road Safety Data, and Australian Bureau of Statistics Survey of Motor Vehicle Use (SMVU) data)

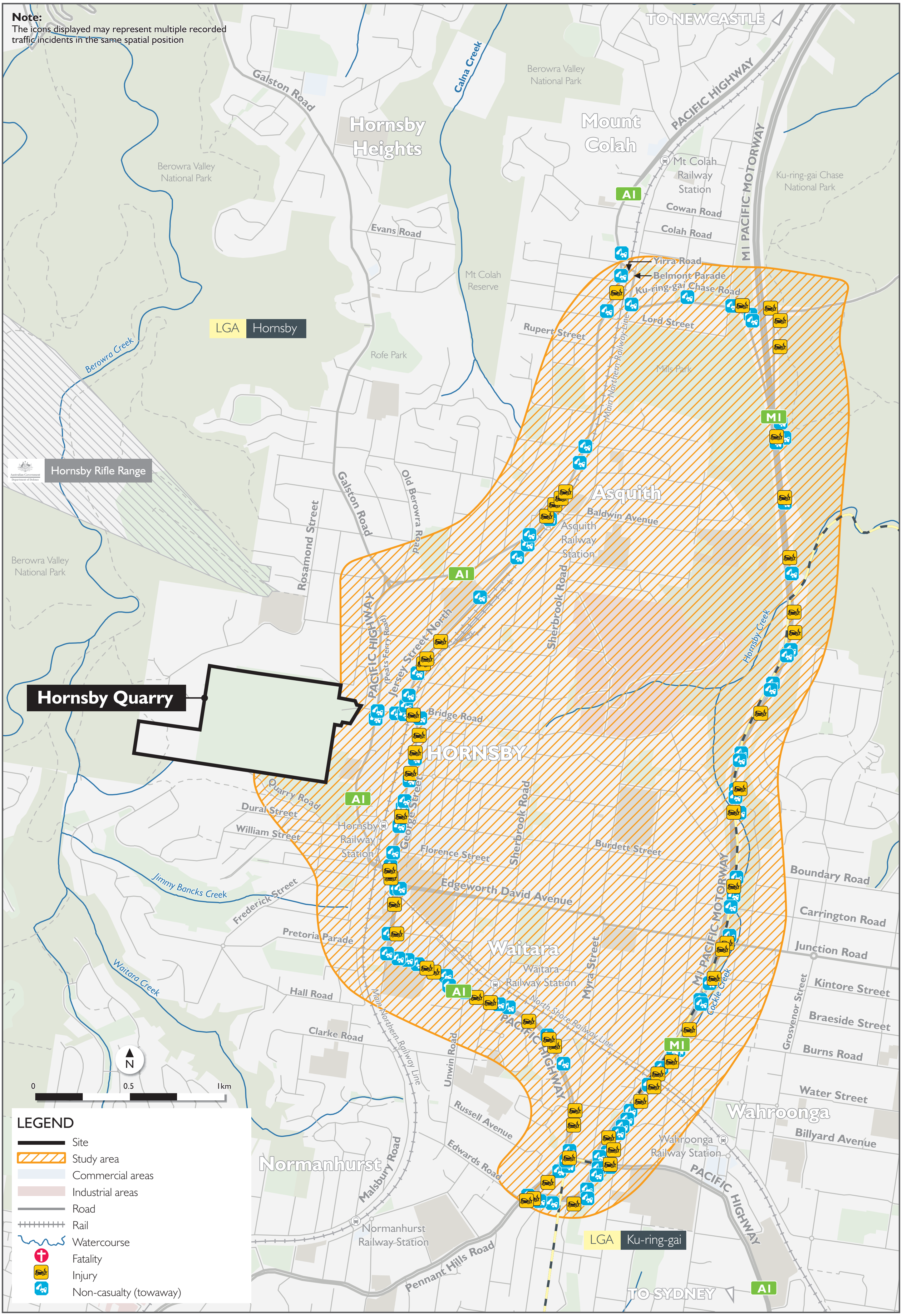

Figure 4-5 Crash location statistics

4.3.2 Operational assessment

Level of service (LoS) is the primary measure to determine the operational conditions and efficiency of a roadway or intersection. The definition of LoS generally outlines the operating conditions in terms of speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and road safety.

Definition of intersection level of service

Average delay is commonly used to assess the operational performance of intersections, with level of service used as an index. A summary of the level of service index is shown in **Table 4-9**.

Table 4-9 Level of service criteria for intersections

Level of service	Average delay / vehicle (secs/veh)	Traffic signals / roundabouts	Give way and Stop signs
A	<14	Good operation	Good operation
B	15 to 28	Good with acceptable delays and spare capacity	Acceptable delays and spare capacity
C	29 to 42	Satisfactory	Satisfactory, but accident study required
D	43 to 56	Operating near capacity	Near capacity and accident study required
E	57 to 70	At capacity; at signals incidents will cause excessive delays	At capacity; requires other control mode
F	>70	Roundabouts require other control mode	At capacity; requires other control mode

(Source: Guide to Traffic Generating Developments, RTA, 2002)

Degree of saturation (DoS) is a measure of assessing the capacity of an intersection using a ratio of intersection traffic volume to intersection traffic capacity between zero and one, with one representing the capacity of the intersection. Intersections are said to reach their practical capacity at a degree of saturation of 0.9. Beyond the practical capacity, any additional traffic would have an increasing impact on delays and the subsequent performance of the intersection.

When an intersection's level of service falls below level of service D, investigations are generally initiated to provide suitable remediation, however constraints in built-up urban areas mean that level of service E and F are regularly experienced by motorists at pinch points on the existing strategic road network in Sydney. These conditions are generally experienced during traffic peak periods. Roads and Maritime have a program of works aimed at relieving congestion at pinch points and improving performance on strategic roads.

Intersection level of service

Table 4-10 provides a summary of the intersection performance level of service at key locations within the study area under existing AM and PM peak hour traffic volumes. The analysis provides the average intersection delays and the level of service for the intersection, calculated using LinSig.

Table 4-10 Modelled intersection performance - existing (AM and PM Peak Hour)

Intersection/Peak	Light Vehicles	Heavy Vehicles	Average Delay	Level of Service
M1 Pacific Motorway / Pacific Highway interchange				
AM Peak	4,450	240	42.3	C
PM Peak	4,970	120	55.3	D
Pennant Hills Road / Pacific Highway				
AM Peak	2,950	200	58.1	E
PM Peak	3,330	110	50.1	D
Pacific Highway / College Crescent / Pretoria Parade				
AM Peak	2,617	161	52.9	D
PM Peak	2,786	153	49.6	D
Pacific Highway / Edgeworth David Avenue				
AM Peak	2,966	183	27.6	B
PM Peak	3,407	90	29.7	C
Pacific Highway / George Street				
AM Peak	2,691	165	37.4	C
PM Peak	3,186	82	49.1	D
Pacific Highway / Bridge Road				
AM Peak	1,906	62	26.4	B
PM Peak	2,104	48	32.3	C
Bridge Road / Jersey Street North				
AM Peak	2,004	48	33.7	C
PM Peak	2,107	34	28.7	C
Pacific Highway / Jersey Street North / Wattle Street				
AM Peak	1,658	64	14.8	B
PM Peak	2,023	58	30.1	C
Pacific Highway / Yirra Road				
AM Peak	2,215	66	31.6	C
PM Peak	2,595	52	44.8	D
Pacific Highway / Ku-ring-gai Chase Road				
AM Peak	497	24	3.2	A
PM Peak	639	12	4.8	A

The intersection performance results demonstrate that the majority of the intersections assessed within the study area operate within the recommended guidelines for intersection operation (LoS D or better). The traffic signals are coordinated to provide priority along each corresponding corridor to reduce the average delays to the major through movements in the peak direction.

However to the south of the study area the intersection performance is approaching capacity with movements recording a poor level of service. The delays illustrate capacity constraints within the network under the current geometry and traffic signal phase splits (derived from IDM).

The poor LoS values indicate that this area of the corridor is susceptible to decreases in performance with any increase in demand without improvements to intersection layouts, or where possible, further optimisation of the signal timings. The intersections susceptible to decreases in performance with a relatively small growth in background demand include:

- M1 Pacific Motorway / Pacific Highway interchange; and
- Pennant Hills Road / Pacific Highway.

5 Traffic Modelling and Forecasting Process

5.1 Introduction to traffic modelling

This chapter provides details of the integrated traffic modelling and forecasting approach that was adopted for the traffic and transport assessment. This approach, as depicted in **Figure 5-1**, involved:

- Use of existing traffic counts (2013/2014/2015) to characterise existing traffic conditions and road network performance.
- Application of a strategic Sydney transport model (Cube traffic modelling package) to determine anticipated future growth in traffic road network and the effects of tolling on road traffic demand.
- Use of strategic (Cube) and corridor (LinSig) traffic models to determine existing and future traffic conditions within the study area. The outputs from these models have been used to assess the operational performance of the intersections within the study area during the operation of construction.

The objective was to make the best use of existing traffic counts (2013/2014/2015), strategic (Cube) and corridor (LinSig) models to determine the existing conditions within the study area and key surrounding roads and assess the performance of the network / corridor during construction (2016), both with and without the project.

The strategic modelling and traffic forecasting was undertaken by Transurban, who then provided the results for the corridor operational traffic modelling, which was undertaken by AECOM.

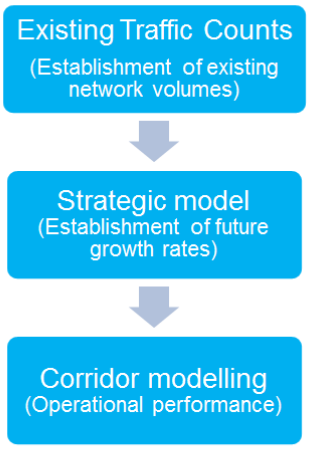

Figure 5-1 Overview of traffic modelling approach

5.2 Strategic model and traffic forecasting methodology

The strategic transport model was developed, progressively updated and enhanced, building from research, models and data files. As such, it provides the foundation for traffic predictions, and remains a comprehensive tool for estimating the impact of significant network changes in terms of both traffic and revenue implications on Sydney toll roads. The traffic model utilises the Cube Voyager software platform.

The forecasting approach comprises:

- A strategic highway network model of the Sydney metropolitan area including all major roads within the network.
- Anticipated of future land use as a basis for estimating future demand for travel for cars and trucks.
- Anticipated changes and updates to the road network up until 2016.
- Representation of future vehicle travel demand to model varying travel patterns and behaviours.
- Explicit modelling of all existing tolls on the wider network with accommodation of different motorist behaviours including willingness to pay a toll to save travel time.

The strategic transport model was used to provide forecasting results for 2016.

5.3 Corridor operational traffic modelling methodology

The modelling methodology used to forecast future traffic volumes for the project, incorporated the following two key stages and sub-tasks:

1) Derivation of base year traffic patterns.
2) Base and future year model development.

5.3.1 Derivation of base year traffic patterns

The primary stage in the traffic modelling process is to construct an accurate representation of base year traffic patterns on the network. In order to ensure an accurate representation of existing conditions, network traffic counts were gathered across the corridor at the following locations:

- M1 Pacific Motorway / Pacific Highway Interchange.
- Pennant Hills Road / Pacific Highway.
- Pacific Highway / Edgeworth David Avenue.
- Pacific Highway / Bridge Road.
- Bridge Road / Jersey Street North.
- Pacific Highway / George Street.
- Pacific Highway / College Crescent.
- Pacific Highway / Jersey Street North / Wattle Street.
- Pacific Highway / Yirra Road.
- Pacific Highway / Ku-ring-gai Chase Road.

The above intersection counts informed the base year models to be used in the construction assessment.

5.3.2 Base and future year model development

Selection of appropriate modelling tool and calibration/validation

To accurately model the road network and assess the existing and construction scenarios, the LinSig corridor modelling software was chosen. LinSig is a macro-simulation model capable of assessing the performance of isolated or co-ordinated networks of traffic intersections. It is Road and Maritime's preferred software package in this line of work.

One of the strengths of LinSig is that it allows for the optimisation of traffic signal timings across the network in accordance with the release of traffic across the network, therefore providing for the greatest network benefits to be captured.

To ensure the accurate representation of existing traffic conditions, the base models were calibrated and validated to align with existing operating conditions on the corridor. The following data sources were used in the calibration and validation process:

- Intersection turning counts.
- Intersection diagnostic monitor data (IDM).
- Signalised intersection intergreen timings.
- Saturation flows.
- Site visits to ensure dead green time, pedestrian delays, intergreen running were captured as well as posted speed limits, intersections configurations, lane usage, location of parking (if applicable), bus stop locations, bottlenecks and pinch points on the study corridor.

Traffic demand – base year model

Corridor assignment in LinSig uses origin-destination (OD) assignment via OD demand matrices formulated within the software. These are based on the creation of a balanced network diagram referenced to surveyed traffic conditions. Vehicles enter and exit the road network via a series of zones which represent key locations or strategic roads within the study area. Light vehicles and heavy vehicles are inserted into the model in a format known as passenger car units (PCU) as identified in the Traffic Modelling Guidelines (Roads and Maritime Services; 2013). These are based on the acknowledgement of the amount of road space differing types of vehicles utilise. The PCU factors applied in the base and construction models for light and heavy vehicles are based on these values. Although a car is nominated as 5.5 metres for one PCU, the actual value of one PCU is equivalent to 6.25 metres to take into consideration the impact of the space left between queuing vehicles. Buses represent two PCU with construction vehicles estimated as a worst case 2.9 PCU.

The models developed during this study represent AM and PM peak hour periods; OD matrices have been developed to reflect one hour demand volumes.

Base year model development

It is standard modelling practice to create a base model to replicate existing traffic conditions before developing any future scenarios. Base models were created for the locations shown in **Figure 5-2**. These models were constructed and calibrated, using the tools discussed in **Section 5.3.2** to ensure that accurate modelling of construction could be undertaken within the study area.

Future year model development

Models representing the construction analysis years of 2016 were developed to assess the future performance of the Pennant Hills Road corridor.

The 2016 models catered for the assessment of the 'with construction and 'without construction' scenarios. The results of the future year corridor modelling are included in **Section 6**.

Future year flow development

The future network volumes have been determined through reference to the strategic model and the surveyed traffic counts in a method known as 'differential growth'. Using the differential growth approach, future traffic growth is determined from the strategic model for each intersection movement over the desired time period. For example, the 2013 AM peak hour to 2016 AM peak hour. This growth in absolute volume is then added to the surveyed existing traffic volume (2013 in this example) to provide the future flow for that time period. This methodology provides the most accurate representation of how the modelled future traffic growth would affect existing network demands and the resultant network operation.

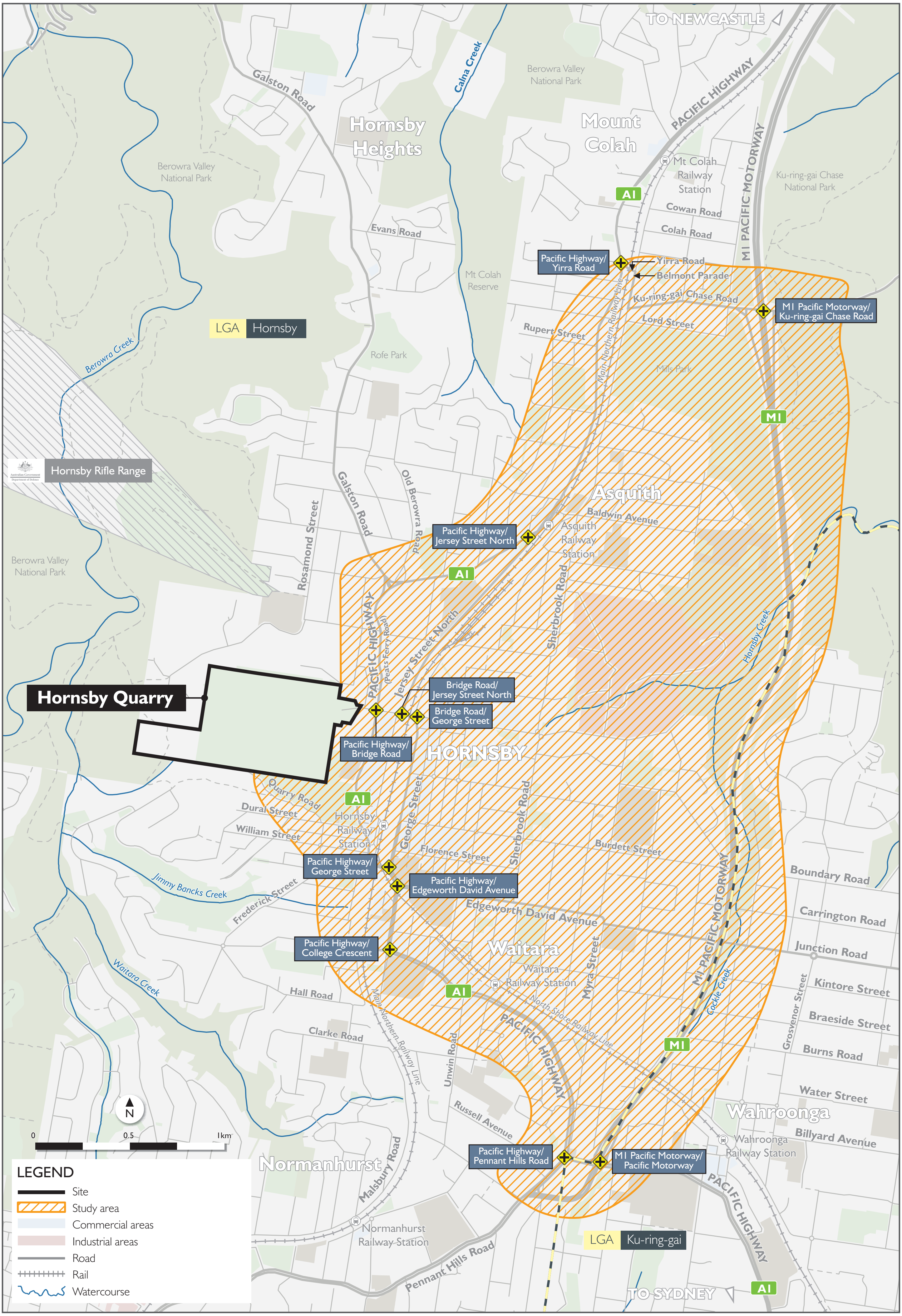

Figure 5-2 Modelled intersection locations

6 Impact Assessment

The key impacts associated with the project, with respect to traffic and transport, are as follows:

- Spoil haulage from the NorthConnex project by truck and stockpiling of spoil within the quarry site over a period of approximately 28 months.
- Spoil emplacement activities, following the completion of the conveyer construction works. These activities are expected to occur concurrently with spoil haulage and stockpiling activities but would also continue for a period after the completion of spoil haulage onto site. Spoil emplacement activities would involve:
  - Stockpiling of spoil.
  - Placement of spoil from the stockpiles into the conveyer.
  - Transport of the spoil via conveyer to the quarry void rim from where the spoil would fall directly into the void.
  - Movement and spreading of spoil along the quarry floor and compaction of the spoil.
- Site demobilisation and rehabilitation at the completion of emplacement activities. The construction compound and conveyer (apart from foundations) would be dismantled and removed from the site. Disturbed areas (e.g. compound area, stockpile areas and the conveyer corridor) would be returned to existing conditions as far as possible. Security fencing would be removed and if the quarry void is deemed to remain an ongoing risk to public safety, security fencing would be reinstated around the void. Public access to the areas outside the void exclusion zone, including the mountain bike trails, would then be reinstated.

An indicative project program is provided in **Table 3-1**.

6.1 Site hours, traffic and haulage routes

Information pertaining to site hours, traffic and haulage routes can be found in **Section 3**.

6.2 Operational Performance (Quantitative Assessment)

6.2.1 Background traffic volumes and patterns

The year 2016 has been used as the assessment year for impacts, which is representative of and aligns with the anticipated program of works for NorthConnex tunnelling and excavation activities. As shown in **Table 6-1**, during the 2013/2014/2015 to 2016 period, the background light vehicle volume increases on the Pennant Hills Road and Pacific Highway network are modest with a maximum growth rate of four per cent at the intersections of Pacific Highway / Bridge Road and Bridge Road / Jersey Street North. The majority of the remaining intersections experience growth in the order of one to three per cent.

During the same period, background heavy vehicle volumes at the same key intersections increase at a higher rate of between one and 33 per cent. The 33 per cent figure is misleading as it occurs at the intersection of M1 Pacific Motorway / Ku-ring-gai Chase Road and in absolute terms is an increase of four vehicles. The majority of heavy vehicle increases fall within 10 per cent and are, again, slightly skewed due to the low base volume from which the percentage is calculated.

Table 6-1 Comparison between 2013/2015 and 2016 background traffic flows

Intersection	Light Vehicles			Heavy Vehicles		
	2013/ 14/15	2016	Change	2013/ 14/15	2016	Change
AM Peak Hour						
M1 Pacific Motorway / Pacific Highway Interchange	4,450	4,520	2%	240	262	9%
Pennant Hills Road / Pacific Highway	2,950	2,940	0%	200	195	-3%
Pacific Highway / College Crescent / Pretoria Parade	2,617	2,670	2%	161	168	4%
Pacific Highway / Edgeworth David Avenue	2,966	3,042	3%	183	200	9%
Pacific Highway / George Street	2,691	2,777	3%	165	175	6%
Pacific Highway / Bridge Road	1,906	1,972	3%	62	68	10%
Bridge Road / Jersey Street North	2,004	2,003	0%	48	48	0%
Pacific Highway / Jersey Street North / Wattle Street	1,658	1,663	0%	64	64	0%
Pacific Highway / Yirra Road	2,215	2,248	1%	66	68	3%
M1 Pacific Motorway / Ku-ring-gai Chase Road	497	511	3%	24	26	8%
PM Peak Hour						
M1 Pacific Motorway / Pacific Highway Interchange	4,970	5,009	1%	120	144	20%
Pennant Hills Road / Pacific Highway	3,330	3,367	1%	110	116	5%
Pacific Highway / College Crescent / Pretoria Parade	2,786	2,822	1%	153	157	3%
Pacific Highway / Edgeworth David Avenue	3,407	3,462	2%	90	97	8%
Pacific Highway / George Street	3,186	3,235	2%	82	88	7%
Pacific Highway / Bridge Road	2,104	2,184	4%	48	54	13%
Bridge Road / Jersey Street North	2,107	2,151	2%	34	33	-3%
Pacific Highway / Jersey Street North / Wattle Street	2,023	2,076	3%	58	59	2%
Pacific Highway / Yirra Road	2,595	2,628	1%	52	55	6%
M1 Pacific Motorway / Ku-ring-gai Chase Road	639	637	0%	12	16	33%

(Source: Strategic transport model, 2014)

6.2.2 Intersection level of service

The intersection performance results for the Pennant Hills Road corridor under the forecast 2016 demand with the additional project traffic and a northbound spoil haulage route are summarised in **Table 6-2**. The analysis provides a comparison of intersection performance with and without project vehicles during the AM and PM peak periods. The haulage routes and demands are illustrated in **Section 6.1**.

Table 6-2 2016 Intersection performance (AM and PM Peak Hour)

Intersection/Peak	2016 – Without project				2016 – With project			
	Light Vehicles	Heavy Vehicles	Average Delay	Level of Service	Light Vehicles	Heavy Vehicles	Average Delay	Level of Service
M1 Pacific Motorway / Pacific Highway Interchange								
AM Peak	4,520	262	35.2	C	4,520	262	35.2	C
PM Peak	5,009	144	68.2	E*	5,009	144	71.4	F**
M1 Pacific Motorway / Pacific Highway Interchange (M1 compound scenario)								
AM Peak	4,520	262	35.2	C	4,520	274	47.7	D
PM Peak	5,009	144	68.2	E*	5,009	156	81.4	F**
Pennant Hills Road / Pacific Highway								
AM Peak	2,940	195	76.3	F#	2,940	230	76.8	F##
PM Peak	3,367	116	45.9	D	3,367	151	45.9	D
Pennant Hills Road / Pacific Highway (M1 compound scenario)								
AM Peak	2,940	195	76.3	F#	2,940	230	90.3	F##
PM Peak	3,367	116	45.9	D	3,367	151	48.1	D
Pacific Highway / College Crescent / Pretoria Parade								
AM Peak	2,670	168	47.1	D	2,670	203	51.5	D
PM Peak	2,822	157	47.0	D	2,822	192	52.9	D
Pacific Highway / Edgeworth David Avenue								
AM Peak	3,042	200	32.2	C	3,042	235	32.2	C
PM Peak	3,462	97	30.8	C	3,462	132	30.9	C
Pacific Highway / George Street								
AM Peak	2,777	175	41.5	C	2,777	210	41.8	C
PM Peak	3,235	88	50.3	D	3,235	123	51.5	D
Pacific Highway / Bridge Road								
AM Peak	1,972	68	29.8	C	1,972	138	58.2	E
PM Peak	2,184	54	46.1	D	2,184	124	74.7	F
Bridge Road / Jersey Street North								
AM Peak	2,003	48	20.9	B	2,003	118	26.3	B
PM Peak	2,151	33	25.3	B	2,151	103	25.4	B
Pacific Highway / Jersey Street North / Wattle Street								
AM Peak	1,663	64	20.2	B	1,663	99	20.6	B
PM Peak	2,076	59	33.4	C	2,076	94	37.0	C
Pacific Highway / Yirra Road								
AM Peak	2,248	68	30.6	C	2,248	103	41.5	C
PM Peak	2,628	55	47.0	D	2,628	90	62.2	E
Pacific Highway / Ku-ring-gai Chase Road								
AM Peak	511	26	3.2	A	511	49	3.5	A
PM Peak	637	16	4.9	A	637	39	4.5	A

Notes to Table 6-2:
* ‘Without project’ scenario result has a degree of saturation forecast of 1.02
# ‘Without project’ scenario result has a degree of saturation forecast of 1.03
** ’With project’ scenario result has a degree of saturation forecast of 1.03
‘With project scenario’ result has a degree of saturation forecast of 1.02

The modelling results highlight that the 2016 ‘without project’ scenario sees the study corridor operating at acceptable levels of average delay and within capacity during the AM and PM peak periods with the exception of the southern end of the study area. Within this region, the intersection performance is at or approaching capacity and experiences high levels of delay due to the linkages with the M1 Pacific Motorway. Under the forecast 2016 demands (without construction traffic), the intersections that have deteriorated from 2013 levels and operate at either LoS E or LoS F include:

- M1 Pacific Motorway / Pacific Highway (PM peak)
- Pennant Hills Road | Pacific Highway (AM Peak).

It is important to appreciate that background growth alone accounts for part of the deterioration of the road network. Whilst the strategic model forecasts indicate capacity is exceeded, it is not anticipated to occur in reality due to the corresponding increase in delay across the wider network which would prevent vehicles from accessing these locations, as noted in the strategic forecasts. Furthermore, the incidence of the intersections operating at, or slightly above, capacity will result in a small degree of peak spreading whereby individuals choose to marginally adjust their travel patterns to react to the change in operating conditions.

As each of these aforementioned intersections are forecast to operate above capacity in 2016 without project vehicles, the additional demands created by project traffic, results in intersection performance decreasing. The M1 compound scenario has the largest impact on the study area, specifically at the intersection of M1 Pacific Motorway / Pacific Highway, as vehicles are required to turn right having exited the M1 and then turn right again at the intersection of Pacific highway / Pennant Hills Road. This movement removes available green time from other phases and causes an increase in delay for competing movements.

The remainder of the study area is forecast to operate within capacity with the addition of project traffic under the ‘with project’ scenario. Operational performance for the majority of intersections does not reach LoS E or LoS F following the introduction of project traffic, other than at the intersections of Pacific Highway / Bridge Road (AM and PM peak) and Pacific Highway / Yirra Road (PM peak). Modelling indicates the right turn movement from the Pacific Highway to Yirra Road at the intersection of Pacific Highway / Yirra Road, during the PM peak, would have a mean maximum queue length of approximately 40 metres and experience a delay of 48.7 seconds (LoS D). For the ‘without project’ scenario the associated queue length is approximately 26 metres. Therefore the project is forecast to increase the mean maximum queue by 14 metres. The average delay recorded under the ‘without project’ scenario is higher at 63.4 seconds compared with the ‘with project’ scenario figure of 48.7 seconds. This is due to the increased demand for the right turn movement resulting in an increase in the green time provided by the traffic signals for this movement. The increase in green time provides greater opportunity for vehicles to turn right, therefore lowering delay for the movement.

This level of delay has been discussed with both internal and external traffic and transport stakeholders such as Roads and Maritime and Hornsby Shire Council who both acknowledge that the magnitude of intersection delay is considered acceptable as it is a temporary impact (associated with the construction of NorthConnex) and due to the high degree of community benefits following project completion. Overall journey time, and therefore average speed, on the corridor will be impacted upon by the increase in delay however the decrease in average speed is anticipated to be minimal as any impacts must be considered in the context of the proposed project vehicle peak movements which equate to one haulage vehicle, on average, every two minutes.

Preliminary consideration of swept path for the Pacific Highway to Yirra Road movement with a truck and dog haulage vehicle indicated the movement could be completed satisfactorily. The swept path analysis for the corresponding right turn movement from Yirra Road to Belmont Parade indicated potential conflicts which will require further investigation as the design develops and the haulage routes are confirmed.

As part of the preparation for construction mitigation measures to reduce the impact to residents and users of the corridor shall also be implemented. These are discussed in greater detail in **Section 7**.

6.3 Operational Performance (Qualitative Assessment)

6.3.1 Preparatory Works

Anticipated maximum traffic volumes for heavy vehicles and light vehicles during each phase of the project are summarised in **Table 6-3**.

Table 6-3 Traffic volumes in each phase of the project

Phase	Daily heavy vehicles (and movements)	Daily light vehicles (and movements)
Preparatory works	10 (20)	10 (20)
Site establishment works	20 (40)	25 (50)
Establishment of conveyer	20 (40)	25 (50)
Spoil emplacement activities (haulage)	385 (770)	20 (40)
Site clean-up and demobilisation and rehabilitation	20 (40)	20 (40)

Traffic volumes of the proposed preparatory works are less than the anticipated peak traffic volumes associated with the haulage of ENM and/or VENM to Hornsby Quarry. As such, given the peak in project traffic generation (spoil emplacement activities – haulage) has been assessed with regards to the road network, any impacts associated with the proposed preparatory works, with respect to the surrounding road network will be lower than those documented in **Section 6.2**.

6.3.2 Project Impacts

Traffic crashes

Construction traffic volumes are expected to be relatively low when compared to existing traffic volumes within the study area. As a worst-case scenario, 385 spoil haulage vehicles per day would be generated by the project. When compared to existing traffic volumes, this equates to approximately:

- One per cent of forecast 2016 total daily traffic on the Pacific Highway (south of Yirra Road).
- Three per cent of forecast 2016 total daily traffic on the Pacific Highway (east of College Crescent).

As the volume of traffic generated by the project is expected to be low compared to existing traffic, the effects of this short-term increase on the existing road network is not expected to significantly impact road safety in the study area. In addition, any foreseen impacts to road safety for all users during the project would be mitigated through the provision of tailored traffic management plans and measures, as detailed in **Section 7**.

Public transport services

An increase in heavy vehicles on the existing road network during the project would potentially result in increased delays at intersections along the project corridor and in surrounding areas. Heavy vehicle volumes would be increased within the study area and surrounding major roads. While the increase in truck volumes, as a proportion of overall traffic, is anticipated to be minor, the following impacts to public transport services could potentially be experienced:

- Buses:
  - An increase in bus service travel times due to slower travel speeds and increased intersection delays.
  - Longer travel times to and from bus stops by supplementary travel modes (e.g. car passenger, walking to/from bus stop, etc) due to an increase in traffic volumes, slower travel speeds and increased intersection delays.
  - Reduced amenity for bus users waiting at stops; an increase in traffic would result in impacts including a reduction in pedestrian roadside safety.
- Rail services:
  - Rail services in the project corridor and surrounding areas are not expected to be affected by the project.

Walking and cycling

An increase in heavy vehicle volumes during the construction period along the project corridor and in surrounding areas would potentially impact on walking and cycling amenity, including:

- Walking:
  - Reduced overall amenity throughout the study area.
- Cycling:
  - Increased delays at intersections for on road cyclists due to an increase in traffic volumes travelling along the corridor.
  - Reduced overall amenity throughout the study area.

Parking

Currently on-street parking is permitted along the eastern side of Bridge Road, south of Roper Lane. To maintain public safety, parking on Bridge Road, south of Roper Lane, would be restricted during Bridge Road upgrade works. Once the upgrade works are complete, parking would be restricted during standard work hours only for the remaining duration of the project. This section of Bridge Road would be ‘No Stopping’ to facilitate safe two-way passage of haulage vehicles. This would result in the temporary loss of approximately 12 parking spaces.

In addition, there may be a need to restrict car parking for the section of Bridge Road west of Pacific Highway/Peats Ferry Road to Roper Lane to facilitate safe two way passage.

Many of the vehicles that use the existing on-street parking are likely to be students and staff of Hornsby TAFE. As such, prior to the parking restrictions being put in place, Hornsby TAFE would be notified of the proposed changes. In addition, the adjacent residents would also be notified regarding the parking arrangements as part of the community consultation to be undertaken.

Parking for site personnel would be provided within the quarry site.

6.3.3 Project Benefits

The temporary increase in traffic on the road network surrounding the Hornsby Quarry as a result of the project gives rise to substantial long term benefits for the environment and community following completion of the project. The project provides the platform for the following key opportunities:

- Facilitating Hornsby Shire Council’s rehabilitation of the quarry void to provide a space for community use and recreation.

- Facilitating the construction of NorthConnex which provides increased transport accessibility for the Hornsby LGA, an extension of Sydney's orbital network to facilitate improved road safety, efficiency and freight transport outcomes; and an ultimate outcome to ease congestion in the region.
- Addressing an ongoing safety risk to the community by stabilising the quarry site so it can be opened to the public by Hornsby Shire Council in the future.
- Recognition for implementing a safe and sustainable solution to a community concern (the quarry site).
- Removing an ongoing maintenance cost to Hornsby Shire Council and the community.

6.4 Cumulative impacts

The program for the Hornsby Quarry project is planned for completion by late 2018. Based on this appreciation of the project timeframe, it is likely that the works for the project would occur at the same time as certain construction stages of other major infrastructure projects, which are planned to be constructed in the general vicinity of Sydney's north west, namely:

- Epping to Thornleigh Third Track (ETTT)
- North West Rail Link (NWRL)
- WestConnex – Stages 1 and 2.

The potential for any cumulative impacts associated with these projects during the construction of these projects has been assessed previously in the NorthConnex EIS where it was noted that the cumulative impacts would not be significant. The study area for the Hornsby Quarry project is located to the north of the study extent for the NorthConnex project. As such, any cumulative impacts are anticipated to be negligible due to the low volume of construction traffic and further isolation of the study area with respect to the previously completed, and approved, NorthConnex EIS.

Construction of residential dwellings at Asquith and Waitara is scheduled to occur in parallel with construction of NorthConnex. Works regarding the Asquith rezoning are anticipated to require single lane closures on the Pacific Highway, north of the Hornsby Quarry site. Construction traffic associated with Hornsby Quarry is currently required to travel north on the Pacific Highway during peak times. In the unlikely event that road capacity was reduced during peak times the impact of construction traffic associated with Hornsby Quarry (one vehicle approximately every two minutes) is anticipated to be minimal with regards to the development of the Asquith and Waitara residential sites.

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7 Mitigation and management measures

As part of the conditions of any approvals, a traffic management plan (TMP) would be prepared as part of the construction environmental management plan (CEMP). The TMP would include the guidelines, general requirements and procedures to be used when project activities would have a potential impact on existing traffic arrangements. Implementation of the measures in the TMP would ensure that delays and disruptions are managed with appropriate measures, and identify and respond to any changes in road safety as a result of the project. A framework traffic management strategy, which will form the basis of the TMP, is presented in **Appendix A**.

The TMP would be submitted in stages to reflect the progress of work and would include:

- Signage requirements (e.g. temporary speed restrictions, changes to the road environment, traffic management controls deployed, truck and pedestrian warning signs for Roper Lane and Bridge Road).
- Traffic control devices, such as temporary traffic signals.
- A communications strategy. This would include methods to provide advanced notice of any major or prolonged impacts.

Some of the principles the TMP would encompass would include:

- Reducing the impacts of construction on road network performance and safety. In addition, to further minimise the potential effects of any major sources of delay, any works which would significantly reduce the performance of the road network in the study area would be scheduled for periods of typically lower traffic volumes, where possible.
- Works sequencing and any temporary works identified would aim to minimise user delay while providing sufficient flexibility for the selected contractor to safely and efficiently construct/operate the project site.
- Signage would be used to clearly indicate the traffic controls in use; this could also include temporary speed restrictions and passing constraints if required to maintain road safety levels.

The TMP would provide details of both the general approach to be used to ensure suitable locations have been chosen for access and egress points to worksites (e.g. minimum sight distances, maximum grade allowances, etc.) and the specific controls required at selected locations (signage, barriers, signalling requirements). Additionally, the TMP would be prepared in consultation with emergency services with a view to planning and executing the works to minimise any impact of the works on their ability to respond to an incident, whenever and wherever possible.

The following strategies have been and continue to be considered in the detailed design phase:

- Identifying potential road user delays during the planning and consultation phases.
- Maintaining existing road network capacities.
- Where possible, maintaining existing road characteristics and environment especially residential streets, schools, business operations, clearways, parking, places of worship and the like.
- Optimising work methods to balance impacts.
- Providing a mechanism for the community to report incidents and delays, for example, an 1800 phone number.
- Analysing traffic volume data to:
  - Identify the capacity requirements of the road.
  - Assess the potential impact on traffic flows.

  - Identify the optimal time to minimise the inconvenience to road users.
- Developing clear and concise guidance and support amongst key stakeholders involved.
- Developing traffic management solutions.

Overall, the TMP would document the strategy and procedures to minimise, mitigate and communicate the impacts of the construction of the project on the capacity, performance and safety of the local road network and traffic systems. The TMP would also address the management of impacts on emergency services, cyclists, pedestrians, public transport and parking identified in this report.

Appendix A – Framework Traffic Management Strategy

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A2 Introduction

The following framework Traffic Management Strategy provides an outline of mitigation and management measures being considered to minimise potential traffic and transport impacts resulting from the Hornsby Quarry Road Construction Spoil Management Project. This framework would continue to be developed as the design develops and would form the basis of the Traffic Management Plan for the project.

A2 Framework Traffic Management Strategy

A2.1 On-Street Parking

Currently on-street parking is permitted along the eastern side of Bridge Road, south of Roper Lane. During the construction phase, this section of Bridge Road would need to be ‘No Stopping’ to facilitate safe two-way passage of haulage vehicles. As such, the existing on-street parking (approximately 12 car spaces) within the area would be affected as all parking would need to be removed on Bridge Road west from the intersection of Peats Ferry Road/Pacific Highway for safety reasons.

It is assumed that the majority of the vehicles that access the existing on-street parking are staff and students of Hornsby TAFE. As such, prior to the parking restrictions being put in place, Hornsby TAFE would be consulted regarding the proposed changes to parking arrangements. In addition, the adjacent residents would also be notified as part of the community consultation process.

Parking for site personnel would be provided within the Quarry site.

A2.2 Pedestrian protection

The Hornsby Quarry is adjacent to the Hornsby TAFE vehicle access location on Bridge Road. Although there are no pedestrian facilities along Bridge Road, south of Roper Lane, it is assumed that some pedestrian access does occur at this location, especially by the on-street parking demand generated by TAFE. Given that there are no footpaths or sufficient verge along Bridge Road, it is assumed that the existing pedestrian access into the TAFE site is via the road surface.

To eliminate the potential conflict between construction vehicles and pedestrians, pedestrian access along Bridge Road, south of Roper Lane, is proposed to be prohibited during the construction phase. This would require appropriate notification at the entrance to Bridge Road, at the intersection of Roper Lane, informing pedestrians to not proceed further onto Bridge Road.

Pedestrian access to the TAFE would be maintained from Peats Ferry Road.

A2.3 Construction Site Identification

The construction site would be easily identifiable and clearly secured from the public. Gate keepers would be positioned to only allow authorised vehicles and personnel to enter the site. Warning and advisory signs would be in place to warn motorists from entering the site and secure fencing would be erected to prevent unauthorised entry at all times.

A2.4 Access Management

To minimise the potential conflict between TAFE and construction traffic along Bridge Road, especially to minimise occurrences of one limiting the access to the other on Bridge Road, a consolidated vehicle control point would be considered. Such management measures would require consultation with TAFE to consider their requirements and management protocols that are currently in place. On the steep section of Bridge Road, controls would be put in place to separate TAFE vehicles from construction vehicles during spoil haul times.

Regardless of the location, the access point would be managed by personnel to not only control access into the site but also regulate the exit volumes from the site.

A2.5 Preservation of Property Access

Access to residential or surrounding business would be maintained as far as possible. If however there are any disruptions to normal property access conditions, traffic controllers would be engaged to ensure access to properties is maintained under supervision.

All vehicle movements would be limited to existing roads and regular inspection of the roads surrounding the quarry would be undertaken to ensure safety around the site, as well as to observe and record any damage caused to property or transport infrastructure by construction vehicles.

A2.6 Emergency Vehicle Access

Access for emergency vehicles is to be in accordance with emergency vehicle requirements and would be maintained into the site at all times. The emergency services would be advised of any planned changes, if any, to traffic arrangements prior to applying the changes. Advice would include information about upcoming traffic switches, anticipated delays to traffic, extended times of work, locations of road possession or any likely major disruptions. The construction contractor should liaise with Emergency Services to minimise the impacts of response times.

Measures to facilitate the movement of emergency vehicles through a worksite would be made available at all times and would be defined in the Traffic Management Plan. The contractor would also consult with NSW Fire and Rescue regarding any specific requirements for quarry type of environments in preparing the site specific Traffic Management Plan to minimise the impact to emergency vehicle response times.

A2.7 Vehicles Exiting the Site

All vehicles would enter and exit the site in a forward movement and wheels would be free of soil to prevent soil being dispersed onto Bridge Road.

The access/egress point to the site at the western end of Bridge Road would be managed by site personnel. Traffic control measures, such as stop go or lights, would be implemented at the site access/egress point to control and regulate the exit volumes from the site.

Works vehicles entering the public roadway from the site would, at all times, observe the road rules and not place any road users in danger.

In addition, safety measures would be in place within the construction site so that vehicle movements are conducted in a safe manner without any risk to workers on the ground or other machine operators.

A2.8 Measures to Reduce Traffic Impacts

Heavy vehicle traffic movements would be kept to a minimum during school zone times and afternoon peak hours so as to maximise safety and reduce possible congestion along the haulage routes.

To ensure road safety is not compromised all heavy vehicles engaged in the project would meet the Australian Road Rules and RMS standards. The majority of heavy vehicle operations on roads would occur during the standard working hours.

Site specific Vehicle Movement Plans would be detailed and toolbox talks held to ensure truck drivers are aware of the approved routes and any special controls and conditions.

A2.9 Traffic Infrastructure Monitoring

The Traffic Management Plan would detail the establishment of an inspection and monitoring program to inspect any temporary works and monitor the traffic movements in and out of the quarry on a regular basis.

Traffic infrastructure would be inspected on a daily basis by field staff (foreman) to ensure traffic management facilities as designed and installed remain in place and have not been vandalised, impacted by vehicle(s), or impaired in any other way. Field staff would also monitor the adequacy of the infrastructure.

The Traffic Manager would carry out periodic inspection of Traffic Control Plan implementation.

In addition to static traffic management facilities, CCTV would be installed adjacent to the quarry access location for both security purposes and to monitor the traffic movements in and out of the quarry. Dependant on the location of the quarry access point, the CCTV could also monitor the adjacent traffic operations, especially at the signalised intersection of Bridge Road / Pacific Highway so as to coordinate the traffic movements from the quarry with the signalised intersection.

A2.10 Oversized Vehicle Movements

During construction works, it may be necessary to deliver oversized machinery to the site. Oversized movements can cause disruptions to traffic operation, therefore such movements would occur during the off-peak periods (but within standard construction hours) where traffic volumes are typically at their minimum.

Transport of oversized equipment and machinery may require the occupation of more than one traffic lane. Therefore, such movements should be in accordance with RMS guidelines for oversized movements (e.g. reduced speed, vehicle escorts, lighting), to warn other road users of its movements.

Prior to any oversized movements, all necessary Oversize and/or Overmass Permits would be obtained from the RMS. If deemed necessary by guidelines, liaisons between Police and relevant local authorities would be held to manage and formulate the route of the oversized vehicles and machinery.

A2.11 Heavy Vehicle Movement Monitoring

The movement of heavy vehicles would be monitored, to ensure the scheduling of heavy vehicles is in line with the assessment undertaken for the site. The monitoring would be coordinated with the Northconnex construction work sites such that the movement of heavy vehicles to Hornsby Quarry are distributed throughout the work period, especially during the AM and PM peak periods, and not result in multiple heavy vehicles queuing along the haulage routes.

The Spoil Management Plan, would detail the heavy vehicle monitoring plan to be implemented during the project and highlight potentially measures to control the distribution of heavy vehicles along the haulage routes.

A2.12 Community Consultation

All affected residents, institutions and surrounding businesses would be notified in advance of any disruption to traffic. The methods of notification may include:

- Variable Message Board Signs
- Driver warning signs
- Newsletters leaflets
- Public notices in local publications
- Emails
- Phone calls
- Text messages
- Face to face door knock

The project newsletter would notify the local community of updates on the project and the current stage of the construction to inform on what changes, if any, are expected within the local road network. Such notifications would only be issued following consultation and approval from the relevant road authorities.

Appendix D

Technical working paper:
Noise and Vibration

Roads and Maritime Services

Hornsby Quarry Road Construction Spoil Management Project

Technical Working Paper: Noise and Vibration

July 2015

Prepared for

Roads and Maritime Services

Prepared by

AECOM Australia Pty Ltd

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Contents

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Executive summary

Background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

The Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts such as noise and traffic within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. On 11 June 2015, the project was declared by the Minister for Planning to be State significant infrastructure. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 11 June 2015 and included a requirement to undertake an assessment of potential impacts of noise and vibration from the project. This noise and vibration assessment has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management facility.

Existing environment

The noise environment surrounding the Hornsby Quarry site is characterised by the local road network, including the Pacific Highway and other transport infrastructure such as Hornsby railway station and the Northern railway line. As a result, the main contributors to the existing noise environment are road traffic (including heavy vehicles using the existing road network) and passenger and freight rail movements. Commercial and light industrial areas along and around the Pacific Highway road corridor would also contribute to the local noise environment. The quarry site is located within a dense bushland area to the west of the Hornsby town centre and is surrounded by residential receivers to the south and north. It is expected that residential receivers in proximity to the quarry would experience a noise amenity consistent with a suburban setting.

Background noise monitoring was undertaken throughout the project area to determine the existing noise environment. Once a survey of the site including operator attended noise measurements was completed the local area was separated into noise catchment areas, based on their existing noise exposure. Appropriate noise criteria were then derived for each catchment area in accordance with the Interim Construction Noise Guideline.

Noise and vibration assessment

Noise was assessed for each phase using SoundPLAN noise modelling software. Work is proposed within standard construction hours only, so this assessment has not considered out of hours work. Five different construction phases of the project have been assessed and no sensitive receivers have been found to be highly noise affected by the works. However for the first row of receivers overlooking the site increases of up to 23 dB(A) could be experienced during times of noise intensive works associated with the site establishment and demobilisation phases.

Noise mitigation surrounding stationary plant and noise mounds about five metres in height surrounding the stockpiling area have been included in the noise modelling. Additional noise management and mitigation would need to be considered in the Construction Noise and Vibration Management Plan (CNVMP) to ensure that any residual exceedances of the NML are controlled as much as is reasonable and feasible.

The increase in noise from haulage of spoil on Pacific Highway would remain compliant with the applicable noise criteria. However construction traffic noise from haulage on Bridge Road is likely to increase noise levels by more than 2 dB(A). The maximum number of movements has been reduced considerably, and as much as is considered reasonably practicable to make the proposal viable. Additional feasible and reasonable noise mitigation will be considered and, if required, included in the CNVMP to ensure that the noise impact for receivers affected by haulage on Bridge Road would be suitably controlled.

Hornsby Shire Council has an existing licence for the pumping of water from the quarry void. The cumulative noise impact from operating maintenance pumping and this project simultaneously has been assessed. This assessment has found that generally noise levels would not be increased by operating the pumping activities simultaneously with other activities. However a small number of increases in noise of up to 1 dB(A) have been predicted.

Detailed consideration of feasible and reasonable noise management and mitigation measures will include consideration the nature and timing of impacts and the sensitivity of individual receivers to noise, so that tailored measures can be implemented to achieve acceptable outcomes for sensitive receivers,

Due to the relatively large offset distances between the site and sensitive receivers and the nature of the work, the project is not predicted to result in exceedances of the applicable structural damage and human comfort vibration criteria.

1 Introduction

1.1 Project background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for NorthConnex identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

The Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts such as noise and traffic within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Hornsby Shire Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 2 July 2015 and included a requirement to undertake an assessment of potential impacts of noise and vibration from the project. This noise and vibration assessment has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management Project.

1.2 Project location

The Hornsby Quarry site is located around 21 kilometres north west of the Sydney Central Business District, in Old Mans Valley to the west of Hornsby town centre. The site covers about 35 hectares and is owned by Hornsby Shire Council (Council) (refer to Figure 1). The site is accessed via local Council roads, including Quarry Road (off Dural Street and other local roads) from the south east and Bridge Road (off the Pacific Highway/Peats Ferry Road) from the north east.

The site comprises a quarry void, internal access roads and a cleared area to the east, which was used as a processing area when the quarry was operational. Disused facilities associated with the previous quarrying operations remain on the site, including concrete office block buildings, a crushing and screening plant, a pipeline, security fencing and gates.

Whilst the site is zoned for public recreation (RE1) under the *Hornsby Local Environmental Plan 2013,* the quarry void itself is unsafe for public access given the steep sides and flooded nature of the void. Council currently maintains exclusion fencing around the void to prevent public access for public safety reasons. The areas outside of the void exclusion fencing are open to public access including mountain bike trails which have been established across the site by Council. However, until the quarry void is filled, full rehabilitation of the site for recreational purposes is not possible.

The site and surrounds are densely vegetated with some cleared areas comprising the void itself, internal access roads and the cleared area to the east. Dense bushland comprising the Berowra Valley National Park lies directly to the west. The Pacific Highway and Main North Railway Line are located to the east, approximately 300 metres and 500 metres respectively.

The general location and key features of the project are shown in **Figure 1-1**.

1.3 Purpose of the report

The SEARs for the project were issued on 2 July 2015. The SEARs have informed the preparation of the EIS for the project. The SEARs include the following requirements specific to potential impacts of noise and vibration:

> *An assessment of the noise impacts of the proposal, consistent with the Interim Construction Noise Guideline (DECCW, 2009), Assessing Vibration: a technical guideline (DEC, 2006), and any other relevant guidelines or policies. The assessment must have regard to the nature of construction activities (including transport, tonal or impulsive noise generating works and the removal of operational noise barriers, as relevant), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially affected receivers, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management), and mitigation and management measures. The assessment should present, as relevant, an indication of potential for works outside standard working hours, including predicted levels and exceedences, justification for the activity and discussion of available mitigation and management measures.*

This Noise and Vibration Technical Working Paper has been prepared to address the SEARs for the project.

The scope undertaken for this construction noise and vibration assessment is as follows:

- Utilisation of background noise measurements to establish the construction noise management levels (NMLs) in accordance with the Interim Construction Noise Guideline (ICNG) (NSW Department of Environment and Climate Change (DECC), 2009).
- Identification of noise sensitive catchment areas likely to be affected by construction noise and vibration.
- Calculation of noise and vibration levels likely to be associated with the project at sensitive receivers and the evaluation of the extent of resulting impacts.
- Consideration of the impacts that may result from the proposed project and mitigation measures to reduce adverse impacts where appropriate. These measures would be developed and implemented through environmental management plans.

1.4 Relevant guidelines

The following legislation, guidelines, policies and / or standards have been considered to inform the impact assessment of the project:

- *NSW Protection of the Environment Operations Act 1997* (POEO Act 1997).
- *NSW Industrial Noise Policy, Environment Protection Authority* (EPA), 2000.
- I*nterim Construction Noise Guideline (ICNG),Department of Environment and Climate Change* (DECC), 2009.
- *Assessing vibration: a technical guideline (AVATG), NSW Department of Environment and Conservation* (DEC), 2006.
- *NSW Road Noise Policy (RNP), Department of Environment, Climate Change and Water* (DECCW), 2011.

- DIN Standard 4150 - Part 3 1999 - *Structural Vibration in Buildings – Effects on Structures.*
- British Standard 7385: Part 2 1993 - *Evaluation and Measurement of Vibration in Buildings.*
- Australian Standard 1055.1-1997 – *Acoustics – Description and measurement of environmental noise, Part 1: General procedures.*

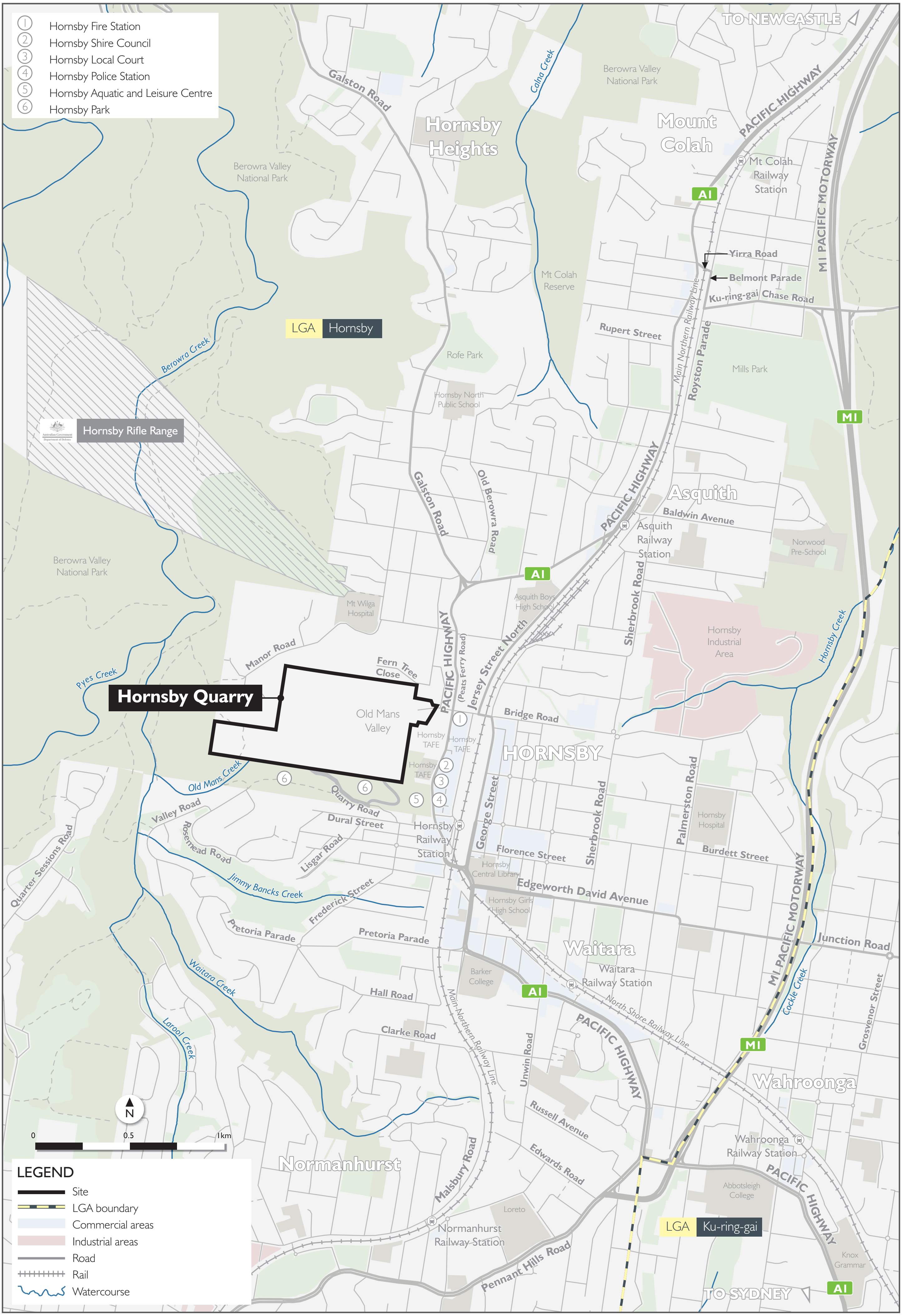

Figure 1-1 Local and site context

1.5 The project

The Hornsby Quarry site would receive up to 1.5 million cubic metres of excavated natural material (ENM) and/ or virgin excavated natural material (VENM) from the approved NorthConnex construction sites. Only ENM and/ or VENM would be received and reused at the Hornsby Quarry site. An indicative site layout is shown in **Figure 1-2**.

Key features of the project would include:

- Widening and sealing of the quarry access road (Bridge Road and track) to facilitate all weather access.
- Clearing and grubbing, and establishment of erosion and sediment controls.
- Establishment of a compound site, security fencing and signage around the construction area.
- Dewatering of the void (to be undertaken by Hornsby Council in accordance with its existing groundwater licence) to a suitable level that allows working within the void.
- Construction of a conveyor from the stockpile site to the rim of the quarry void.
- Spoil haulage by truck from the NorthConnex construction sites to the Hornsby Quarry site over a period of approximately 28 months.
- Stockpiling of spoil at stockpile sites within the Hornsby Quarry site using dozers.
- Transport of the spoil via the conveyor from the stockpiles to the rim of the quarry void, where the spoil would fall directly into the void.
- Spreading and grading of the spoil on the quarry floor.
- Site demobilisation and rehabilitation of the compound site, stockpile areas and the conveyer corridor.

The project is anticipated to commence in late 2015 and is expected to take around 33 months to complete.

An indicative project program is provided in **Table 1-1**.

Table 1-1 Indicative program

Phase	Indicative timeframe 2015				2016				2017				2018			
Site establishment works				■												
Establishment of conveyer					■											
Spoil haulage and stockpiling					■	■	■	■	■	■	■	■	■	■		
Spoil emplacement activities (operation of conveyor)						■	■	■	■	■	■	■	■	■	■	
Site clean-up and demobilisation														■	■	

Figure 1-2 Indicative Site layout

An overview of project activities is included in **Table 1-2.** Detailed descriptions of each activity can be found in Section 4.1 of the environmental impact statement for the project.

Table 1-2 Overview of project works

Phase	Typical activities
Site establishment (including preparatory works)	The following works would completed: • Dewatering of the void to a suitable working level • Clearing and grubbing, and establishment of erosion and sediment controls • Establishment of a compound site • Establishment of security fencing and signage around the construction site • Widening and sealing of the currently unsealed quarry access road (Bridge Road) to facilitate all weather access.
Establishment of conveyor	The construction of the conveyor works would occur concurrently with the establishment of the site.
Spoil haulage and stockpile maintenance	Trucks would enter and leave via Bridge Road during standard construction hours over a maximum period of 28 months. Spoil would be unloaded from the dump trucks and stockpiled using dozers. It is expected that this activity would commence whilst the conveyer is still being constructed.
Spoil emplacement (operation of conveyor)	Once the conveyer is constructed, these works would occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto the site. The activities include: • Placement of spoil from the stockpiles into the conveyor by front end loader • Transport of the spoil via overhead conveyor to the quarry void rim where the spoil would fall directly into the void. • Front-end loaders and articulated trucks would move the spoil along the quarry floor with dozers and rollers spreading the material. Periodic maintenance pumping of water from the void would be conducted during all phases. Maintenance pumping has been assessed to account for cumulative noise impacts.
Site demobilisation and rehabilitation	The construction compound and conveyor would be dismantled and removed from the site. Disturbed areas would be rehabilitated to a standard agreed with the Council. Security fencing would be removed, however would be retained around the quarry void if the void is deemed to remain an ongoing risk to public safety. Public access would then be reinstated to the areas outside the void exclusion zone.

1.5.1 Project works hours

Works would be undertaken in accordance with the ICNG recommended standard hours for construction, as presented below:

- 7am to 6pm Monday to Friday.
- 8am to 1pm Saturdays.
- No work on Sundays or Public Holidays.

Whilst no construction works would occur outside of standard hours there may be circumstances where out-of-hours activities associated with the project are necessary. Works which may be undertaken outside of standard daytime hours without further approval (in accordance with Section 2.3 of the ICNG) would include the following circumstances:

- The delivery of materials or oversized plant as required by the Police or other authorities for safety reasons.
- Where it is required to avoid the loss of lives, property and / or to prevent environmental harm in an emergency.
- Activities which are determined to comply with the relevant Noise Management Level (NML) at the most affected sensitive receiver, with the exception of spoil transport or emplacement activities. Examples include refuelling of plant or maintenance of equipment.
- Where agreement is reached with affected receivers.

Out of hours work may also be undertaken where explicitly approved through an Environment Protection Licence.

The acoustic terminology used in this report is explained in the glossary of terms and abbreviations in **Appendix A**.

2 Existing ambient noise environment

2.1 Existing noise environment

The noise environment surrounding the Hornsby Quarry site is characterised by the local road network, including the Pacific Highway and other transport infrastructure such as Hornsby railway station and the Main North Railway Line. As a result, the main contributors to the existing noise environment are road traffic (including heavy vehicles using the existing road network) and passenger and freight rail movements. Commercial and light industrial areas along and around the Pacific Highway road corridor would also contribute to the local noise environment. The quarry site is located within a dense bushland area to the west of the Hornsby town centre and is surrounded by residential receivers to the south and north. It is expected that residential receivers in proximity to the quarry would experience a noise amenity consistent with a suburban setting.

2.2 Noise sensitive receivers

The project area is predominantly a residential area consisting of one to two storey detached and semi-attached residences, townhouses or villas with occasional residential apartment buildings.

Commercial receivers are concentrated along the Pacific Highway, with key local centres clustered at Hornsby. This includes retail, office and accommodation providers. Pockets of light industrial areas occur within the project area.

A site visit was undertaken to assist in identifying sensitive receiver locations. Passive and active recreational areas as well as educational establishments are located throughout the study area. Receivers and their use are identified in **Appendix B.**

Noise sensitive receivers were identified by aerial photography. Cadastral information and Google Street View were used to determine the classification of residential, commercial, industrial, educational, recreational and other use (sheds and the like) buildings.

Four noise catchment areas (NCA) have been determined for the noise and vibration assessment and all four NCAs are identified in **Appendix B.**

2.3 Ambient noise monitoring

Ambient noise monitoring was undertaken at six locations throughout the study area. Four locations were located surrounding the Hornsby Quarry site, while an additional two locations measured traffic noise on the Pacific Highway. Noise monitoring was undertaken in two separate periods, December 2013 and March/April 2015. The initial set of measurements was undertaken as part of the NorthConnex noise monitoring regime. Additional measurement locations were identified through the course of this project and undertaken during the second period of measurements. Considering there have been no appreciable changes to the local noise environment, both sets of measurements are considered representative.

The noise monitoring locations were chosen through examination of aerial photography and a site inspection to determine surrounding sensitive receivers. Attended noise measurements were also undertaken to determine the nature of the local noise environment. The purpose of the attended noise measurements was to gain an appreciation of the local noise environment. The results of the attended measurements corroborate the unattended noise logging data, which are presented in **Appendix C.**

The background noise logging locations are illustrated in **Appendix B.** The noise logging results are provided graphically in **Appendix C.**

A noise logger measures the noise level over the sample period and then determines L_{A1}, L_{A10}, L_{A90}, L_{Amax} and L_{Aeq} levels of the noise environment. The L_{A1}, L_{A10} and L_{A90} levels are the levels exceeded for 1%, 10% and 90% of the sample period respectively. The L_{Amax} is indicative of maximum noise levels due to individual noise events. The L_{A90} is taken as the background noise level. The L_{Amax} is the energy averaged noise level over a defined period.

The results of the noise monitoring have been processed in accordance with the procedures contained in the RNP, INP and the ICNG. Weather data recorded during the noise monitoring survey periods was obtained from the Bureau of Meteorology weather station, located at Terrey Hills. Periods which were affected by noise from extraneous wind and rain were omitted from the results.

Details of each noise logging location and the noise monitoring equipment are provided in **Table 2-1**.

Table 2-1 Noise logging locations

Noise logging location	Address	Logger type / Serial number	Measurement period
NL01	Manor Road	ARL 215 / 194444	11 December 2013 to 17 December 2013
NL02	Quarry Road	ARL 215 / 194535	11 December 2013 to 17 December 2013
NL03	Bridge Road	ARL 316 / 16-707-038	11 December 2013 to 17 December 2013
NL04	Rosemead Road	Rion NL21 376378	4 March 2015 to 10 March 2015
NL05	1 Lodge Street	ARL 215 / 15-203-504	26 March 2015 to 2 April 2015
NL06	140 Pacific Highway	ARL 215 / 15-203-506	26 March 2015 to 2 April 2015

2.4 Unattended background noise monitoring results

The background noise monitoring results are provided in **Table 2-2**. These noise levels were used to define the appropriate construction noise management levels, consistent with the ICNG.

The assessment background levels (ABL) were established by determining the lowest tenth-percentile level of the L_{A90} noise data acquired over each assessment period of interest. The background noise level or rating background levels (RBL) representing the day, evening and night-time assessment periods were based on the median of individual ABLs determined over the entire monitoring duration.

Table 2-2 Rating background levels

Noise logging location	Rating background level dB(A)		
	Day (7am to 6pm) $L_{A90,15\ minute}$	Evening (6pm to 10pm) $L_{A90,15\ minute}$	Night (10pm to 7am) $L_{A90,15\ minute}$
NL01	43	36	32
NL02	39	33	33
NL03	37	37(39)1	32
NL04	34	34(36)1	31

Note 1: Application notes to the INP indicate that the community generally expects a greater control of noise during the evening and night as compared to the day time. Therefore the evening is set to no more than that for the daytime and the night-time to no more than the evening.

The noise levels presented in **Table 2-2** indicate that the measurement locations are typical of suburban noise environments located alongside transport corridors (such as the Pacific Highway), where daytime and evening background levels are higher due to heavy and continuous traffic flows. The night-time background levels tend to decrease as a result of reduced traffic flows.

2.5 Operational road noise monitoring results

Table 2-3 and **Table 2-4** show the average noise levels measured at each noise monitoring location for arterial/sub-arterial roads and local roads respectively, which would be potentially affected by increased traffic travelling to the site.

Table 2-3 Existing arterial / sub-arterial road traffic noise monitoring results

Noise logging location	Ambient road traffic noise level dB(A)	
	Day (7 am – 10 pm) ($L_{Aeq, (15 hour)}$)	Night (10 pm – 7am) ($L_{Aeq, (9 hour)}$)
NL05	62	54
NL06	75	71

Table 2-4 Existing local road traffic noise monitoring results

Noise logging location	Ambient road traffic noise level dB(A)	
	Day (7 am – 10 pm) ($L_{Aeq, (1 hour)}$)	Night (10 pm – 7am) ($L_{Aeq, (1 hour)}$)
NL02	53	49

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3 Assessment criteria

3.1 Construction noise

The risk of adverse impact of construction noise on a community is determined by the extent of its exceedance beyond existing background noise levels, the duration of the event and the characteristics of the noise.

The ICNG is a NSW Government document that sets out ways to assess and manage the impact of construction noise on noise sensitive land receivers. It presents assessment approaches tailored to the scale of the construction project and identifies practices to minimise noise impacts.

As discussed in **Section 1.5** the project would facilitate the construction of the approved NorthConnex project. The works would be temporary and would take place over a defined term (rather than indefinitely). The project is directly related to construction activities associated with the NorthConnex project. The generation of spoil and the need for an appropriate spoil management location is a fundamental and unavoidable consequence of the construction of a road and associated road infrastructure facilities. On this basis the ICNG is the appropriate policy under which to assess the noise impacts of the project.

The ICNG recommends that a quantitative assessment is carried out for all major construction proposals that are typically subject to the environmental impact assessment processes. A quantitative assessment, based on the likely construction scenarios, has therefore been carried out for the project.

Predicted noise levels at nearby noise sensitive receivers (e.g. residences, schools, hospitals, places of worship, passive and active recreation areas) are compared to the levels provided in Tables 2 and 3 and section 4.1.3 of the ICNG (as reproduced below).

Where an exceedance of the management levels is predicted, the ICNG advises that receivers can be considered 'noise affected' and the proponent should apply all feasible and reasonable work practises to minimise the noise impact. The proponent should also inform all potentially impacted receivers of the nature of the works to be carried out, the expected noise level and duration, as well as contact details.

Where construction noise levels reach 75 dB(A) residential receivers can be considered as 'highly noise affected' (as per Table 2 of the ICNG, reproduced below) and the proponent should, in consultation with receivers, consider restricting hours to provide respite periods.

The ICNG defines what is considered to be feasible and reasonable as follows:

- *Feasible*

A work practice or abatement measure is feasible if it is capable of being put into practice or of being engineered and is practical to build given project constraints such as safety and maintenance requirements.

- *Reasonable*

Selecting reasonable measures from those that are feasible involves making a judgment to determine whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the measure.

Work that is proposed outside of standard working hours, as defined in the ICNG, generally requires strong justification.

Noise management levels for residential receivers are derived using the information in **Table 3-1**.

Table 3-1 Noise at residences using quantitative assessment, extract from Table 2 of the Interim Construction Noise Guideline

Time of day	Management level LAeq (15 min)1	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB(A)	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: – Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences. – If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB(A)	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see Section 7.2.2 of the ICNG.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 meters above ground level. If the property boundary is more than 30 metres from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 metres of the residence. Noise levels may be higher at upper floors of the noise affected residence.

3.1.1 Noise catchment areas

The study area has been divided into four distinct NCAs. The noise environment at each of the sensitive receivers within a NCA is considered to have a similar noise environment to the unattended monitoring location within that NCA. As such, each of these sensitive receivers is assigned the same background noise level and noise management level.

The location of each NCA is provided graphically in **Appendix B.** Noise catchment areas have been defined through operated attended noise measurements and a detailed site survey of the area.

- NCA01 was located on the northern side of the Hornsby Quarry. It was generally setback from major transport infrastructure corridors, which generally control background noise throughout the study area. The noise logger was setback from the transport infrastructure corridors a considerable distance to ensure that a conservative noise criteria was calculated.
- NCA02 was selected as it is located closer to, and hence was more affected by, the transport infrastructure corridors. The noise logger location was chosen to be the least affected by road and rail noise, hence providing conservative noise criteria for the catchment area.
- Like NCA01, NCA03 was chosen to be set back from the transport infrastructure corridors on the southern side of the proposed works.
- NCA04 was selected as it is further into the valley than the other catchment areas, providing additional shielding from transport infrastructure, which controls background noise levels throughout the local area. The noise logger was located adjacent to sensitive receivers that would be most highly affected throughout the catchment area.

Provided in **Table 3-2** are details of the construction noise management levels for each NCA.

Table 3-2 Noise catchment areas and noise management levels

NCA	Representative logger	Period	Rating background level[1] (RBL)	Noise management levels (NML) [2,3]
NCA01	NL04[4]	Day	34	44
		Evening	34	39
		Night	31	36
NCA02	NL02	Day	39	49
		Evening	33	38
		Night	33	38
NCA03	NL03	Day	37	47
		Evening	37	42
		Night	32	37
NCA04	NL04	Day	34	44
		Evening	34	39
		Night	31	36

Note 1: Application notes to the Industrial Noise Policy indicate that the community generally expects a greater control of noise during the evening and night as compared to the day time. Therefore the rating background level for the evening is set to no more than that for the daytime and the night-time to no more than the evening.
Note 2: Day noise management levels = RBL + 10 dB
Note 3: Evening / night noise management levels = RBL + 5 dB
Note 4: Previous noise logging in the area has identified that noise levels can be considerably lower to those measured for this project. The increased noise levels measured for this project have been attributed to seasonal conditions. To account for the lower noise levels a more conservative representative noise logger from the project has been selected.

3.1.2 Non-residential criteria

Noise management levels recommended by the ICNG for other sensitive land uses, such as schools, hospitals or places of worship are shown in **Table 3-3**. Noise management levels for commercial and industrial premises are provided in **Table 3-4**.

Table 3-3 Construction noise management levels – Sensitive land uses other than residential, extract from Table 3 of the Interim Construction Noise Guideline

Land use	Management level, $L_{Aeq\ (15\ min)}$ (applies when properties are in use)
Classrooms at schools and other educational institutions	Internal noise level 45 dB(A)
Hospital wards and operating theatres	Internal noise level 45 dB(A)
Places of worship	Internal noise level 45 dB(A)
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dB(A)
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, for example, reading, meditation)	External noise level 60 dB(A)
Community centres	Dependent on the intended use of the centre. Refer to the recommended "maximum" internal levels in AS2107 for specific uses.

Table 3-4 Construction noise management levels – Commercial and industrial land uses, extract from Section 4.1.3 of the Interim Construction Noise Guideline

Land use	Management level, $L_{Aeq\ (15min)}$ (applies when properties are in use)
Industrial premises	External noise level 75 dB(A)
Offices, retail outlets	External noise level 70 dB(A)

3.1.3 Sleep disturbance

The ICNG requires a sleep disturbance assessment to be undertaken where construction works are planned to extend over more than two consecutive nights. The ICNG makes reference to the EPA's NSW Environment Criteria for Road Traffic Noise (ECRTN), now superseded by the NSW Road Noise Policy (RNP), for assessment of sleep disturbance. The RNP references the recommendations in the ECRTN as providing the most appropriate assessment guidance.

The guidance provided in the RNP for assessing the potential for sleep disturbance recommends that to minimise the risk of sleep disturbance during the night-time period (10pm to 7am), the LA1(1 min) noise level outside a bedroom window should not exceed the $L_{A90\ (15\ minute)}$ background noise level by more than 15 dB. The EPA considers it appropriate to use this metric as a screening criterion to assess the likelihood of sleep disturbance. If this screening criterion is found to be exceeded then a more detailed analysis must be undertaken and include the extent that the maximum noise level exceeds the background noise level and the number of times this is likely to happen during the night-time period.

The RNP contains a review of research into sleep disturbance which represents NSW EPA advice on the subject of sleep disturbance due to noise events. It concludes that having considered the results of research to date that, 'Maximum internal noise levels below 50-55 dB(A) are unlikely to cause awakening reactions'. Therefore, given that an open window provides around 10 dB(A) in noise attenuation from outside to inside, external noise levels of 60-65 dB(A) are unlikely to result in awakening reactions.

Provided in **Table 3-5** are the sleep disturbance screening and sleep disturbance awakening reaction criteria that would apply to the project if night works were undertaken. However it is not proposed that any works be undertaken outside of standard construction hours.

Table 3-5 Construction Noise sleep disturbance criteria

NCA	Rating background level (RBL)	Sleep disturbance screening $L_{A1(1min)}$ criteria, dB(A)	Sleep disturbance awakening reaction $L_{A1(1min)}$ criteria, dB(A)
NCA01	31	46	65
NCA02	33	48	65
NCA03	32	47	65
NCA04	31	46	65

3.1.4 Construction road traffic noise

The ICNG does not provide direct reference to an appropriate criterion to assess the noise arising from construction traffic on public roads. However, as the RNP is the current state policy document for assessing road traffic noise and in absence of any alternative guidance it has been used to assess the noise arising from construction traffic movements generated by the project. The RNP does not require assessment of noise impact to commercial or industrial receivers.

The Pacific Highway and Bridge Road will provide the only access roads for spoil haulage to the site. While the functional use of the Pacific Highway can be considered to be arterial/sub-arterial, Bridge Road west of the Pacific Highway is considered to be a local road, in accordance with the RNP. Provided in **Table 3-6** are the road traffic noise criteria from the RNP. The external noise criteria are applied 1 metre from the external facade of the affected building.

Table 3-6 Road traffic noise criteria

Road category	Type of project/land use	Assessment criteria, dB(A) Day (7 am to 10 pm)	Night (10 pm to 7 am)
Arterial/sub-arterial roads	Existing residences affected by additional traffic on existing roads generated by land use developments	$L_{Aeq,15hr}$ 60	$L_{Aeq,9hr}$ 55
Local roads	Existing residences affected by additional traffic on existing roads generated by land use developments	$L_{Aeq,1hr}$ 55	$L_{Aeq,1hr}$ 50

In cases where existing traffic noise levels are above the noise assessment criteria, the primary objective is to reduce these through feasible and reasonable measures to meet the assessment criteria. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

This project will see a relatively small increase of traffic movements on existing arterial roads such as the Pacific Highway. For these roads (arterial/sub arterial road) the applicable daytime noise criterion is $L_{Aeq(15\ hour)}$ 60 dB(A) which applies to existing residences affected by additional traffic on existing roads. There are no proposed movements during the night-time period hence the night-time criterion is not relevant.

Considering Bridge Road is a local road, the applicable noise criteria is $L_{Aeq,1\ hour}$ 55 dB(A).

There are no proposed movements during the night-time period hence the night-time criterion is not relevant.

3.2 Construction vibration criteria

The relevant standards / guidelines for the assessment of construction vibration are summarised in **Table 3-7**.

Table 3-7 Standards / guidelines used for assessing construction vibration

Item	Standard / guideline
Structural damage	German Standard DIN 4150 – Part 3 – Structural Vibration in Buildings – Effects on Structures (DIN 4150)
Human comfort (tactile vibration) 1	Assessing Vibration: A Technical Guideline (AVATG)
Human comfort (regenerated noise)	Interim Construction Noise Guideline (ICNG)

Note 1: This document is based upon the guidelines contained in British Standard 6472:1992, "Evaluation of human exposure to vibration in buildings (1-80 Hz)". This British Standard was superseded in 2008 with BS 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings – Part 1: Vibration sources other than blasting" and the 1992 version of the Standard was withdrawn. Although a new version of BS 6472 has been published, the Environment Protection Authority still requires vibration to be assessed in accordance with the 1992 version of the Standard at this point in time.

Vibration and its associated effects are usually classified as continuous, impulsive or intermittent as follows:

- Continuous vibration continues uninterrupted for a defined period and includes sources such as machinery and continuous construction activities for example, a tunnel boring machine.

- Impulsive vibration is a rapid build up to a peak followed by a damped decay. It may consist of several cycles at around the same amplitude, with a duration of typically less than two seconds and no more than three occurrences in an assessment period. This may include occasional dropping of heavy equipment or loading activities.
- Intermittent vibration occurs where there is interrupted periods of continuous vibration, repeated periods of impulsive vibration or continuous vibration that varies significantly in magnitude. This may include intermittent construction activity, impact pile driving, jack hammers.

3.2.1 Structural damage

At present, no Australian Standards exist for the assessment of building damage caused by vibration.

DIN 4150 provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are presented in **Table 3-8**. DIN 4150 states that buildings exposed to higher levels of vibration than recommended limits would not necessarily result in damage.

Table 3-8 DIN 4150: Structural damage safe limits for building vibration

Group	Type of structure	Vibration velocity in mm/s			
		At foundation at a frequency of			Vibration at the horizontal plane of the highest floor
		Less than 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Lines 1 or 2 and have intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 8	8 to 10	8

3.2.2 Human comfort

Intermittent vibration

The assessment of intermittent vibration outlined in the EPA guideline Assessing Vibration: A Technical Guideline is based on Vibration Dose Values (VDVs). The VDV accumulates the vibration energy received over the daytime and night-time periods.

Maximum and preferred VDVs for intermittent vibration arising from construction activities are listed in Table 3-9. The VDV criteria are based on the likelihood that a person would be annoyed by the level of vibration over the entire assessment period.

Table 3-9 Preferred and maximum vibration dose values for intermittent vibration (m/s1.75)

Location	Daytime		Night-time	
	Preferred	Max	Preferred	Max
Critical areas	0.1	0.2	0.1	0.2
Residences	0.2	0.4	0.13	0.26
Offices, schools, educational institutions and places of worship	0.4	0.8	0.4	0.8
Workshops	0.8	1.6	0.8	1.6

Continuous and impulsive vibration

Acceptable levels of human exposure to continuous and impulsive vibration are dependent on the time of day and the activity taking place in the occupied space. Guidance on preferred values for continuous and impulsive vibration are presented in Table 3-10.

There is low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values in Table 3-10. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short duration. Vibration levels above those indicated in Table 3-10 may be dealt with through negotiation with the regulator of the affected community. The following axes are defined in relation to the human body:

- x – back to chest.
- y – right side to left side.
- z – foot to head.

Table 3-10 Preferred and maximum weighted root mean square values for continuous and impulsive vibration acceleration (m/s1.75) 1-80 Hz

Location	Assessment period	Preferred		Maximum	
		z axis	x and y axes	z axis	x and y axes
Continuous vibration					
Critical areas1	When in use	0.005	0.0036	0.010	0.0072
Residences	Day Night	0.010 0.007	0.0071 0.005	0.020 0.014	0.014 0.010
Offices, schools, educational institutions and places of worship	When in use	0.020	0.014	0.040	0.028
Workshops	When in use	0.040	0.029	0.080	0.058
Impulsive vibration					
Critical areas	When in use	0.005	0.0036	0.010	0.0072
Residences	Day Night	0.300 0.100	0.21 0.071	0.60 0.20	0.42 0.14

Location	Assessment period	Preferred		Maximum	
		z axis	x and y axes	z axis	x and y axes
Offices, schools, educational institutions and places of worship	When in use	0.640	0.46	1.28	0.92
Workshops	When in use	0.640	0.46	1.28	0.92

Note 1: Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria.

3.3 Ground-borne noise

Vibration generated by activities such as vibratory rolling or tunnelling may enter buildings via the ground. This causes the floors, walls and ceilings to vibrate and to radiate noise. This noise is commonly referred to as structure or ground-borne noise or regenerated noise. Ground-borne noise is typically low frequency and if audible, is perceived as a 'rumble'.

In general, ground-borne noise level values are relevant only where they are higher than the airborne noise from the construction activities such as where tunnelling activities are being undertaken. Regenerated noise levels would typically be masked by airborne noise associated with construction activities associated with surface road construction activities.

For these works, due to construction techniques and the large offset distances between the work site and sensitive receivers, ground-borne noise is very unlikely to be an issue. On this basis a detailed assessment of ground-borne noise from the project activities has not been undertaken.

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4 Construction noise and vibration assessment

4.1 Assessed activities

Provided in **Table 4-1** are the assessed stages and the typical equipment that will be used. The noisiest activities have been considered as part of this assessment. Council has an existing licence for the extraction (pumping) of water from the quarry void and at present Council undertakes dewatering on an as-needed basis to maintain the water levels of the void. The initial dewatering of the void by Council, which would be undertaken under its existing licence and is expected to occur ahead of the commencement of any other site works, is not anticipated to involve any additional noise impacts than current Council dewatering operations and as such has not been considered further in this assessment. However the cumulative noise impact from maintenance pumping and the proposed activities assessed here are considered further in **Section 4.6**.

There are currently no proposed out of hours works for this project. As such out of hours works are not considered in this assessment. However, as detailed in **Section 1.5.1**, limited works may be undertaken outside of standard daytime construction hours in the following circumstances:

- The delivery of materials as required by the Police or other authorities for safety reasons.
- Where it is required to avoid the loss of lives, property and / or to prevent environmental harm in an emergency.
- Where agreement is reached with affected receivers.
- Activities which are determined to comply with the relevant Noise Management Level (NML) at the most affected sensitive receiver, excluding activities associated with the transport and handling of spoil. Such activities may include refuelling of plant and equipment maintenance.

Table 4-1 outlines the project activities and associated equipment and sound power levels. The table also identifies controlling noise sources for each phase. Controlling sources are plant or equipment which emit the highest sound power levels and therefore have the highest contribution to noise levels in that phase.

These sound power levels are typical values taken from data provided in the Australian Standard AS2436-2010, Guide to noise control on construction, demolition and maintenance sites and the UK Department for Environment, Food and Rural Affairs (DEFRA) noise database and assume equipment is modern and in good working order. Based on experience of the acoustic consultant, L_{A1} sound power levels are typically up to 8 dB(A) above LAeq sound power levels. The range and types of equipment used may be subject to change and would be confirmed during the detailed design phase.

Table 4-1 Construction equipment

Scenario	Activity	Assumptions	Equipment used	SWL, dB(A)
1	Preparatory works / site establishment	Based on the duty cycle and simultaneous equipment operating provided by the contractor, the overall Sound Power Level (SWL) has been calculated to be 117 dB(A).	Mulchers with fixed hoarding	110*
			Water pumps	96
			Tipper Trucks	98
			Roller	101
			Grader	105
			Fuel Delivery / service truck	98
			Lighting tower	93
			Generator	93
			Excavator	112*
2	Maintenance	This work is	Lighting tower	93

Scenario	Activity	Assumptions	Equipment used	SWL, dB(A)
	pumping of the quarry void	approved under the existing Council licence conditions. Assessed as a cumulative impact. The overall SWL has been calculated to be 99 dB(A).	Fuel delivery / service truck	98
			Generator	93
			Submersible pump	90
3	Conveyor construction works	Based on the duty cycle and simultaneous equipment operating provided by the contractor, the overall SWL has been calculated to be 117 dB(A).	Excavator + breaker	112*
			Lifting crane	98
			Tipper trucks	98
			Water cart	100
			Lighting tower	93
			Fuel delivery / service truck	98
			Generators	93
			Concrete truck	105
			Concrete pump	105
			Vibrators	97
			Submersible pump	90
			Backhoe	102
			Delivery truck	98
4	Spoil emplacement activities	Based on the duty cycle and simultaneous equipment operating provided by the contractor, the overall SWL has been calculated to be 119 dB(A).	Belt conveyors	105
			Dozers D7	111*
			Dozers D8	114*
			Front end loaders	110*
			Roller	101
			Dump truck	95
			Water Cart	100
			Trucks out	106
			Trucks in	102
			Fuel delivery / service truck	98
			Generators	93
			Workshop	95
5	Site demobilisation	Based on the duty cycle and simultaneous equipment operating provided by the contractor, the overall SWL has been calculated to be 117 dB(A).	Dozer	114*
			Lifting cranes	98
			Tipper trucks	95
			Excavators	112
			Water cart	110*
			Grader	105
			Roller	105
			Fuel delivery / service truck	98
			Generator	93

* Controlling noise source(s) in the identified phase.

Work within the quarry void (spoil emplacement scenario) has been assessed with an RL of 64 metres which is equivalent to the approximate level that will be achieved once 1.5 million cubic metres of spoil has been placed in the quarry. This is considering plant operating at a worst case floor height within the quarry void. In reality works within the void would be operating at a lower height for the majority of the works and noise levels generated by the works would experience additional shielding from the void. However the worst case location of works has been assessed here to present a conservative assessment.

Preparatory works would last approximately one month and be immediately followed by site establishment works for an approximate total three month duration. These works have been assessed as one phase. The conveyor establishment would last about three months, of which about two months would overlap the site establishment works. The conveyor establishment phase includes equipment used in the site establishment phase to ensure the cumulative nature of the works would be accounted for. Spoil disposal activities would last about 28 months and would be followed by site clean up, demolition and rehabilitation which would extend for no more than about two months. In total the entire project would last for around 33 months.

4.2 Construction noise modelling and prediction

Noise levels resulting from the project have been predicted at nearby residences using SoundPLAN noise modelling software v7.3. The modelling used the ISO9613 algorithm and includes ground topography, buildings and structures and representative construction noise sources as detailed in **Table 4-1**. Free field point receivers at 1.5 metres high were assumed.

The noise modelling has assumed that as a worst-case the most noise intensive activities are occurring at the closest point to each sensitive receiver location. In practice this is either unlikely to occur, or would only occur for a short period of time. As such the noise modelling can be considered somewhat conservative. To account for this, a range of noise levels has been presented in the results tables. The average noise level has been presented indicating the typical noise level throughout the NCA while the maximum noise level shows the highest noise level that could be experienced at the most affected noise sensitive receiver in that NCA.

It can be expected that there may be differences between predicted and measured noise levels due to variations in instantaneous operating conditions, plant in operation during the measurement and also the location of the plant equipment. The acoustic shielding calculated in the model due to fixed building structures would also vary as the construction equipment moves around the site. Neutral weather conditions were assumed for all construction scenarios.

Noise mounds of approximately five metres surrounding the stockpiling area have been included in the noise modelling to provide a practicable level of noise mitigation. The noise mounds would be established during the site establishment phase (once works on Bridge Road are completed) and will take approximately three weeks to establish. During peak times stockpiles will be up to about five metres high and provide additional shielding, further reducing noise levels at sensitive receiver locations. Stockpiles have not been accounted for in the noise modelling in order to provide a conservative assessment.

Hoarding has also been included surrounding stationary plant (feeders and mulchers). Unless otherwise stated all construction equipment has been assumed to be operating simultaneously.

4.2.1 Construction noise assessment

The noise modelling results for standard hours of work are provided in **Table 4-2**. The table presents the NMLs and the averaged noise levels for residential receivers in each noise catchment area. The table also presents the number of residential receivers where the noise levels are predicted to exceed the NML and the highly noise affected level for each NCA. The impact at individual receivers is provided graphically in the form of noise contours in Appendix D.

Table 4-2 Standard hours work predicted noise at residential receivers

NCA	L_{Aeq} Noise management level dB(A)[1]	Predicted average L_{Aeq} noise level in the NCA dB(A)	Predicted maximum L_{Aeq} noise level in the NCA dB(A)	Maximum exceedance above criteria	Number of receivers where NMLs are exceeded	Number of highly noise affected receivers[2]
Preparatory works (1 month) / Site establishment (3 months)						
NCA01	44	55	67	23	126	0
NCA02	49	57	72	23	93	0
NCA03	47	61	67	20	63	0
NCA04	44	52	60	16	34	0
Total					**316**	0
Conveyor construction works (3 months)						
NCA01	44	48	64	20	81	0
NCA02	49	48	62	13	44	0
NCA03	47	52	58	11	50	0
NCA04	44	35	48	4	2	0
Total					**177**	0
Conveyor construction and haulage (during final month of conveyor construction phase)						
NCA01	44	48	64	20	79	0
NCA02	49	49	66	17	46	0
NCA03	47	52	58	11	47	0
NCA04	44	36	48	4	2	0
Total					**174**	0
Spoil emplacement activities and spoil haulage (28 months)						
NCA01	44	49	63	19	89	0
NCA02	49	50	67	18	54	0
NCA03	47	52	58	11	49	0
NCA04	44	39	50	6	2	0
Total					194	0
Site demobilisation (no more than 2 months)						
NCA01	44	55	67	23	126	0
NCA02	49	57	72	23	93	0
NCA03	47	61	67	20	63	0

NCA	L_{Aeq} Noise management level dB(A)[1]	Predicted average L_{Aeq} noise level in the NCA dB(A)	Predicted maximum L_{Aeq} noise level in the NCA dB(A)	Maximum exceedance above criteria	Number of receivers where NMLs are exceeded	Number of highly noise affected receivers[2]
NCA04	44	52	60	16	34	0
Total					**316**	0

Note 1: Noise management levels are explained in Table 3-1.

Note 2: Highly noise affected is considered to be ≥ 75 dB(A).

It is important to consider that this assessment is representative of the worst case 15 minute periods of activity and does not necessarily represent the noise impact at noise sensitive receivers for an extended period of time. Particularly noisy activities, such as mulching, are likely to persist for only a fraction of the overall construction period. In addition the predictions use the shortest separation distance to each sensitive receiver, however in reality separation distances would vary between plant and sensitive receivers. The works with the highest noise impact are also the works with the shortest duration at the start of the project. Due to the nature of the works, they would take place prior to establishing the noise mounds.

The noise levels in **Table 4-2** indicate that noise levels during the most intensive activities would generally exceed the applicable NML at the most affected residential receivers. For the first row of receivers (the most affected receivers) overlooking the site, exceedences of up to 23 dB(A) could be experienced during times of noise intensive works. Rather than a criterion, the NML is a trigger level that requires all feasible and reasonable noise management and mitigation measures to be employed within the project. This exceedance of the NML is typical of a construction project and highlights the need for a detailed CNVMP to ensure that all feasible and reasonable noise management and mitigation measures are employed. Noise management and mitigation measures are discussed further in **Section 5.1**.

The ICNG states that where a construction noise impact level of greater than 75 dB(A) is predicted, a receiver must be considered ‘highly noise affected’ and afforded additional consideration. While all feasible and reasonable noise mitigation would be considered for receivers exceeding the NMLs, highly affected receivers are a much greater concern for construction noise. The modelling for this project has identified that no receivers are likely to be highly noise affected. The potential for highly noise affected receivers would be confirmed during detailed project planning and, if required, additional consideration of specific timing and impacts of works would be undertaken. Respite periods would also be considered if any highly affected receivers are identified, in accordance with the ICNG.

The predictions indicate that noise levels at commercial and industrial receivers would remain compliant with the applicable noise management levels.

Considering the predicted noise levels are generally considered to be worst-case the exceedances are not considered to be significant, given the nature of the work. Due to local terrain conditions, sensitive receivers look directly over the top of the site and reasonable hoarding height is unlikely to be effective in achieving compliance with the NMLs. As such alternative reasonable and feasible noise management and mitigation measures must be employed by the contractor to minimise potential noise impact from the project wherever practicable. Detailed consideration of feasible and reasonable noise management measures and consultation with individual affected receivers should be undertaken to further minimise impacts as the design develops. Section 5.1 provides an outline of management and mitigation measures that are recommended to be considered in the Contractor’s CNVMP.

4.2.2 Construction noise assessment discussion

Discussion has been provided below for each catchment area providing more detail on the potential impacts of the project. The discussion has focused on the existing ambient noise levels rather than the NML. The existing ambient noise levels are the typical noise levels across the day. At times the noise levels will drop below the typical ambient noise levels, at which point the severity of impacts would increase. The NMLs provide a means of identifying which activities are likely to cause the worst case impacts. It is important to consider the NMLs as they provide a target which should be strived for through the provision of feasible and reasonable noise mitigation.

However, the NMLs do not provide realistic understanding of what the impact would be most of the time. The discussion below is based on the highest noise impacts for the most affected receivers and typical receivers (located one or two rows behind the most affected receiver). While the noise levels discussed are accurate, qualitative assessment of the noise levels referenced (based on the amount construction noise impedes on ambient noise levels) is flexible. This will change as noise levels rise and fall throughout the day (as discussed above, background noise levels may also be seasonally dependent at this location).

It is noted that the NMLs are generally more than 5 dB(A) below the ambient noise levels. In some cases noise levels at the NML would be approaching inaudibility.

NCA1

The existing background noise level (the noise level exceeded 90% of the time) in the area during the daytime is 34 dB(A). The daytime NML is 44 dB(A). The existing ambient noise levels within the catchment area are 51 dB(A) (based on the noise logging location at Rosemead Road (NL04)).

The phase with the highest noise impact would be the site establishment phase. During this phase the most affected receiver could experience noise levels up to 67 dB(A). This noise level would be appreciably higher than the ambient noise levels and noise from this phase could be intrusive at times. Typical noise levels as equipment moves further away or works become less intensive would generally remain above ambient noise levels. Respite would be provided during periods of low work intensity when noise levels from works are expected to drop below ambient noise levels.

The maximum noise level experienced by receivers in the second or third row back from the site during the site establishment phase would be approximately 55 dB(A). This noise level would be 4 dB(A) higher than existing ambient noise levels, which although clearly audible would not be expected to be intrusive. Typical noise levels as equipment moves further away or works become less intensive would be expected to drop below ambient noise levels.

Activities associated with spoil haulage and emplacement would occur over the longest duration. During spoil emplacement works, the most affected receiver within NCA1 is predicted to experience noise levels up to 63 dB(A). This noise level would be 12 dB(A) higher than ambient noise levels and is likely to be moderately intrusive. An increase of 10 dB(A) is considered to sound like a doubling of noise. Typical noise levels as equipment moves further away or works become less intensive would generally remain above existing ambient noise levels. Respite would be provided during periods of low work intensity when noise levels associated with project works are expected to drop below ambient noise levels.

The maximum noise level experienced for receivers in the second or third row back from the site during the spoil haulage and emplacement phase would be approximately 49 dB(A). This noise level would be below existing ambient noise levels, which although audible would not be expected to be intrusive. Typical noise levels as equipment moves further away or works become less intensive would approach, and in some cases comply with, the NML.

NCA2

The existing background noise level (the noise level exceeded 90% of the time) in the area during the daytime is 39 dB(A). The daytime NML is 49 dB(A). The existing ambient noise levels within the catchment area are 51 dB(A).

The phase with the highest noise impact would be the site establishment phase. During this phase the most affected receivers on Bridge Road and Roper Lane could experience noise levels up to 72 dB(A). This noise level would be appreciably higher than the ambient noise levels and would likely be intrusive at times. These noise levels would not result in receivers being highly noise affected. Typical noise levels as equipment moves further away or works become less intensive would generally remain above ambient noise levels. Respite would be provided during periods of low work intensity.

The maximum noise level experienced for receivers in the second or third row back from the site during the site establishment phase would be approximately 57 dB(A). This noise level is 6 dB(A) higher than existing ambient noise levels and is likely to be audible during the most noise intensive activities. Typical noise levels as equipment moves further away and works become less intensive would be expected to drop below ambient noise levels.

Activities associated with spoil haulage and emplacement would occur over the longest duration. During this period the most affected receiver within NCA2 is predicted to experience noise levels up to 67 dB(A). This noise level would be 16 dB(A) higher than ambient noise levels and is likely to be moderately intrusive. An increase of 10 dB(A) is considered to sound like a doubling of noise. Typical noise levels as equipment moves further away or works become less intensive would generally remain above existing ambient noise levels. Respite would be provided during periods of low work intensity when works are expected to drop below ambient noise levels.

The maximum noise level experienced for receivers in the second or third row back from the site during the spoil haulage and emplacement phase would be approximately 50 dB(A). This noise level is below existing ambient noise levels and maybe audible, however it would not be expected to be intrusive. Typical noise levels as equipment moves further away or works become less intensive would approach and may often comply with the NML.

Some receivers within NCA2 would also be affected by construction traffic noise. This is discussed further in **Section 4.3**.

Some classrooms located in the Hornsby TAFE look directly over the project site. The internal noise criterion is 45 dB(A) for educational institutions. With windows closed, a typical noise insertion loss of 20 dB(A) can be achieved as defined in Section 4, Table 4.2 of the Roads and Maritime Services (formerly Roads and Traffic Authority) Environmental Noise Management Manual (Roads and Traffic Authority, 2001). External noise levels at the Hornsby TAFE are predicted to be up to 74 dB(A) during noise intensive activities associated with the site establishment phase of the project. This equates to an internal noise level of 54 dB(A), resulting in an exceedance of the internal noise criterion. It is noted that these noise levels would only be for a limited portion of the overall establishment phase, which in total is approximately three months and as the controlling noise sources are the mulchers which would not be used continuously during site establishment. External noise levels for the ‘conveyor construction and haulage’ and ‘spoil haulage and emplacement’ phases are predicted to be up to 67 dB(A) and 66 dB(A) respectively, which would exceed the external noise levels at the TAFE for these phases by 2 dB(A) and 1 dB(A), respectively. Ongoing consultation will be undertaken with Hornsby TAFE to ensure potential noise impacts are appropriately managed. Noise management and mitigation measures are discussed further in **Section 5.1**.

NCA3

The existing background noise level (the noise level exceeded 90% of the time) in the area during the daytime is 37 dB(A). The daytime NML is 47 dB(A). The existing ambient noise levels within the catchment area are 51 dB(A) during the daytime.

The phase with the highest noise impact would be the site establishment phase. During this phase the most affected receivers on Bridge Road and Roper Lane could experience noise levels up to 67 dB(A). This noise level is appreciably higher than the ambient noise levels and is likely to be moderately intrusive at times. These noise levels would not result in receivers being highly noise affected. Typical noise levels as equipment moves further away or works become less intensive would generally remain above ambient noise levels. Respite would be provided during periods of low work intensity.

The maximum noise level experienced for receivers in the second or third row back from the site during the site establishment phase would be approximately 61 dB(A). This noise level is 10 dB(A) higher than existing ambient noise levels, and is likely to be moderately intrusively at times. Typical noise levels as construction plant moves further away and works become less intensive would be expected to remain above ambient noise level.

Activities associated with spoil haulage and emplacement would occur over the longest duration. During this period the most affected receiver within NCA3 is predicted to experience noise levels up to 58 dB(A). This noise level would be 7 dB(A) higher than ambient noise levels and is likely to be clearly audible. Typical noise levels as equipment moves further away or works become less intensive would at times drop below ambient noise levels.

The maximum noise level experienced for receivers in the second or third row back from the site during the spoil haulage and emplacement phase would be approximately 52 dB(A). This noise level would be marginally higher than existing ambient noise levels, which although audible would not be expected to be intrusive. Typical noise levels as equipment moves further away or works become less intensive would approach, and in some cases comply with, the NML.

NCA4

The existing background noise level (the noise level exceeded 90% of the time) in the area during the daytime is 34 dB(A). The daytime NML is 44 dB(A). The existing ambient daytime noise levels within the catchment area are 51 dB(A).

The phase with the highest noise impact would be the site establishment phase. During this phase the most affected receivers on Bridge Road and Roper Lane could experience noise levels up to 60 dB(A). This noise level would be higher than the ambient noise levels and would be likely to be moderately intrusive at times. These noise levels would not result in receivers being highly noise affected. Typical noise levels as equipment moves further away or works become less intensive would generally remain above ambient noise levels. Respite would be provided during periods of low work intensity.

The maximum noise level experienced for receivers in the second or third row back from the site during the site establishment phase would be approximately 52 dB(A). This noise level would be 1 dB(A) higher than existing ambient noise levels, which may be audible at times, but would generally not be considered intrusive. Typical noise levels as equipment moves further away and works become less intensive would be expected to drop to or below the NML, which is below ambient noise levels.

Activities associated with spoil haulage and emplacement would occur over the longest duration. During this phase the most affected receiver within NCA4 is predicted to experience noise levels up to 50 dB(A). This noise level would be 1 dB(A) below ambient noise levels. While these noise levels may be audible at times, they would not be expected to be intrusive.

The maximum noise level experienced for receivers in the second or third row back from the site during spoil haulage and emplacement would be approximately 39 dB(A). This noise level would be compliant with the NML and would be well below existing ambient noise levels, which would be approaching inaudibility. It is unlikely that the works would be intrusive for these receivers.

As detailed in **Section 4.2**, the predicted noise levels for the project are conservative due to the conservative assumptions of the noise modelling and in practice noise levels would typically be lower than discussed in this section. Acoustic shielding provided by stockpiles, likely to be up to about five metres high, has not been included in the model. Additionally, the noise modelling has been completed on a worst case basis, assuming the most noise intensive activities would be occurring at the closest point to each sensitive receiver and that all equipment would be operating simultaneously. While this worst case situation is unlikely, in practice if it did occur it is likely the noise would occur for only a short time and at lower levels than those discussed in this section.

4.2.3 Out of hours work activities

As discussed in **Section 4.1** out of hours work is currently not proposed. As such out of hours work and a sleep disturbance assessment has not been undertaken.

4.3 Construction road traffic noise

Construction road traffic noise would be generated by vehicles associated with the project, including heavy vehicles transporting spoil. The majority of traffic flows would be along major roads. Bridge Road is the only local road proposed to be used for haulage truck entry and exit to the stockpiling area in Old Mans Valley, and therefore only a short length of road would be influenced.

In order to consider a worst case scenario, the road traffic noise assessment has been based on the following:

- Predicted existing road traffic noise levels, using traffic projections for traffic volumes for 2016 in the 15-hour day time period for arterial/sub arterial roads and in the 1-hour day time period for local roads (refer to technical working paper: traffic and transport (AECOM, 2015)).
- The peak period of construction activity and vehicle movements, being the tunnelling stage of the NorthConnex project. The assessment considers truck movements during the day-time only.
- The haulage of spoil to the Hornsby Quarry site requires all heavy vehicles transporting spoil to use the same routes. All construction vehicles would be on the road network at the same time (presenting a cumulative impact).

Initially a peak number of 50 trucks per hour into the site was considered by the project and this noise assessment. A maximum of 550 trucks per day into the site was considered best for project to enable a reduced overall project timeframe that aligned with the anticipated spoil generation from the NorthConnex project. On this basis, the predicted increase in road traffic noise for the AM and PM peaks are expected to be under 2 dB(A) for arterial/sub arterial roads and are therefore within the recommended construction traffic noise goal.

Traffic movements would increase significantly on Bridge Road as a result of the spoil haulage. Road traffic noise levels were predicted to increase by almost 12 dB(A)at sensitive receiver locations, exceeding the increase of 2 dB(A) road traffic noise criterion.

A sensitivity analysis was undertaken to determine a more manageable number of movements that would achieve compliance. It was determined that a maximum of five trucks per hour would achieve compliance. However this number of movements is not feasible to make the project viable as it would unacceptably extend the duration of spoil haulage and would not be consistent with the rate of spoil generation by the NorthConnex project. To ensure the potential noise impact from the project is minimised as far as practicable, while adopting a number that makes the project viable, the maximum number of haulage trucks per hour into the site was decreased to 35. This decrease resulted in exceedances on Bridge Road (west of Pacific Highway) being reduced to 7.3 dB(A) in the peak hour and 10 dB(A) in the hour with the lowest existing traffic flows. Whilst these levels are still non-compliant, they are considered a realistic balance between the project’s objectives and ensuring all noise impacts are minimised as far as feasibly and reasonably possible.

Mitigation and management recommendations have been provided in **Section 5.1**. Additional noise management and mitigation measures would be considered in detail in consultation with sensitive receivers where there are residual noise exceedances. Detailed consideration of feasible and reasonable noise management and mitigation measures will include consideration of the nature and timing of impacts and the sensitivity of individual receivers to noise, so that tailored measures can be implemented to achieve acceptable outcomes for sensitive receivers.

Provided in **Table 4-3** is a summary of the existing, forecast additional traffic flow and the resultant noise increases for arterial/sub-arterial roads (as per **Table 3-6**). The flows are for both directions.

Table 4-3 Road traffic movements during day-time (15 hours) –arterial/ sub arterial roads

Route | Direction	15-hour flow Existing		Additional		Relative Noise Level increase, dB(A)
	Light	Heavy	Light	Heavy[1]	
Pacific Highway - North of Yirra Rd	13,185	401	0	770	1.5
Pacific Highway - South of Yirra Rd	19,943	718	0	770	1.0
Yirra Rd - East of Pacific Hwy	11,588	370	0	770	1.7
Pacific Highway - North of Wattle St	19,291	682	0	770	1.1
Pacific Highway - South of Wattle St	10,873	356	0	770	1.8
Jersey Street North	10,288	370	0	770	1.8
Pacific Highway - North of Bridge Rd	22,109	534	0	770	1.0
Pacific Highway - South of Bridge Rd	14,753	762	0	770	1.2
Pacific Highway - North of William St	14,152	835	0	770	1.2
Pacific Highway - South of William St	15,542	1,165	0	770	1.0
Pacific Highway - between Bridge Rd and Edgeworth David Ave	32,786	1,983	0	770	0.6
Pacific Highway - between Edgeworth David Ave and College Cres	31,756	1,989	0	770	0.6
Edgeworth David Avenue	14,194	605	0	770	1.3
Pacific Highway - between Bridge Rd and College Cres	28,119	1,824	0	770	0.6
Pacific Highway - East of Pretoria Parade	15,101	1,656	0	770	0.9

Note 1: 770 represents the number of haulage vehicles entering and leaving the site in the 15 hour period, noting that spoil haulage for the project is restricted to standard work hours (11 hours).

Provided in **Table 4-4** are the predicted noise impacts on the local road, Bridge Road, west of the Pacific Highway.

Table 4-4 Road traffic movements during day-time (1 hour) – local roads

Route | Direction	1-hour flow Existing		Additional		Relative Noise Level increase, dB(A)
	Light	Heavy	Light	Heavy	
Bridge Road (west of Pacific Highway) – Peak traffic hour	154	2	0	70	7.3
Bridge Road (west of Pacific Highway) – Lowest traffic hour	86	0	0	70	10.0

Given the speed limits on the local roads and the road gradients and curvatures it is unlikely that engine (compression) braking would be utilised by project traffic. In addition, spoil would only be transported during the day.

Access and egress by haulage trucks from the spoil emplacement area would be via Bridge Road. The receivers located on Bridge Road, to the east of Pacific Highway, would experience a relative noise increase of less than 2 dB(A).

It is noted that the results in **Table 4-4** appreciably exceed the increase in noise trigger level of 2 dB(A) during the peak and off-peak periods. At the most affected sensitive receiver (221 Pacific Highway, Hornsby) the maximum noise level is $L_{Aeq(1hour)}$ 57 dB(A) for west facing facades. With additional construction traffic the noise levels would increase to $L_{Aeq(1hour)}$ 64 dB(A), representing an increase of 7 dB(A). The existing noise levels for north facing façades are $L_{Aeq(1hour)}$ 64 dB(A) during the peak period (affected by Pacific Highway).

With the additional traffic this noise level would increase to 68 dB(A) (including traffic from the Pacific Highway. This represents an increase of 4 dB(A). This increase is lower than the 7 dB(A) increase for west facing façades due to the impact from existing traffic on Pacific Highway.

Similarly during the off peak period a smaller increase (than the 10 dB increase reported in **Table 4-4**) in overall road traffic noise levels would be expected for façades exposed to the Pacific Highway, however the maximum increase in noise of 10 dB(A) could be experienced for façades that are not exposed to the Pacific Highway.

Mitigation is considered for these receivers in **Section 5.1.5**.

4.4 Construction vibration

Vibration intensive works may occur during each phase of the project as a result of the proposed works. The safe working distances that relate to cosmetic / structural damage and human discomfort for the proposed works are presented in **Table 4-5**.

Table 4-5 Recommended safe working distances for vibration intensive plant

Plant	Rating/description	Safe working distance	
		Cosmetic damage (metres)	Human response (metres)
Vibratory roller	< 50 kN (Typically 1-2 t)	5	15-20
	< 100 kN (Typically 2-4 t)	6	20
	< 200 kN (Typically 4-6 t)	12	40
	< 300 kN (Typically 7-13 t)	15	100
	> 300 kN (Typically 13-18 t)	20	100
	> 300 kN (> 18 t)	25	100
Small hydraulic hammer	(300 kg – 5-12 t excavator)	2	7
Medium hydraulic hammer	(900 kg – 12-18 t excavator)	7	23
Large hydraulic hammer	(1,600 kg – 18-34 t excavator)	22	73
Vibratory pile driver	Sheet piles	2–20	20
Pile boring	≤ 800 mm	2 nominal	N/A
Jack hammer	Handheld	Avoid contact with structure	Avoid contact with structure

Note: More stringent conditions may apply to heritage or other sensitive structures. Any heritage property would need to be considered on a case by case basis.

Due to the site layout and existing offset distances to sensitive receiver locations it is unlikely that safe working distances would be encroached for most activities. However, there is the potential that work may be undertaken within the safe working distances during the site establishment phase of the project, although the equipment used may not be vibration intensive. Further consideration is required by the contractor to determine the required equipment on site. The primary form of mitigation of vibration would be ensuring vibration intensive works do not occur within the safe working distances. If vibration intensive works are planned within the safe working distances identified, alternative equipment would be identified and vibration monitoring would be implemented. Further mitigation of vibration would not be required where the safe working distances are adhered to.

In some circumstances, construction activity within the safe working distance cannot be avoided due to the work required and the prevalent geological site conditions. These conditions may not be fully understood until work has commenced, resulting in a potential change in operating equipment. Approaches to manage such circumstances are discussed in **Chapter 5**.

4.5 Blast emission assessment

Blasting would not be undertaken for this site. As such a blasting emission assessment is not required.

4.6 Cumulative construction noise impacts

As discussed in **Section 4.1**, Council has an existing approval for the maintenance pumping of the quarry void. To ensure that the impacts have been appropriately considered, the cumulative noise impact from these works and the project has been assessed. The potential cumulative impacts associated with maintenance pumping (which would occur during all phases) are assessed in this section.

A summary of the cumulative noise impacts from the project is provided in **Table 4-6**. The sound power level of the pumping activities is appreciably lower than other activities, as such the noise levels are generally unaffected by the pumping works. The exception to this is the conveyor construction phase. Noise levels would increase at some receiver locations, predominantly because the sources would be closer to those locations however the increase would be less than 1 dB(A).

Table 4-6 Standard hours work predicted cumulative noise levels at residential receivers

NCA	L_{Aeq} Noise management level dB(A)[1]	Predicted average LAeq noise level for the NCA dB(A)	Predicted maximum L_{Aeq} noise level for the NCA dB(A)	Maximum exceedance above criteria	Number of receivers where NMLs are exceeded	Number of highly noise affected receivers[2]
Preparatory works (1 month) / Site establishment and dewatering (3 months)						
NCA01	44	55	67	23	126	0
NCA02	49	57	72	23	93	0
NCA03	47	61	67	20	63	0
NCA04	44	52	60	16	35	0
Total					317	0
Conveyor construction works and dewatering (3 months)						
NCA01	44	48	64	20	81	0
NCA02	49	48	62	13	44	0
NCA03	47	52	58	11	50	0
NCA04	44	35	48	4	2	0
Total					177	0
Conveyor construction and haulage and dewatering (during final month of conveyor construction phase)						
NCA01	44	49	64	20	81	0
NCA02	49	48	66	17	46	0
NCA03	47	52	58	11	52	0

NCA	L_{Aeq} Noise management level dB(A)[1]	Predicted average LAeq noise level for the NCA dB(A)	Predicted maximum L_{Aeq} noise level for the NCA dB(A)	Maximum exceedance above criteria	Number of receivers where NMLs are exceeded	Number of highly noise affected receivers[2]
NCA04	44	36	48	4	2	0
Total					181	0
Spoil emplacement activities and spoil haulage and dewatering (28 months)						
NCA01	44	49	63	19	89	0
NCA02	49	50	67	18	54	0
NCA03	47	52	58	11	49	0
NCA04	44	39	50	6	2	0
Total					194	0
Site demobilisation and dewatering (no more than 2 months)						
NCA01	44	55	67	23	126	0
NCA02	49	57	72	23	93	0
NCA03	47	61	67	20	63	0
NCA04	44	52	60	16	35	0
Total					317	0

Note 1: Noise management levels are explained in Table 3-1.

Note 2: Highly noise affected is considered to be ≥ 75 dB(A).

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5 Noise and vibration mitigation

This section of the report presents noise and vibration mitigation measures to be considered for implementation to minimise and manage project noise impacts.

The assessment presented in **Chapter 4** of this report detailed a number of exceedances of the NMLs for this project. These were predicted as a result of various different construction activities. As a result of these exceedances, and potential exceedances of vibration criteria, the following generic and receiver specific mitigation measures have been identified. As the project progresses and the design develops, feasible and reasonable noise management and mitigation measures will continue to be considered in detail and in consultation with affected receivers so that tailored measures can be implemented to achieve acceptable noise outcomes for sensitive receivers.

5.1 Construction noise

5.1.1 Construction noise and vibration management plan

A CNVMP would be prepared. The CNVMP would include the following:

- Identification of nearby residences and other sensitive land uses.
- Description of approved hours of work.
- Description and identification of all construction activities, including work areas, equipment and duration.
- Description of what work practices (generic and specific) would be applied to minimise noise and vibration.
- A complaints handling process.
- Noise and vibration monitoring procedures.
- Overview of community consultation required for identified high impact works.

The CNVMP would include consideration of the following issues:

- Cumulative construction noise impacts of the maintenance pumping of the quarry void.

Feasible and reasonable mitigation measures would be detailed within the CNVMP to manage predicted noise levels at sensitive receivers. Consultation with the affected community is currently being undertaken and would also occur prior to and during construction.

5.1.2 Community consultation and complaints handling

All residents impacted by noise from the proposed works which are expected to exceed the construction NML would be notified prior to the commencement of the project.

The information provided to the residents would include:

- Programmed times and locations of construction work.
- The hours of proposed works.
- A 24-hour telephone hotline and complaints management process.

Community consultation regarding construction noise and vibration would be detailed in the Community Involvement Plan for the project.

5.1.3 Work practices

Induction and training would be provided to relevant staff and sub-contractors outlining their responsibilities with regard to noise. Drivers would be informed during induction of techniques and practices to minimise noise from tipping of materials.

5.1.4 Construction hours and work scheduling

At this stage no works outside of standard hours are proposed. Where required, details of any circumstances where out of hours work would be required would be detailed in the CNVMP.

Particularly noisy activities associated with the site establishment and demobilisation would be scheduled where feasible and reasonable around times of high background noise to provide masking.

Deliveries would be carried out during standard construction hours where feasible and reasonable.

Consideration would be given to construction timetabling, such as respite periods, to minimise noise impacts.

5.1.5 Project traffic

Appreciable noise impacts as a result of project haulage traffic have been predicted on Bridge Road between the Pacific Highway and Hornsby Quarry. To comply with the increase in noise criterion, the maximum number of trucks accessing the site would need to be limited to less than 10 per hour. Reducing trucks to less than 10 per hour would make the project unviable as spoil emplacement activities need to operate generally within the timeframe of spoil generation by NorthConnex. A significant reduction of truck numbers would place additional pressure on other spoil emplacement sites located at greater distances from NorthConnex and therefore would have greater impacts on the wider road network, community and environment.

However reducing truck movements from 50 (as initially proposed) to 35 per hour would reduce the noise increase to approximately 7-10 dB(A) depending on the time of day. This would minimise the noise impact on sensitive receiver locations, providing a practicable balance between the project requirements and minimising the noise impacts on the local community.

It is acknowledged that the increase in noise, although reduced, is still appreciable. Hoarding has been considered on both sides of Bridge Road to reduce this impact. In most cases hoarding has the potential to achieve compliance with the $L_{Aeq(1hour)}$ criterion of 55 dB(A), however the effectiveness of hoarding for some receivers is limited due to the necessity of maintaining access to an existing driveway on Bridge Road. Further noise mitigation management measures, including hoarding would be investigated by the Contractor and presented in the CNVMP. Residents would also be consulted to ensure that the most appropriate combination of noise mitigation will be implemented to minimise the impacts on sensitive receivers.

The following measures would be implemented to reduce and manage noise impacts:

- Truck drivers would be advised of designated vehicle routes, parking locations, acceptable delivery hours or other relevant practices (i.e. minimising the use of engine brakes, and no extended periods of engine idling).
- Deliveries and spoil removal would be planned to avoid queuing of trucks in or around the compounds.
- The site would be arranged to limit the need for reversing associated with regular / repeatable movements (e.g. trucks transporting spoil) to minimise the use of reversing alarms.
- Where feasible and reasonable, non-tonal reversing alarms would be used, taking into account the requirements of Workplace Health and Safety legislation.
- Spoil would be moved during the day, and feasible and reasonable management strategies would be detailed in the CNVMP.

5.1.6 Hornsby quarry site – spoil emplacement works

The noise associated with the project would primarily result from the operation of fixed and mobile plant and truck movements. Consideration would be given to the layout of the site in order to maximise distance and shielding to nearby receivers. Noise mounds about 5 metres high would be installed surrounding the stock-piling area. Wherever possible, stockpiling would be used as temporary noise barriers to manage the sites noise impacts.

5.1.7 Plant and equipment selection and location

The selection of plant and equipment can have a significant impact on noise levels. Appropriate plant would be selected for each task to minimise the noise contributions.

Alternative works methods such as use of hydraulic or electric-controlled units in place of diesel units would be considered and implemented where feasible and reasonable. The use of alternative machines that perform the same function (such as rubber wheeled plant) would be considered in place of steel tracked plant.

Equipment would be regularly inspected and maintained to ensure it is in good working order.

Plant would be located on site with as much distance as possible between the plant and noise sensitive receivers. Noisy equipment would be orientated away from residential receivers where feasible and reasonable.

5.1.8 Noise barriers

Noise mounds about five metres high surrounding the stock piling area are currently proposed to provide a practicable level of noise reduction. Additional shielding would be provided by the spoil stockpiles, which would be about 6 m high during peak periods. Hoarding would also be located surrounding some fixed sources such as the mulchers.

Apart from the spoil emplacement works, due to the location of sensitive receivers with respect to noise sources, noise barriers would have limited effect for this project. However, the CNVMP should consider the erection of suitable noise barriers wherever they prove to be feasible and reasonable.

5.1.9 Noise monitoring

A noise monitoring program would be implemented to assist in confirming and controlling the site specific potential for disturbance at particularly sensitive localities at the commencement of activities and periodically during the subsequent stages of the project. The results would be reviewed to determine if additional mitigation measures are required. All measurements would be undertaken in accordance with appropriate monitoring standards and guidelines.

The noise monitoring program would be presented in the CNVMP.

5.1.10 Respite measures

A protocol would be developed to identify the respite measures for noise intensive activities in accordance with the ICNG. Respite measures may include starting noise intensive activities after 8 am, operating in three hour time blocks with one hour respite between blocks other appropriate measures. The protocol would form part of the CNVMP.

5.2 Vibration

Vibration intensive activities associated with the project are not expected to encroach safe working distances. However in some circumstances, activities within the safe working distance may not be able to be avoided due to the work required and the prevalent geological site conditions. These conditions will not be fully understood until work has commenced. For vibration intensive activities that occur within the safe working distances, management methods to mitigate impacts would include:

- Construction scheduling.
- Supplementary vibration monitoring.

- Equipment selection and maintenance

5.2.1 Equipment selection and maintenance.

Equipment size would be selected taking into account the safe working distances and the distance between the area of construction and the most affected sensitive receiver.

The use of less vibration intensive methods of construction or equipment would be considered where feasible and reasonable.

Equipment would be maintained and operated in an efficient manner, in accordance with manufacturer's specifications, to reduce the potential for adverse vibration impacts.

5.2.2 Works scheduling

Wherever reasonable and feasible, vibration intensive works would be limited to least sensitive times of the day.

5.2.3 Supplementary vibration monitoring

If the use of vibration intensive plant cannot be avoided within the safe working distance for cosmetic damage the following procedure would occur as a minimum:

- Notification of the works to the affected residents and community.
- Vibration measurements would be undertaken to confirm vibration levels and compliance with the DIN guideline.

6 Conclusion

The Hornsby Quarry site would receive up to 1.5 million cubic metres of ENM and/or VENM from the approved NorthConnex construction sites.

This report has provided a detailed construction noise and vibration assessment to determine the likely noise and vibration impacts from the proposed works. Where appropriate, noise and vibration mitigation measures have been proposed to appropriately manage noise and vibration impacts.

Work is proposed within standard construction hours only, so this assessment has not considered out of hours work. Five different construction phases of the project have been assessed. For the first row of receivers overlooking the site, exceedances of up to 23 dB(A) could be experienced during times of noise intensive works however no sensitive receivers are predicted to be highly noise affected by the works. Noise mitigation surrounding stationary plant and five metre noise mounds surrounding the stock piling area have been included in the noise modelling. As the project progresses, noise management and mitigation measures will continue to be considered in detail and in consultation with affected receivers to so that residual exceedances of the NML are controlled as much as is feasible and reasonable.

The increase in noise from haulage of spoil on Pacific Highway would remain compliant with the applicable noise criteria. However construction traffic noise from haulage on Bridge Road is likely to increase noise levels by more than 2 dB(A). The maximum number of project traffic movements has been reduced considerably through design optimisation, and as much as is considered reasonably practicable to make the proposal viable. Feasible and reasonable noise mitigation will be considered in detail and included in the CNVMP, to minimise and suitably control noise impacts for receivers affected by haulage on Bridge Road.

Hornsby Shire Council pumps water from the quarry void in accordance with an existing groundwater licence. The cumulative noise impact from operating maintenance pumping and this project simultaneously has been assessed. This assessment has found that generally noise levels would not be increased by operating the pumping activities simultaneously with other activities. However a small number of increases in noise of less than 1 dB(A) have been predicted. The cumulative noise impact would need to be considered further and noise management and mitigation measurements considered in the contractor’s CNVMP.

Due to the relatively large offset distances between the site and sensitive receivers and the nature of the work, the project is not predicted to result in exceedances of the applicable structural damage and human comfort vibration criteria. The CNVMP would include requirements relating to safe working distances and measures to be implemented for vibration intensive works.

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Appendix A – Acoustic Glossary

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The following is a brief description of acoustic terminology used in this report.

Term	Definition
Sound power level	The total sound emitted by a source
Sound pressure level	The amount of sound at a specified point
Decibel [dB]	The measurement unit of sound
A Weighted decibels [dB(A])	The A weighting is a frequency filter applied to measured noise levels to represent how humans hear sounds. The A-weighting filter emphasises frequencies in the speech range (between 1 kHz and 4 kHz) which the human ear is most sensitive to, and places less emphasis on low frequencies at which the human ear is not so sensitive. When an overall sound level is A-weighted it is expressed in units of dB(A).
Decibel scale	The decibel scale is logarithmic in order to produce a better representation of the response of the human ear. A 3 dB increase in the sound pressure level corresponds to a doubling in the sound energy. A 10 dB increase in the sound pressure level corresponds to a perceived doubling in volume. Examples of decibel levels of common sounds are as follows: 0 dB(A) Threshold of human hearing 30 dB(A) A quiet country park 40 dB(A) Whisper in a library 50 dB(A) Open office space 70 dB(A) Inside a car on a freeway 80 dB(A) Outboard motor 90 dB(A) Heavy truck pass-by 100 dB(A) Jack hammer / subway train 110 dB(A) Rock Concert 115 dB(A) Limit of sound permitted in industry 120 dB(A) 747 take off at 250 metres
Frequency [f]	The repetition rate of the cycle measured in Hertz (Hz). The frequency corresponds to the pitch of the sound. A high frequency corresponds to a high pitched sound and a low frequency to a low pitched sound.
Equivalent continuous sound level [L_{eq}]	The constant sound level which, when occurring over the same period of time, would result in the receiver experiencing the same amount of sound energy.
Insertion loss	Reduction in noise by inserting a barrier between the source and receiver
L_{max}	The maximum sound pressure level measured over the measurement period
L_{min}	The minimum sound pressure level measured over the measurement period
L_{10}	The sound pressure level exceeded for 10% of the measurement period. For 10% of the measurement period it was louder than the L_{10}.
L_{90}	The sound pressure level exceeded for 90% of the measurement period. For 90% of the measurement period it was louder than the L_{90}.
Ambient noise	The all-encompassing noise at a point composed of sound from all sources near and far.
Background noise	The underlying level of noise present in the ambient noise when extraneous noise (such as transient traffic and dogs barking) is removed. The L90 sound pressure level is used to quantify background noise.

Term	Definition
Traffic noise	The total noise resulting from road traffic. The L_{eq} sound pressure level is used to quantify traffic noise.
Day	**Construction noise** The period from 0700 to 1800 h Monday to Saturday and 0800 to 1800 h Sundays and Public Holidays. **Road traffic noise** The period from 0700 to 2200 h every day of the week.
Evening	**Construction noise** The period from 1800 to 2200 h Monday to Sunday and Public Holidays. **Road traffic noise** Not applicable.
Night	**Construction noise** The period from 2200 to 0700 h Monday to Saturday and 2200 to 0800 h Sundays and Public Holidays. **Road traffic noise** The period from 2200 to 0700 h every day of the week.
Assessment background level [ABL]	The overall background level for each day, evening and night period for each day of the noise monitoring.
Rating background level [RBL]	The overall background level for each day, evening and night period for the entire length of noise monitoring.

*Definitions of a number of terms have been adapted from Australian Standard AS1633:1985 “Acoustics – Glossary of terms and related symbols”, the EPA’s Industrial Noise Policy and Road Noise Policy.

Appendix B – Noise Catchment Areas, Logger Locations and Sensitive Receivers

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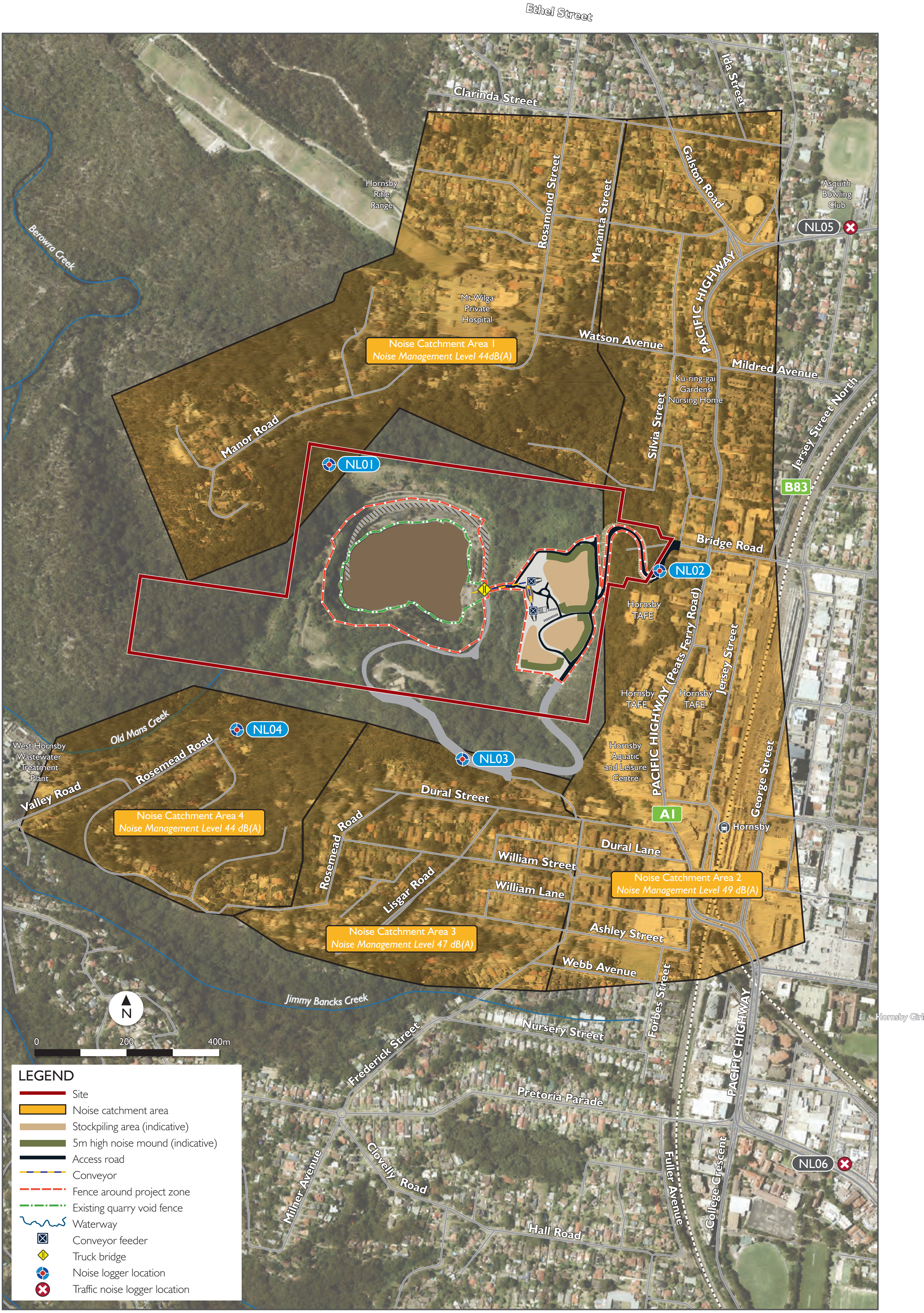
Appendix B Figure 1 Receiver types within noise catchment areas



Appendix B Figure 2 Noise catchment areas and logger locations

Appendix C – Noise Logger Results

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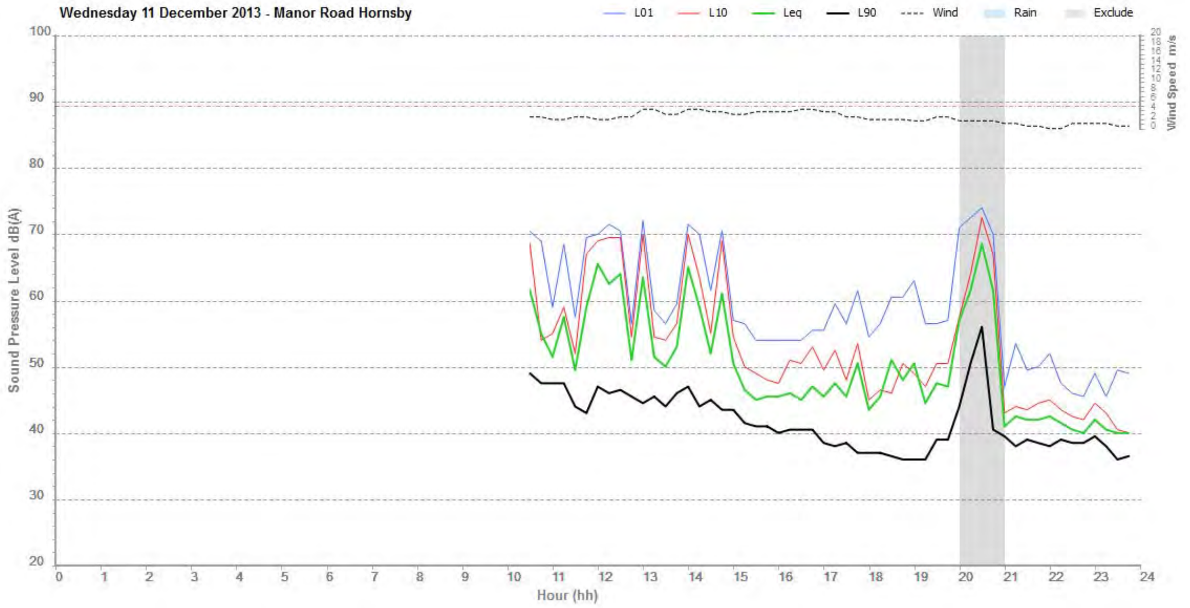

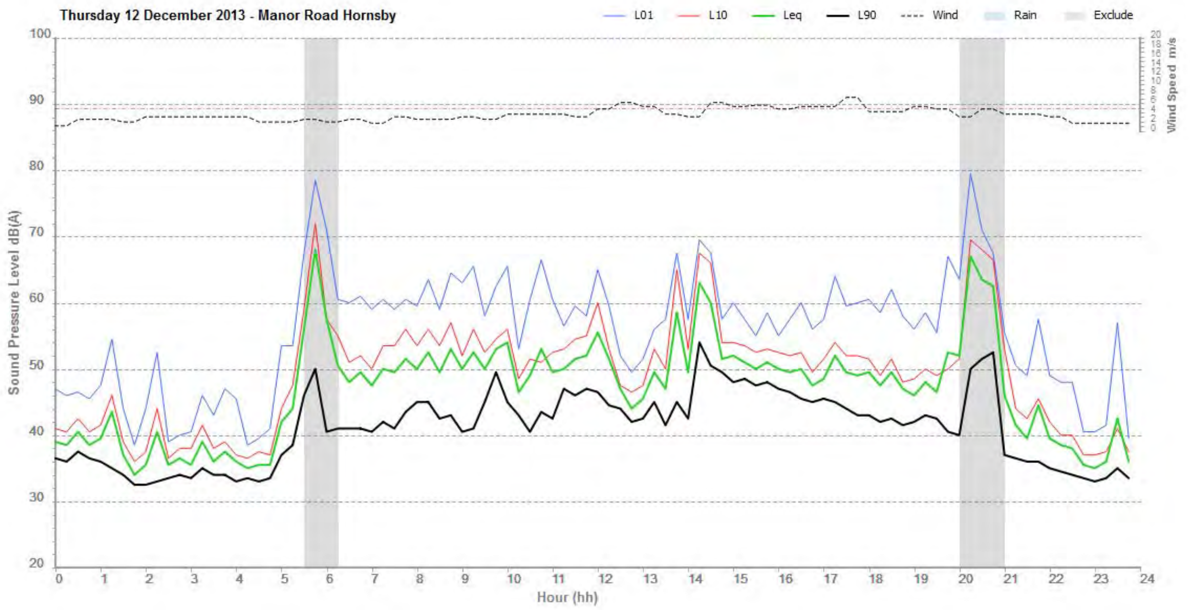

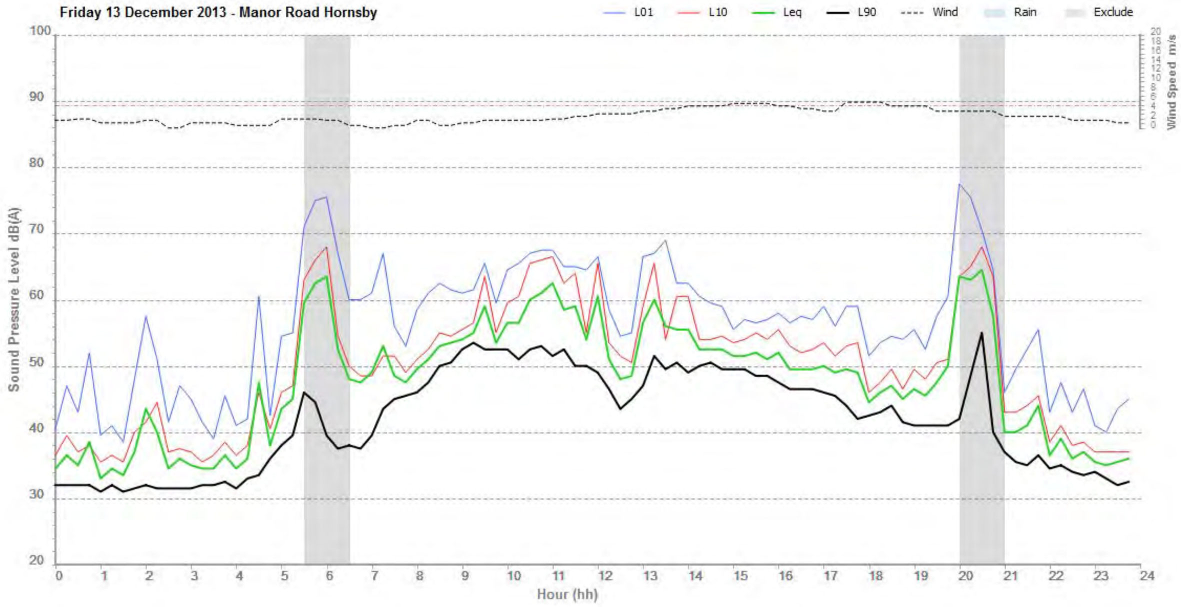

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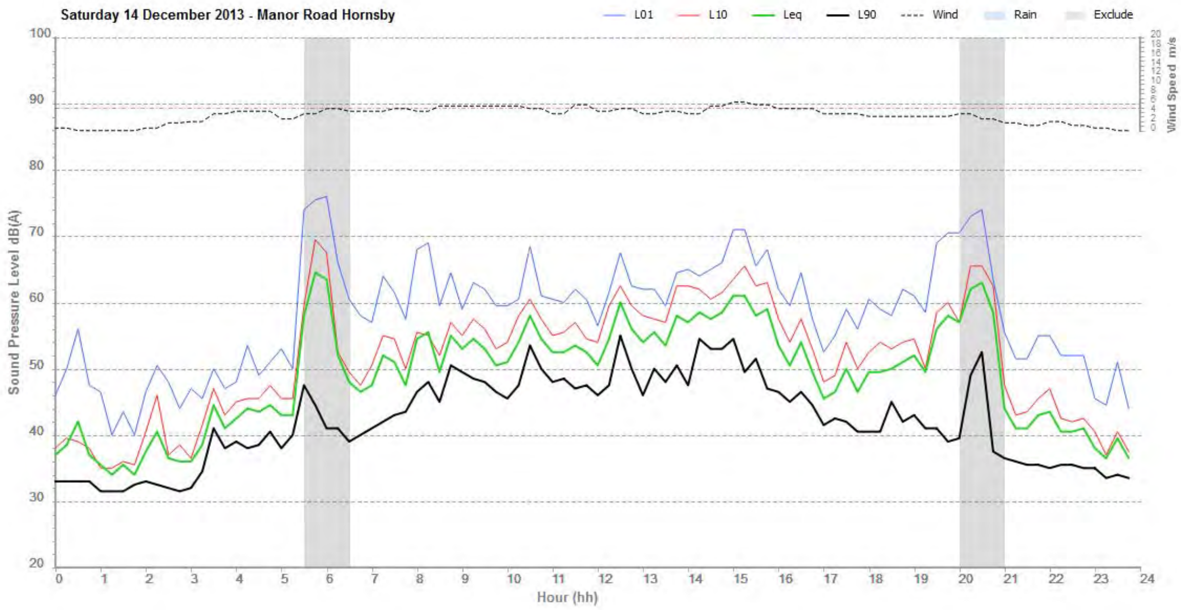

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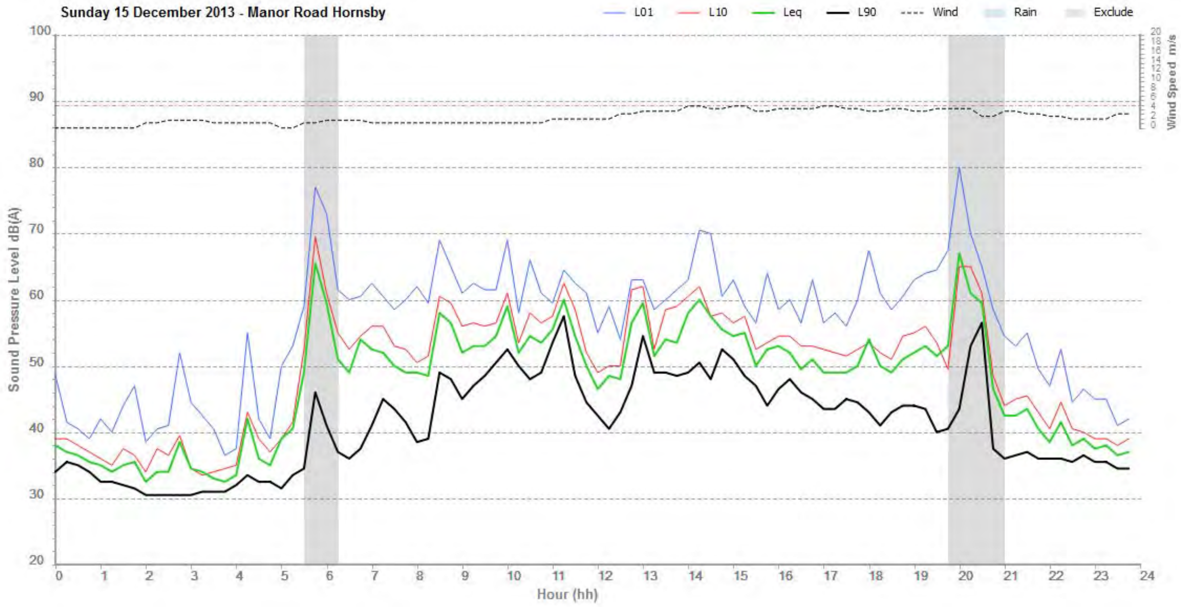

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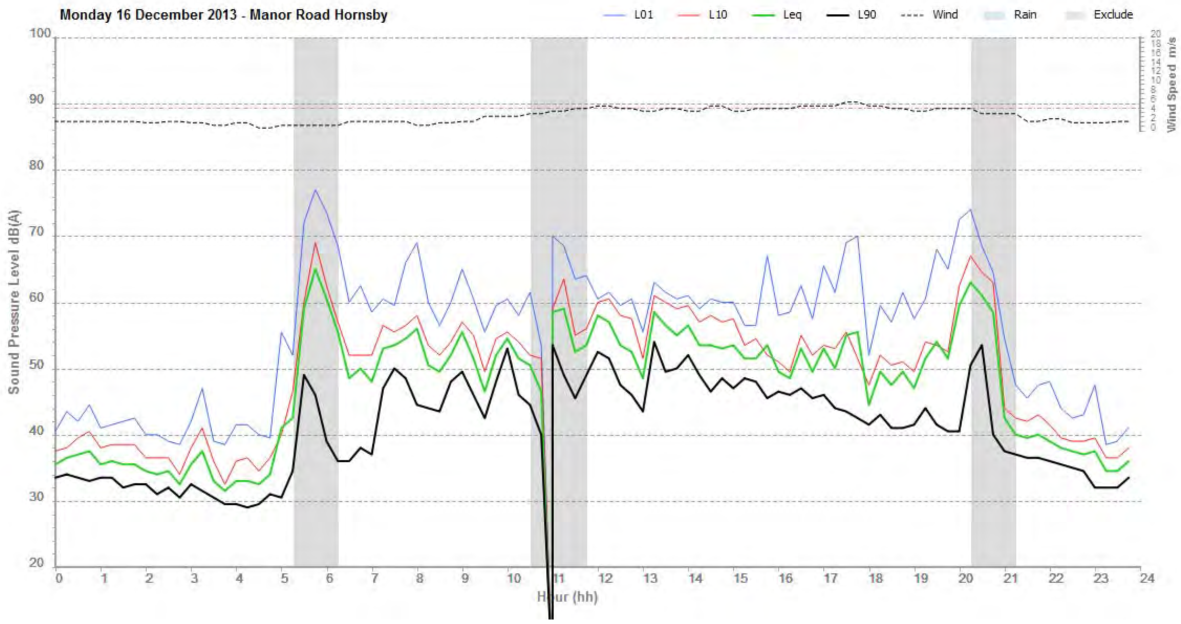

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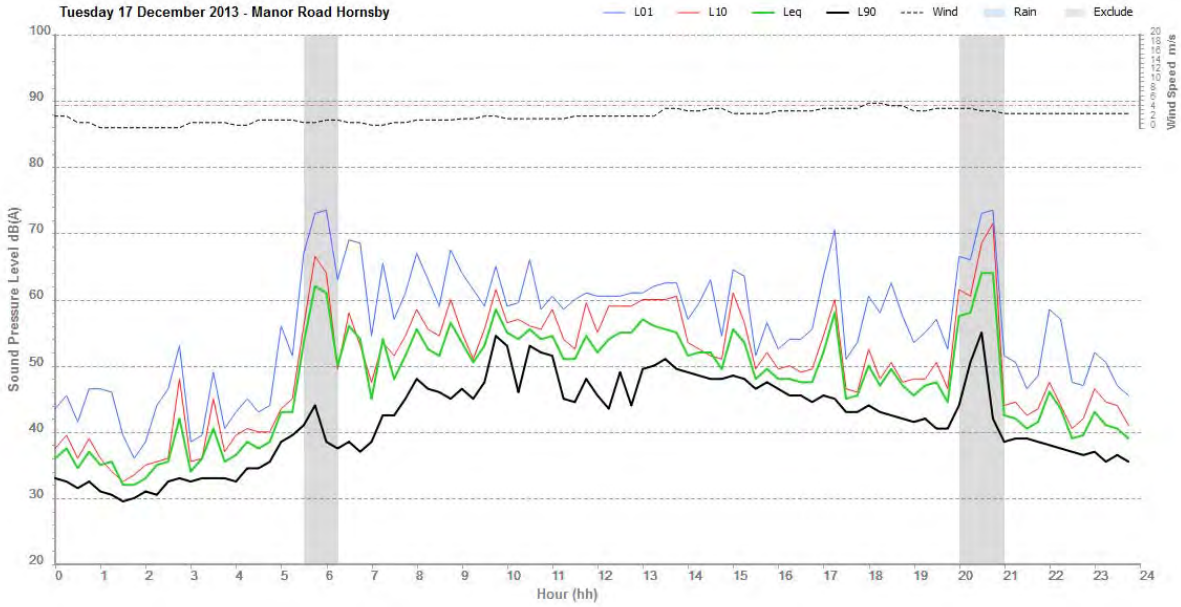
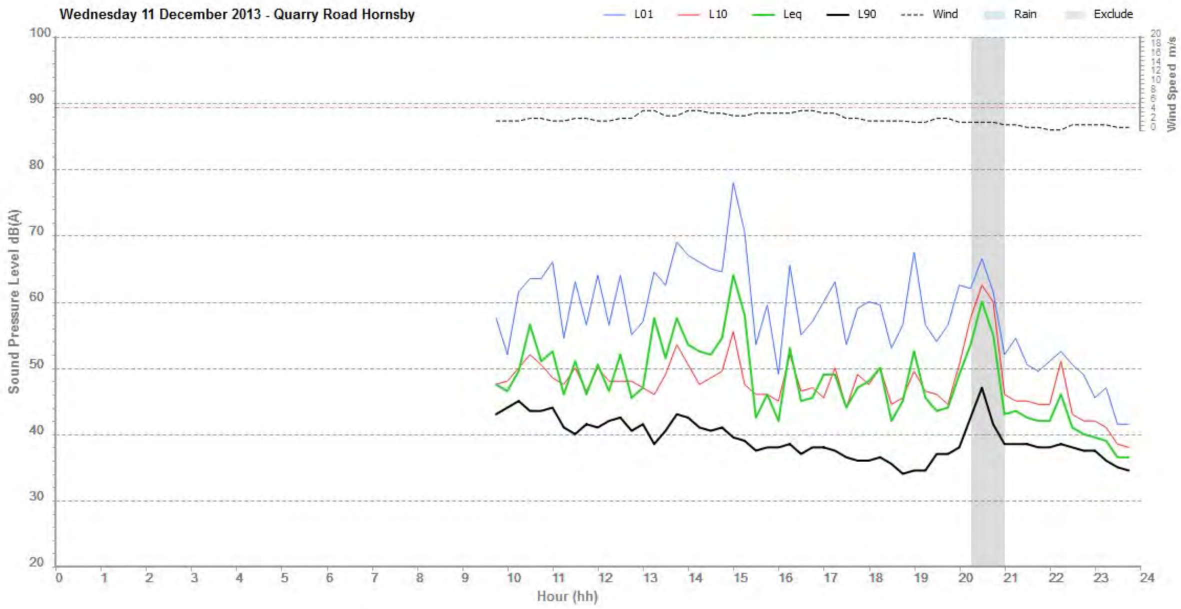
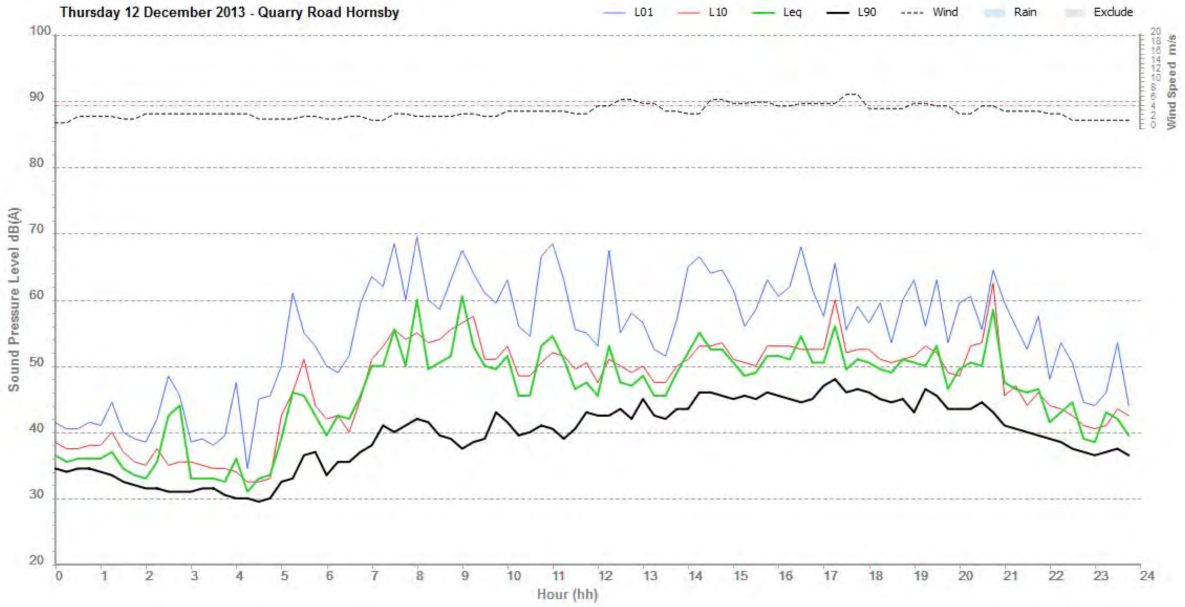


NL02 – Quarry Road

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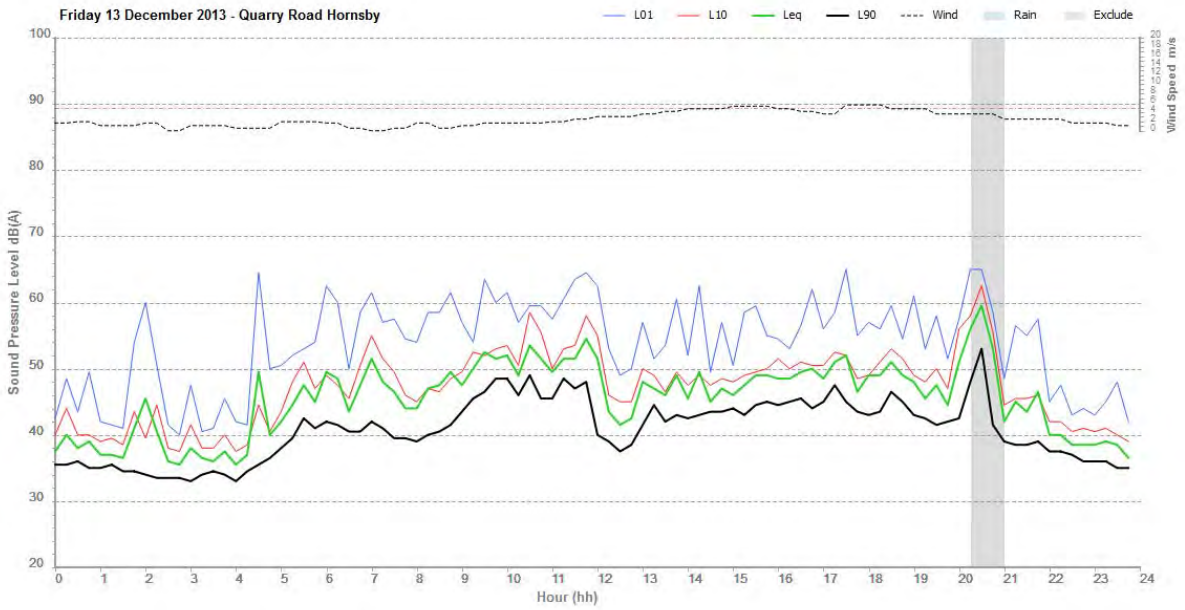
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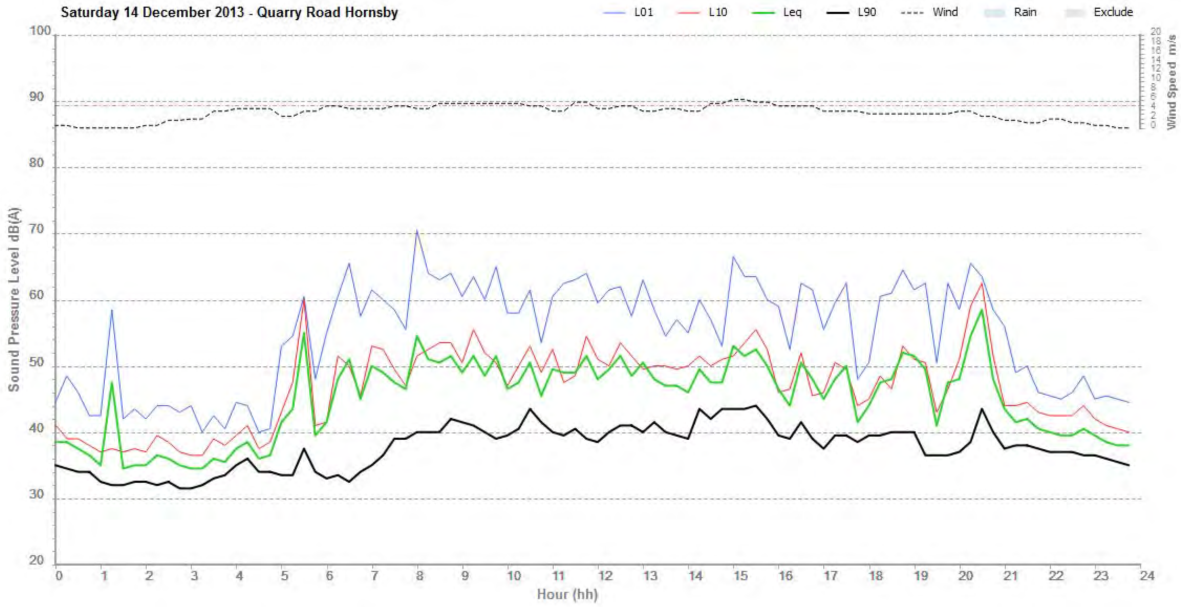
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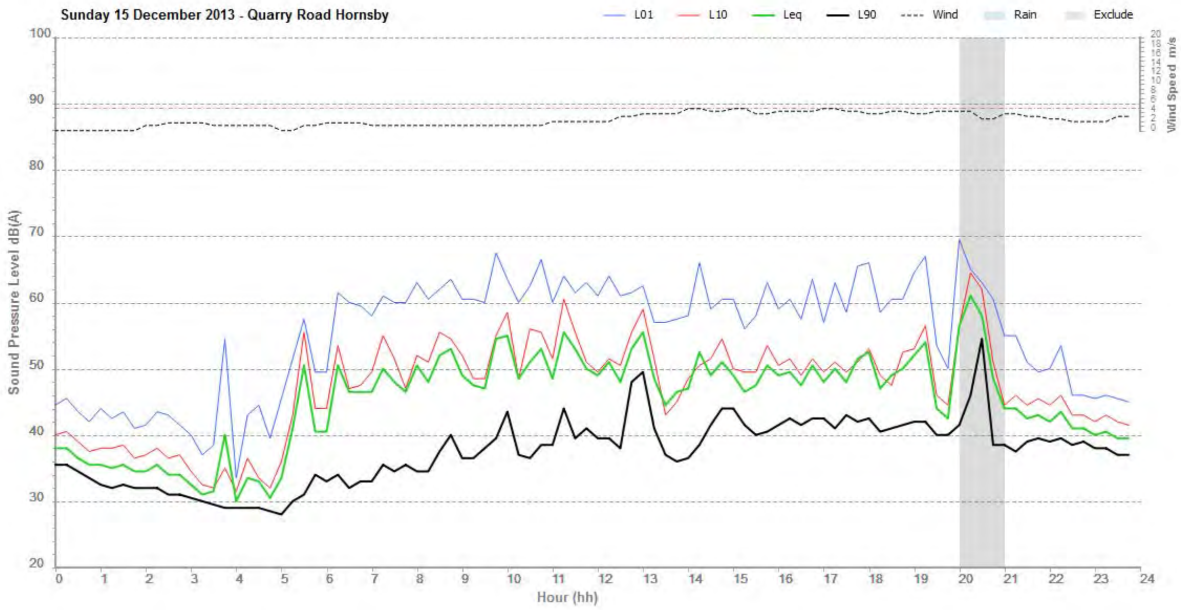
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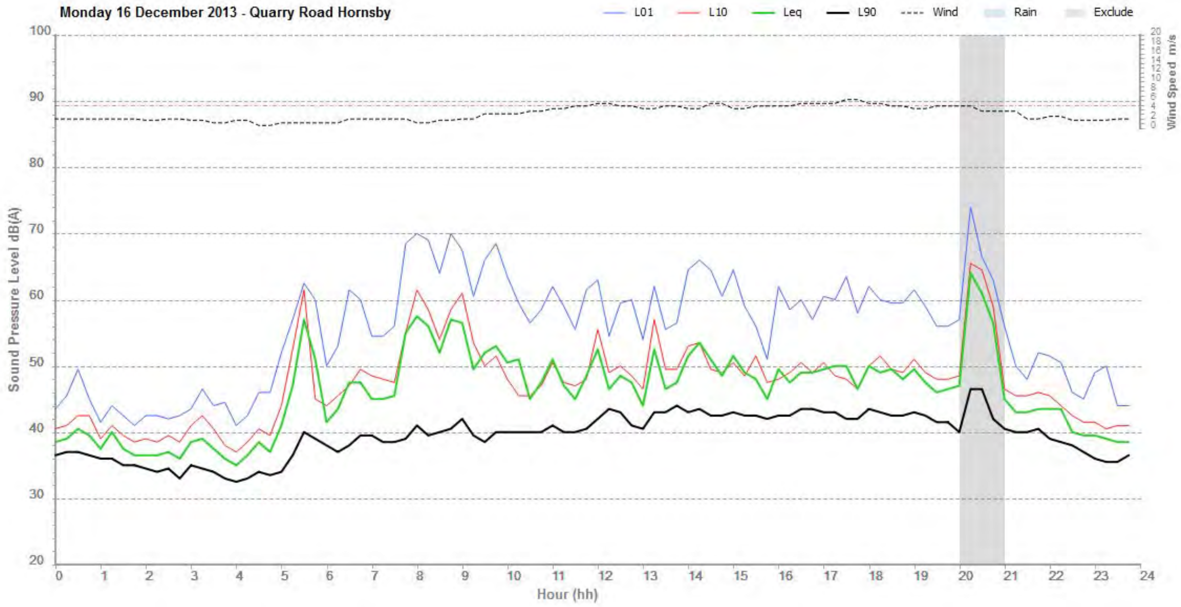

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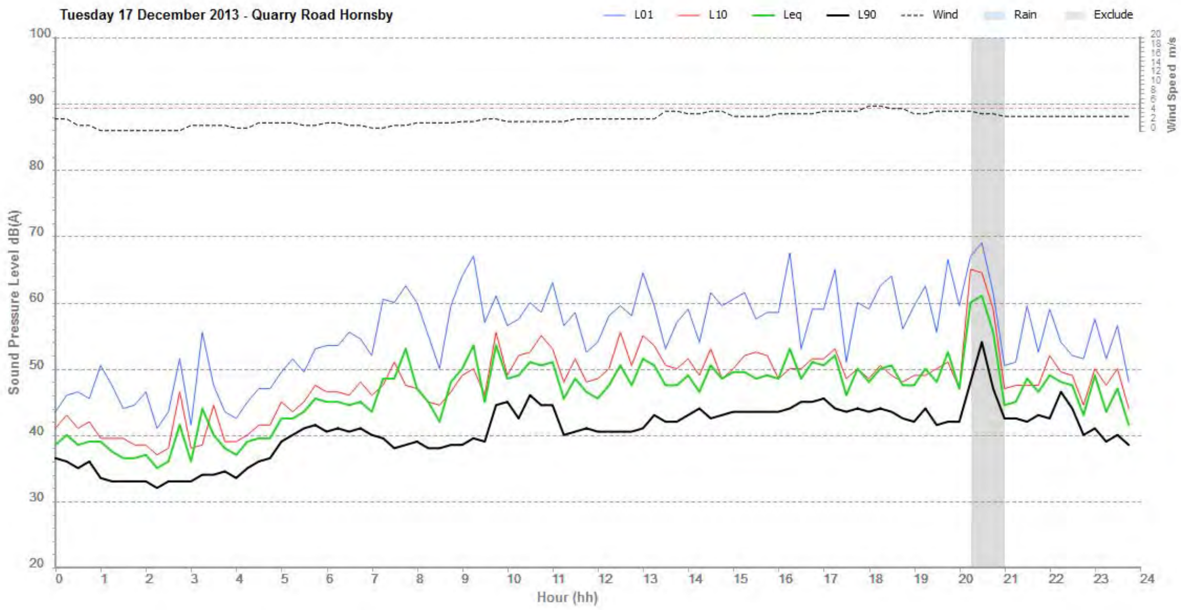

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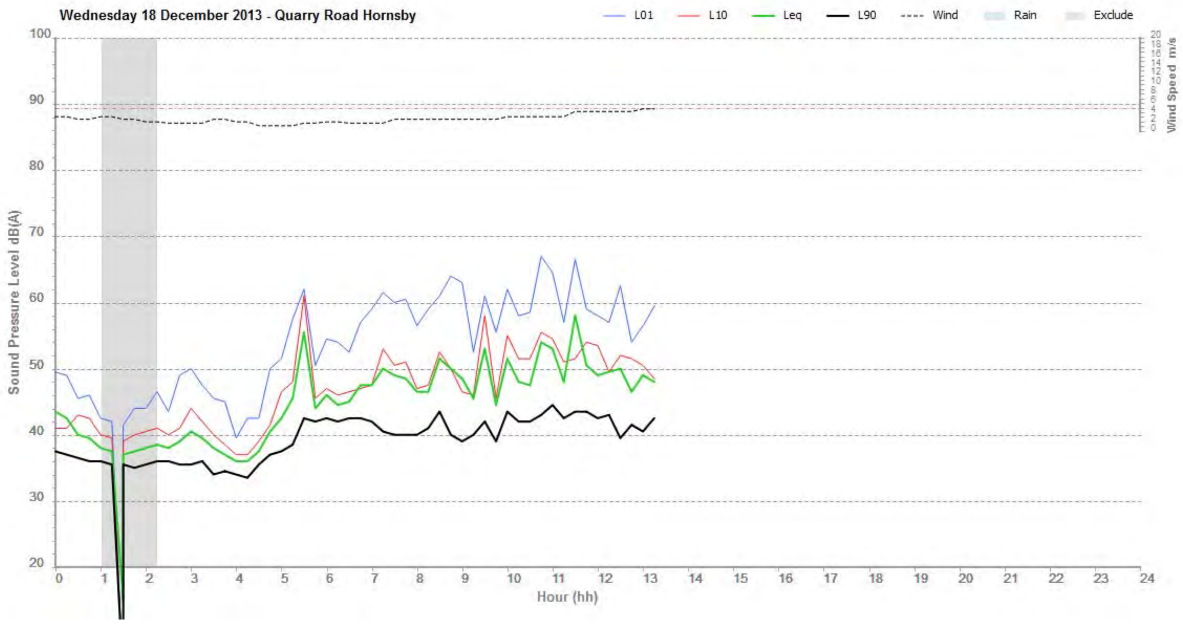
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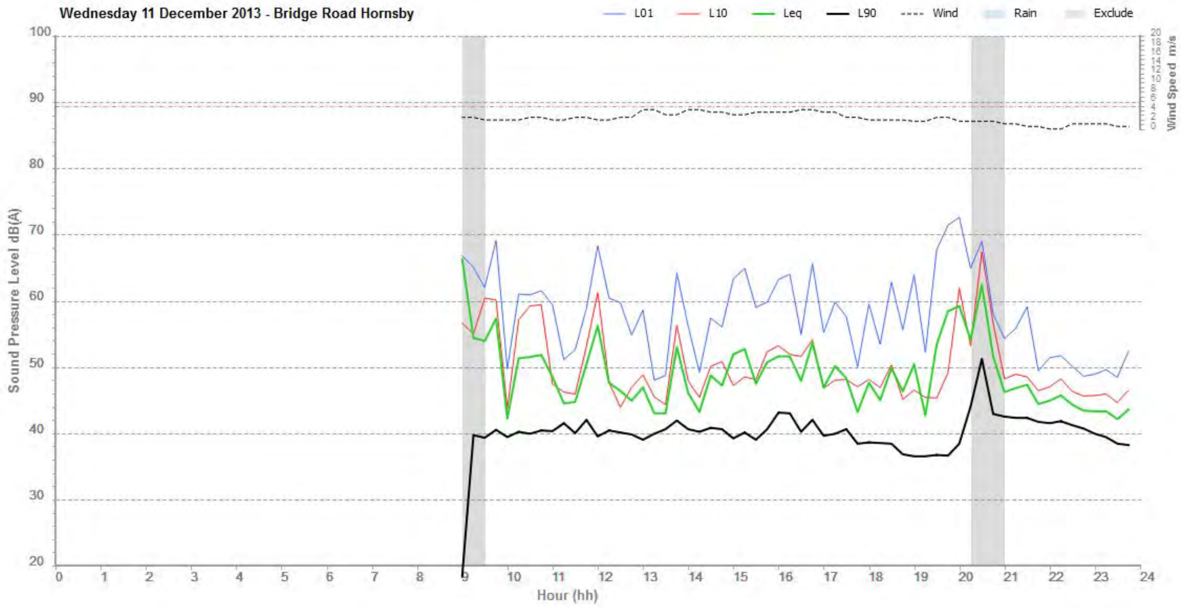
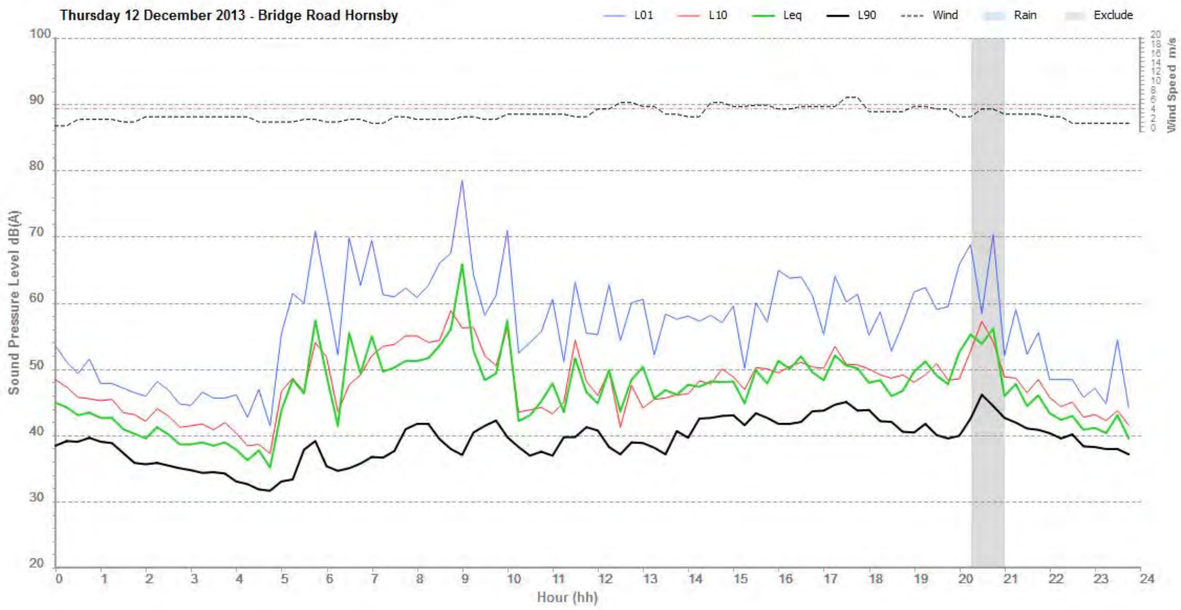
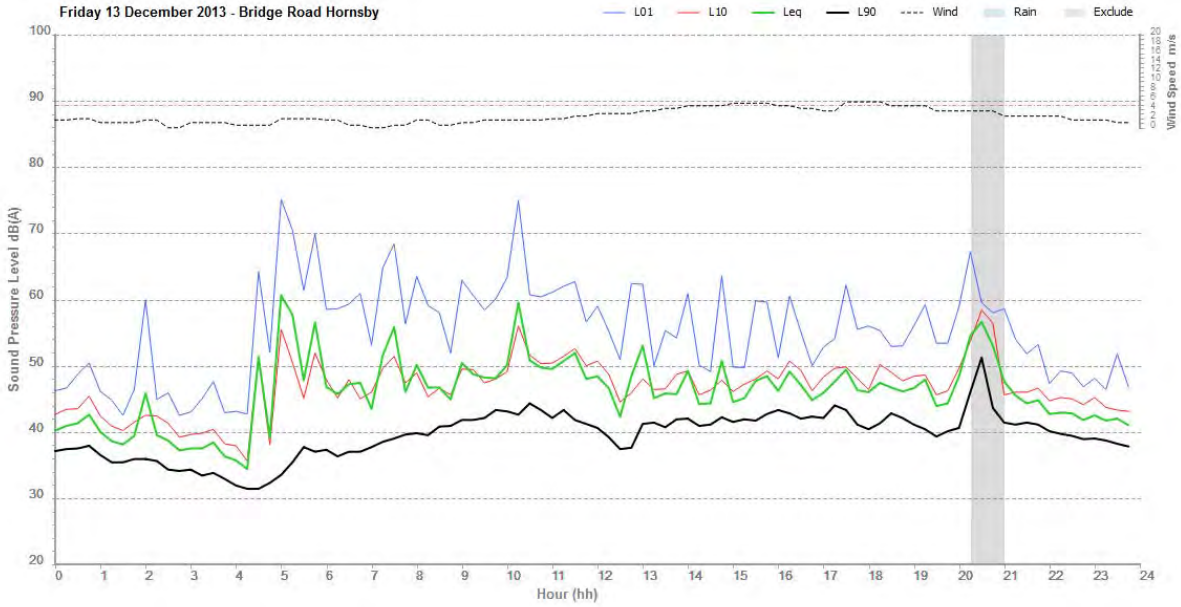
NL03 – Bridge Road



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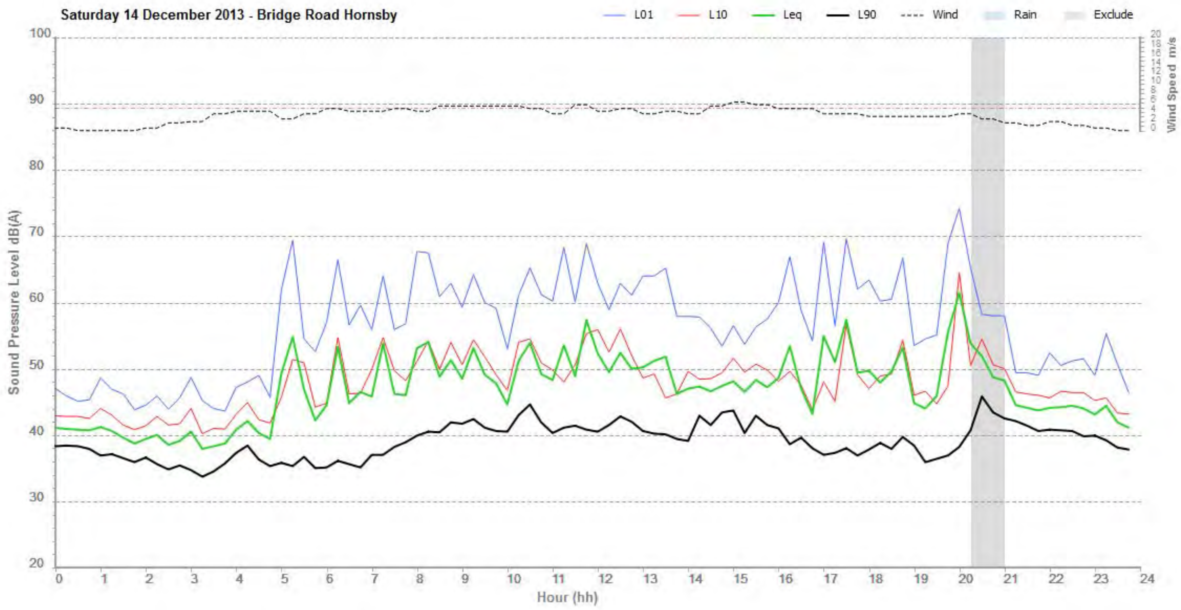
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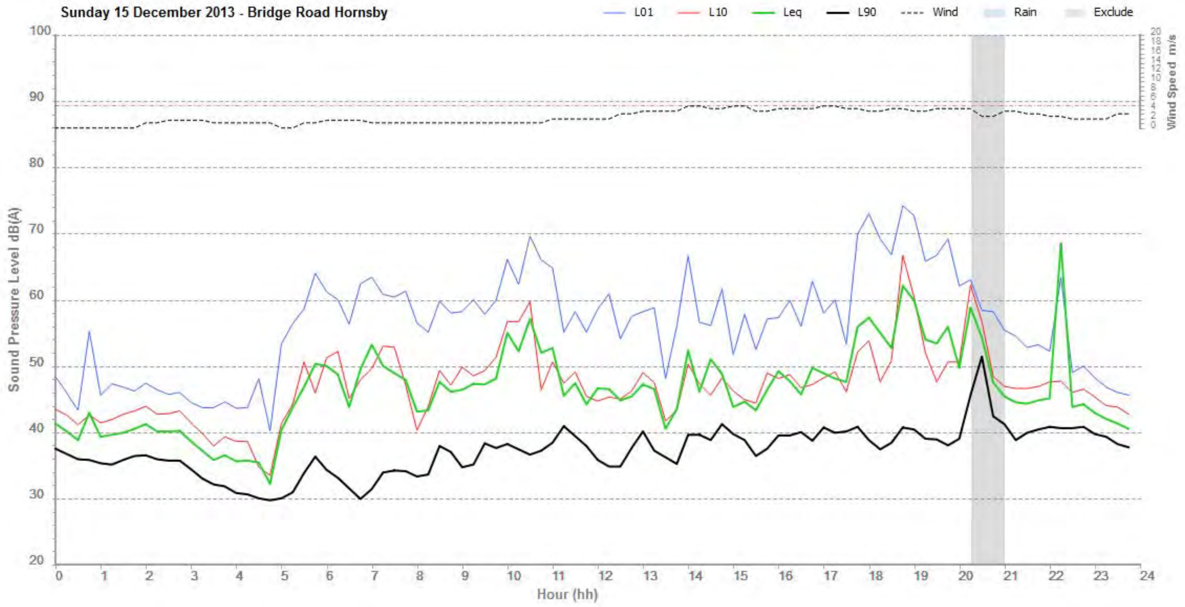

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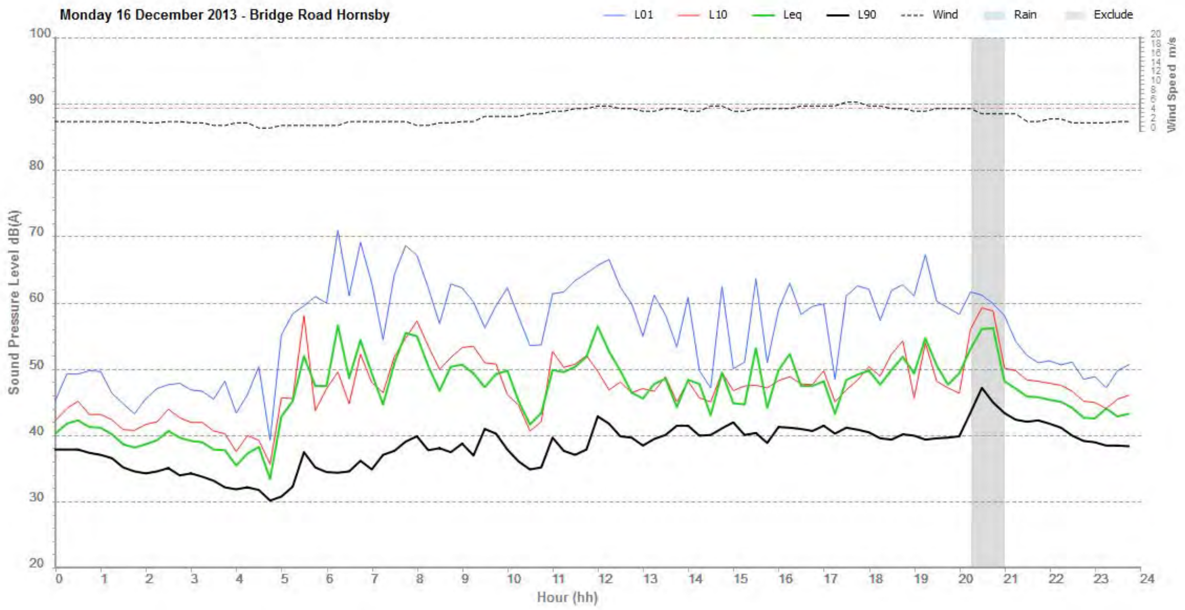

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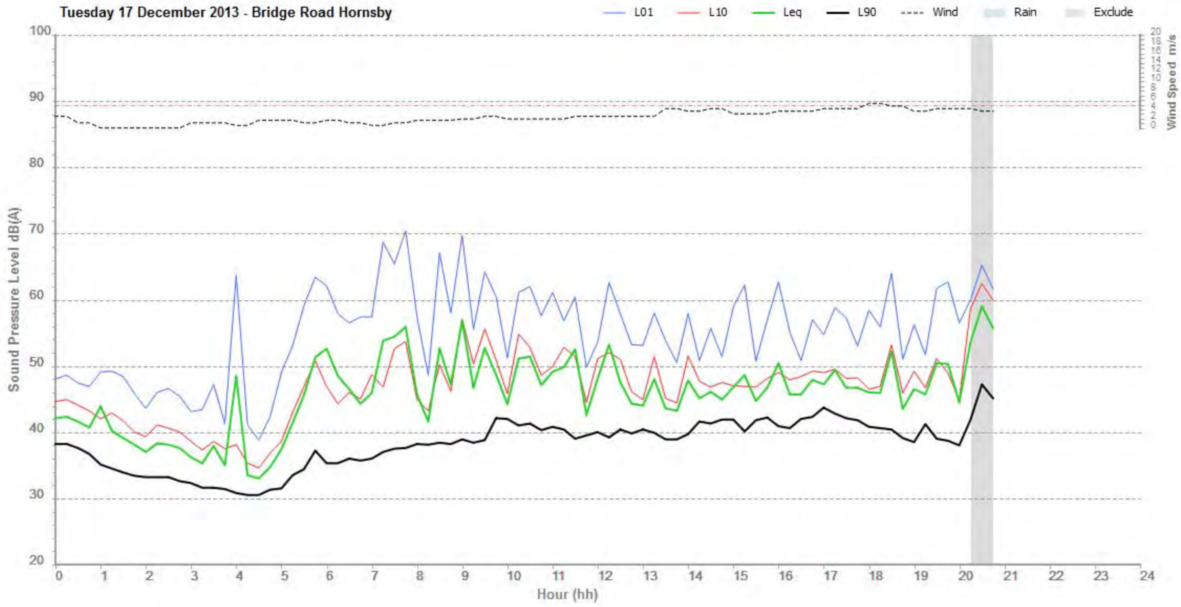
Wind Speed m/s
Hour (hh)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20
0
1
2
3
4
5
6
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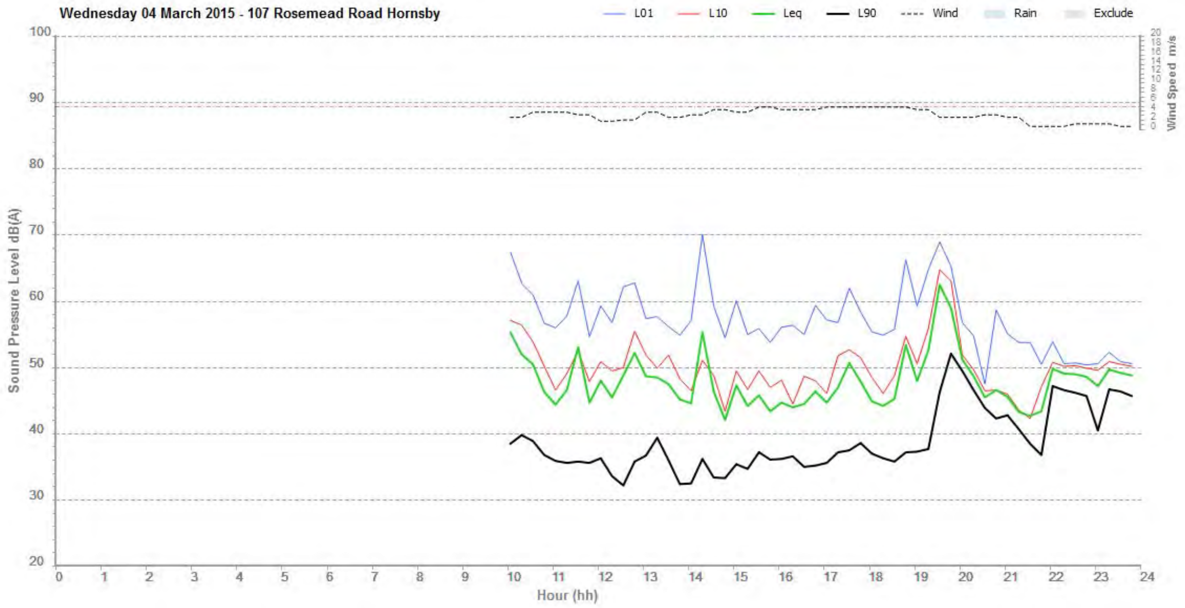
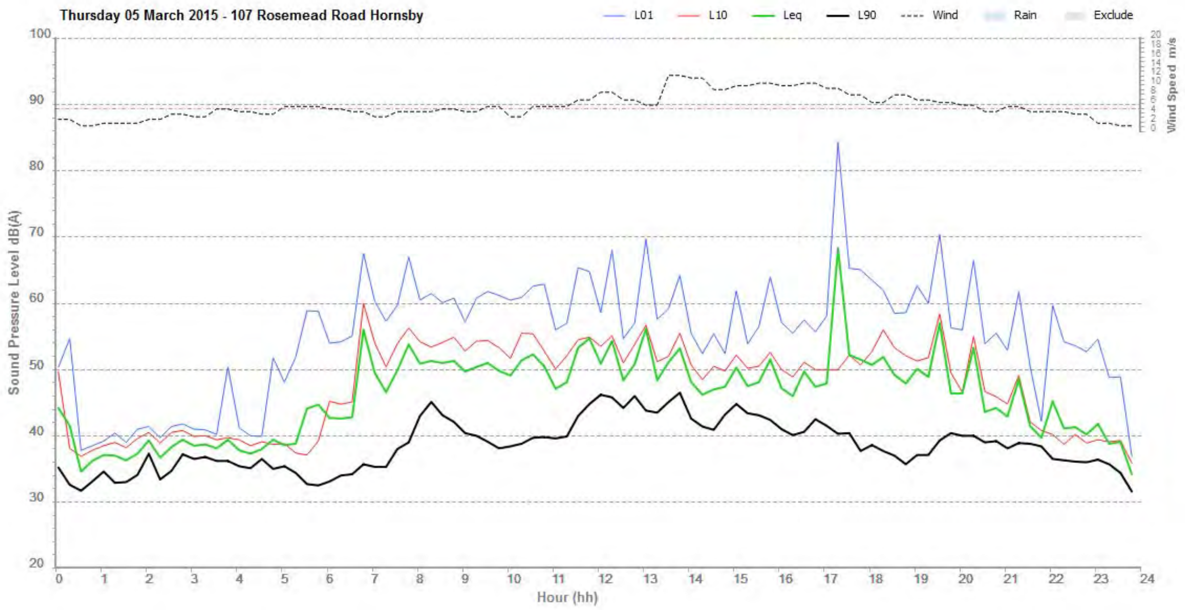
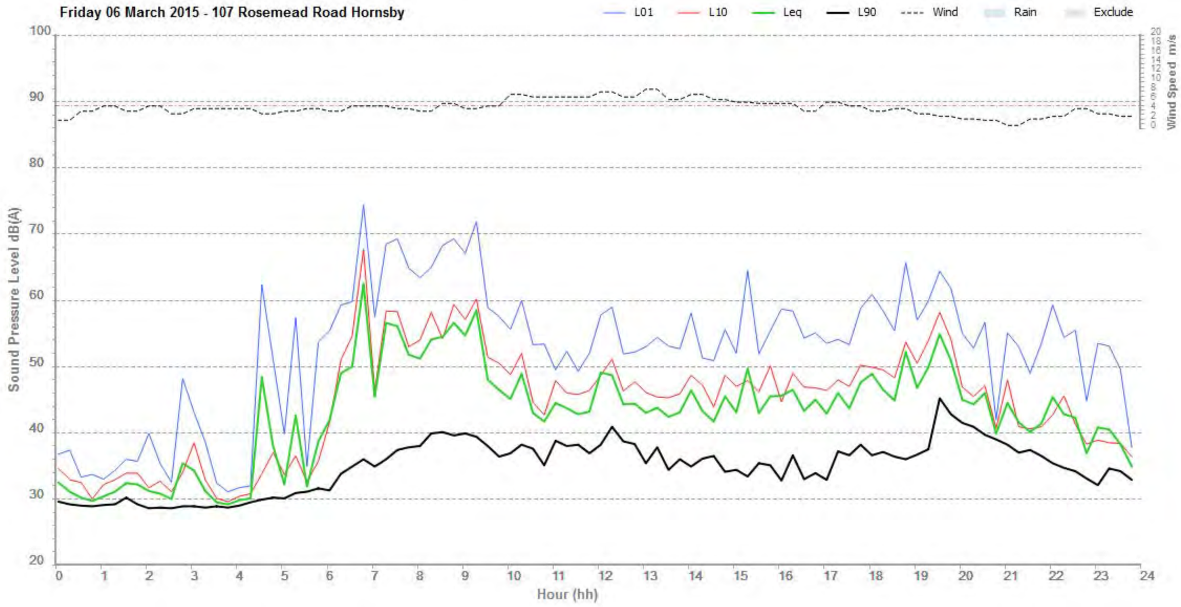
NL04 – Rosemead Road



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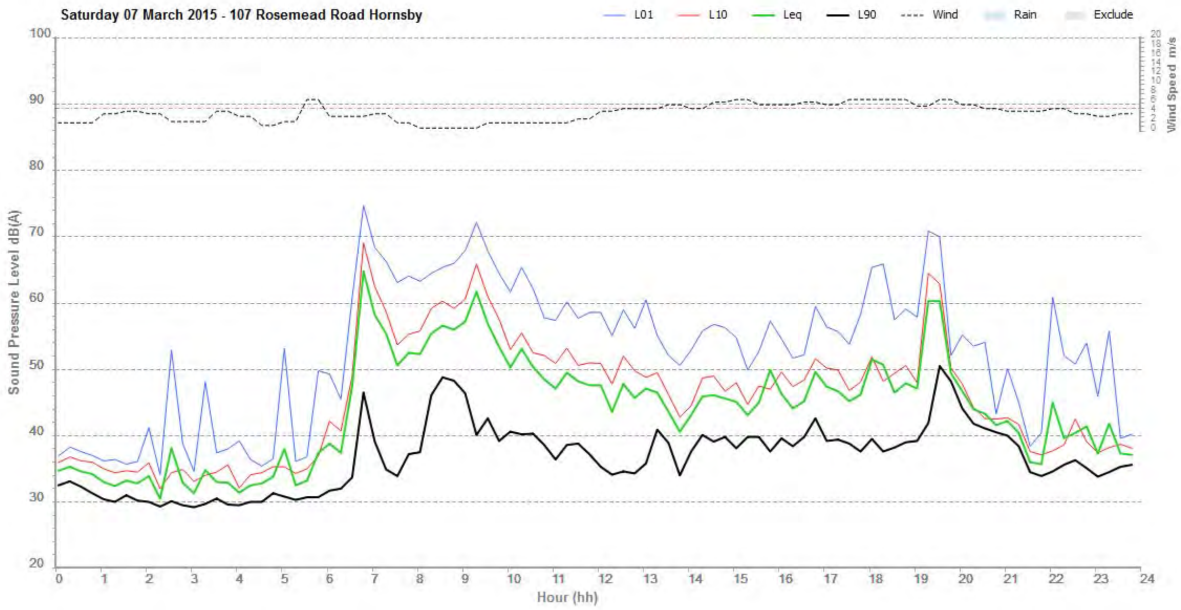
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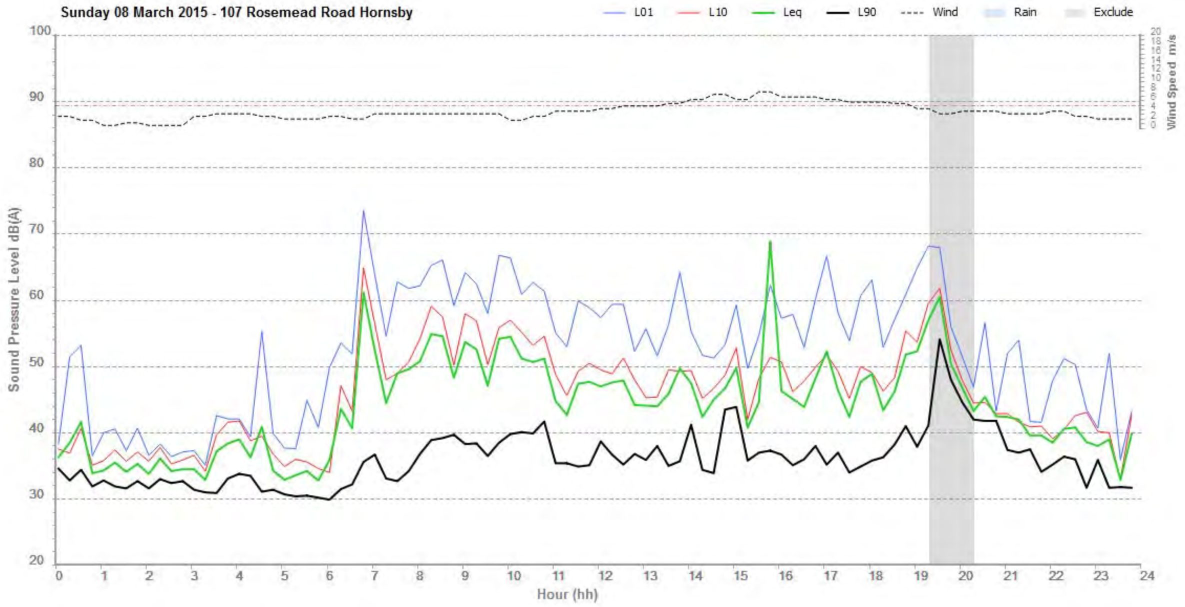
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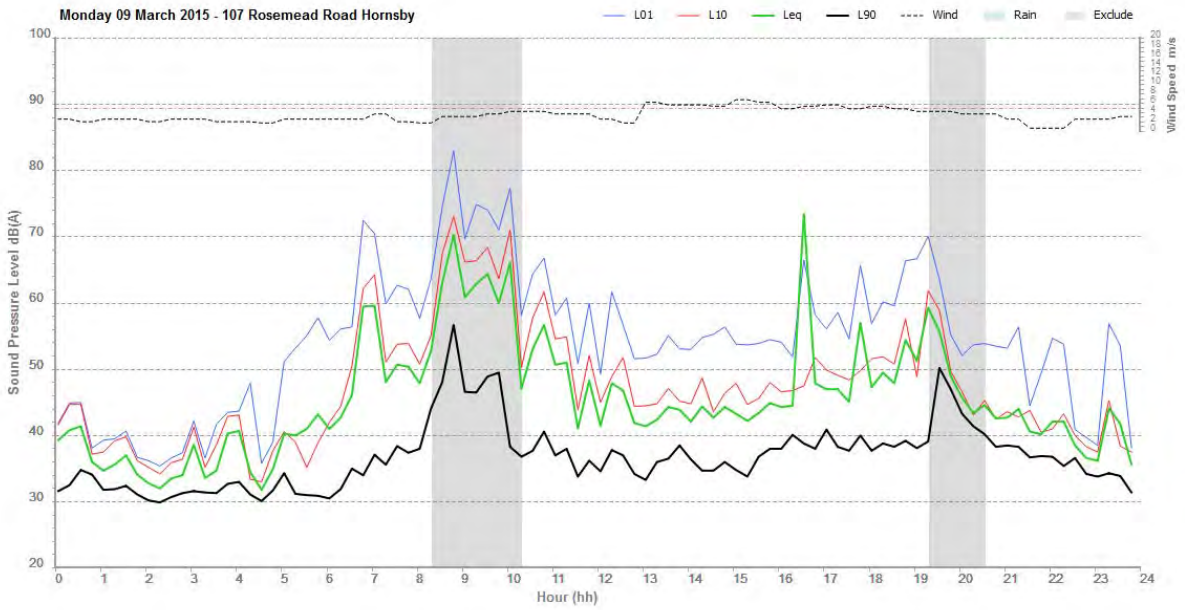
Hour (hh)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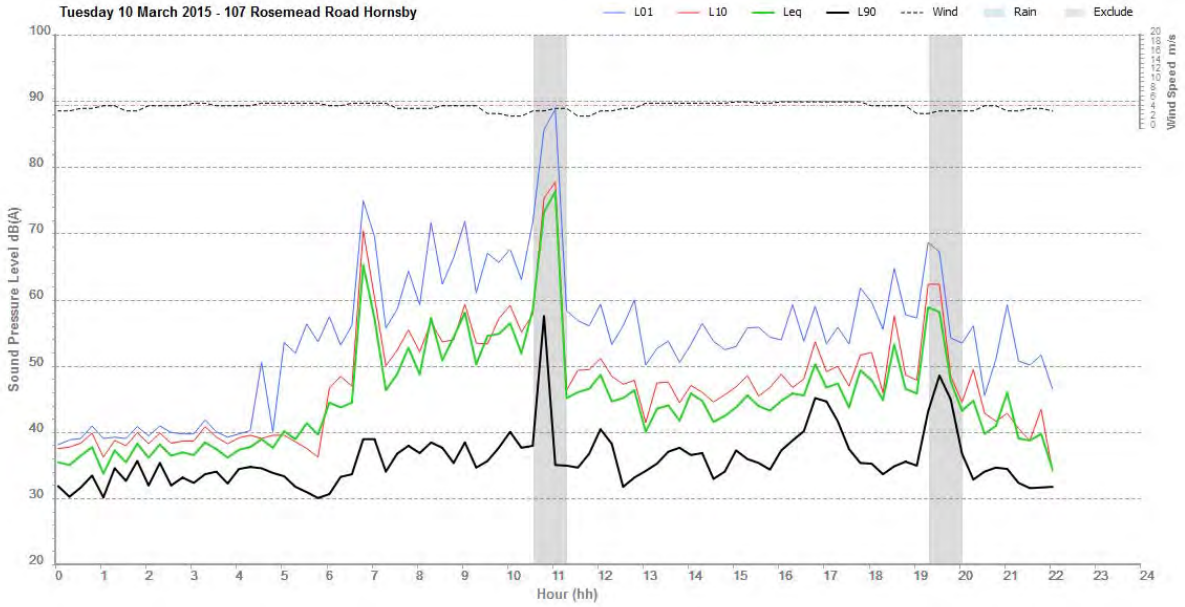
Hour (hh)



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Hour (hh)

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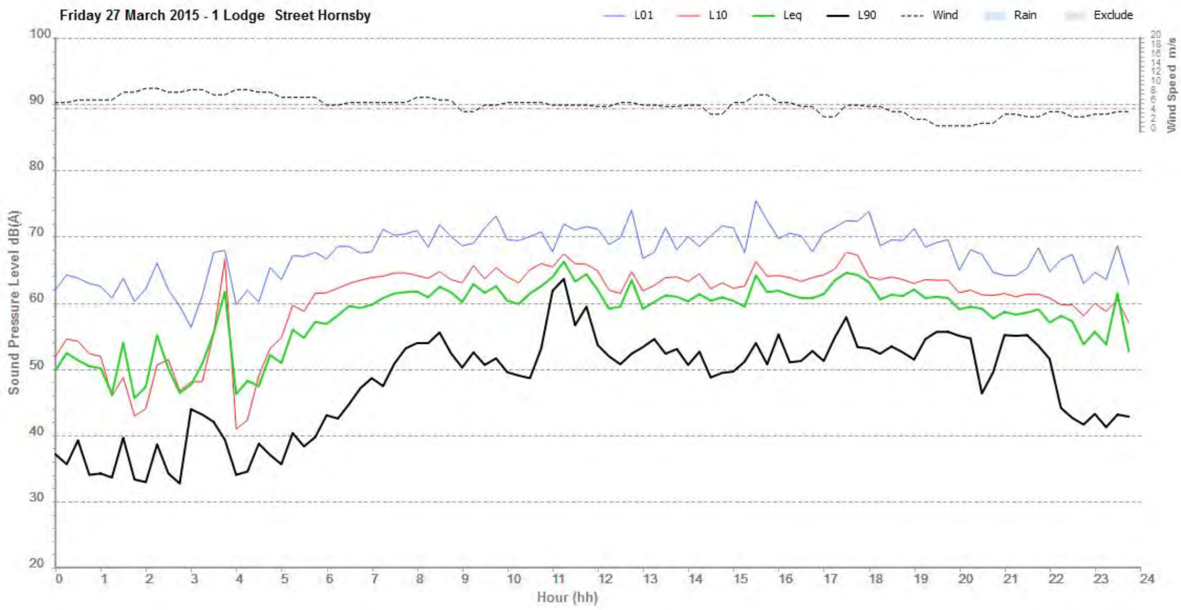


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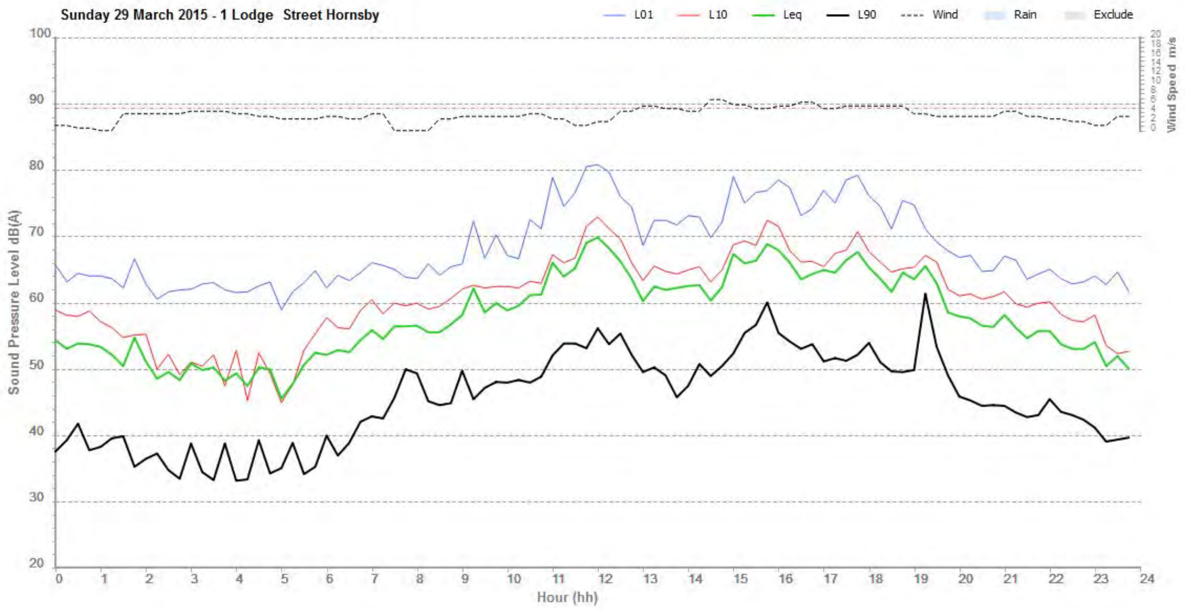
Hour (hh)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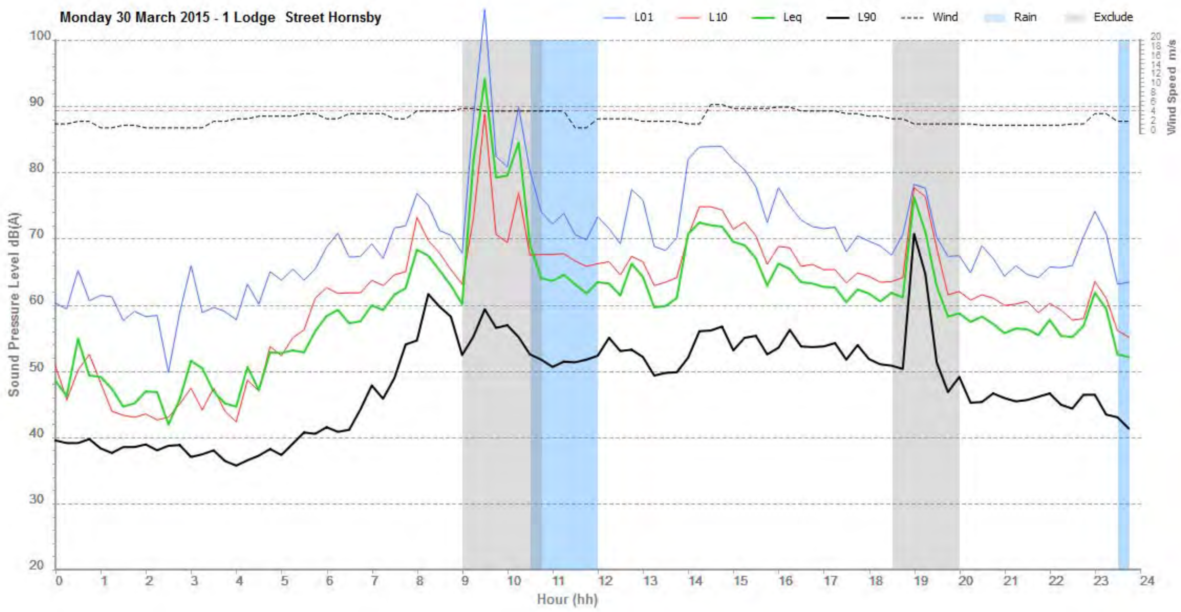
Hour (hh)



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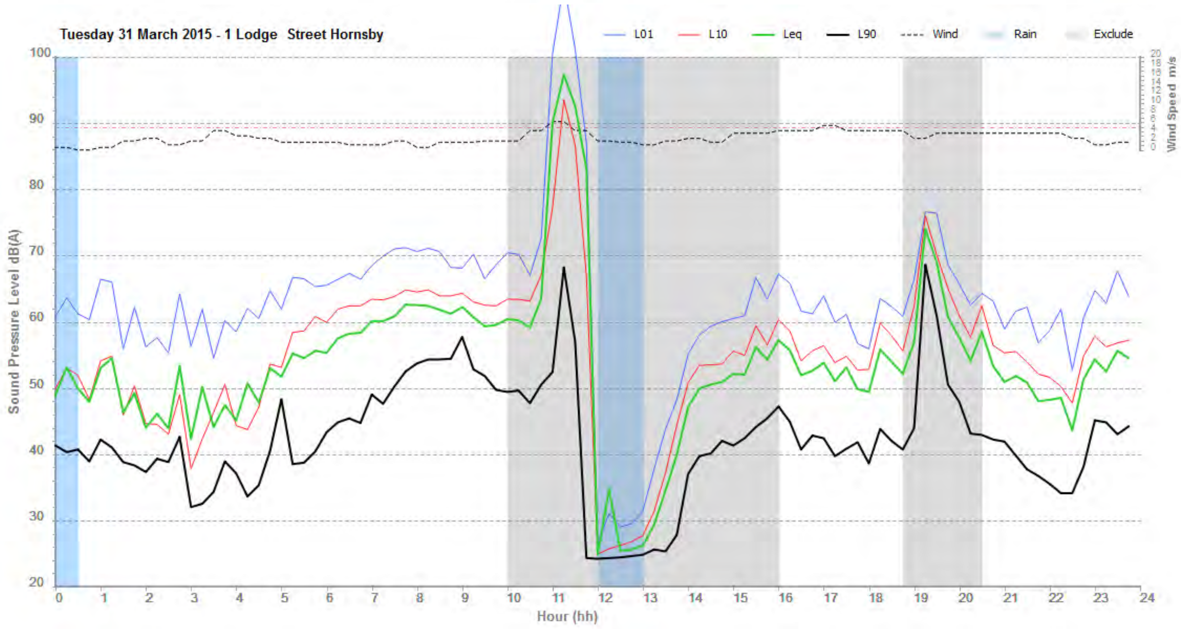

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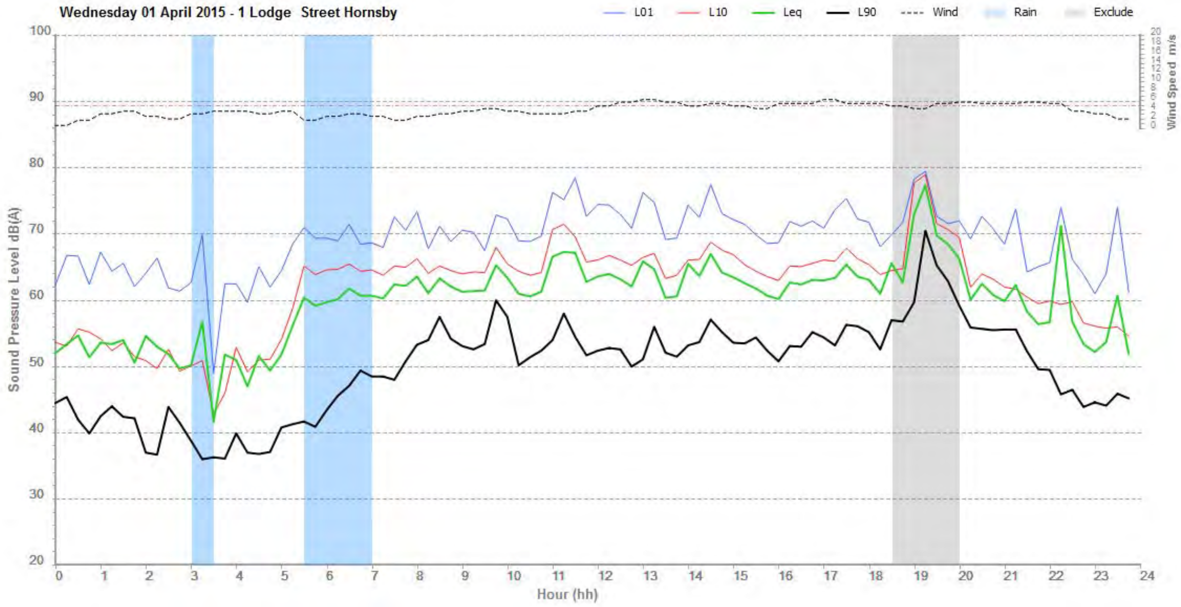
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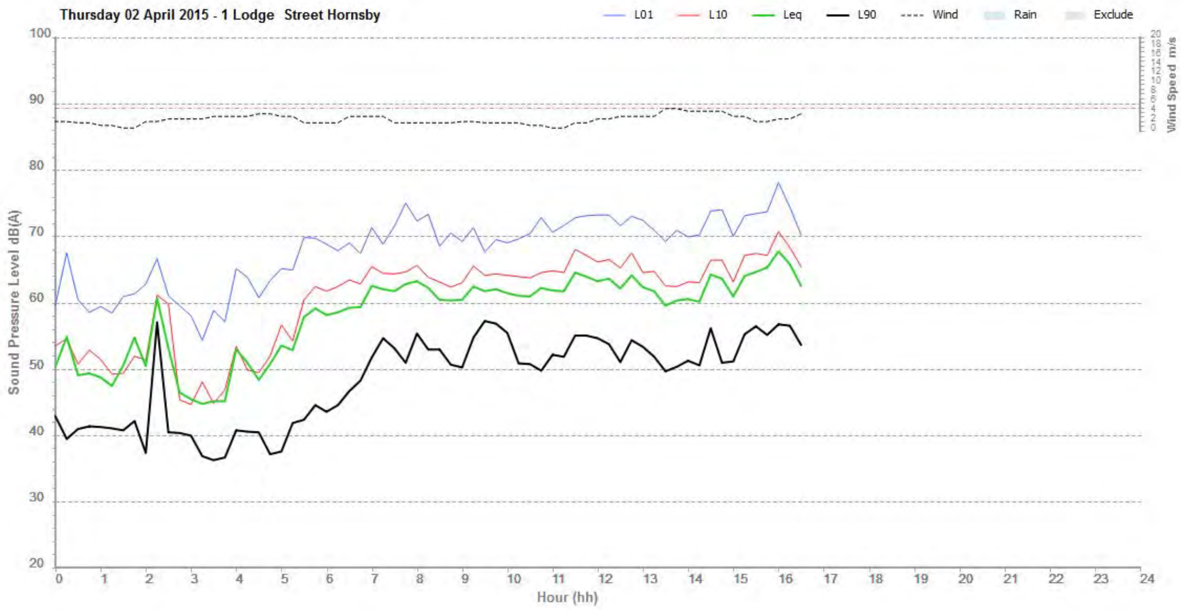
Hour (hh)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Hour (hh)

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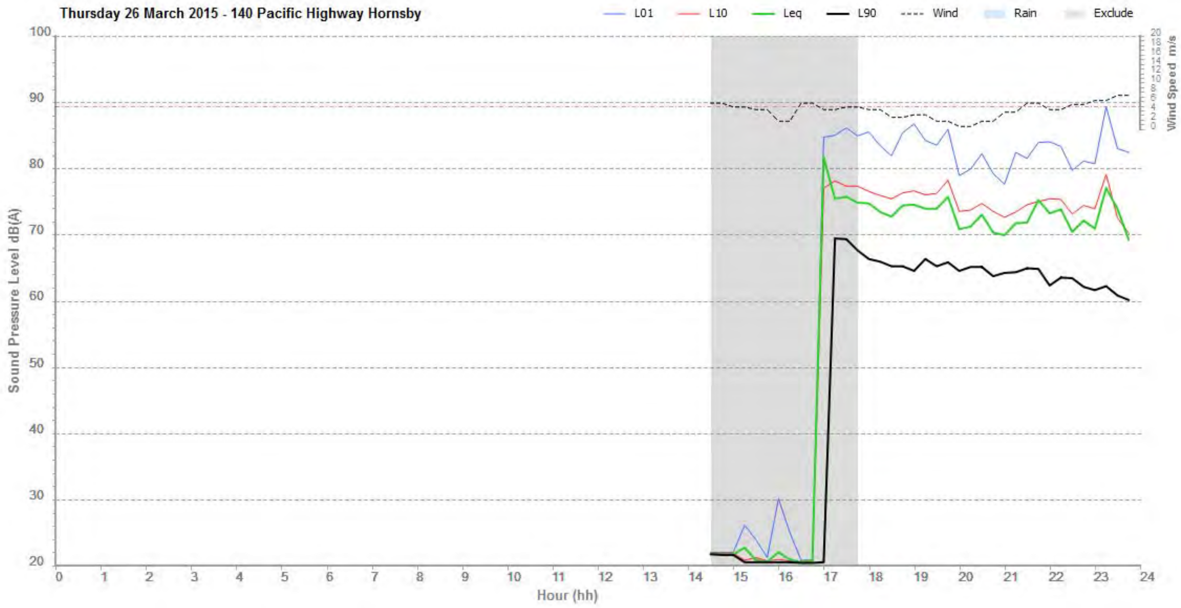

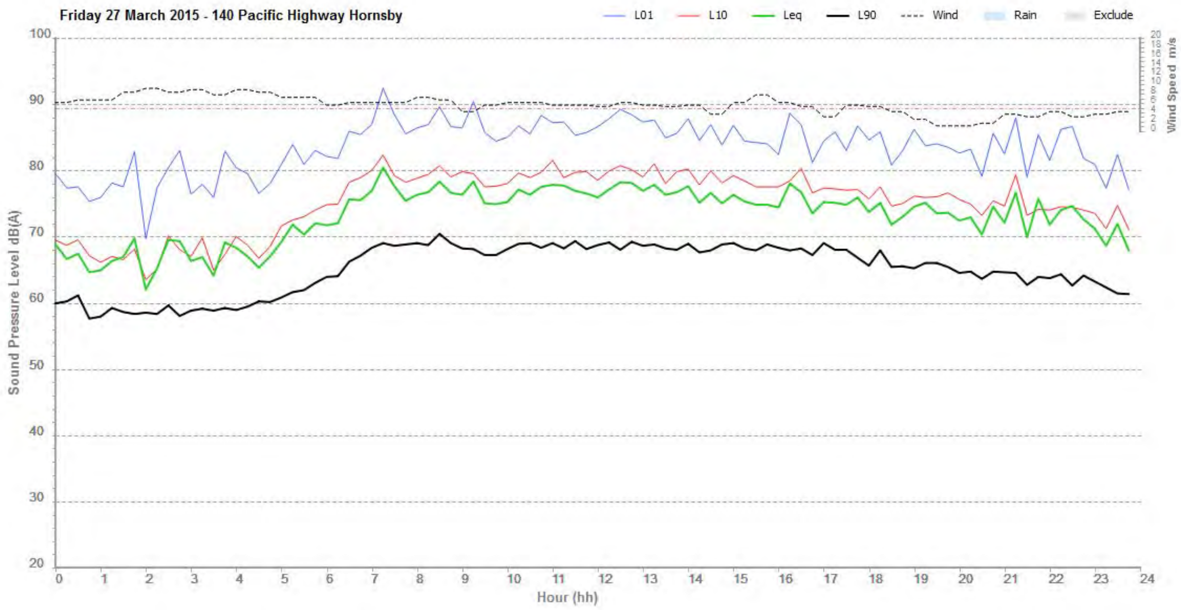

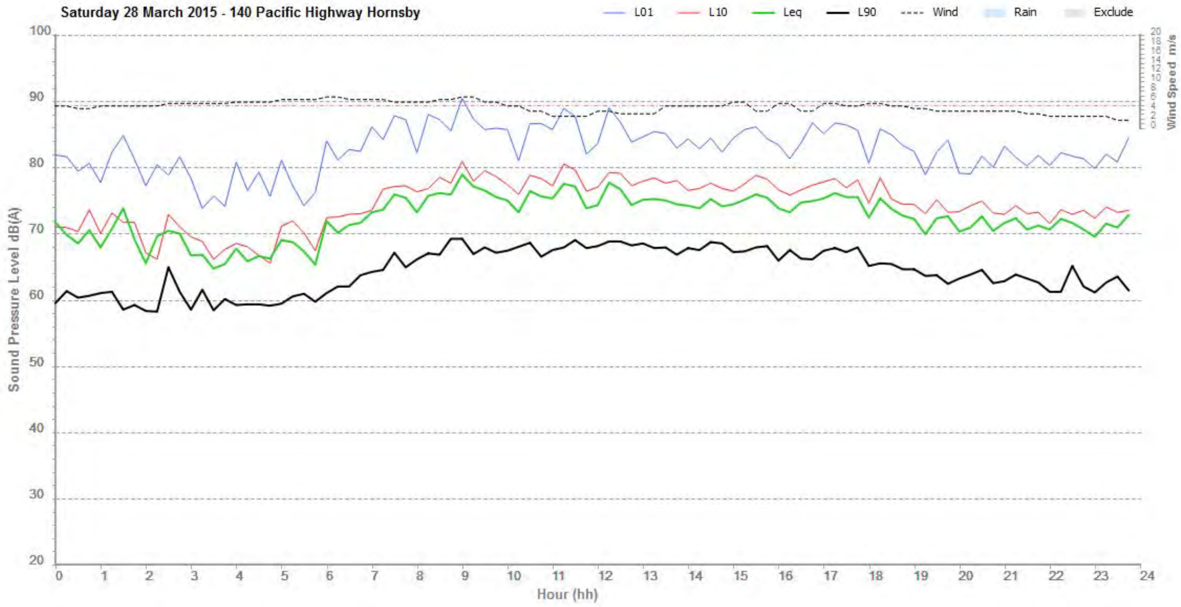

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Rain
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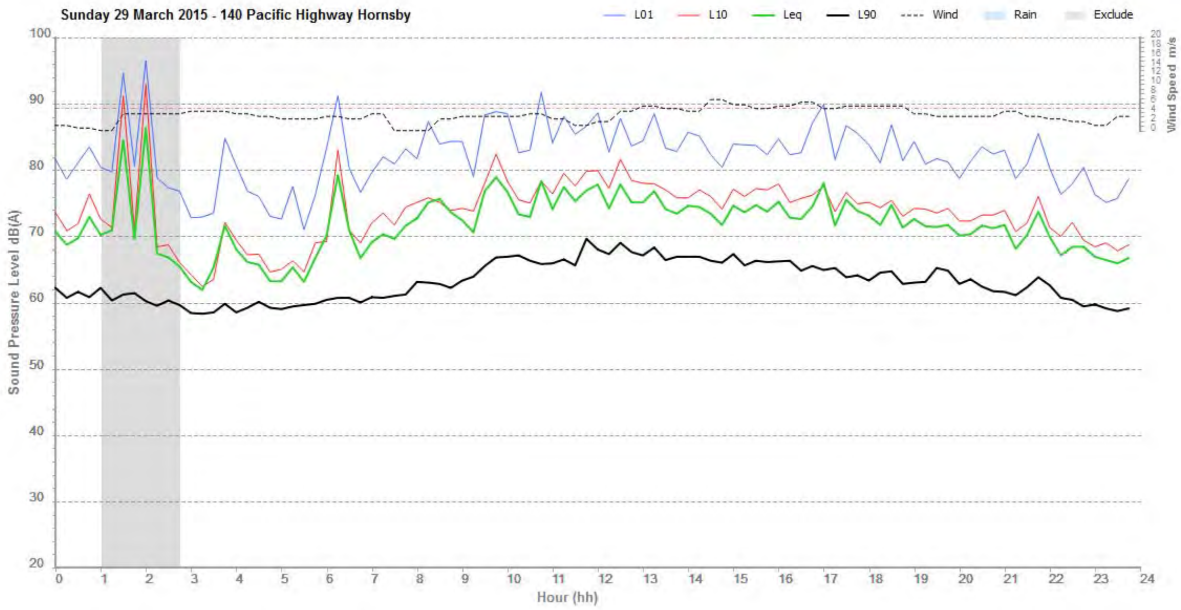
Wind Speed m/s
Hour (hh)



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Wind
Rain
Exclude
Sound Pressure Level dB(A)
Wind Speed m/s
Hour (hh)


Monday 30 March 2015 - 140 Pacific Highway Hornsby
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Wind
Rain
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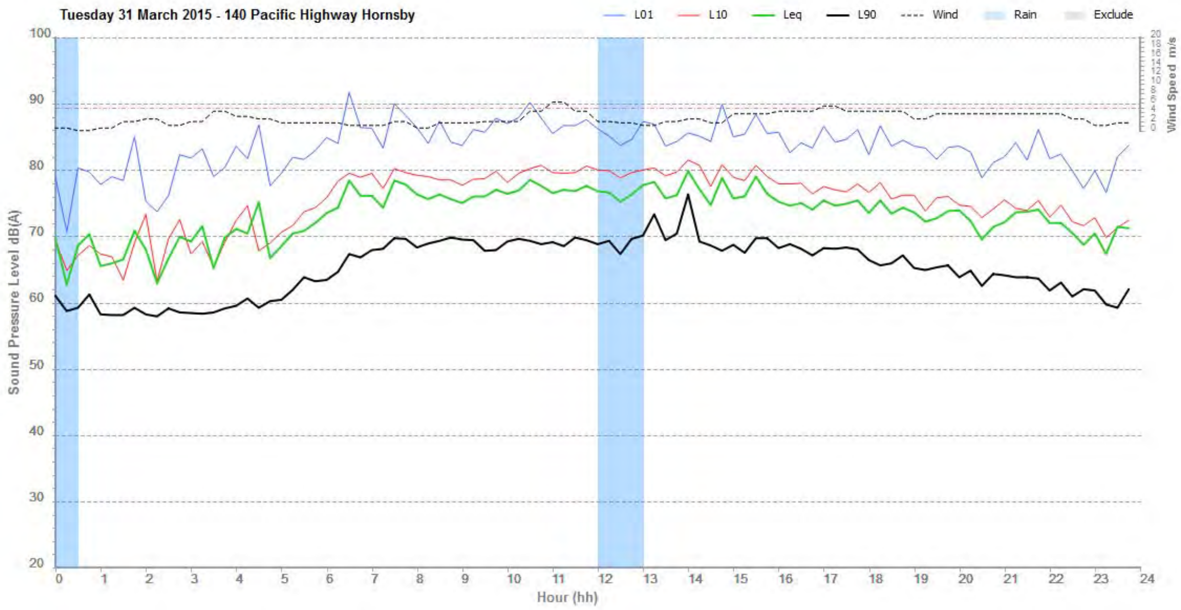
Wind Speed m/s
Hour (hh)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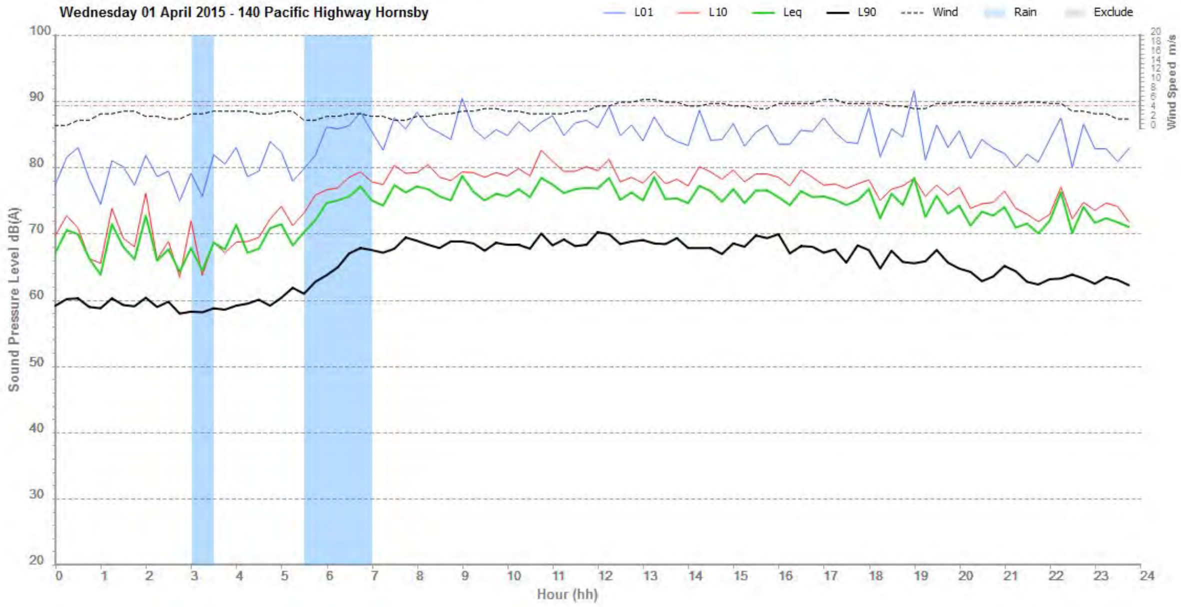
Hour (hh)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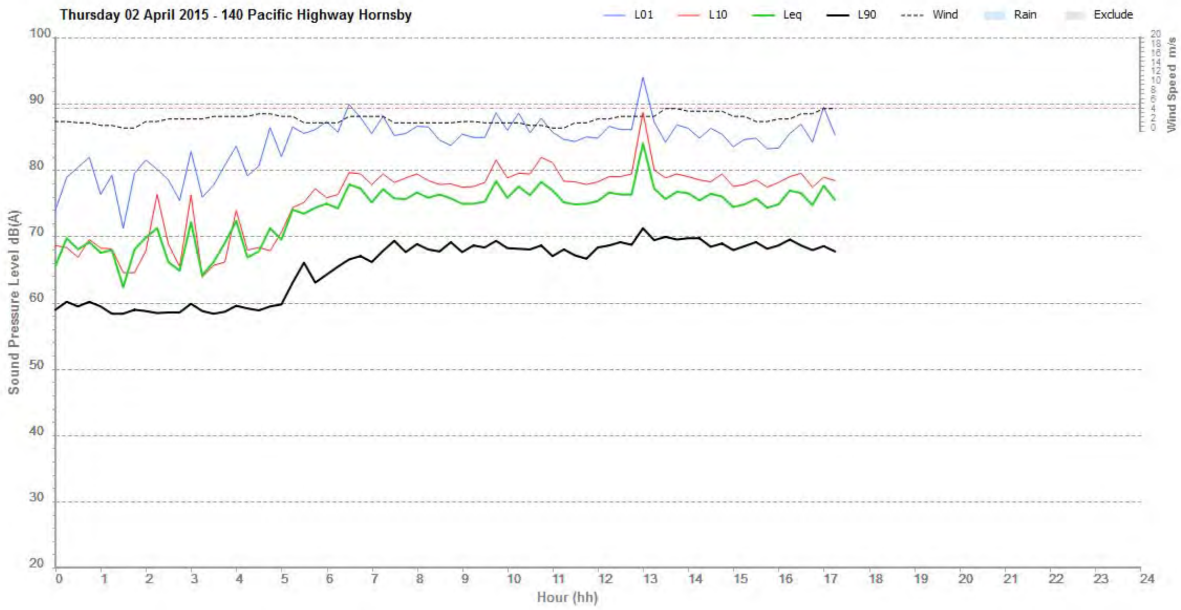
Wind Speed m/s
Hour (hh)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Wind
Rain
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Sound Pressure Level dB(A)
Wind Speed m/s
Hour (hh)

Appendix D – Airborne Noise Maps

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Appendix D Figure 1 Site establishment noise contours

Appendix D Figure 2 Conveyor construction noise contours

Appendix D Figure 3 Conveyor construction and haulage noise contours

Appendix D Figure 4 Spoil emplacement noise contours

Appendix D Figure 5 Site demobilisation noise contours

Appendix D Figure 6 Site establishment noise contours (cumulative)

Appendix D Figure 7 Conveyor construction noise contours (cumulative)

Appendix D Figure 8 Conveyor construction and haulage noise contours (cumulative)

Appendix D Figure 9 Spoil emplacement noise contours (cumulative)

Appendix D Figure 10 Site demobilisation noise contours (cumulative)

Appendix E

Technical working paper:
Air Quality

Technical Working Paper: Air Quality

Hornsby Quarry: Road Construction Spoil Management Project

Client: Roads and Maritime Services

ABN: 76 236 371 088

Prepared by

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27-Jul-2015

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Glossary

Term	Description
Airshed	Part of the atmosphere that shares a common flow of air and is exposed to similar influences.
Ambient	Used interchangeably with 'background' in this report. Ambient/background pollutant concentrations refer to the concentrations of pollutants in the air, which are generated by all local pollutant sources, i.e. the term refers to the general pollutant loads in the air.
bcm	Bank cubic metres. The volume of rock or spoil when measured in situ, prior to extraction or excavation. In this report the volume of rock transported to the Hornsby Quarry site is reported in bcm.
BOM	Bureau of Meteorology
CO	Carbon monoxide
Contemporaneous	Existing at or occurring in the same period of time. For contemporaneous pollutant assessments presented in this report (for example, for PM_{10}, $PM_{2.5}$ and NO_2, the measured ambient pollutant concentration for a particular hour (or 24 hour period) was added to the modelled pollutant contribution from the project for the same hour (or 24 hour period) at each relevant receiver location).
Cumulative assessment	The cumulative assessment was undertaken by summing the project contributions with the ambient pollutant concentrations where relevant, and comparing the predicted cumulative pollutant concentrations to the impact assessment criteria.
ENM	Excavated natural material
EPA	Environment Protection Authority
LiDAR	Light Detection and Ranging
LPI	NSW Land and Property Information
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen, including nitric oxide (NO) and NO_2
O_3	Ozone
OEH	Office of Environment and Heritage
PAHs	Polycyclic aromatic hydrocarbons
Particulate matter	Very small solid particles or liquid droplets, which may become suspended in air.
Plume	An atmospheric body in which substances (air pollutants) are present at concentrations higher than their normal ambient levels.
PM_{10}	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less.
$PM_{2.5}$	Particulate matter with an equivalent aerodynamic diameter of 2.5 micrometres or less.
Receivers	Discrete receivers are identified by the EPA as anywhere someone works or resides or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds, recreational centres, and the like.
Spoil mass	Mass of spoil discussed in tonnes (t)
Spoil volume	Discussed in cubic metres (m^3) and referred to as the volume of rock or spoil after extraction or excavation
TPAHs	Total polycyclic aromatic hydrocarbons
TSP	Total suspended particulates; a type of particulate matter.
TVOCs	Total volatile organic compounds
US EPA	United States Environmental Protection Agency

Term	Description
VENM	Virgin excavated natural material
VOCs	Volatile organic compounds with a high vapour pressure at room temperature. Total VOCs refers to multiple VOCs considered together.
VPH	Vehicles per hour

1.0 Introduction

1.1 Background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for NorthConnex identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

The Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Hornsby Shire Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 2 July 2015 and included a requirement to undertake an assessment of air quality. This air quality technical working paper has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management Project.

1.2 Purpose of this report

The SEARs for the project with respect to air quality were issued on 2 July 2015. The SEARs have informed the preparation of the EIS for the project and include the following requirements specific to air quality:

- *An assessment of activities that have the potential to impact on local and regional air quality; and*
- *Details of the proposed methods to minimise adverse impacts on air quality, particularly in relation to spoil haulage and emplacement, and mobile plant.*

This report should be read in conjunction with the *Technical Working Paper: Air Quality, NorthConnex* (AECOM, 2014) and the *Submissions and Preferred Infrastructure Report: NorthConnex* (AECOM, 2014) for a comprehensive understanding of the potential construction air quality impacts associated with the NorthConnex project.

1.3 Scope of work

The emissions resulting from activities within the Hornsby Quarry site (including materials handling, stockpiling and conveyer emplacement into the void) and exhaust emissions from truck haulage on local/ residential roads have been assessed.

The works undertaken for this assessment consisted of:

- Gathering existing information regarding regional air quality and meteorological data relevant to the study area.
- Identification of the activities and relevant pollutants associated with the proposed spoil management activities.
- Identification of the relevant assessment criteria specified in *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005).
- Quantitative assessment of the potential effects on air quality associated with the proposed spoil management activities through dispersion modelling. Activities included in the assessment were the spoil handling, storage and disposal activities at the Hornsby Quarry site and heavy vehicle traffic associated with spoil transport along the haulage route.
- Where required, identification of reasonable and feasible mitigation and management measures to minimise potential air quality emissions during the proposed works.

The assessment has been undertaken in accordance with *Approved Methods for the Modelling and Assessment of Air Pollution in NSW* (DEC, 2005). The assessment considered local dispersion conditions, existing background levels of pollutants, and changes in vehicle emissions on surface roads. Background monitoring data from representative regional air quality monitoring station(s) have been used in the assessment, in addition to data collected from project-specific air quality monitoring stations.

1.4 Report structure

The structure of this report is summarised in **Table 1**.

Table 1 Report structure

Content	Reference
Introduction	**Section 1.0**
Project description	**Section 2.0**
Existing environment	**Section 3.0**
Assessment methodology	**Section 4.0**
Impact assessment	**Section 6.0**
Mitigation and management measures	**Section 7.0**
Conclusion	**Section 8.0**
References	**Section 9.0**
Relevant pollutants	**Appendix A**
Meteorological monitoring data review	**Appendix B**
Dispersion model details	**Appendix C**
Sensitive receivers	**Appendix D**
Emission calculations	**Appendix E**
NO_X to NO_2 conversion	**Appendix F**
Pollutant concentrations along haul routes	**Appendix G**

2.0 Project description

2.1 Project location

The Hornsby Quarry site is located around 21 kilometres north west of the Sydney Central Business District, in Old Mans Valley to the west of Hornsby town centre. The site covers about 35 hectares and is owned by Hornsby Shire Council (Council) (refer to Figure 1). The site is accessed via local Council roads, including Quarry Road (off Dural Street and other local roads) from the south east and Bridge Road (off the Pacific Highway) from the north east.

The site comprises a quarry void, internal access roads and a cleared area to the east, which was used as a processing area when the quarry was operational. Disused facilities associated with the previous quarrying operations remain on the site, including concrete office block buildings, a crushing and screening plant, a pipeline, security fencing and gates.

Whilst the site is zoned for public recreation (RE1) under the *Hornsby Local Environmental Plan 2013*, the quarry void itself is unsafe for public access given the steep sides and flooded nature of the void. Council currently maintains exclusion fencing around the void to prevent public access for public safety reasons. The areas outside of the void exclusion fencing are open to public access including mountain bike trails which have been established across the site by Council. However, until the quarry void is filled, full rehabilitation of the site for recreational purposes is not possible.

The site and surrounds are densely vegetated with some cleared areas comprising the void itself, internal access roads and the cleared area to the east. Dense bushland comprising the Berowra Valley National Park lies directly to the west. The Pacific Highway and Main North Railway Line are located to the east, approximately 300 metres and 500 metres respectively.

2.2 The project

2.2.1 Project overview

The Hornsby Quarry site would receive up to 1.5 million cubic metres of excavated natural material (ENM) and/or virgin excavated natural material (VENM) from the approved NorthConnex construction sites. Only ENM and/or VENM would be received and reused at the Hornsby Quarry site.

Key features of the project would include:

- Widening and sealing of the quarry access road (Bridge Road and track) to facilitate all weather access.
- Clearing and grubbing, and establishment of erosion and sediment controls.
- Establishment of a compound site, security fencing and signage around the construction area.
- Dewatering of the void (to be undertaken by Hornsby Council in accordance with its existing groundwater licence) to a suitable level that allows working within the void.
- Construction of a conveyor from the stockpile site to the rim of the quarry void.
- Spoil haulage by truck from the NorthConnex construction sites to the Hornsby Quarry site over a period of approximately 28 months.
- Stockpiling of spoil at stockpile sites within the Hornsby Quarry site using dozers.
- Transport of the spoil via the conveyor from the stockpiles to the rim of the quarry void, where the spoil would fall directly into the void.
- Spreading and grading of the spoil on the quarry floor.
- Site demobilisation and rehabilitation of the compound site, stockpile areas and the conveyer corridor.

The project is anticipated to commence in late 2015 and is expected to take around 33 months to complete.

Spoil emplacement activities are expected to occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto site.

Figure 1 Site location and layout

An indicative project program is provided in **Table 2**.

Table 2 Indicative program of works

Phase	Indicative timeframe															
	2015				2016				2017				2018			
Site establishment (including preparatory works)				■												
Establishment of conveyer					■											
Spoil haulage and stockpiling					■	■	■	■	■	■	■	■	■	■		
Spoil emplacement (operation of conveyor)						■	■	■	■	■	■	■	■	■	■	
Site clean-up and demobilisation														■	■	

An overview of project works is included in **Table 3**. Descriptions of each phase can be found in Section 4.1 of the EIS for this project.

Table 3 Overview of works

Phase	Proposed activities
Site establishment (including preparatory works)	The following works would be completed: - Dewatering of the void to a suitable working level. - Clearing and grubbing, and establishment pf erosion and sediment controls. - Establishment of a compound site. - Establishment of security fencing and signage around the construction site. - Widening and sealing of the currently unsealed quarry access road (Bridge Road) to facilitate all weather access.
Establishment of conveyor	The construction of the conveyor works would include establishment of footings and the conveyor.
Spoil haulage and stockpile maintenance	Trucks would enter and leave via Bridge Road during standard construction hours over a maximum period of 28 months. Spoil would be unloaded from the dump trucks and stockpiled using dozers. It is expected that this activity would commence whilst the conveyer is still being constructed.
Spoil emplacement	Once the conveyer is constructed, these works would occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto the site. The activities include: - Placement of spoil from the stockpiles onto the conveyor by front end loader. - Transport of the spoil via conveyor to the quarry void rim where the spoil would fall directly into the void. - Front-end loaders and articulated trucks would move the spoil along the quarry floor and dozers and rollers will spread the material. Periodic maintenance pumping of water from the void would be conducted during all phases.
Site demobilisation and rehabilitation	The construction compound and conveyor would be dismantled and removed from the site. Disturbed areas would be rehabilitated to a standard agreed with the Council. Security fencing would be removed, however would be retained around the quarry void if the void is deemed to remain an ongoing risk to public safety. Public access would then be reinstated to the areas outside the void exclusion zone.

2.2.2 Haulage routes

The expected haulage routes to and from the Hornsby Quarry site have been identified in consultation with Hornsby Shire Council and the NorthConnex construction contractor with the aim of minimising potential impacts on the community. Expected haulage routes are identified below. These routes would be subject to further investigation as part of detailed design.

- **Haulage Into Site:** Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.
- **Truck Movements Out From Site (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road.
- **Truck Movements Out From Site (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

Construction vehicles during site preparation and establishment would also use the above traffic routes. Only light vehicles (for construction personnel) and delivery trucks would access the site (in and out) via Quarry Road. There may be instances, however, when heavy vehicles would be required to access the site from Quarry Road, namely during an emergency and where entry and/or exit via Bridge Road is impeded due to vehicle breakdown.

2.2.3 Operational hours and duration

The project is planned to commence in the last quarter of 2015, with completion in the first quarter of 2018. The total period of works is expected to be around 33 months. The indicative program of works is shown in **Table 2**.

All emplacement activities associated with spoil management on the Hornsby Quarry site would be confined to the following standard hours which are consistent with standard construction hours:

- 7 am to 6 pm Monday to Friday.
- 8 am to 1 pm Saturdays.
- No work on Sundays or public holidays.

2.2.4 Onsite Operations

At the peak of site activity (year 2017) a maximum of 35 trucks per hour hauling 12 bank cubic metres (bcm) of spoil per load would be transported to the temporary stockpile area in the eastern portion (Old Mans Valley) (to be referred to as the flats in this report) of the Hornsby Quarry site. From the stockpiles on the flats, spoil would then be transported via conveyor to the quarry void. A summary of the spoil handling activities onsite is presented in **Figure 2**.

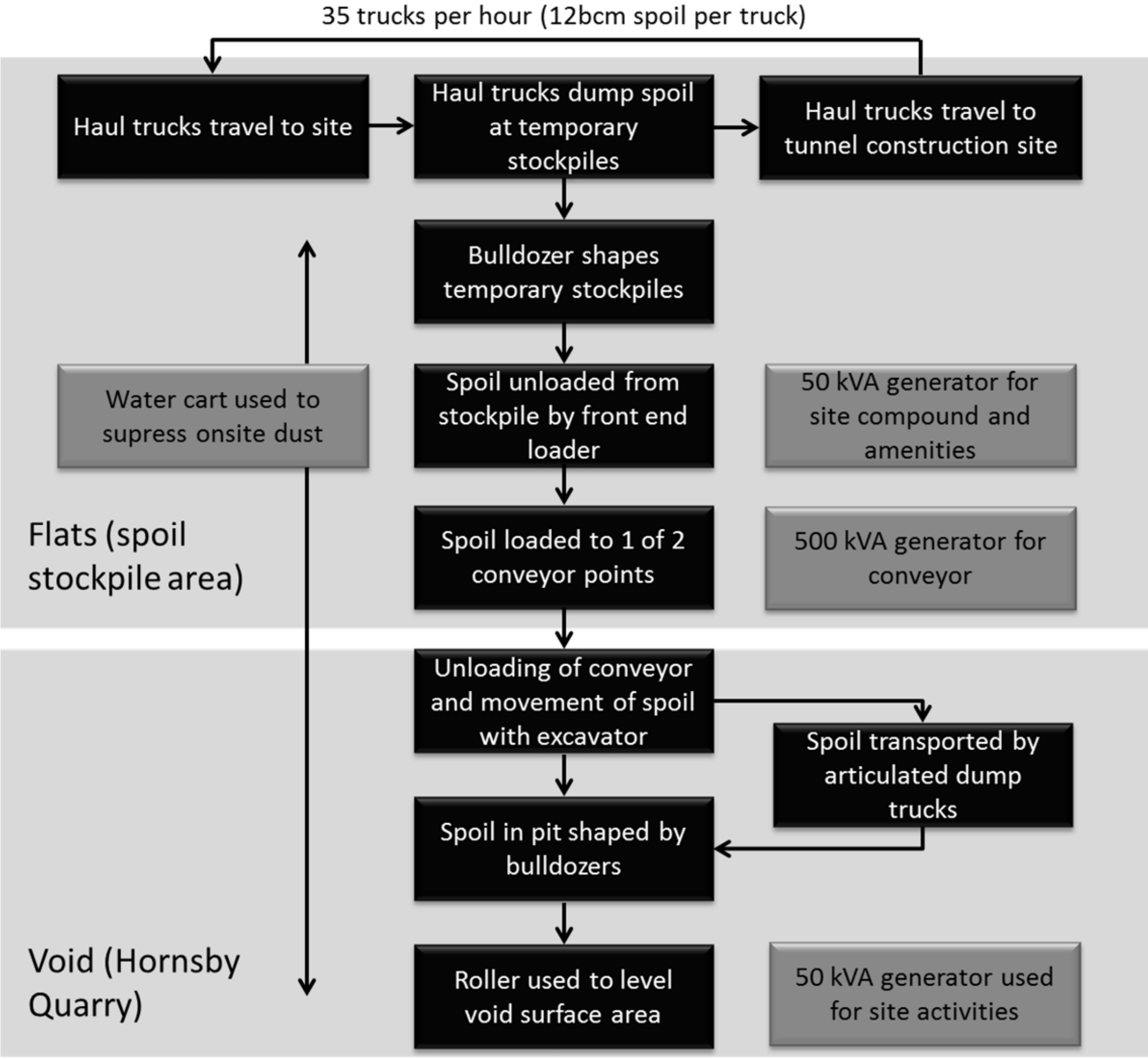

Figure 2 Summary of onsite spoil handling activities

2.3 Relevant pollutants

The proposed works would generate dust during spoil stockpiling and emplacement activities. Dust-generating activities include the handling of material from haul trucks dumping spoil, transfer of spoil from temporary stockpiles to the conveyor and the distribution of spoil within the quarry void. Spoil truck haulage routes within the site would be sealed.

Diesel exhaust emissions from truck haulage activities, mobile equipment and onsite generators would also result in the emission of combustion products including oxides of nitrogen, carbon monoxide, particular matter, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs).

As such, the following pollutants were assessed in this report:

- Particulate matter (TSP, PM_{10}, $PM_{2.5}$ and deposited dust);
- Oxides of nitrogen;
- Carbon monoxide;
- PAHs; and
- VOCs.

Carbon dioxide generated through the consumption of fuel in plant and equipment has been assessed separately in the greenhouse gas assessment presented in Section 7.3 of the Environmental Impact Statement.

Further details of these pollutants are provided in **Appendix A**.

3.0 Existing environment

3.1 Regional air quality

The most recent NSW State of the Environment Report (EPA, 2012a) states that transport emissions are the most important human-related source of air pollution in Sydney. In 2008, motor vehicles were the largest source of emissions of oxides of nitrogen (63 per cent of total emissions) and the second largest source of VOC emissions (24 per cent of total emissions) in the Sydney region.

NSW is considered to have generally good air quality in relation to international standards. Concentrations of carbon monoxide, nitrogen dioxide and volatile organic compounds are consistently lower than national standards in most areas and according to the EPA (2012a), emissions of these pollutants in the Sydney region have decreased by 20 to 40 per cent since the early 1990s. These reductions are considered to be primarily a result of initiatives to reduce air pollution associated with industry, businesses, motor vehicles and residential premises, which have been implemented since the 1980s. Concentrations of measured pollutants appear to be stable over the past few years (EPA, 2012a).

Exceedences of PM_{10} criteria do, however, occur in Sydney, primarily as a result of bushfires and dust storms. The Air NEPM sets a national standard for PM_{10} of 50 micrograms per cubic metre ($\mu g/m^3$) as a 24 hour average, with an allowable five exceedences per year to account for potentially unavoidable and significant events such as bushfires and dust storms. As shown in **Chart 1**, the national PM_{10} standard was exceeded an average of eight times per year and a maximum of 26 times per year across all monitoring locations in the Sydney region between 1994 and 2011. Bushfires and dust storms were the major contributors to the exceedences in 1994, 2001 – 03 and 2009, while hazard reduction burns and local construction activities close to individual sampling stations were likely to have caused the exceedences recorded in 2011. Most exceedences occurred in spring and summer (EPA, 2012a), which is consistent with the most common timing of bushfires and dust storms.

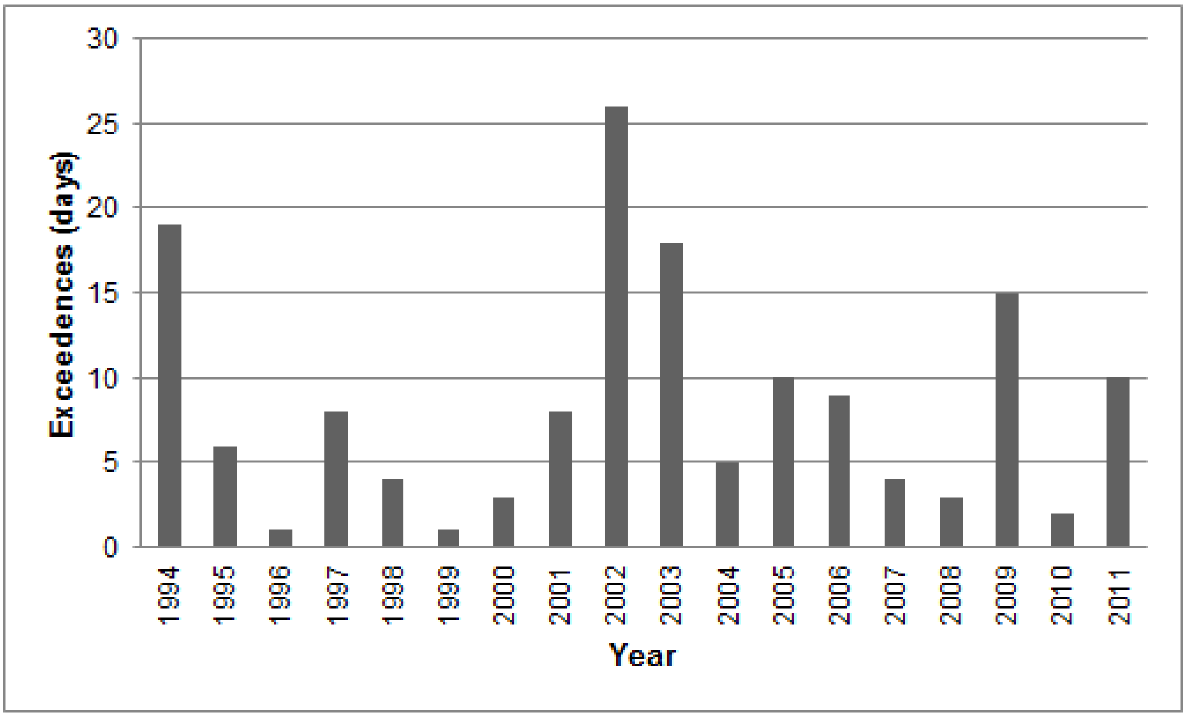

Chart 1 24 hour PM_{10} exceedences: Sydney, 1994 – 2011 (source: EPA, 2012)

The OEH undertook ambient monitoring of a number of air toxics between 1996 and 2001 at 25 sites (DEC, 2004). Samples were collected for 81 pollutants, including VOCs. Of the measured pollutants, only three required further investigation to ensure they remained at acceptable levels in the future – these were benzene, 1,3-butadiene and benzo(a)pyrene. Additional testing conducted between 2008 and 2009 measured concentrations of a number of pollutants including benzene, toluene and xylenes at Turella and Rozelle. Concentrations of all measured pollutants were all well below the monitoring investigation levels. As such, concentrations of air toxics in the Sydney region are not considered to be a primary issue of concern.

3.2 Project monitoring

Five air quality monitoring stations were installed and commissioned along the NorthConnex project corridor in late 2013, hereafter referred to as the NorthConnex project monitoring (refer to **Table 4**). Monitoring at these stations ceased in April 2015. The parameters monitored at James Park monitoring station and the data collection standards are summarised in **Table 5**.

The monitoring station sites were chosen to represent receivers in proximity to Pennant Hills Road (designated as road stations) and receivers away from the major roads (designated as ambient stations). The three ambient monitoring stations, James Park, Headen Sports Park and Rainbow Farm were commissioned to supplement air quality data collected at the OEH's Prospect and Lindfield air quality monitoring stations. The locations of these stations were determined with consideration of a number of criteria, including distance from major roads. The locations of the monitoring stations were intended to gather background air quality information to characterise the subregional airshed and to appreciate the levels of pollutants experienced by suburban receivers.

James Park is the closest ambient classified monitoring station to the Hornsby Quarry site and has been used in this assessment for the assessment of background air quality levels. The data for James Park monitoring station, measured for the latest full calendar year of data (2014) are summarised in **Table 6**.

Table 4 Ambient monitoring network details

Site Name	Coordinates		Height above Sea (m)	Commencement Date	Station Designation
Headen Sports Park	33º43'26.6"S	151 º4'44.42"E	176	20/11/13	Ambient
James Park	33º42'2.59"S	151 º6'48.46"E	177	03/12/13	Ambient
Observatory Park	33º44'25.29"S	151 º3'49.81"E	193	05/12/13	Road
Brickpit Park	33º43'25.12"S	151 º5'23.76"E	235	13/12/13	Road
Rainbow Farm Reserve	33º45'38.83"S	151 º2'40.25"E	112	16/1/14	Ambient

Table 5 James Park monitoring parameters of the ambient monitoring stations and standards

Parameter measured	Relevant standard
NO, NO_2, NOx	AS 3580.5.1 – 1993
CO	3580.7.1-1992
Methane / non-methane / VOC	AS 3580.11.1-1993
Sulfur dioxide (SO_2)	AS 3580.1.1-2008
Ozone (O_3)	AS 3580.6.1-1990
PM_{10} (BAM 1020)	3580.9.11-2008
$PM_{2.5}$ (BAM 1020)	In-house Ecotech method
Vector wind speed (horizontal)	AS 3580.14-2011
Vector wind direction	AS 3580.14-2011
Sigma	AS 3580.14-2011
Rain	AS 3580.14-2011
Solar radiation	AS 3580.14-2011
Ambient temperature	AS 3580.14-2011
Relative humidity	AS 3580.14-2011

Table 6 Data summary: project ambient monitoring stations 2014

Pollutant	Averaging Period	Statistic	Concentration (µg/m^3)
PM_{10}	24 Hour Average	Maximum	43
	Annual Average	Annual Average	18.1
$PM_{2.5}$	24 Hour Average	Maximum	27
	Annual Average	Annual Average	7.6
NO_2	1 Hour Average	Maximum	94
	Annual Average	Annual Average	17
CO	1 Hour Average	Maximum	1,693
	8 Hour Average	Maximum	967
O_3	1 Hour Average	Maximum	196

3.3 Local climate

The Australian Government Bureau of Meteorology (BOM) records long-term meteorological data at a number of automatic weather stations across the country. The Prospect Reservoir BOM station is the closest station to the Hornsby Quarry site that monitors long-term climatic averages and is located approximately 21 kilometres south west of the Hornsby Quarry site (latitude: 33.82 °S; longitude: 150.91 °E, elevation 61 metres). The BOM station commenced operation in 1887 and is currently active. The Prospect Reservoir BOM station climatic average data are provided in **Table 7**.

The mean maximum temperature was 23.1 °C, with peak temperature recorded in January. The mean minimum temperature was 12.2 °C, with the mean minimum recorded in July. The mean rainfall was highest in February and March with 97 mm of rainfall each and lowest in September with 46.7 mm, with an annual mean rainfall of 870.1 mm.

The 9 am and 3 pm data are provided in **Table 7** for temperature, humidity and wind speed. The data show that, as expected, temperatures are higher in the afternoon than in the morning, with mean temperatures for both time periods recorded in January and minima for both in July. Humidity was higher in the morning than in the afternoon, with a peak mean morning humidity of 80 per cent in May and a peak mean afternoon humidity of 57 per cent, also in May. Measured wind speeds are higher in the afternoon, with an annual 3 pm mean speed of 13.1 kilometres per hour compared to 8.3 kilometres per hour at 9 am. The highest mean winds occurred in October for both morning and afternoon periods (10.0 kilometres per hour and 15.4 kilometres per hour respectively), with the lowest mean wind speeds measured in February at 9 am (seven kilometres per hour) and in May at 3 pm (10.3 kilometres per hour).

Table 7 Prospect Reservoir BOM monitoring station climate averages

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual		Years
Average temperature															
Maximum (°C)	28.4	27.9	26.3	23.7	20.3	17.3	16.8	18.8	21.3	23.7	25.4	27.4	23.1	48	1965 2013
Minimum (°C)	17.7	17.8	16.1	12.9	9.9	7.4	6.1	6.8	9.4	12.1	14.3	16.3	12.2	48	1965 2013
Average rainfall															
Rainfall (mm)	93.8	97.0	97.0	74.7	71.4	75.8	56.6	49.5	46.7	58.7	73.6	74.9	870.1	127	1887 2014
Number of days of rain ≥ 1 mm	8.0	8.2	8.4	7.0	6.5	7.0	5.6	5.7	6.1	6.9	7.3	7.5	84.2	127	1887 2014
Average 9 am conditions															
Temperature (°C)	21.3	21.0	19.6	16.9	13.5	10.7	9.6	11.1	14.5	17.4	18.4	20.6	16.2	42	1968 2010
Relative humidity (%)	75	79	79	77	80	79	76	70	65	65	70	70	74	37	1974 2010
Wind speed (km/h)	7.5	7.0	7.3	8.0	7.7	8.0	8.1	9.2	9.7	10.0	8.5	8.2	8.3	44	1965 2010
Average 3 pm conditions															
Temperature (°C)	26.8	26.3	24.8	22.4	19.2	16.5	15.9	17.4	19.6	22.1	23.4	25.9	21.7	33	1968 2001
Relative humidity (%)	52	54	55	52	57	55	50	45	45	46	50	49	51	28	1974 2001
Wind speed (km/h)	12.7	12.4	12.0	11.5	10.3	12.3	12.4	14.3	15.3	15.4	14.4	14.5	13.1	30	1968 2001

3.4 Terrain and land use

The site and surrounds are densely vegetated. Dense bushland comprising the Berowra Valley Regional Park occurs directly to the west. Residential development occurs to the south (off Dural Road) and north (off Fern Tree Close and Manor Road). Other surrounding land use includes the Mt Wilga Private Hospital to the north and the Hornsby Town Centre to the east, including Hornsby Park, Hornsby TAFE off Bridge Road, the Hornsby Aquatic Centre, various businesses along the Pacific Highway and the Hornsby railway station.

The terrain along the project site rises from an elevation of 8 metres (Australian Height Datum) within the existing void to an elevation of around 160 metres (Australian Height Datum) at Old Mans Valley Park. The elevation of nearby sensitive receptors are presented in **Appendix D**.

3.5 Receivers

Receivers are identified by the EPA as anywhere someone works or resides or may work or reside, including residential areas, hospitals, hotels, shopping centres, play grounds, recreational centres, and the like. Due to its location in a highly built-up suburban area, there are a large number of sensitive receivers in the project area. Many of the residential receivers are located adjacent to the existing major road network, which would be most affected by emissions from the vehicles using those roads. Further details about the way sensitive receivers were addressed in this assessment are provided in **Section 4.5**.

Sensitive receivers in the vicinity of the project site are shown in **Figure 3**, **Figure 4**, and **Figure 5** and include:

- Residential properties.
- Commercial properties such as cafes, restaurants, shopping centres and some office blocks.
- Places of worship including St Peter's Parish Centre and Hornsby Community Church.
- Recreational and open space areas including Old Man's Valley, Hornsby Park playground, Berowra Valley National Park, the Benowie Walking Track (partially located on the main access road to the quarry), Hornsby Shire mountain bike trail and the Hornsby Aquatic and Leisure Centre.
- Light industrial areas along the Pacific Highway.
- Key community or education facilities including the Hornsby TAFE and Hornsby Shire Council, Hornsby fire station and Mount Wilga Hospital.

Figure 3 Sensitive receiver locations to the north

Figure 4 Sensitive receiver locations to the east

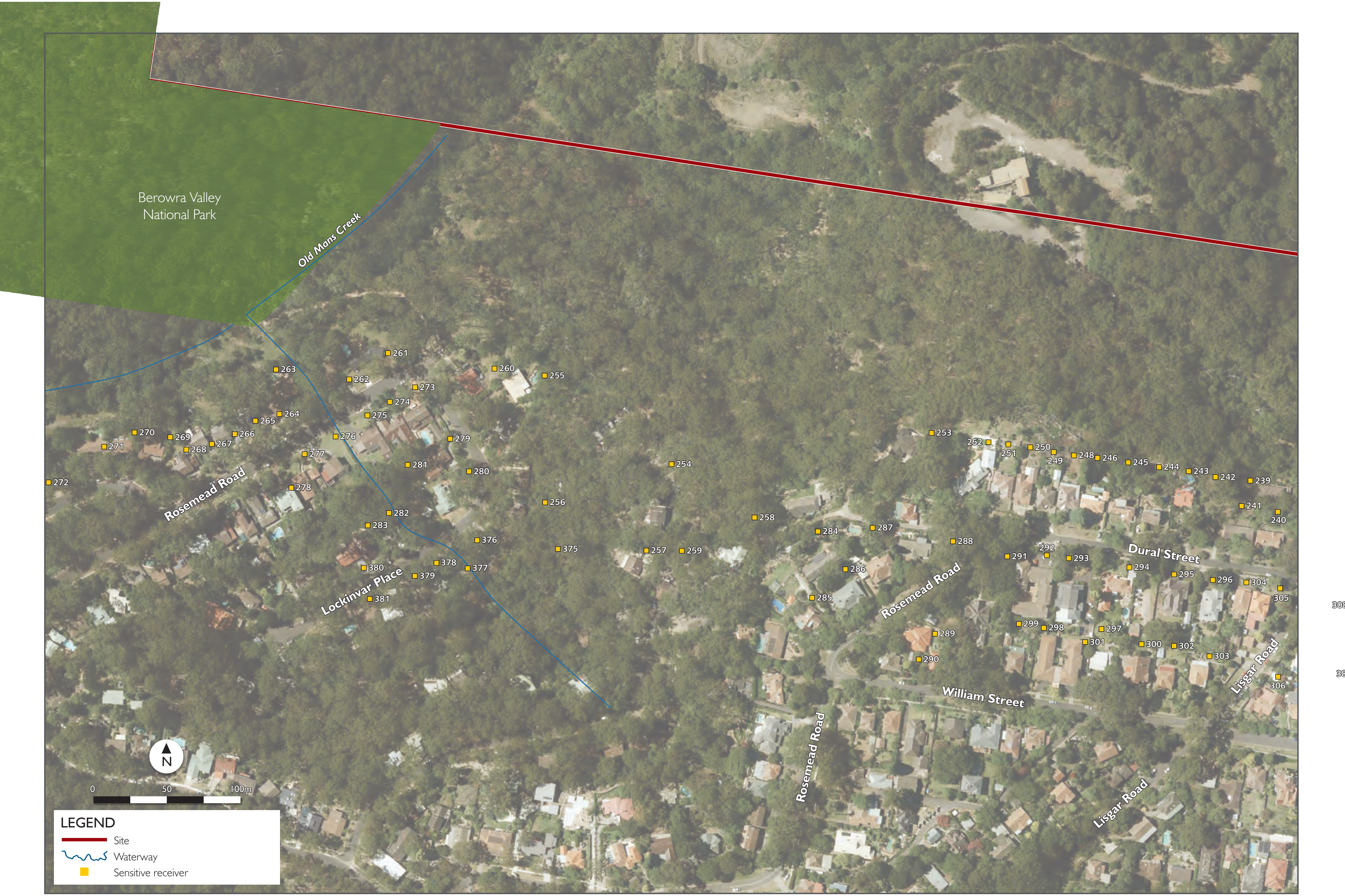

Figure 5 Sensitive receiver locations to the south

4.0 Assessment Methodology

4.1 Assessment scenarios

Two operational scenarios have been modelled as part of this assessment and are described below in **Table 8**.As the timing of stockpiling and void filling is likely to be staggered (refer to **Table 2**) Scenario 1 accounts for only stockpiling activities while Scenario 2 takes into account both stockpiling and void filling occurring concurrently.

For each scenario it is assumed that the generator powering the onsite conveyor and all mobile equipment used for the shaping and redistribution of spoil from the temporary stockpiles to the void would operate for 80 per cent of the time within the confines of the operational hours stated in **Section 2.2.2**. This 80 percent utilisation rate has been applied to account for normal day to day periods of down time including during refuelling, staff breaks, equipment maintenance and scheduling of onsite operations.

Table 8 Modelling Scenarios

Scenario	Scenario Description
Scenario 1	- Movement of up to 4,620 bcm/day of spoil from NorthConnex project construction sites to the Hornsby Quarry sites. - Storage of 170,000 m^3 of spoil in temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site.
Scenario 2	- Movement of up to 4,620 bcm/day of spoil from NorthConnex project construction sites to the Hornsby Quarry site. - Storage of 170,000 m^3 of spoil in temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site. - Transport of up to 7920 t/day of spoil from the temporary stockpiles via conveyor to the quarry floor. A minimum volume of 1,000,000 m^3 of spoil would be used to fill the void.

4.2 Dispersion models

The CALPUFF suite of models has been used to model pollutant dispersion from the stockpiling and filling activities at the Hornsby Quarry site and to estimate the effects of the project on ambient air quality. The CAL3QHCR model has been used to model pollutant concentrations associated with emissions from vehicles on surface roads around the project. The outputs from CALPUFF and CAL3QHCR have been combined with the adopted ambient (background) pollutant concentrations (where applicable) to provide a cumulative estimate of pollutant concentrations in the vicinity of the project during the spoil management activities.

The models are briefly described in the following sections, with further details provided in **Appendix C**. The modelling has been undertaken in accordance with relevant guidance documents (DEC, 2005; Barclay & Scire, 2011).

4.2.1 CALPUFF

The CALPUFF suite of programs, including meteorological (CALMET), dispersion (CALPUFF) and post processing modules (CALPOST), is an advanced non-steady state modelling system designed for meteorological and air quality modelling. CALPUFF is approved for use in NSW by the EPA, particularly in applications involving complex terrain, non-steady-state conditions, in areas where coastal effects may occur, and/ or when there are high frequencies of stable or calm meteorological conditions. CALPUFF was selected for use in this assessment as the topography of the area surrounding the project is complex and is considered close enough to the coast to be potentially affected by coastal breeze circulation.

4.2.2 CAL3QHCR

The CAL3QHCR model is a specialised model for the assessment of road emissions. The line source model predicts pollutant concentrations of carbon monoxide, nitrogen dioxide, particulate matter, and other inert gases from idle or moving motor vehicles based on the Gaussian diffusion equation. The model was accessed through the CALRoads View user interface.

4.3 Meteorological data

Meteorological data for meteorological modelling has been sourced from selected NorthConnex monitoring stations and for consistency from BoM and the OEH monitoring stations used in the NorthConnex EIS assessment (AECOM, 2014).The most recent calendar year of full data, 2014 has been used in the assessment and analysis of available meteorological data is presented in Appendix B.

The meteorological data used in the dispersion model are of fundamental importance, as these data drive the predictions of the transport and dispersion of the air pollutants in the atmosphere. The most critical parameters are:

- Wind direction, which determines the initial direction of transport of pollutants from their sources.
- Wind speed, which dilutes the plume in the direction of transport and determines the travel time from source to receiver.
- Atmospheric turbulence, which indicates the dispersive ability of the atmosphere.

Both measured and prognostic meteorological data were used in this assessment. Meteorological data were sourced from six local surface meteorological stations located in the Sydney basin. NorthConnex monitoring stations James Park and Brickpit were incorporated into the meteorological model due to the site’s proximity to the Hornsby Quarry, while collectively data from BoM and EPA sites (Terrey Hills, Richmond RAAF Base, Prospect and Sydney Airport) were chosen to provide good coverage over the wider modelling domain. Additionally Sydney Airport and Richmond RAAF monitoring stations are also able to provide air pressure data, which is required for at least one observational site for input into CALMET. Additional information regarding the selection of these six sites is provided in Appendix B.

These measured data were used in conjunction with CSIRO’s The Air Pollution Model (TAPM) prognostic three-dimensional meteorological data to simulate the three-dimensional complex meteorological patterns that exist within the modelling domain, accounting for the effects of local topography and changes in land surface characteristics. Gridded three-dimensional TAPM data were input into the CALMET model to generate the initial guess wind field[1] in CALMET, after which observational data from meteorological stations were included by the program to generate the final three-dimensional wind fields for use in CALPUFF. The dispersion modelling was undertaken using one year of meteorological data (January 2014 – December 2014).

4.4 Terrain and land use data

The underlying terrain and dominant land use are important functions of plume transport modelling. Gridded terrain elevations for the modelling domain were derived from the Shuttle Radar Topography Mission (SRTM) three arc-second or around 90 metre resolution data[2] for the meteorological modelling, while higher one metre resolution NSW Land and Property Information (LPI) Light Detection and Ranging (LiDAR) data[3] was used for point source terrain heights and all gridded receptors for the air dispersion modelling. Land use within the study area primarily consists of urban areas, which are interspersed with rangeland and forest land. Land use data within the study area has been derived from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and supplied to AECOM by the OEH. The data are representative of the actual area associated with the project, are recent and of a very fine resolution to increase the accuracy of the modelling.

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[1] CALMET uses a two step procedure in developing final wind fields. The “initial guess” wind field is developed based on a domain-average wind profile, and this domain-average profile of winds is adjusted for terrain effects and divergence minimisation to produce a ‘Step 1’ wind field. The second step is the processing of the wind field is the introduction of observational data into the terrain adjusted Step 1 field.

[2] Based on the findings described in the *North Connex Environmental Impact Statement; Submissions and Proffered Infrastructure Report Chapters 1-5 2014* SRTM is accurate with relatively low error magnitudes on average, Where errors do occur, they are more likely to overestimate the height of topography. Here the risk of over estimation of sensitive receptor heights around elevated point sources may lead to over estimation of potential impacts at these locations. Given emissions from the spoil management facility are from largely ground based sources the risk of overestimation of impacts resultant form overestimation of receptor heights is minimal in this case.

[3] The LPI LiDAR 2011 data set has a horizontal spatial accuracy of 0.8 and a vertical spatial accuracy of 0.3.

The land use data used in this application are different to the default land use data used in TAPM and for most CALMET model applications outside of the United States, which are the USGS one kilometre land use data. Until recently, the USGS one kilometre global land use data set was the most readily available data set for air quality applications. Limitations of the USGS data set, however, include its age (more than 20 years old), coarse resolution (between 900 metres and 1.2 kilometres), and the fact that it is categorised according to the North American land use category system, which does not correspond to all relevant Australian land use types.

As stated above, plume transport is an important function of the underlying dominant land use. The inclusion of the Australian land use data set is, therefore, an important relevant addition to this modelling application as the data are recent, relevant and of a very fine resolution. For this project, specific surface characteristics, albedo, roughness length and leaf area index for the Sydney basin were determined from Gero and Voidman (2006) for bushland, agricultural land, dense urban, new urban and established urban areas. Bushland is described as natural vegetation (primarily around 20 metre trees with 40 per cent cover). Agricultural land incorporates all agricultural activity in western Sydney, which is mostly pasture for grazing or market gardens. Urban categories are split into dense urban (which is confined to the Sydney and Parramatta central business districts), new urban (newly established residential suburbs lacking mature trees), and established urban (residential suburbs with mature trees).

4.5 Sensitive receivers

A total of 420 sensitive receivers were specifically considered in this assessment. That is, pollutant concentrations were calculated at these specific locations. Pollutant concentrations were also calculated at each of the grid points within the modelling domain (refer to **Section 4.6**). Locations of the sensitive receiver are shown in **Figure 3**, **Figure 4** and **Figure 5** and details of the sensitive receivers are provided in **Appendix D**.

Existing background concentrations for 2014 at sensitive receiver locations were assumed to be equal to air quality concentrations recorded at the closest ambient air quality monitoring station James Park for 2014 (see **Section 3.2**)

4.6 Model input parameters

A summary of the data and parameters used as input parameters for CALMET and CALPUFF is shown in **Table 9**.

Table 9 Summary of meteorological and CALPUFF input parameters – operational assessment

Parameter	Input
CALMET (v6.42)	
Meteorological grid domain	60 kilometres x 62.5 kilometres
Meteorological grid resolution	250 metre resolution (240 x 250 grid cells)
Reference grid coordinate of southwest corner	295.000 E, 6232.000 S
Cell face heights in vertical grid	0, 20, 40, 80, 160, 320, 700, 1300, 1700, 2300 and 3000 m
Simulation length	1 year (2014)
Surface meteorological stations	CALMET Hybrid Mode: Run using a combination of TAPM gridded numerological data supplemented by data from six surface meteorological stations operated by NorthConnex, BOM and OEH (described below). **James Park NorthConnex Monitoring Station** *Hourly data:* Temperature, precipitation, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 325.161 E 6269.429 S **Brickpit Park NorthConnex Monitoring Station** *Hourly data:* Temperature, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 323.028 E 6266.847 S

Parameter	Input
	Terry Hills BOM Monitoring Station (Station No. 066059) *Hourly data:* Temperature, precipitation, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 335.509 E, 6270.714 S **Richmond RAAF BOM Monitoring Station (Station No. 067105)** *Hourly data:* Temperature, precipitation, humidity, pressure, wind speed and wind direction. *MGA Coordinates (km)*: 293.651 E, 6279.933 S
	Prospect OEH Monitoring Station *Hourly data:* Temperature, humidity, wind speed and wind direction. *MGA Coordinates (km)*: 306.745 E, 6258.646 S **Sydney Airport BOM Monitoring Station (Station No. 066307)** *Hourly data:* Temperature, precipitation, humidity, pressure, wind speed and wind direction. *MGA Coordinates (km)*: 331.173 E, 6242.272 S
Upper air meteorological station	No upper air stations. The 3-dimensional gridded prognostic data from TAPM were used as the initial guess wind-field for CALMET.
Wind field input parameters	RMAX = 2, RMAX1 = 8 and RMAX3 = 10, TERRAD = 6, R1 = 0.8, R2 = 3, IEXTRP = -4 and all layer dependant biases = 0
Terrain data	Terrain elevations were extracted from the NASA Shuttle Radar Topography Mission data set (SRTM 90 metre, 3-arc sec).
Land use data	Land use information for CALMET was derived from the OEH land use data set between June 2000 and June 2007 for NSW. The data set has a resolution of 150 square metres over the modelling domain. Higher resolution LPI LiDAR data was used for point source terrain heights and all gridded receptors for the air dispersion modelling.
TAPM	
TAPM Version	v4.04
Number of grids (spacing)	5 (30 km, 10 km, 3 km, 1km, 0.3km)
Number of grid points	40 x 40 x 30
Simulation period	2014
Terrain information	AUSLIG 9 second (horizontal resolution 9”)
Centre of analysis	33°46 S, 151°7.5 E
Local data assimilation	None
Mode	Meteorology mode only
CALPUFF (v6.42)	
Modelling domain	**Computation grid:** 22.5km x 20km **Sampling grid:** No gridded receivers. Discrete receipts only. *MGA SW Coordinates (km)*: 322.150 E, 6268.450 S *MGA NE Coordinates (km)*: 334.600 E, 6270.950 S
Modelling grid resolution	Grid resolution of approximately 50m. A higher density of receivers have been placed within close proximity to the facility and strategic placement of receivers along the haul routes was required to account for assimilation of results with CAL3QHCR data.

Parameter	Input
Number of sensitive receivers	All grid resolutions provided above were modelled as discrete receiver locations (i.e. no gridded receivers) to account for varying grid resolution over the modelling domain. A total of 2,999 discrete receiver locations resulted from the modelling grids, including 420 sensitive receivers around the spoil management facility and an additional 58 receivers along the haul route.
Dispersion algorithm	Turbulence-based coefficients
Hours modelled	8,760 hours
Meteorological modelling period	1 January 2014 – 31 December 2014

4.6.1 Emissions calculation

Vehicle emission rates have been based on internationally recognised emission factors coupled with projected traffic volumes, including the proportion of heavy vehicles and tunnel and outlet emission characteristics. Emissions associated with the spoil management activities have been based on Australian Government Department of Environment's National Pollution Inventory (NPI) Emission Estimation Technique Manuals and the United States Environmental Protection Agency (US EPA)*AP-42, Compilation of Air Pollutant Emission Factors*.

4.6.1.1 Vehicle emission factors

Pollutant emissions from the trucks on the public roads has been estimated using internationally recognised vehicle emission factors prepared by the World Road Association (PIARC, 2012), which provide Australian-specific emissions based on respective fleet compositions. The PIARC emissions dataset has been used for the calculation of ventilation design parameters for the NorthConnex project, and is considered to be an appropriate, if conservative, approach[4].

PIARC (2012) provides emissions data for the year 2010 for fine particulate matter (PM_{10}) (referenced as opacity), carbon monoxide and oxides of nitrogen for passenger car, light duty vehicle (LDV; < 3.5 tonnes) and heavy duty vehicle (HDV; > 3.5 tonnes) classifications. Factors are provided to account for varying vehicle speeds and road gradients. Non-exhaust related particulate emissions ($PM_{2.5}$), based on brake wear and the re-suspension of particulates from road surfaces, are also provided.

PIARC (2012) provides adjustment factors that can be used to forecast future emissions that are based on agreed assumptions on the expected continuous improvement in engine technologies, the phase-out of older, less efficient cars and the gradual tightening of emissions legislation. The adjustment factors are provided for each year up to 2020 and as such the 2016 adjustment factors were applied in the assessment for the project year of 2016.

The surface road modelling has reviewed the emissions from diesel heavy vehicles (material delivery trucks) only. Additional relevant road vehicle emissions not contained within PIARC (2012) (that is, exhaust-related $PM_{2.5}$ and total volatile organic compounds) were sourced from the National Pollutant Inventory (DEWHA, 2008). Total suspended particulates have not been included in the modelling because the particulate emissions from vehicle exhausts primarily comprise the smaller fractions (i.e. PM_{10} and $PM_{2.5}$). As a result, PIARC and the National Pollutant Inventory do not include emission factors for total particulates.

[4] The recently developed database and calculation tool, COPERT Australia, was reviewed as part of the assessment process. While the software was designed specifically for road transport emission inventories across Australia, discussions with the developer determined that, due to a lack of a valid fleet mix model to allow the calculation of fleet emissions, it was not considered suitable for use in project-related road source dispersion modelling.

4.6.1.2 Emissions from haul roads

The haul road assessment has modelled the emissions from the spoil haulage trucks to and from the site only, to avoid double counting of emissions from the existing suburban traffic conditions. Background air quality monitoring data from James Park monitoring station for the year 2014 has been used in the assessment to represent the background air quality environment and hence separate baseline modelling of existing road use has not been undertaken. The surface roads for the haul route used in the project have been converted to 50 road links with associated gradients, which have then been entered into the CAL3QHCR model. Hourly pollutant emission rates were estimated for each road link applying emissions for heavy diesel vehicles at the respective grades and speeds from PIARC (2012). Pollutants have been modelled for the operational year 2016 using meteorological data from 2014 to capture the likely meteorological conditions. Further information regarding calculation of emissions from haul roads is presented in **Appendix E**.

4.6.1.3 Emissions from spoil management activities

Combustion emissions from mobile and stationary plant and equipment for spoil management activities have been calculated using the NPI *Emission Estimation Technique Manual for Combustion Engines, Version 3.0* (DEWHA 2008). Dust emissions associated with spoil management and materials handling activities have been calculated using the *Emission Emissions Estimation Technique Manual for Mining, Version 3.1* (DSEWPC 2012), and the US EPA *AP-42, Compilation of Air Pollutant Emission Factors*, Fifth edition (1995) (and updates).

A summary of the assumptions used in the calculation of emissions from spoil management activities is provided in **Table 10**. A description of the emission calculations and assumptions is presented in **Appendix E**.

Table 10 Emission calculation assumptions

Parameter	Assigned Value
Correction Parameters	
Moisture Content (%)	10
Silt Content (%)	12
Sealed Road Silt Loading (g/m^2)	0.6
Unsealed Road Silt Content (%)	7.1
Mean Wind Speed (m/s)	1.96
Mean Vehicle Speed (km/h)	5
Precipitation >0.25mm (d/y)	229
All hours where wind speed > 5.4m/s (h)	20
Activity Rates	
Volume of spoil per truck (BCM)	12
Maximum haul trucks per hour	35
Rate of Stockpiling and throughput to conveyor[1] (t/h)	900
Equipment utilisation[2] (%)	80
Surface Areas	
Exposed area on flats (ha)	4.3
Exposed area in void (ha)	7.5
Equipment Numbers	
Haul Trucks present onsite at any one time	6
Bulldozer on flats	2
Bulldozer in void	2
Excavator / Front-end loader on flats	2

Parameter	Assigned Value
Correction Parameters	
Excavator / Front-end loader in void	2
Roller in void	2
Articulated dump trucks	2
Water cart	1
Onsite generator (50KVA) (Site & Amenities)	1
Onsite generator (500KVA) (Conveyor)	1
Onsite generator (50KVA) (Pit Amenities)	1

[1] A utilisation rate of 80 percent has been applied to the maximum capacity of the conveyor for emissions rate calculations; equating to 720t/h (refer to **Appendix E**).
[2] Refers to the generator powering the onsite conveyor and all mobile equipment used for the shaping and redistribution of spoil from the temporary stockpiles to the void

4.6.2 Emission rates

Emission rates for Scenario 1 and Scenario 2 are summarised in **Table 11** and **Table 12** respectively. Emission calculations are provided in Appendix E.

Table 11 Scenario 1 emission rates

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours#	Number of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
Bulldozer working on temporary stockpiles	Combustion	Point	Flats	6.27×10^{-2}	2.28×10^{-1}	2.02×10^{-2}	2.02×10^{-2}	1.86×10^{-2}	8.48×10^{-6}	2.20×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Trucks dumping spoil	Dust	Volume	Flats	N/A	N/A	5.15×10^{-3}	2.44×10^{-3}	3.65×10^{-4}	N/A	N/A	Normal	2
Haul trucks (full)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	7.67×10^{-2}	1.47×10^{-2}	3.56×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	2.11×10^{-1}	5.83×10^{-2}	5.83×10^{-3}	N/A	N/A	Normal	1
Haul trucks (empty)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	2.34×10^{-2}	4.50×10^{-3}	1.09×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	1.25×10^{-1}	3.45×10^{-2}	3.45×10^{-3}	N/A	N/A	Normal	1
Water cart	Combustion	Point	Flats	4.15×10^{-2}	9.97×10^{-2}	8.15×10^{-3}	8.15×10^{-3}	7.48×10^{-3}	3.70×10^{-6}	9.09×10^{-3}	Normal	1
Wind erosion from exposed areas	Dust	Area	Flats	N/A	N/A	3.65×10^{-5}	1.83×10^{-5}	2.74×10^{-6}	N/A	N/A	When wind speed >5.4m/s	1
Onsite generator (50KVA) (Amenities)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1

*Number of modelled sources refers to the number of sources modelled per actual emission source. For the number of actual sources refer to Appendix E.
#Normal operating conditions refer to Weekdays 7am to 6pm and Saturdays 8am to 1pm.

Table 12 Scenario 2 emission rates

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours#	No. of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
Front-end loader transferring spoil from stockpiles to conveyor	Combustion	Point	Flats	8.63×10^{-2}	2.81×10^{-1}	2.57×10^{-2}	2.57×10^{-2}	2.36×10^{-2}	1.47×10^{-5}	3.78×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	N/A	N/A	Normal	2
Bulldozer working on temporary stockpiles	Combustion	Point	Flats	6.27×10^{-2}	2.28×10^{-1}	2.02×10^{-2}	2.02×10^{-2}	1.86×10^{-2}	8.48×10^{-6}	2.20×10^{-2}	Normal	2
	Dust	Volume	Flats	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Trucks dumping spoil	Dust	Volume	Flats	N/A	N/A	5.15×10^{-3}	2.44×10^{-3}	3.65×10^{-4}	N/A	N/A	Normal	2
Haul trucks (full)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	7.67×10^{-2}	1.47×10^{-2}	3.56×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	2.11×10^{-1}	5.83×10^{-2}	5.83×10^{-3}	N/A	N/A	Normal	1
Haul trucks (empty)	Combustion	Point	Flats	7.75×10^{-3}	2.15×10^{-2}	6.32×10^{-3}	6.32×10^{-3}	6.01×10^{-3}	6.31×10^{-7}	1.60×10^{-3}	Normal	3
	Dust (paved)	Volume	Flats	N/A	N/A	2.34×10^{-2}	4.50×10^{-3}	1.09×10^{-3}	N/A	N/A	Normal	3
	Dust (unpaved)	Volume	Flats	N/A	N/A	1.25×10^{-1}	3.45×10^{-2}	3.45×10^{-3}	N/A	N/A	Normal	1
Conveyor transfer points	Dust	Volume	Flats	N/A	N/A	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	N/A	N/A	Normal	3
Water cart	Combustion	Point	Flats	4.15×10^{-2}	9.97×10^{-2}	8.15×10^{-3}	8.15×10^{-3}	7.48×10^{-3}	3.70×10^{-6}	9.09×10^{-3}	Normal	1
Wind erosion from exposed areas	Dust	Area	Flats	N/A	N/A	3.65×10^{-5}	1.83×10^{-5}	2.74×10^{-6}	N/A	N/A	When wind speed >5.4m/s	1
Onsite generator (50KVA) (site compound and amenities)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1
Onsite generator (500KVA)	Combustion	Point	Flats	3.11×10^{-1}	3.56×10^{-1}	1.78×10^{-2}	1.78×10^{-2}	1.78×10^{-2}	5.33×10^{-9}	1.16×10^{-1}	Normal	1

Operation/Activity Description	Emission Type	Source Type	Location	Emission Rate per Modelled Source (g/s)							Operating Hours[#]	No. of Modelled Sources*
				CO	NO_x	TSP	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		
(conveyor)												
Arterial dump trucks	Combustion	Point	Void	1.25×10^{-1}	2.89×10^{-1}	1.79×10^{-2}	1.79×10^{-2}	1.64×10^{-2}	5.05×10^{-6}	1.33×10^{-2}	Normal	2
	Dust (full)	Volume	Void	N/A	N/A	1.64×10^{-1}	4.51×10^{-2}	4.51×10^{-3}	N/A	N/A	Normal	2
	Dust (empty)	Volume	Void	N/A	N/A	1.19×10^{-1}	3.28×10^{-2}	3.28×10^{-3}	N/A	N/A	Normal	2
Excavators transferring spoil from conveyor	Combustion	Point	Void	7.20×10^{-2}	2.97×10^{-1}	2.09×10^{-2}	2.09×10^{-2}	1.92×10^{-2}	1.38×10^{-5}	3.54×10^{-2}	Normal	2
	Dust	Volume	Void	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	7.49×10^{-3}	3.54×10^{-3}	5.37×10^{-4}	7.49×10^{-3}	Normal	2
Bulldozers working in void	Combustion	Point	Void	8.34×10^{-2}	3.04×10^{-1}	2.69×10^{-2}	2.69×10^{-2}	2.47×10^{-2}	1.13×10^{-5}	2.93×10^{-2}	Normal	2
	Dust	Volume	Void	N/A	N/A	2.86×10^{-1}	6.21×10^{-2}	3.00×10^{-2}	N/A	N/A	Normal	2
Rollers working in void	Combustion	Point	Void	8.71×10^{-2}	1.89×10^{-1}	1.12×10^{-2}	1.12×10^{-2}	1.03×10^{-2}	5.50×10^{-6}	1.40×10^{-2}	Normal	2
	Dust	Volume	Void	N/A	N/A	5.28×10^{-2}	2.36×10^{-2}	3.78×10^{-3}	N/A	N/A	Normal	2
Conveyor transfer points	Dust	Volume	Void	N/A	N/A	2.14×10^{-2}	1.01×10^{-2}	1.53×10^{-3}	N/A	N/A	Normal	1
Wind erosion from exposed areas	Dust	Area	Void	N/A	N/A	5.22×10^{-5}	2.61×10^{-5}	3.92×10^{-6}	N/A	N/A	When WS >5.4m/s	1
Onsite generator (50KVA) (Site and water pump)	Combustion	Point	Flats	5.56×10^{-2}	5.22×10^{-2}	4.44×10^{-3}	4.44×10^{-3}	4.44×10^{-3}	6.67×10^{-10}	1.44×10^{-2}	Normal	1

*Number of modelled sources refers to the number of sources modelled per actual emission source. For the number of actual sources refer to Appendix E.
[#]Normal operating conditions refer to Weekdays 7am to 6pm and Saturdays 8am to 1pm.

The information relevant to the surface road modelling emissions is provided in **Table 13** and is applicable for both scenarios. The data is provided for each of the 50 links for both peak and non-peak hours, where peak hours are assigned to 7am-9am and 3pm-5pm and non-peak hours are 9am-3pm. The emission rates have been calculated using PIARC emission factors, as described in **Sections 4.6.1.1** and **4.6.1.2**. Further information on emission calculations are provided in **Appendix E**.

Table 13 Surface road emissions rates

Link	Vehicles Per Hour (VPH)	Peak hours (7am-9am and 3pm 5pm)						Vehicles per Hour (VPH)*	Non Peak hours (9am-3pm)					
		Emission rates (g/v mile)							Emission rates (g/v mile)					
		CO	NOx	PM_{10}	$PM_{2.5}$	PAHs	TVOCs		CO	NOx	PM_{10}	$PM_{2.5}$	PAHs	TVOCs
1	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
2	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
3	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
4	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
5	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
6	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
7	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
8	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
9	35	0.431	0.622	0.248	0.235	3.51×10^{-5}	8.89×10^{-2}	70	1.75	10.4	0.494	0.470	1.43×10^{-4}	0.361
10	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
11	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
12	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
13	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
14	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
15	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
16	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
17	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311

18	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
19	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
20	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
21	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
22	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	70	1.68	8.24	0.460	0.437	1.37×10^{-4}	0.347
23	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	70	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311
24	35	0.334	0.470	0.225	0.214	2.72×10^{-5}	6.89×10^{-2}	70	2.11	13.7	0.567	0.539	1.72×10^{-4}	0.436
25	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
26	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
27	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
28	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
29	35	3.35	5.63	0.758	0.721	2.72×10^{-4}	0.690	70	6.17	22.8	1.24	1.18	5.02×10^{-4}	1.27
30	35	1.03	2.89	0.334	0.318	8.40E-05	0.213	0	-	-	-	-	-	-
31	35	1.03	2.89	0.334	0.318	8.40E-05	0.213	0	-	-	-	-	-	-
32	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
33	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
34	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
35	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
36	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
37	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
38	35	3.07	20.2	0.741	0.705	2.50×10^{-4}	0.633	0	-	-	-	-	-	-
39	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
40	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
41	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-

42	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
43	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
44	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
45	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
46	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
47	35	1.51	6.68	0.427	0.406	1.23×10^{-4}	0.311	0	-	-	-	-	-	-
48	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	0	-	-	-	-	-	-
49	35	2.33	13.6	0.585	0.557	1.90×10^{-4}	0.480	0	-	-	-	-	-	-
50	35	1.03	2.89	0.334	0.318	8.40×10^{-5}	0.213	0	-	-	-	-	-	-
*Number of vehicle movements refers to the sum of haul trucks entering (35 trucks per hour) and leaving (35 trucks per hour) the Hornsby Quarry site.														

4.7 Mitigation measures applied into the modelling

Best industry practice mitigation measures would be applied on a day to day basis and are largely source based, where dust generation is minimised through the application of specific measures designed to reduce dust emissions at the source of generation. The measures that were assumed to be undertaken were:

- All site haul roads will be sealed.
- Water sprays will be used on the spoil stockpiles and conveyor transfer points.
- Water carts will wet down the material being transported by arterial dump trucks and worked by the roller and bulldozers.
- Wind barriers, such as shade cloth on boundary fencing, will be erected around the stockpile site perimeter.
- Management of speed limits on internal site haul roads.

Mitigation measures are described in further detail in **Section 7.1**.

4.8 Assessment of pollutants

For most of the assessed pollutants, the model's output data were in a form that could be directly used for the assessment. For NO_2 and VOCs, additional analysis of the model output data was required. For PM_{10}, $PM_{2.5}$, NO_2 and CO, consideration of existing pollutant concentrations in the ambient air also required consideration. Further information is provided in the following sections.

4.8.1.1 Conversion of NO_X to NO_2

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including nitric oxide (NO) and nitrogen dioxide (NO_2). NO will generally comprise 95 per cent of the volume of NO_X at the point of emission. The remaining NO_X will consist of NO_2. The conversion of NO to NO_2 requires ozone to be present in the air, as ozone is the catalyst for the conversion. Ultimately, however, all NO emitted into the atmosphere is oxidised to NO_2 and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) is the most common method adopted in NSW for the estimation of the conversion of ground level concentrations of NO to NO_2. The OLM is based on the generic assumption that 10 per cent of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 per cent of the predicted NO_X concentrations, all the NO_X is assumed to be converted to NO_2, otherwise NO_2 concentrations are predicted using the OLM equation outlined in the NSW EPA Approved Methods (NSW EPA, 2005). This method assumes instant conversion of NO to NO_2 in the plume, which overestimates concentrations close to the source since conversion usually occurs over periods of hours.

The assumptions inherent to the OLM equation result in the methodology being considered to be a conservative approach to NO_2 estimation (as explained in **Appendix F**). The assumption most relevant to this investigation that should be considered is the initial NO_2 proportion assumed by the OLM equation. As advised by the NSW EPA as part of the NorthConnex air quality investigation, NO_2 emissions from vehicle exhausts are closer to 16 per cent rather than the 10 percent accounted for in the OLM. On this basis, it was recommended that for the NorthConnex investigation that the 0.1 value be increased to 0.16 to account for the vehicle specific emissions.

For the emissions associated with this project, there is a mix of sources which are dominated by on-site diesel generators rather than vehicle emissions. On this basis the use of vehicle dominated OLM equation may not be appropriate for the calculation of emissions. However as the use of the 16% initial NO_2 concentration would result in predictions accounting for the higher initial NO_2 value for the vehicles that are on site and as a result, the 0.16 initial NO_2 ratio has been adopted for the OLM equation which is as follows:

$$NO_2 = 0.16 \times NO_X + \min\{(46/48 \times O_3),(0.84 \times NO_X)$$

Background ozone data from the James Park monitoring station (refer to **Section 5.1**) were used to convert the modelled NO_2 concentrations in accordance with the EPA-approved OLM (Method 2, Level 2 Assessment; DEC, 2005)

4.8.1.2 VOCs – vehicle emissions

The total VOC concentrations for heavy vehicle have been speciated using the profile (i.e. the types of pollutants) provided in OEH (2012). The vehicle fleet has been solely based on diesel emissions from heavy vehicles, accounting for both mobile vehicle on site and haul trucks. These data are summarised in **Table 14**.

The VOCs considered for the vehicle emissions were benzene, toluene, xylenes, 1,3-butadiene, acetaldehyde and formaldehyde. The mass fraction percentages reported in **Table 14** were multiplied by the 99.9th percentile total VOC concentrations predicted by the dispersion modelling to estimate the concentrations of the individual VOC species at sensitive receiver locations around the project.

Table 14 VOC speciation profile for vehicle emissions

VOC	Mass fraction for vehicle fleet in project (% VOC) (heavy vehicles diesel emissions)
1,3-butadiene	0.4
acetaldehyde	3.81
benzene	1.07
formaldehyde	9.86
xylenes	0.38
toluene	0.47
VOC speciation from OEH (2012)	

4.8.2 Cumulative assessment

The assessment investigated pollutant concentrations associated with emissions from the spoil disposal activities (via CALPUFF) and from trucks transporting the spoil to the site (CAL3QHCR). The predicted pollutant concentrations for each sensitive receiver location from each model have been summed to provide a total project contribution (i.e. site plus haul route contributions).

For the criteria pollutants (TSP, PM_{10}, carbon monoxide and nitrogen dioxide) and $PM_{2.5}$, the predicted concentrations were added to the relevant ambient (background) pollutant concentrations and compared to the relevant assessment criteria. For PM_{10}, $PM_{2.5}$ and NO_2, ambient pollutant concentrations were added contemporaneously – that is, the ambient pollutant concentrations for each hour of the modelling period were added to the modelling predictions from the same hour at each receiver location.

For PAHs and VOCs, cumulative assessment using background data is not required by the EPA (DEC, 2005). Furthermore, background data are not available to conduct a cumulative assessment of these pollutants. As such, the cumulative assessment for these pollutants was limited to summing the contributions from the spoil disposal and transport activities at sensitive receiver locations.

4.8.3 Contemporaneous assessment methodology

Where predicted pollutant concentrations added to maximum measured values exceeded (or approached) their criteria a contemporaneous assessment in accordance with the EPA Approved Methods (DEC 2005) has been completed. The Approved Method provides that emissions can be modelled during the same hourly time period as the measured background concentration i.e. add the first hourly average dispersion model prediction to the first hourly average background concentration and so on. This allows a cumulative assessment of the predicted impacts and the background in relation to the time of year the release occurs. Background emissions are generally higher during winter months where temperatures and wind speeds are lower resulting in less dispersion. Assessing the total predicted ground level concentrations using a contemporaneous approach provides a more realistic estimation of the likely actual impacts. Where suitable background data are available, the contemporaneous method discussed has been applied in the assessment.

The contemporaneous assessment methodology has been applied to short term particulate averaging period concentrations due to the background concentrations exceeding the EPA ambient criteria and to NO_2 as the Approved Methods NO conversion calculation Level 1 (Method 2 – maximum predicted NO_2 concentration with maximum NO_2 background not paired in time) resulted in exceedences.

4.8.4 Limitations

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

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

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

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

This assessment was undertaken with the data available at the time of the assessment. Should changes to the project be made, further assessment may be required to determine if the findings of this assessment are still applicable.

5.0 Impact assessment criteria

5.1 NSW assessment criteria

In addition to specifying the statutory methods that are to be used to model and assess emissions of air pollutants from sources in NSW, the *Approved Methods for the Modelling and Assessment of Air Pollutants* (DEC, 2005) (to be referred to as the *Approved Methods*) provides assessment criteria against which the emissions from a site or activity are to be assessed. These criteria are intended to minimise the adverse effects of airborne pollutants on sensitive receivers and are summarised in **Table 15**.

There are currently no criteria for the assessment and regulation of $PM_{2.5}$ in NSW. For the purpose of this assessment, the advisory reporting standards and goals for airsheds were adopted from the *National Environment Protection Measure for Ambient Air Quality* (Air NEPM) (NEPC, 2003). It should be noted that these standards are not criteria for specific facility emissions, but have nonetheless been applied in a similar manner as other air quality criteria for the purpose of consistency and completeness. The advisory reporting standards for $PM_{2.5}$ are summarised in **Table 16**.

The assessment criteria for the criteria pollutants (PM_{10}, NO_2 and CO) apply to the maximum predicted total pollutant concentrations (that is, the 100th percentile incremental contribution from the site or activity added to the background pollutant concentration). The assessment criteria for the principal and individual air toxic pollutants (benzene,1,3-butadiene and formaldehyde) and individual odorous air pollutants (toluene, xylenes and acetaldehyde) apply to the 99.9th percentile incremental concentrations (that is, concentrations from the assessed source(s) alone) from the activity for a refined dispersion modelling assessment, such as the current study.

In addition to impact assessment criteria for pollutant concentrations the *Approved Methods* provides dust deposition criteria for both the maximum increase in contribution of deposited dust levels and the maximum total deposited dust level. These are presented in **Table 17**.

Table 15 NSW air quality criteria adopted by the EPA

Pollutant	Averaging Period	Percentile	Criteria (μg/m^3)	Source
PM_{10}	24 hour	100	50	DEC (2005)
	Annual	100	30	DEC (2005)
Total suspended particulates (TSP)	Annual	100	90	DEC (2005)
Nitrogen dioxide (NO_2)	1 hour	100	246	DEC (2005)
	Annual	100	62	DEC (2005)
Carbon monoxide (CO)	1 hour	100	30,000	DEC (2005)
	8 hours	100	10,000	DEC (2005)
Benzene (VOC)	1 hour	99.9*	29	DEC (2005)
Toluene (VOC)	1 hour	99.9*	360	DEC (2005)
Xylenes (VOC)	1 hour	99.9*	190	DEC (2005)
1,3-butadiene	1 hour	99.9*	40	DEC (2005)
acetaldehyde	1 hour	99.9*	42	DEC (2005)
formaldehyde	1 hour	99.9*	20	DEC (2005)
PAHs (as benzo[a]pyrene)	1 hour	99.9*	0.4	DEC (2005)

* The 99.9th percentile concentrations are used for Level 2 assessments, which are those that are conducted using at least one year of site-specific meteorological data. These concentrations are appropriate for this assessment.

Table 16 Advisory reporting standards for $PM_{2.5}$ in the Air NEPM

Pollutant	Averaging Period	Percentile	Criteria ($\mu g/m^3$)	Source
$PM_{2.5}$	24 hours	100	25	NEPM (2003)
	Annual	100	8	NEPM (2003)

Table 17 NSW dust deposition criteria

Pollutant	Averaging Period	Percentile	Criteria (g/m^2/month)		Source
			Maximum Increase	Maximum Total	
Deposited Dust*	Annual	100	2	4	DEC (2005)
*Dust is assessed as insoluble solids as defined by AS 3580.10.1-1991 (AM-19)					

6.0 Impact assessment

As discussed in **Section 4.2**, dispersion modelling was used to predict resultant pollutant concentrations from the spoil management facility (using CALPUFF) and return trips from haul trucks carrying spoil from the NorthConnex project site (using CAL3QHCR). The predicted emission concentrations from each model at each receiver location (where relevant) were combined to provide a total project contribution for each pollutant for each assessment scenario.

For PM_{10}, $PM_{2.5}$, NO_2 and CO, the predicted concentrations were added to the relevant ambient (background) pollutant concentrations to estimate cumulative pollutant concentrations, which were compared to the relevant assessment criteria. For PM_{10}, $PM_{2.5}$ and NO_2, the ambient pollutant concentrations were added contemporaneously – that is, the measured ambient pollutant concentrations were added to the associated model predictions for each receiver for that same time period. The maximum of the CAL3QHCR predictions and the James Park monitoring data at each receiver location were used to represent ambient pollutant concentrations.

The predicted pollutant concentrations reported below refer to concentrations at the identified 420 sensitive receptors. Outside this, impacts from combustion emissions from haul trucks travelling from the NorthConnex Project to the spoil disposal facility on receptors adjacent to haul routes were found to be negligible. These values are presented in **Appendix E**.

6.1 Total suspended particulates

Table 18 shows the predicted annual average TSP concentrations for each scenario; including the project contribution and the maximum cumulative concentration. In the absence of local TSP monitoring data the annual average TSP concentration has been based on the annual average PM_{10} concentration at James Park representing 40 percent (NSW Minerals Council 2000) of the total TSP concentration. That is an annual average TSP concentration equating to 45 µg/m^3.

The predicted project contribution for annual average TSP concentration was 3.5 µg/m^3 and 18.4 µg/m^3 for Scenario 1 and Scenario 2 which equates to 4 and 20 percent of the OEH criterion for the airshed. Combined with the annual average background of 45 µg/m^3 the maximum cumulative concentration for TSP reported in **Table 18** is well below the assessment criterion of 90 µg/m^3 for both Scenario 1 and Scenario 2.

Table 18 Predicted maximum TSP pollutant concentrations

Averaging period	Source	Predicted maximum TSP concentrations (µg/m^3)		Impact Assessment Criteria (µg/m^3)
		Scenario 1	Scenario 2	
Annual	Peak project contribution	3.5	18.4	-
	Peak cumulative concentration (project plus background)	48.5	63.4	90

6.2 Particulate matter (PM_{10})

Predicted PM_{10} ground level concentrations at the nearby worst affected receiver (receptor 327 situated at the Hornsby TAFE building immediately to the east of the stockpiles on the flats) found to have the highest maximum cumulative 24-hour PM_{10} concentration for each scenario are presented in **Table 19**. **Table 19** ranks the ten highest predicted 24-hour PM_{10} concentration for 2014 at this receptor in order of background, increment (project contribution) and cumulative concentration.

For Scenario 1 there are no exceedences of the maximum 24-hour PM_{10} concentration OEH criterion of 50 µg/m^3 at the highest cumulative concentration ranking discrete receptor with a maximum predicted cumulative 24-hour concentration of 49.5 µg/m^3. Nine out of ten of the highest predicted cumulative concentration values are also the highest ranked values based on background concentration at this sensitive receptor (refer to **Table 19**). Top ten background concentrations make up 71 to 88 percent of the OEH criterion in isolation. The maximum project contribution was found to be 14.0 µg/m^3 which represents 28 percent of the OEH criterion.

In **Table 19** higher 24-hour PM_{10} project contributions for Scenario 2, are attributed to materials handling activities both on the flats and within the void. For Scenario 2 there is one exceedence of the maximum 24-hour OEH criterion at the highest cumulative concentration ranking discrete receptor with a predicted value of 53.6 µg/m^3. When the data is analysed in terms of the data ranked for highest cumulative concentration at Receptor 327, the background concentration is 35.5 µg/m^3 contributing 71 percent of the allowable criterion and the predicted project contribution is 18.1 µg/m^3, contributing 36 per cent of the allowable criterion for the airshed.

As discussed above the existing background 24-hour PM_{10} concentration takes up a large proportion allowable for the air shed. When the data is analysed in terms of the data ranked for highest project contribution concentration, the highest ranked project contribution for sensitive receptor 327 is 22.1 µg/m^3 which equates to 44 percent of the OEH criterion and falls to 10.9 µg/m^3 for the tenth highest day representing 22 percent of the criterion. There were no exceedences of the 24-hour criterion at other sensitive receptors.

Table 19 Predicted maximum background, incremental and cumulative PM_{10} concentrations (µg/m^3)

Rank	Ranked by Highest Background Concentration (µg/m^3)			Ranked by Highest Increment Concentration (µg/m^3)			Ranked by Highest Cumulative Concentration (µg/m^3)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
Scenario 1									
1	43.8	1.3	45.0	20.3	15.7	36.0	35.5	14.0	49.5
2	43.6	0.0	43.6	35.5	14.0	49.5	43.8	1.3	45.0
3	41.1	0.5	41.6	16.2	11.4	27.6	43.6	0.0	43.6
4	40.8	1.4	42.2	14.9	10.8	25.8	40.8	1.4	42.2
5	40.5	0.9	41.4	13.3	10.3	23.7	41.1	0.5	41.6
6	38.8	0.1	38.9	16.4	10.2	26.6	40.5	0.9	41.4
7	37.1	0.1	37.2	11.1	9.7	20.8	35.3	5.1	40.4
8	36.3	0.1	36.3	22.6	9.3	31.9	38.8	0.1	38.9
9	35.7	3.0	38.7	12.5	9.3	21.8	35.7	3.0	38.7
10	35.5	14.0	49.5	25.9	8.5	34.4	37.1	0.1	37.2
Scenario 2									
1	43.8	1.4	45.2	20.3	22.1	42.4	35.5	18.1	53.6
2	43.6	0.0	43.6	35.5	18.1	53.6	43.8	1.4	45.2
3	41.1	0.4	41.6	16.2	15.7	31.9	43.6	0.0	43.6
4	40.8	1.6	42.4	13.3	13.3	26.6	20.3	22.1	42.4
5	40.5	1.0	41.5	14.9	13.0	27.9	40.8	1.6	42.4
6	38.8	0.1	38.9	7.9	12.6	20.5	35.3	6.5	41.8
7	37.1	0.0	37.1	22.6	12.2	34.8	41.1	0.4	41.6
8	36.3	0.0	36.3	16.4	11.3	27.7	40.5	1.0	41.5
9	35.7	3.4	39.1	20.5	10.9	31.4	35.7	3.4	39.1
10	35.5	18.1	53.6	11.1	10.9	22.0	38.8	0.1	38.9

Table 20 shows the results of the ten highest ranking discrete receptors for predicted cumulative annual average PM_{10} concentrations for Scenario 1 and Scenario 2. **Table 20** shows for the 10 predicted highest values for each scenario there are no exceedences of the PM_{10} annual average concentration OEH criteria (30 µg/m^3) with a maximum cumulative impact of 20.1 µg/m^3 for Scenario 1 and 20.5 µg/m^3 for Scenario 2. Here the maximum incremental impact was found to be 2.0 µg/m^3 for Scenario 1 and 2.4 µg/m^3 for Scenario 2 which equates to 7 percent and 8 percent of the criterion respectively.

Contour plots showing the project contribution for 24-hour and annual average PM_{10} for both scenarios are shown in **Figure 6** to **Figure 9**.

Table 20 Predicted annual average cumulative PM_{10} concentrations (µg/m^3)

Receptor	Scenario 1			Receptor	Scenario 2		
	Concentration (µg/m^3)				Concentration (µg/m^3)		
	Background	Increment	Cumulative		Background	Increment	Cumulative
327	18.1	2.0	20.1	**327**	18.1	2.4	20.5
219	18.1	1.1	19.2	**219**	18.1	1.5	19.6
223	18.1	1.0	19.1	**223**	18.1	1.3	19.4
328	18.1	0.9	19.0	**328**	18.1	1.2	19.3
221	18.1	0.8	18.9	**209**	18.1	1.1	19.2
218	18.1	0.8	18.9	**218**	18.1	1.1	19.2
222	18.1	0.8	18.9	**210**	18.1	1.1	19.2
220	18.1	0.8	18.9	**220**	18.1	1.1	19.2
217	18.1	0.7	18.8	**221**	18.1	1.1	19.2
210	18.1	0.7	18.8	**222**	18.1	1.1	19.2

Additional analysis of the frequency of predicted cumulative concentrations was undertaken to understand more clearly the expected PM_{10} concentrations and the potential for future exceedences. **Figure 10** shows the frequency of occurrence of cumulative 24 hour PM10 concentrations for Receptor 327 (Hornsby TAFE). This is the predicted worst affected receptor location and it shows that there are a low number of exceedences (one exceedance out of the year of modelled data) and a small number of predicted concentrations close to the criteria i.e. less than 3% of the time the receptor is expected to have a PM_{10} concentration greater than 40µg/m^3.

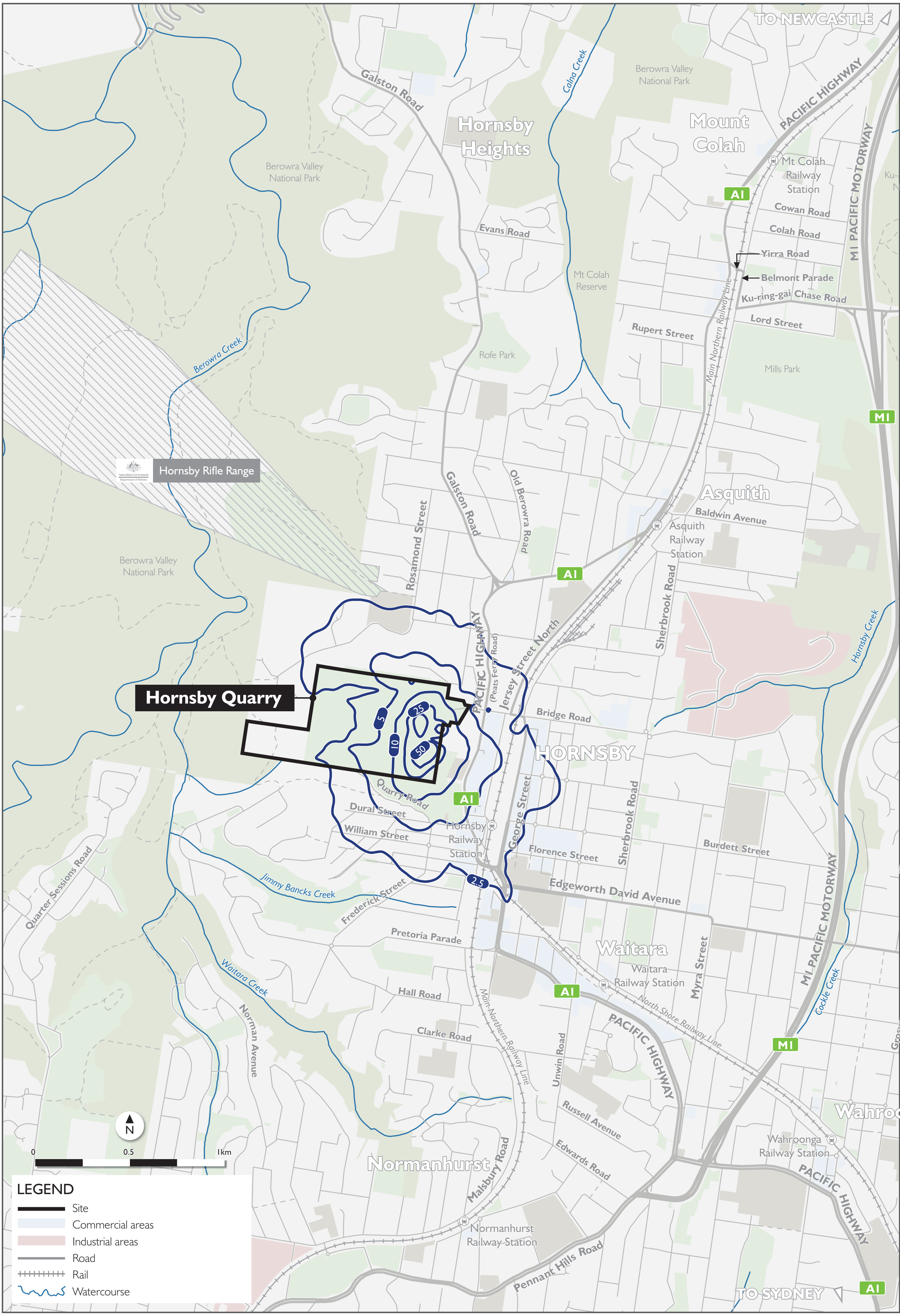

Figure 6 Scenario 1: Maximum 24-hour PM_{10} project contribution concentration ($\mu g/m^3$)

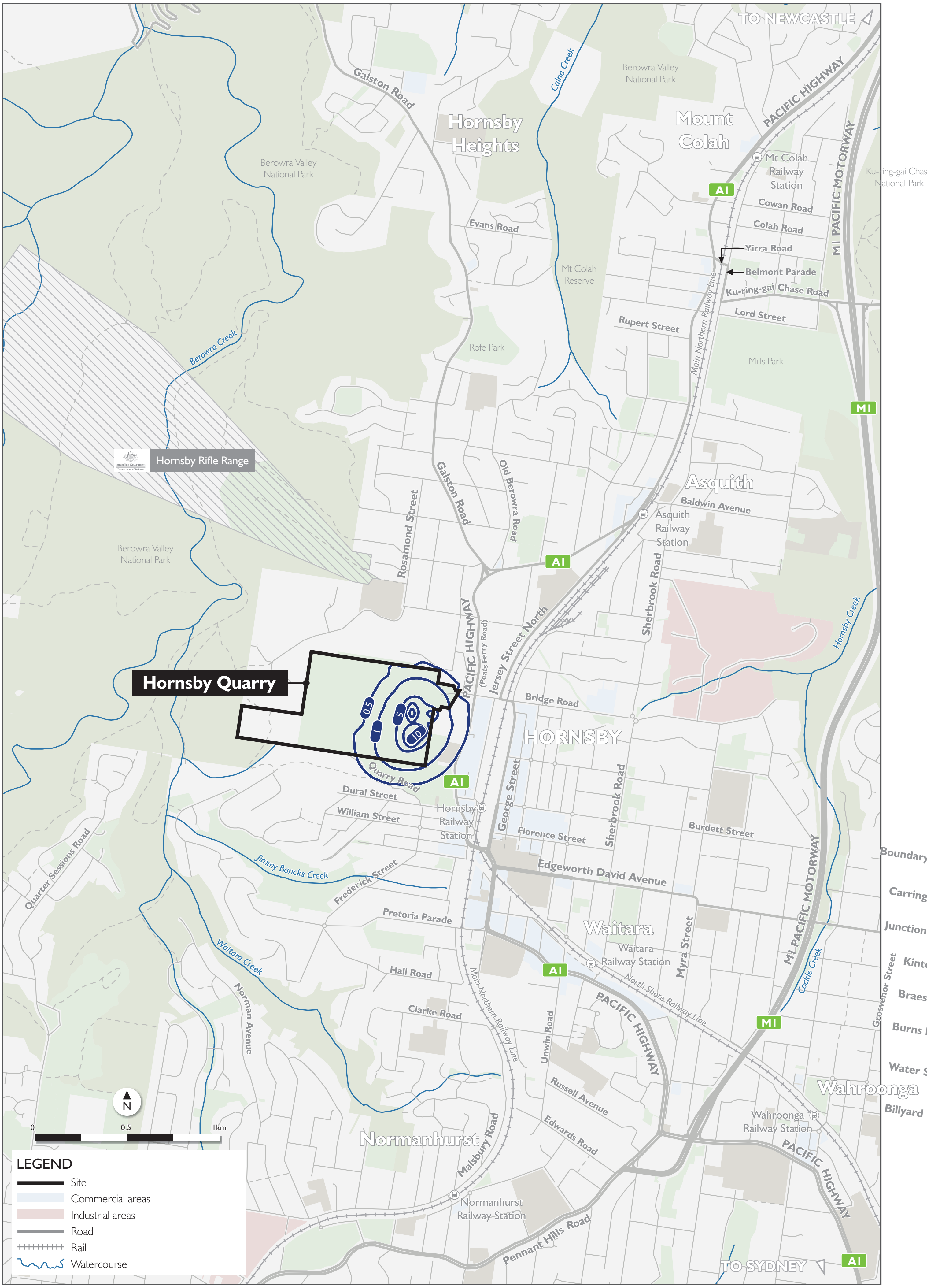

Figure 7 Scenario 1: Annual average PM_{10} project contribution concentration (µg/m^3)

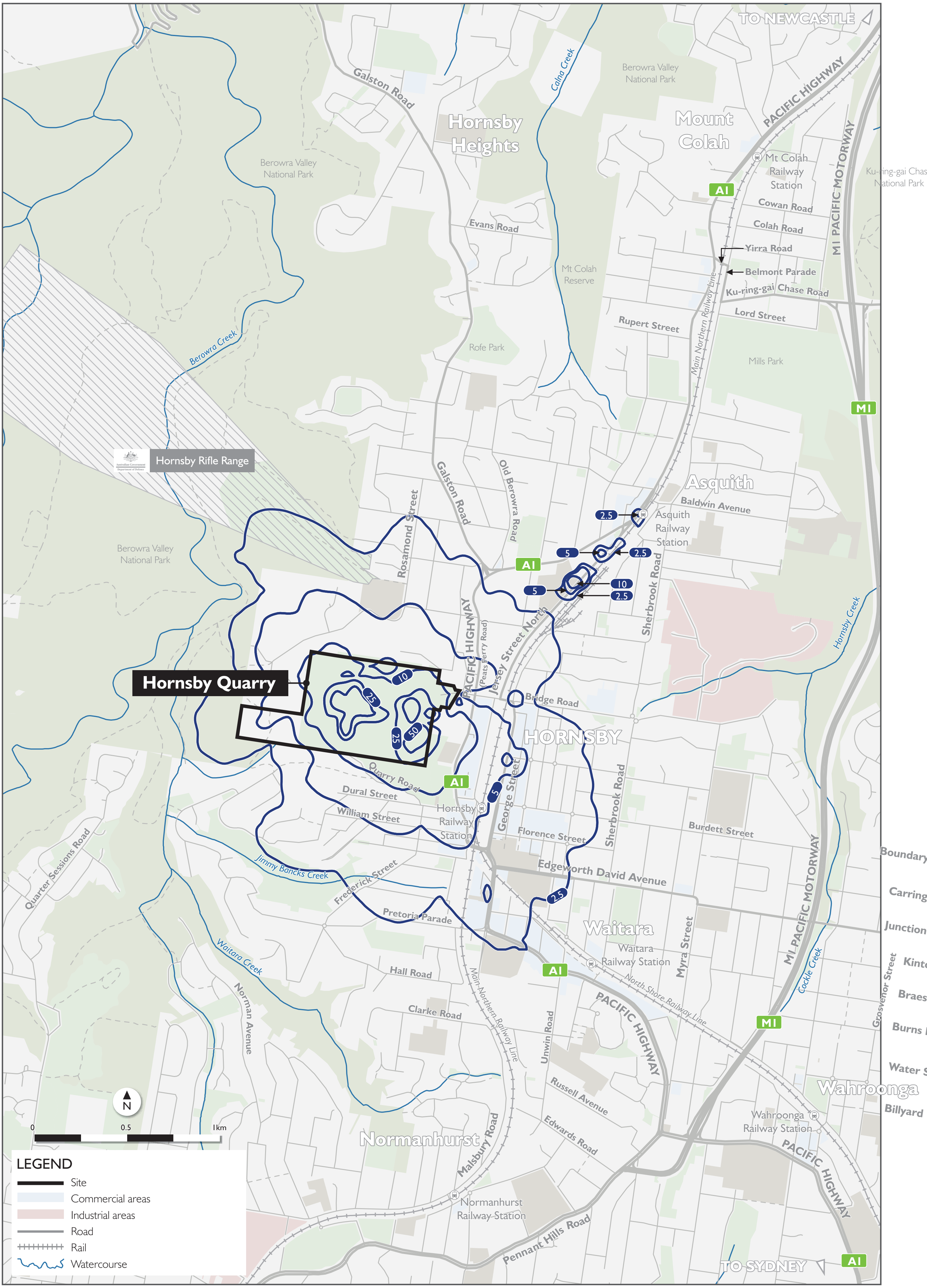

Figure 8 Scenario 2: Maximum 24-hour PM_{10} project contribution concentration ($\mu g/m^3$)

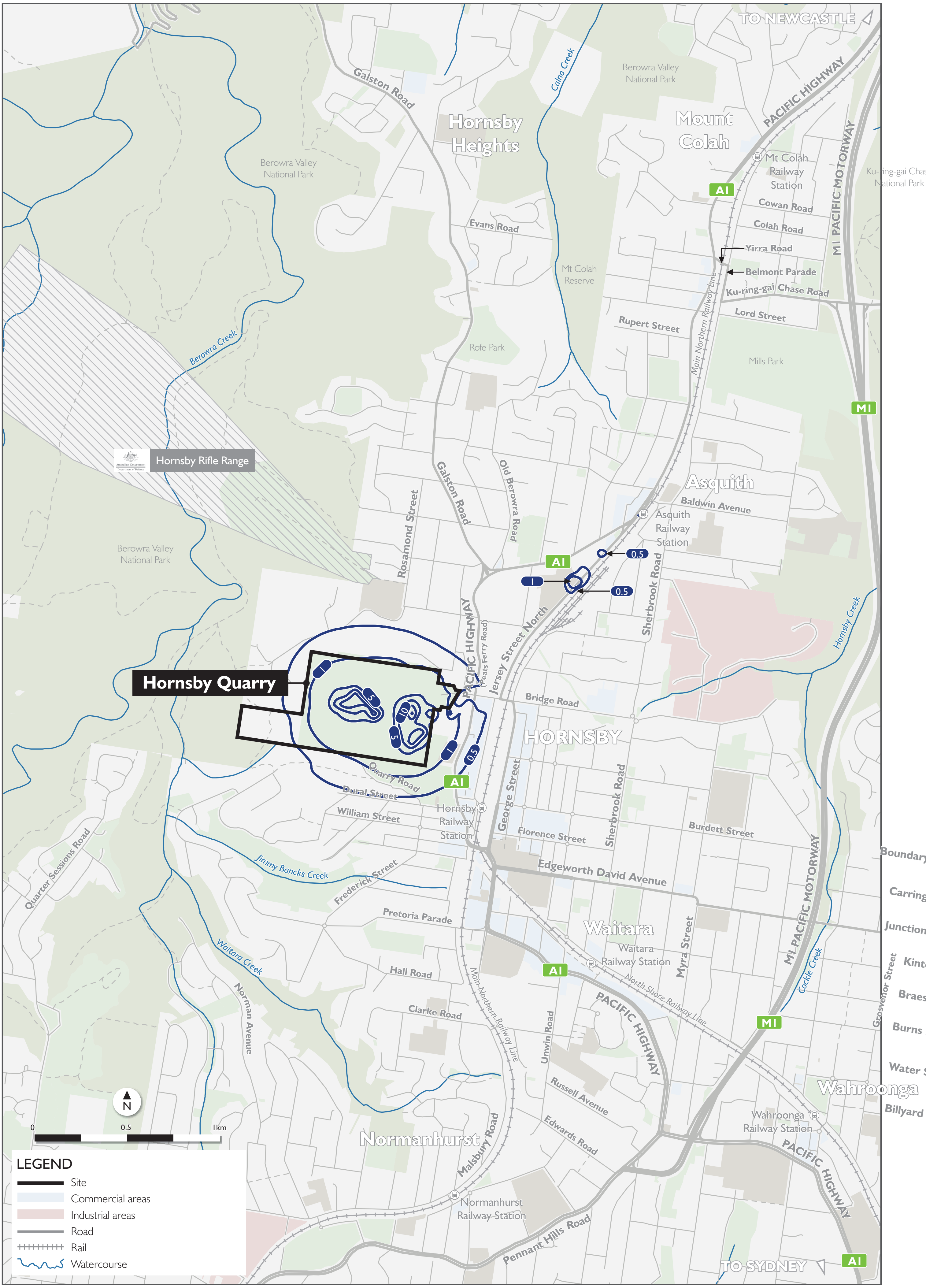

Figure 9 Scenario 2: Annual average PM_{10} project contribution concentration ($\mu g/m^3$)

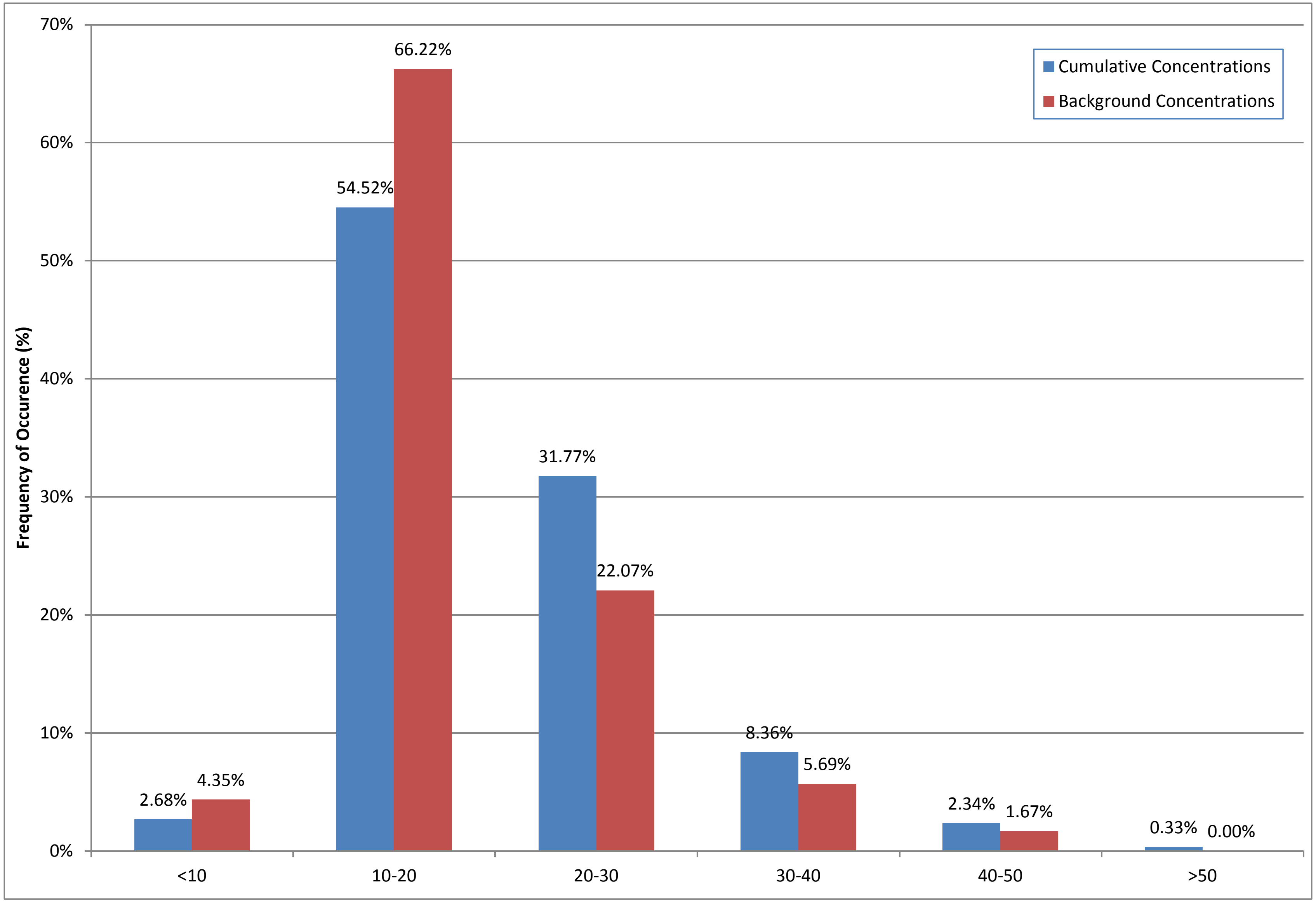

Figure 10 Cumulative 24-hour PM10 Occurrence at Receptor 327 (Hornsby TAFE)

6.3 Particulate matter ($PM_{2.5}$)

Predicted $PM_{2.5}$ ground level concentrations at the worst effected sensitive receiver found to have the highest maximum cumulative 24-hour $PM_{2.5}$ concentration for each scenario are presented in **Table 21** (worst affected receptor was receptor 327 situated at the Hornsby TAFE building immediately to the east of the stockpiles on the flats). **Table 21** ranks the ten highest predicted 24-hour $PM_{2.5}$ concentration for 2014 at this receptor in order of background, increment (project contribution) and cumulative concentration.

For Scenario 1 there are two exceedences of the maximum 24-hour NEPM advisory standard of 25 µg/m^3 at the highest cumulative concentration ranking discrete receptor with predicted 24-hour concentrations of 30.9 µg/m^3 and 27.8 µg/m^3. The two highest predicted cumulative concentration values are also the two highest concentrations based on background concentration (refer to **Table 21**). Here the maximum project contribution is relatively small on both accounts (5.8 µg/m^3 and 2.0 µg/m^3) when compared to the background contribution (25.1 µg/m^3 occurring on 30 August 2014 and 25.8 µg/m^3 occurring on 15 April 2014), which exceeds the 24-hour $PM_{2.5}$ NEPM advisory standard in isolation. The high background concentration recorded on 30 August 2014 of 25.1 µg/m^3 may be attributed to hazard reduction burning undertaken by the NSW Rural Fire Service along Lisgar Road, Hornsby (RFS 2014).

For Scenario 2, 24-hour $PM_{2.5}$ project contributions are notably higher which can largely be attributed to materials handling activities both on the flats and within the void. For Scenario 2 there are also two exceedences of the maximum 24-hour advisory standard at the highest cumulative concentration ranking discrete receptor. Similar to Scenario 1 this occurs on the two same days in 2014 where the 24-hour recorded background concentration exceeds the NEPM advisory standard in isolation. The highest project contribution for 14-hour PM_{10} was predicted to be 8.0 µg/m^3, approximately 32 percent of the advisory standard.

Results of the ten highest ranking discrete receptors for predicted cumulative annual average $PM_{2.5}$ concentrations for both scenarios are presented in **Table 22**. **Table 22** shows the 10 predicted highest values for each scenario are on or above the NEPM advisory standard of 8 µg/m^3. Additionally there were a total of 11 receptors where annual average concentration for Scenario 1 and 70 receptors for Scenario 2 was predicted to be equal to or above the advisory standard. The exceedences however can largely be attributed to the background contribution of 7.6 µg/m^3 (which equates to 95 percent of the advisory standard) due to high $PM_{2.5}$ levels recorded between March and August of 2014. The highest project contributions are small in comparison equating to 14 percent (1.1 µg/m^3) for Scenario 1 and 18 percent (1.4 µg/m^3) for Scenario 2 of the advisor standard.

Contour plots showing the project contribution for 24-hour and annual average $PM_{2.5}$ for both scenarios are shown in **Figure 11** to **Figure 14**.

Table 21 Predicted maximum background, incremental and cumulative $PM_{2.5}$ concentrations (µg/m^3)

Rank	Ranked by Highest Background Concentration (µg/m^3)			Ranked by Highest Increment Concentration (µg/m^3)			Ranked by Highest Cumulative Concentration (µg/m^3)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
Scenario 1									
1	25.8	2.0	27.8	13.1	6.5	19.6	25.1	5.8	30.9
2	25.1	5.8	30.9	25.1	5.8	30.9	25.8	2.0	27.8
3	22.3	0.3	22.6	9.2	5.5	14.7	22.3	0.3	22.6
4	19.1	0.1	19.2	10.4	5.5	15.9	17.1	4.2	21.3
5	18.1	1.9	20.0	4.4	5.5	9.9	18.1	1.9	20.0
6	17.4	2.1	19.6	7.4	5.3	12.7	13.1	6.5	19.6
7	17.1	0.0	17.1	11.7	5.0	16.7	17.4	2.1	19.6
8	17.1	4.2	21.3	0.9	4.5	5.4	19.1	0.1	19.2
9	16.7	2.1	18.7	13.2	4.4	17.6	16.7	2.1	18.7
10	15.5	0.0	15.5	7.4	4.4	11.7	14.4	4.2	18.6
Scenario 2									

Rank	Ranked by Highest Background Concentration (µg/m³)			Ranked by Highest Increment Concentration (µg/m³)			Ranked by Highest Cumulative Concentration (µg/m³)		
	Background	Increment	Cumulative	Background	Increment	Cumulative	Background	Increment	Cumulative
1	25.8	2.8	28.6	13.1	9.9	23.1	25.1	8.0	33.1
2	25.1	8.0	33.1	25.1	8.0	33.1	25.8	2.8	28.6
3	22.3	0.3	22.6	9.2	7.5	16.7	13.1	9.9	23.1
4	19.1	0.1	19.2	9.2	6.8	16.0	22.3	0.3	22.6
5	18.1	2.9	21.0	10.4	6.8	17.2	17.1	5.3	22.4
6	17.4	3.0	20.5	4.4	6.3	10.7	18.1	2.9	21.0
7	17.1	0.0	17.1	10.8	6.3	17.1	17.4	3.0	20.5
8	17.1	5.3	22.4	13.2	6.1	19.3	14.4	5.2	19.6
9	16.7	2.1	18.7	7.4	5.8	13.1	13.2	6.1	19.3
10	15.5	0.0	15.5	0.9	5.6	6.5	19.1	0.1	19.2

Table 22 Predicted annual average cumulative $PM_{2.5}$ concentrations (µg/m³)

Receptor	Scenario 1 Concentration (µg/m³)			Receptor	Scenario 2 Concentration (µg/m³)		
	Background	Increment	Cumulative		Background	Increment	Cumulative
327	7.6	1.1	8.7	327	7.6	1.4	9.0
219	7.6	0.7	8.3	219	7.6	0.9	8.5
223	7.6	0.6	8.2	223	7.6	0.8	8.4
218	7.6	0.5	8.1	218	7.6	0.7	8.3
328	7.6	0.5	8.1	328	7.6	0.7	8.3
217	7.6	0.5	8.1	217	7.6	0.7	8.3
221	7.6	0.5	8.1	210	7.6	0.7	8.3
222	7.6	0.5	8.1	220	7.6	0.7	8.3
220	7.6	0.5	8.1	221	7.6	0.7	8.3
210	7.6	0.4	8.0	222	7.6	0.7	8.3

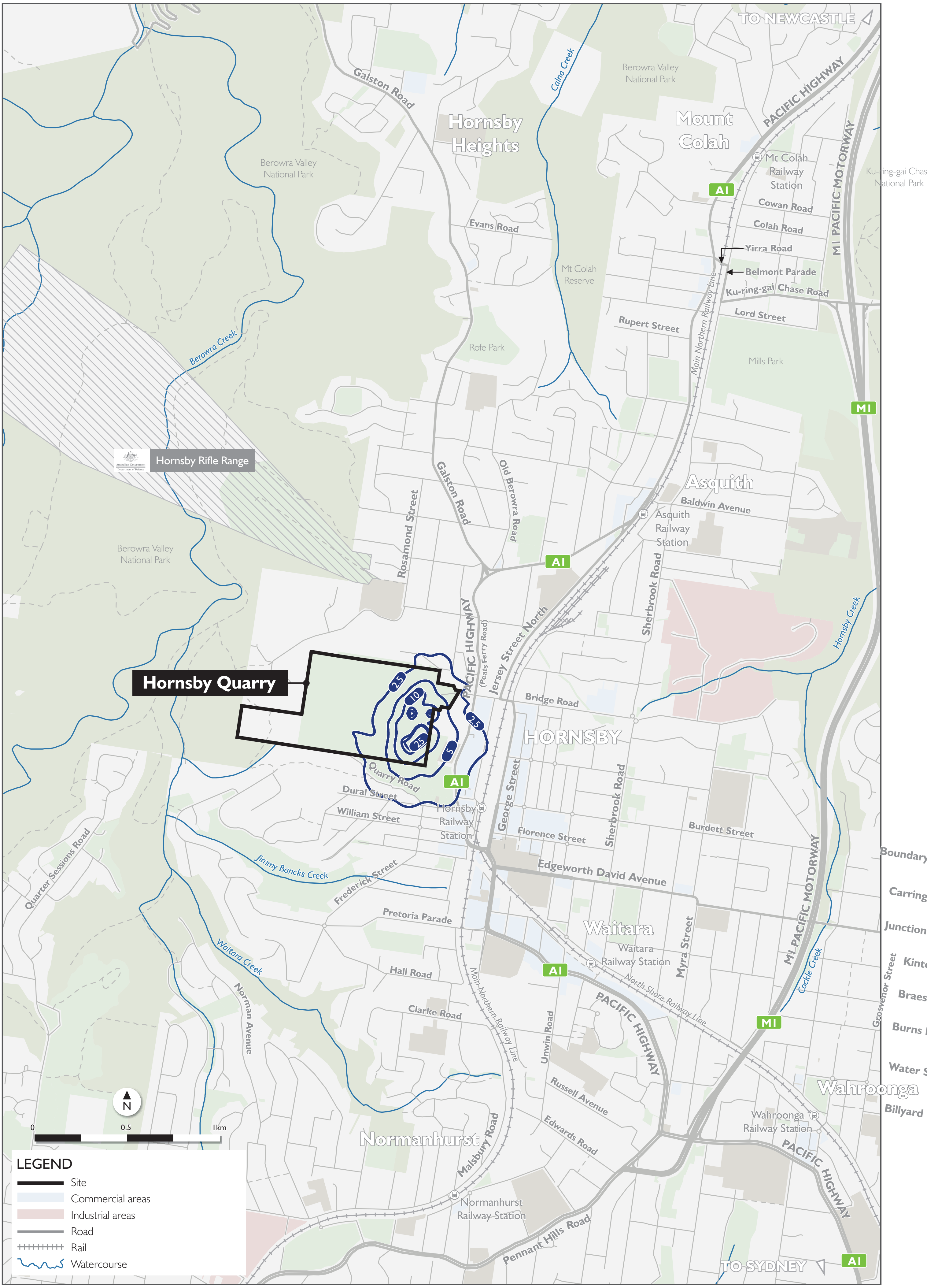

Figure 11 Scenario 1: Maximum 24-hour $PM_{2.5}$ project contribution concentration (µg/m^3)

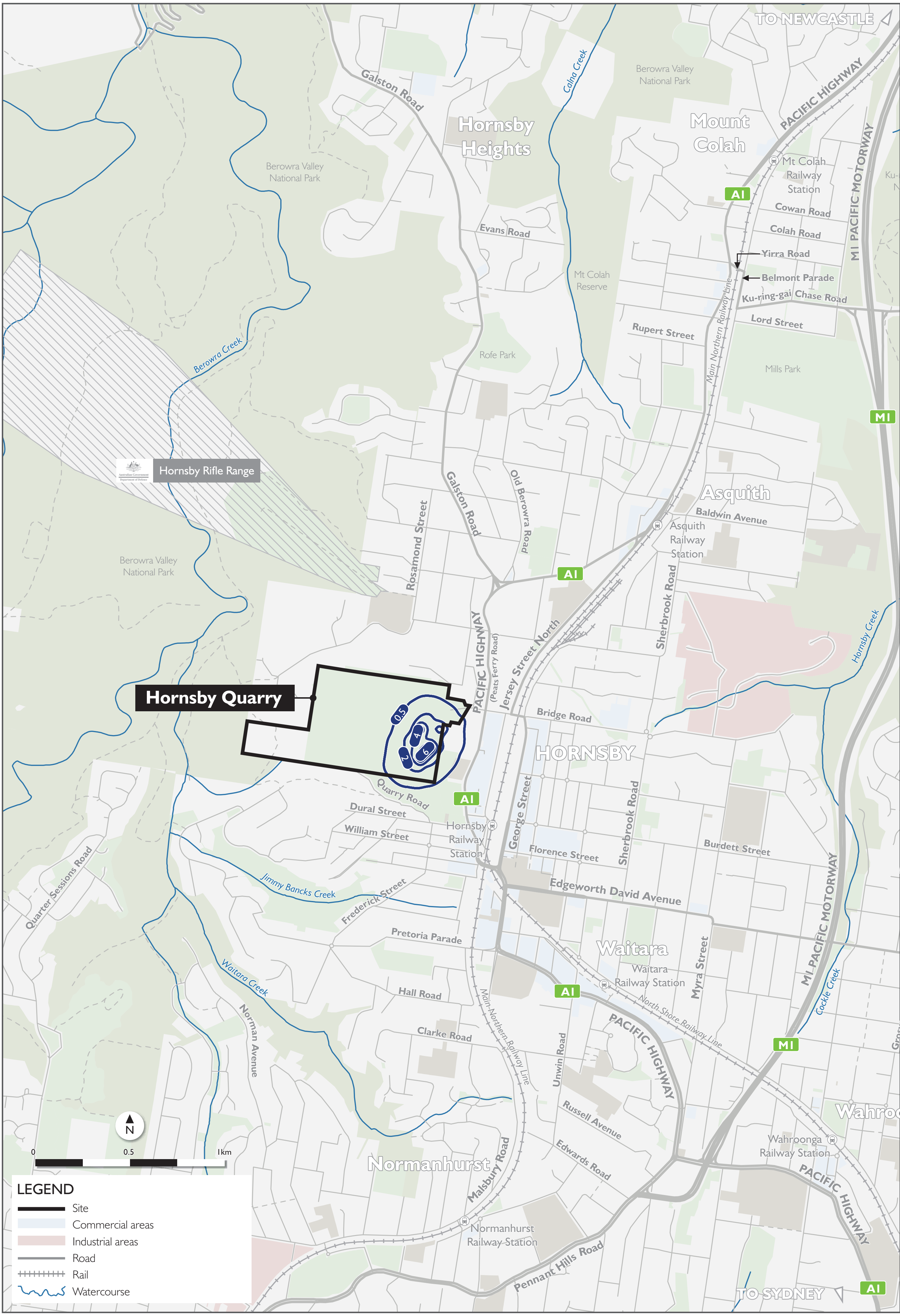

Figure 12 Scenario 1: Annual average $PM_{2.5}$ project contribution concentration ($\mu g/m^3$)

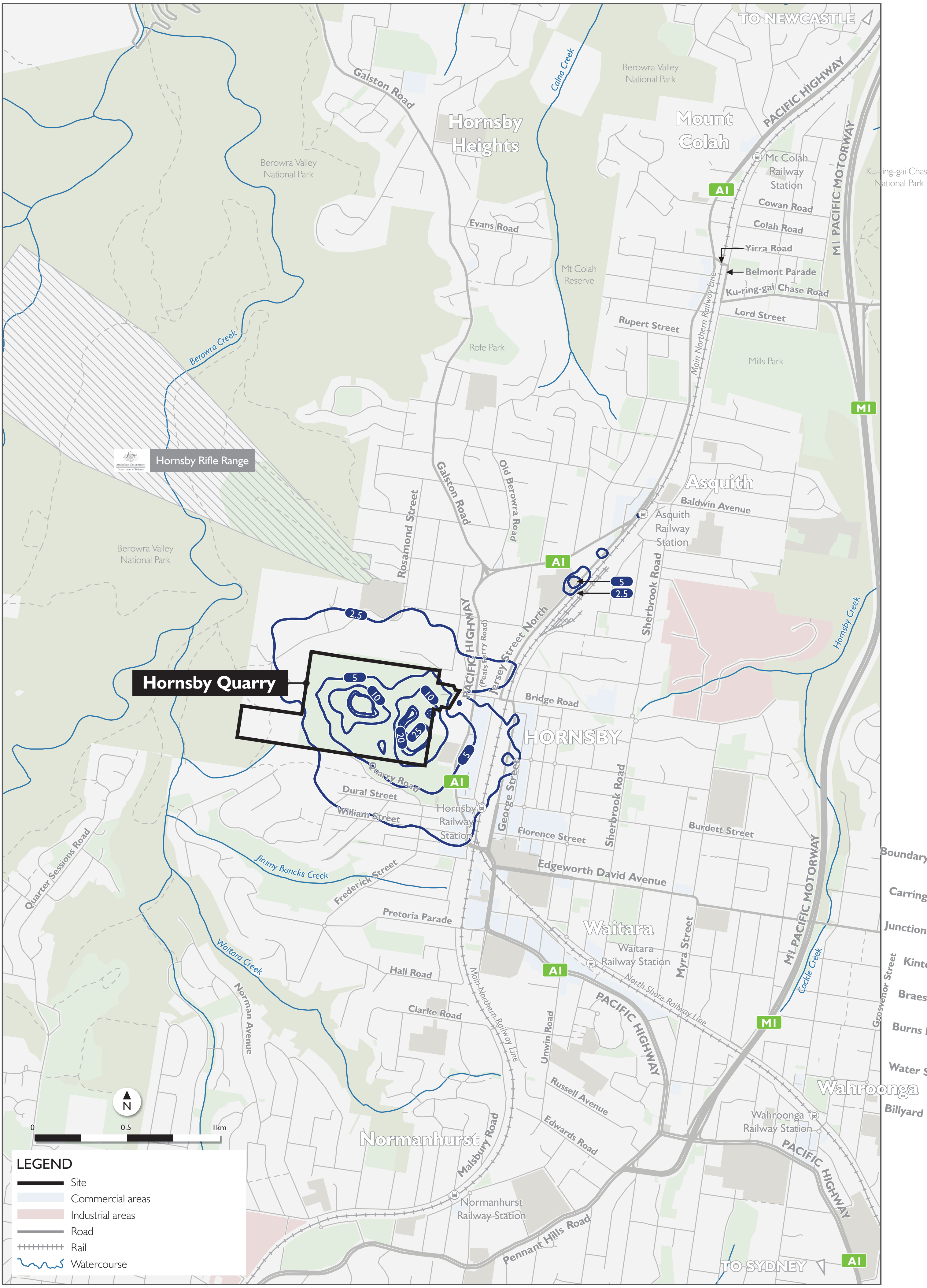

Figure 13 Scenario 2: Maximum 24-hr $PM_{2.5}$ project contribution concentration (µg/m³)

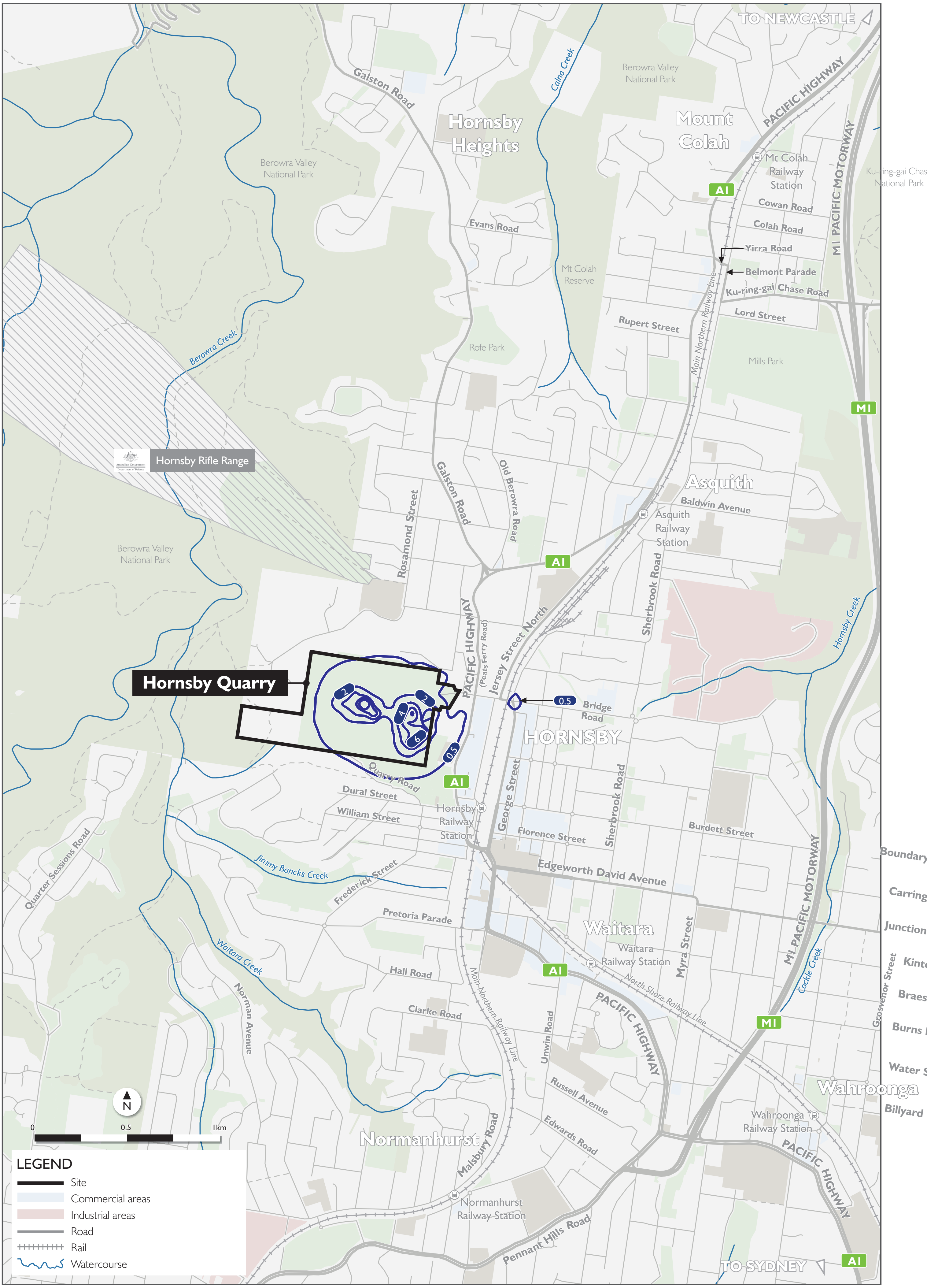

Figure 14 Scenario 2: Annual average $PM_{2.5}$ project contribution concentration (µg/m³)

6.4 Deposited dust

The predicted maximum deposited dust contribution for each scenario is shown in **Table 23**. It can be seen that both Scenario 1 (0.8g/m^2/month) and Scenario 2 (0.8g/m^2/month) are below the project contribution criterion of 2g/m^2/month. The predicted dust deposition rates equate to 20 per centand 25 percent of the cumulative OEH criterion of 4.0 g/m^2/month for Scenario 1 and 2 respectively, however this does not account for local background dust deposition rates for which available data is absent.

It should be noted that dust deposition attributed from the activities at the spoil management facility are temporary in nature with stockpiling and void filling activities expected to occur concurrently over 28 months, and predicted dust deposition rates have been based on the highest intensity of site operational activities during 2017.

Table 23 Predicted maximum dust deposition levels

Averaging period	Source	Predicted maximum dust deposition (g/m^2/month)		Impact Assessment Criteria (g/m^2/month)
		Scenario 1	Scenario 2	
Annual	Peak project contribution	0.8	1.0	2

6.5 Nitrogen dioxide

Predicted 1-hour nitrogen dioxide ground level concentrations were calculated using the adapted OLM method as described in **Section 4.8.1.1**. **Table 24** shows the predicted cumulative concentrations for both maximum 1-hour and annual average NO_2 were below the criteria of 246 μg/m^3 and 62 μg/m^3 respectively for both scenarios. Project contributions for the peak 1-hour NO_2 concentrations were predicted to be 38 (93.1 μg/m^3) and 49 (121.4 μg/m^3) percent of the OEH criterion for Scenario 1 and Scenario 2 respectively. While this represents a large proportion of the allowable NO_2 concentration for the air shed; the maximum recorded background concentration at James Park for 2014 is 93.8 μg/m^3, approximately 38 percent of the OEH criterion. Thus when the maximum background concentration is added to the predicted maximum 1-hour NO_2 project contribution for Scenario 1 (186.9 μg/m^3) and Scenario 2 (215.2μg/m^3) the sum still does not exceed the criterion.

The largest contributor of NO_2 emissions from the site would be from onsite generators providing power to the onsite amenities, compound and conveyer.

Table 24 Predicted maximum NO_2 pollutant concentrations

Averaging period	Source	Predicted maximum NO_2 concentrations (μg/m^3)		Impact Assessment Criteria (μg/m^3)
		Scenario 1	Scenario 2	
1 Hour	Peak project contribution	93.1	121.4	-
	Peak cumulative concentration (project plus background)	106.8	139.8	246
Annual	Peak project contribution	3.2	5.3	-
	Peak cumulative concentration (project plus background)	20.6	22.7	62

6.6 Carbon monoxide

Table 25 shows both the project contribution and cumulative predicted maximum 1-hour and 8-hour concentrations for carbon monoxide for each modelling scenario. The results for both scenarios show the maximum predicted project contributions for both scenarios and averaging periods equate to 1 percent of the OEH criterion for the airshed and when combined with maximum background concentrations the predicted maximum cumulative concentrations for both averaging periods are well below the criterion

The predicted maximum 1-hour and 8-hour concentrations for carbon monoxide reported in **Table 25** are based on non-reactive mitigation dispersion modelling results.

Table 25 Predicted maximum CO pollutant concentrations

Averaging period	Source	Predicted maximum CO concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
1 Hour	Peak project contribution	245	391	-
	Peak cumulative concentration (project plus background)	1938	1983	30,000
8 Hour	Peak project contribution	92	119	-
	Peak cumulative concentration (project plus background)	1059	1086	10,000

6.7 Volatile Organic Compounds

The total VOC concentrations from **Table 14** were speciated using the profile for diesel emissions from heavy vehicles provided in OEH (2012). As shown in **Table 26**, the predicted concentrations of individual VOC species for both modelled scenarios were all orders of magnitude below the applicable impact assessment criteria for the individual compounds.

Predicted 99.9th percentile concentrations for VOCs reported in **Table 26** are based on non-reactive mitigation dispersion modelling results.

Table 26 Predicted 99.9th percentile concentration of speciated VOCs (µg/m³) (project contribution).

Pollutant	Averaging period	Predicted 99.9th percentile VOC concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
Total VOCs	1 hour 99.9%	15.02	40.61	-
1,3-butadiene	1 hour 99.9%	0.06	0.16	40
Acetaldehyde	1 hour 99.9%	0.57	1.55	42
Benzene	1 hour 99.9%	0.16	0.43	29
Formaldehyde	1 hour 99.9%	1.48	4.00	20
Xylenes	1 hour 99.9%	0.06	0.15	190
Toluene	1 hour 99.9%	0.07	0.19	360

6.8 Polycyclic Aromatic Hydrocarbons

Table 27 shows the predicted 99.9th concentration of total PAHs (reported benzo(a)pyrene) for each modelling scenario. The results for both scenarios are orders of magnitude below the impact assessment criterion of 0.4 µg/m3.

The predicted 99.9th percentile concentrations for total PAHs reported in **Table 27** are based on non-reactive mitigation dispersion modelling results.

Table 27 Predicted 99.9th percentile concentration of speciated PAHs (µg/m³) (project contribution).

Pollutant	Averaging period	Predicted maximum PAH concentrations (µg/m³)		Impact Assessment Criteria (µg/m³)
		Scenario 1	Scenario 2	
Total PAHs (as benzo(a)pyrene)	1 hour 99.9%	0.00362	0.00769	0.4

7.0 Mitigation and management measures

7.1 Best industry practice mitigation measures

Dust emissions can generally be well managed through best practice management and mitigation strategies. A hierarchy of emission controls is recommended as best practice, where prevention of emissions is the primary goal of management actions, followed by suppression and containment. The management and mitigation measures described in **Table 28** would be included in the Construction and Operational Environmental Management Plan(s) and associated sub plans for the project.

Table 28 Proposed air quality management and mitigation measures

Proposed management and mitigation measures
General
Site inductions and ongoing toolbox talks would be provided to make construction works aware of sound air quality control practices and responsibilities.
Construction activities would be modified, reduced or controlled during high or unfavourable wind conditions if they may potentially increase off-site dust emissions.
All site haul roads will be sealed.
Control measures would be implemented to control dust emissions, which could include water carts, sprinklers, sprays, internal site road speed limits and dust screens.
Exposed areas will be minimised as much as practical to prevent or minimise windblown dust
Controls would be implemented to minimise the tracking of dirt onto public roads.
Drop height from excavators and front-end loaders would be maintained at 1.5m or less
Ensure that all material handled by bulldozers is kept moist through the use of water carts, sprinklers or sprays.
Hardstand areas and surrounding public roads would be cleaned, as required and good housekeeping practices will be implemented to minimise dust on hardstand areas.
Speed limits would be posted and observed by all vehicles on the site.
Vehicular access will be confined to designated access roads. Haul road lengths will be minimised.
All loaded haulage trucks would be covered at all times on public roads and onsite where there is a risk of release of dust or other materials.
Haul trucks and plant equipment would be switched off when not used for periods of greater than 15 minutes.
Engines of plant located next to residential properties would be switched off when not in operation. Vehicle engines will be turned off while parked on site.
Construction plant, vehicles and machinery would be maintained in good working order and in accordance with manufacturers' specifications.
Where required onsite generators would be switched off when facilities and associated plant equipment are non-operational.
Spills will be immediately cleaned up.
A complaints management system will be implemented and maintained
Monitoring
The weather forecast would be reviewed daily, and appropriate measures implemented where unfavourable weather conditions (dry weather, strong winds) are anticipated.

Proposed management and mitigation measures
A formal dust observation program would be implemented during the works, involving daily observations of meteorological conditions and dust generation. This would inform activities that could be undertaken and mitigation measures implemented during unfavourable weather conditions (see **Section 7.2**)

7.2 Air quality monitoring program

No ambient air quality monitoring has been undertaken at the Hornsby Quarry site to date. The closest monitoring stations are the former NorthConnex stations at James Park and Brickpit Park, which have now been decommissioned. Due to the close proximity of sensitive receptors to the spoil handling facility a comprehensive dust management plan would be prepared incorporating an air quality monitoring program. The dust management plan would include:

- A reactive management strategy with site procedures for targeting the visual observation of dust leaving the site. Dust observations would be undertaken on a regular basis by trained site staff with all staff encouraged to make proactive dust observations whenever on-site. Should visible dust be observed to be crossing the site boundary, contingency measures would be implemented to reduce the potential for off-site impacts.
- Details of contingency measures that would be further considered as part of the reactive management strategy where dust is observed to be crossing the site boundary. Contingency measures would be confirmed as part of detailed design and would target activities that are expected to result in the highest dust generation. Contingency measures are expected to include measures such as:
    - Increases to active mitigation measures such as additional watering, covering stockpiles (where practical) etc.
    - Temporary modifications to dust generating activities e.g. focusing on activities to the pit when dust problems occur on the flats (where practicable).
    - Temporary reductions in materials handling intensity (where practicable).
- Key performance indicators (KPIs) for dust management at the site. The emissions inventory assumptions used in project modelling, which are considered to be key controlling factors for dust generation for the project (such as, the number of trucks per hour delivering spoil to the site) would form the basis of KPIs for dust management in the plan. The plan would detail the KPIs and monitoring measures for each to measure their performance during the project.

8.0 Conclusion

Roads and Maritime is seeking approval for the use of the Hornsby Quarry site for the handling, management and beneficial reuse of spoil generated by the NorthConnex project. The Environmental Impact Statement exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The Hornsby Quarry site has been identified as one of the preferred options for the management of spoil generated during construction of the NorthConnex project from late 2015. This technical working paper assesses the potential effects on air quality associated with the handling, management and beneficial reuse of spoil at the Hornsby Quarry site.

A quantitative assessment of the project was undertaken using the CALPUFF suite of models, and was coupled with estimations of emissions along the haul roads from the CAL3QHCR model. Two operational scenarios were modelled as part of this assessment to account for potential staggering of stockpiling and void filling activities. Scenario 1 accounts for only stockpiling activities while Scenario 2 takes into account both stockpiling and void filling consecutively. Both operational scenarios have been modelled at the greatest intensity of activities on site for the year 2017.

The results of the dispersion modelling determined that project dust deposition rates and cumulative concentrations of total suspended particulates, carbon monoxide, volatile organic compounds and polycyclic aromatic hydrocarbons for both modelled scenarios would all be well below the applicable impact assessment criteria.

Predicted maximum 1-hour and annual cumulative concentrations for NO_2 ground level concentrations also complied with the criteria, however project contributions for the peak 1-hour NO_2 concentrations represent a large proportion of the allowable NO_2 concentration for the air shed. The largest contributor of NO_2 emissions from the site would be from onsite generators which would provide power to the onsite amenities, compound and conveyer.

Results for predicted 24-hour PM_{10} concentrations should comply with OEH criterion for Scenario 1 with a single exceedence predicted for Scenario 2, likely attributable to materials handling activities both on the flats and within the void. Background concentrations were also found to be a contributing factor to high cumulative concentrations at nearby sensitive receptors with the top ten 24-hour PM_{10} concentrations from James Park monitoring station making up 71 to 88 percent of the OEH criterion in isolation. Results for the PM_{10} modelling indicated no exceedences for annual average concentrations for both scenarios.

For $PM_{2.5}$ there were two exceedences of the 24-hour advisory criterion at all sensitive receptors. This was attributed to the high background concentration which exceeded the NEPM advisory standard in isolation. Similarly to predicted 24-hour PM_{10} concentrations the project contribution for Scenario 2 was higher due to materials handling activities both on the flats and within the void. There were also a number of exceedences for the annual average NEPM advisory standard for both scenarios. Here the project contributions were found to be relatively small in comparison to the local background concentration which already takes up 95 percent of the advisory standard for the airshed.

Based on the proximity of nearby sensitive receptors and existing elevated background concentrations for particulates it is recommended that the comprehensive dust management plan for the project incorporate a monitoring program, to confirm the findings of this assessment and to aid in the efficient implementation of mitigation and management measures as required and based on information and data obtained during site activities.

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Appendix A

Relevant Pollutants

Appendix A Pollutants of Potential Concern

Particulate matter - PM_{10}, $PM_{2.5}$ and TSP

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. Particles with a diameter of less than or equal to 50 micrometres (μm) are collectively referred to as total suspended particulates (TSP). TSP primarily cause aesthetic impacts associated with coarse particles settling on surfaces, which also causes soiling and discolouration. These large particles can, however, cause some irritation of mucosal membranes; they pose a greater risk to health when ingested if they are contaminated. Particles with diameters less than or equal to 10 μm (known as PM_{10}) are primarily created through crushing and grinding of rocks and soil, and typically comprise soot, dirt, mould and pollen. These particles tend to remain suspended in the air for longer periods than larger particles (minutes or hours), and can penetrate into human lungs. Fine particulates (those with diameters less than or equal to 2.5 μm, known as $PM_{2.5}$) are typically generated from vehicle exhaust, bushfires and some industrial activities, and can remain suspended in the air for days or weeks. As these fine particulates can travel further into human lungs than the larger particulates and are often made up of heavy metals and carcinogens, fine particulates are considered to pose a greater risk to health.

Exposure to particulate matter has been linked to a variety of adverse health effects, such as respiratory problems (for example coughing, aggravated asthma, chronic bronchitis), lung damage and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from inhalation of the dust.

Particulate Matter - PM_1

There are a large number of studies establishing links between concentration of ambient aerosols level of air pollution and adverse health and environmental effects. While PM_{10} and $PM_{2.5}$ measures provide very important steps toward air quality assessment, it is also apparent that more accurate descriptors of the actual atmosphere are still needed. There is a growing consensus that PM_1 would be a more suitable size than $PM_{2.5}$ to assess health impacts; there is, however, a limited amount of data for the sub-micrometre ambient particle fraction available. Very little data currently exist relating to ambient PM_1 concentrations, and existing PM_1 data sets are restricted to measurements of limited time periods from field campaigns, and little information exists regarding the chemical compositions of these particles.

Small particles around 1 μm in size are affected by relative humidity, wind speed and traffic. Knowledge regarding this fraction of particulate matter includes the following points:

- Particles in 1 μm range are equally spread throughout air layer, and evenly spread regionally, meaning that fine particles in this size range are transported globally.
- Increasing humidity causes these particles to grow in size to the $PM_{2.5}$ due to hygroscopic growth; similarly, evaporation can cause particles to reduce in size again.
- As wind speed increases, dispersion of PM_1 is increased.
- As traffic increases, fine particles increase.

A study conducted in Austria (Gomiscek et al., 2004) determined that PM_1 counted for about 50 – 60 percent and $PM_{2.5}$ accounted for about 70 percent of all PM_{10}.

As no monitoring of PM_1 is currently conducted in Sydney, and no criteria for this fraction exist, PM_1 was not modelled in this assessment.

Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless gas produced by the incomplete combustion of fuels containing carbon (e.g. oil, gas, coal and wood). CO is absorbed through the lungs, where it reacts to reduce the blood's oxygen-carrying capacity. In urban areas, motor vehicles account for up to 90 per cent of all CO emissions.

Nitrogen dioxide

Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as oxides of nitrogen (NO_x). As NO_x is a product of combustion processes, motor vehicles and industrial combustion processes are the major sources of ambient NO_x in urban areas. NO_2 can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. NO_2 can also cause damage to plants, especially in the presence of other pollutants such as ozone and sulfur dioxide. NO_x are primary ingredients in the reactions that lead to photochemical smog formation.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a group of over 100 chemicals, which are formed through the incomplete combustion of organic materials, such as petrol. Exposure to these chemicals can cause a range of adverse reactions, including irritation of the eyes, nose and throat and skin. Exposure to very high levels can result in symptoms such as headaches, nausea, damage to the liver and kidneys, and damage to red blood cells. A number of PAHs were declared to be probably or possibly carcinogenic to humans by the IARC.

PAHs can attach to dust particles and be transported through the air. The compounds break down over days or weeks through chemical reactions in the atmosphere.

PAHs are moderately or highly acutely toxic to birds and aquatic organisms and moderately/highly chronic toxicity to aquatic life. Some can cause damage and death to crops. PAHs can bioaccumulate, and are moderately persistent in the environment.

Volatile organic compounds

Organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa are referred to as volatile organic compounds (VOCs). VOCs were implicated as a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation and respiratory problems. VOCs are emitted from vehicle exhausts.

Three primary VOCs (benzene, toluene and xylenes) are components of petroleum and diesel fuel and are typically the focus for assessments of engine combustion emissions.

Benzene

Benzene is an airborne substance that is a precursor to photochemical smog. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure result from car exhaust.

Benzene is considered to be a toxic health hazard and a carcinogen. It has high acute toxic effects on aquatic life and long-term effects on marine life and agricultural crops. Human exposure to very high levels for even brief periods of time can potentially result in death, while lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, damage to the immune system, leukaemia and birth defects.

Toluene

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. Due to relatively fast degradation, toluene emissions are usually confined to the local area in which it is emitted. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions. The substance can cause membrane damage in plant leaves, and is moderately toxic to aquatic life with long-term exposure.

Xylenes

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing. Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. High-level exposure can cause death. The substances have high acute and chronic toxicity to aquatic life and can adversely affect crops.

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Appendix B

Meteorological Monitoring Data Review

Appendix B Meteorological Monitoring Data Review

Prior to incorporation into the meteorological model, review of available 2014 meteorological monitoring data measured by the NorthConnex project, Office of Environment and Heritage (OEH) and Bureau of Meteorology (BoM) was conducted to determine the suitability of each data set.

Commissioned in December 2013, the NorthConnex project currently has five operating monitoring stations, which measure both meteorological conditions and ambient pollutant levels within the study area. Of these, three stations - Headen Sports Park, James Park and Brickpit Park - are within 3 kilometres of the Hornsby Quarry site. Data recorded at James Park and Brickpit Park were incorporated into the meteorological model due to the proximity of the sites to the Hornsby Quarry. The data from Headen Sports Park were, however, not used due the absence of wind flow data from north and northeast directions. Observatory Park and Rainbow Farm monitoring stations, situated 5 kilometres and 8 kilometres from the project site respectively were not used as the local meteorological conditions at these sites were considered to have little influence over conditions at the project area.

For the NorthConnex Technical Working Paper: Air Quality (AECOM 2014), meteorological modelling was undertaken using data from 2009 to 2011 from five meteorological stations run by the BoM and the OEH. For consistency, 2014 data from those monitoring stations (Lindfield, Prospect, Terrey Hills, Richmond RAAF and Sydney Airport) were reviewed for this study. While the BoM and EPA sites are generally sited further from the project site than the NorthConnex monitoring stations, their data are collectively thought to provide good coverage over the wider modelling domain. Sydney Airport and Richmond RAAF monitoring stations also record air pressure data, which are needed by the model. For these reasons, data from these stations were included in the meteorological model with the exception of the Lindfield station. The use of Lindfield data was criticised in the NorthConnex assessment as data from the station were considered to be unrepresentative of conditions outside its immediate area due to the siting of the station. As such, data from Lindfield were excluded from this assessment.

The table below shows the 2014 data available for each station; the following subsections provide more detailed information regarding the data at each station, including frequency distribution tables and wind rose plots.

Station Operator	Location	Available 2014 Data					
		Wind Speed (m/s)	Wind Direction	Temperature (°C)	Relative Humidity (%)	Pressure (mb)	Precipitation (mm)
NorthConnex	Headen Sports Park	x	x	x	x		
	James Park	x	x	x	x		x
	Brickpit Park	x	x	x	x		
	Observatory Park	x	x	x	x		
	Rainbow Farm	x	x	x	x		x
Office of Environment and Heritage (OEH)	Lindfield	x	x	x	x		
	Prospect	x	x	x	x		
Bureau of Meteorology (BoM)	Terrey Hills	x	x	x	x		
	Richmond RAAF	x	x	x	x	x	x
	Sydney Airport	x	x	x	x	x	x

Headen Sports Park

Headen Sports Park monitoring station is located approximately three kilometres southwest of Hornsby Quarry, sited at the northwestern end of the park oval. The station is situated at the base of a slope, with screening vegetation backing onto residential premises approximately 30 metres to the north. The station is located at approximately 175 metres above MSL, with the slope rising approximately 6 metres to the northwest within 6 metres of the site.

Due to the siting of this monitoring station on a slope and tall trees located within 30 metres of the station, calm winds are recorded more than 22 per cent of the time, and wind flow data are not recorded for the north to northeast directions (i.e. almost a quadrant of wind directions are missing in the recorded data). Data recorded at Headen Park are summarised below.

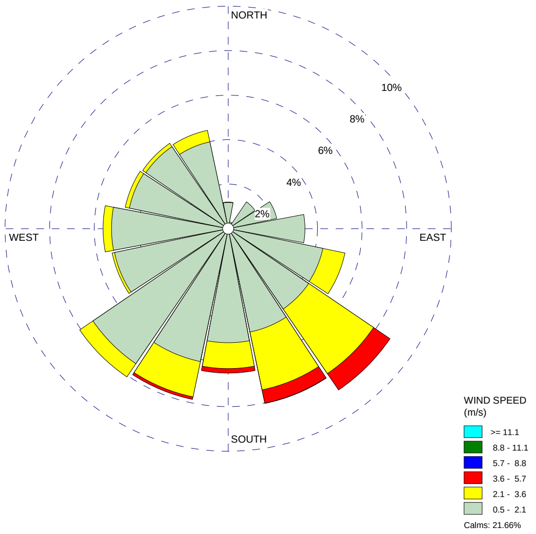
Aerial view of Headon Park. The location of the monitoring station is marked by a red cross (Image taken from Google Earth 2015)

View of monitoring station from Sinclair Avenue facing east (Image taken from Google Earth street view 2015)

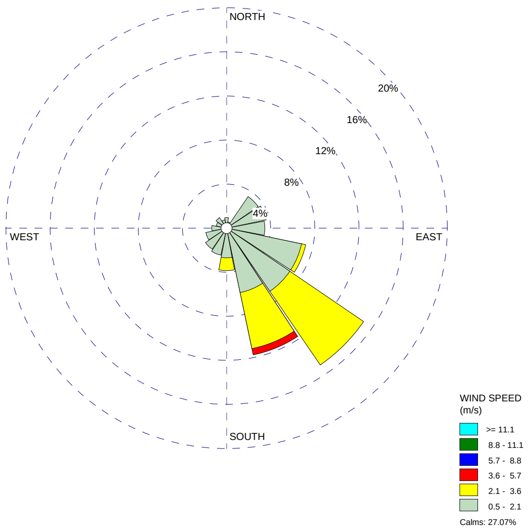
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	1.142%	0.023%	0.000%	0.000%	0.000%	0.000%	1.164%
NNE	0.297%	0.000%	0.000%	0.000%	0.000%	0.000%	0.297%
NE	1.416%	0.000%	0.000%	0.000%	0.000%	0.000%	1.416%
ENE	2.158%	0.000%	0.000%	0.000%	0.000%	0.000%	2.158%
E	3.345%	0.000%	0.000%	0.000%	0.000%	0.000%	3.345%
ESE	4.212%	0.982%	0.000%	0.000%	0.000%	0.000%	5.194%
SE	4.247%	3.413%	0.868%	0.000%	0.000%	0.000%	8.527%
SSE	4.612%	2.580%	0.594%	0.011%	0.000%	0.000%	7.797%
S	4.977%	1.130%	0.194%	0.000%	0.000%	0.000%	6.301%
SSW	5.925%	1.575%	0.114%	0.000%	0.000%	0.000%	7.614%
SW	7.135%	0.696%	0.000%	0.000%	0.000%	0.000%	7.831%
WSW	5.057%	0.103%	0.000%	0.000%	0.000%	0.000%	5.160%
W	5.080%	0.365%	0.000%	0.000%	0.000%	0.000%	5.445%
WNW	4.395%	0.183%	0.000%	0.000%	0.000%	0.000%	4.578%
NW	4.338%	0.171%	0.000%	0.000%	0.000%	0.000%	4.509%
NNW	3.870%	0.514%	0.000%	0.000%	0.000%	0.000%	4.384%
SUM	62.203%	11.735%	1.769%	0.011%	0.000%	0.000%	75.719%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,530; Calm wind periods = 1,897; Calm winds: 21.655%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	41.2		100.1	356.9	5.9
Minimum	0.0		0.0	0.0	0.0
Average	17.1		73.9	193.2	1.1

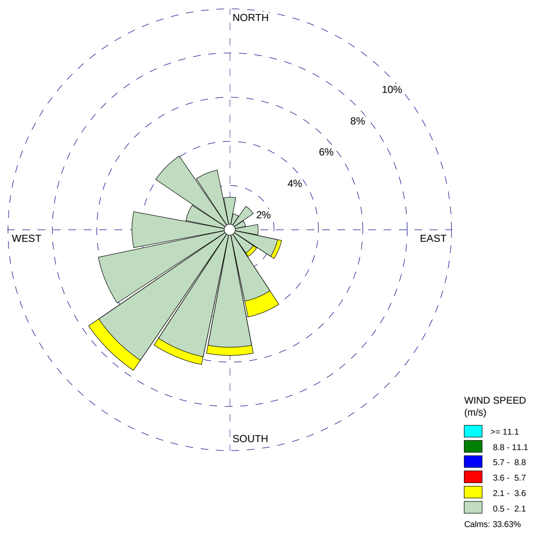
Annual 2014



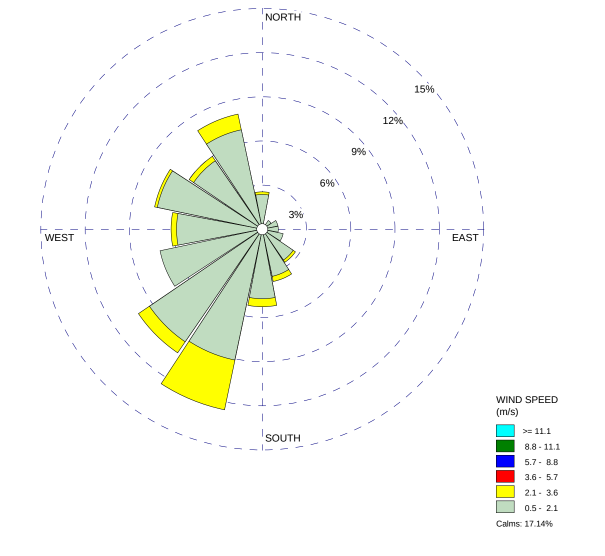
Summer 2014



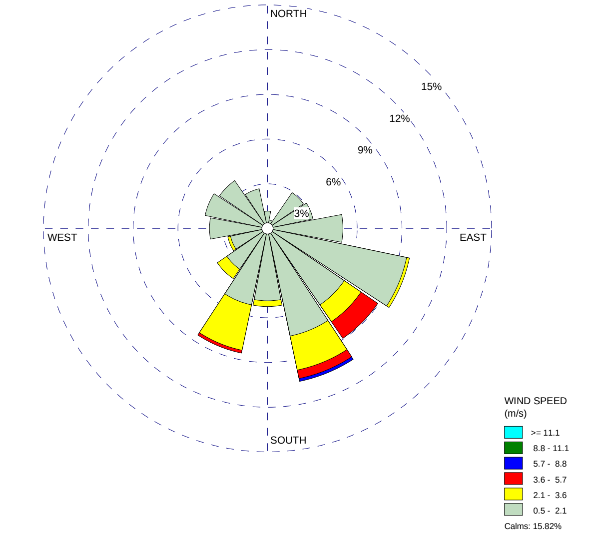
Autumn 2014



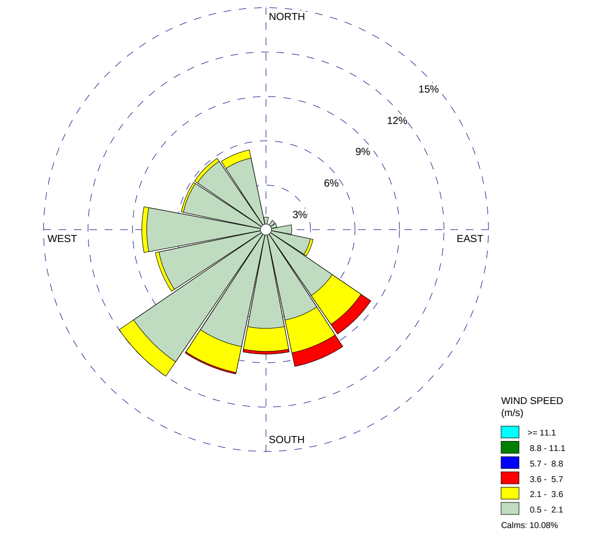
Winter 2014



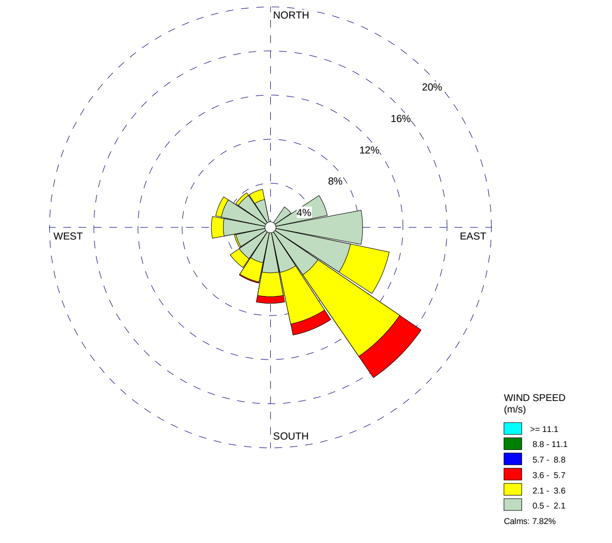
Spring 2014



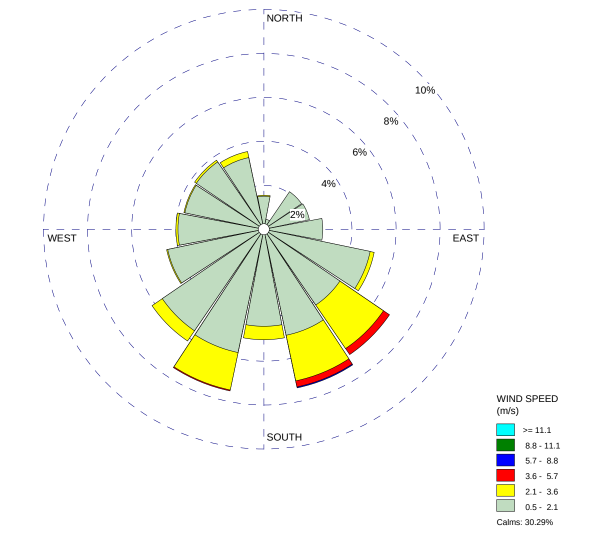
Morning (07h – 12h)



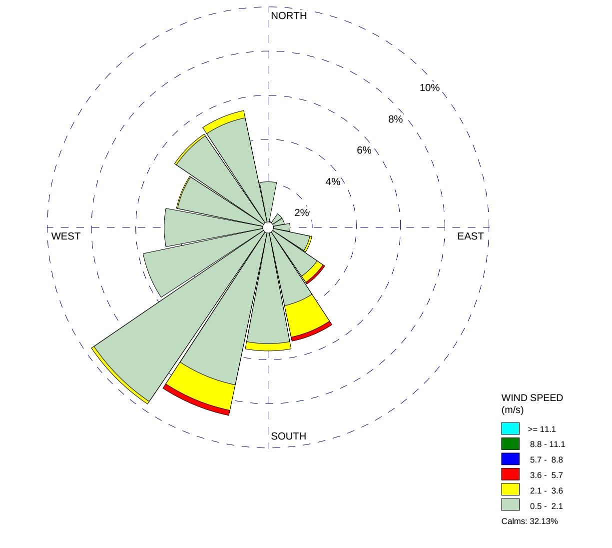
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



James Park

The NorthConnex monitoring station at James Park is the closest monitoring station to the project site, located approximately two kilometres east of Hornsby Quarry. Potential issues with the James Park data include missing winds from the north and a high percentage of light winds and calms. Data from this station are summarised below.

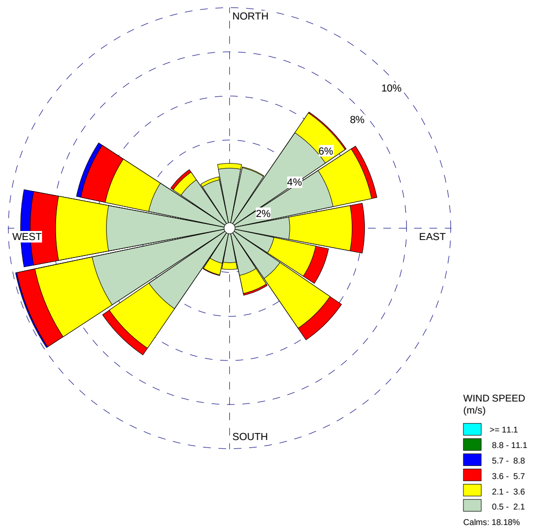
Aerial View of James Park. The location of the monitoring station is marked by a red cross (image from Google Earth 2015).

View of monitoring station location (marked by red cross) from Lowe Road facing north (image from Google Earth street view 2015).

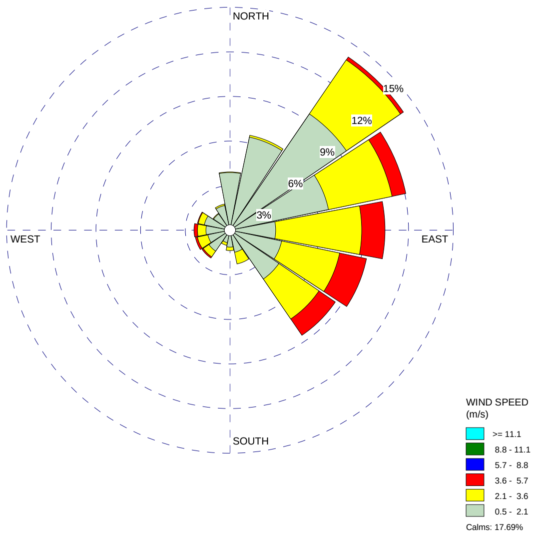
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	2.705%	0.217%	0.000%	0.000%	0.000%	0.000%	2.922%
NNE	2.785%	0.034%	0.000%	0.000%	0.000%	0.000%	2.820%
NE	5.205%	1.073%	0.057%	0.000%	0.000%	0.000%	6.336%
ENE	4.749%	1.769%	0.240%	0.000%	0.000%	0.000%	6.758%
E	2.705%	2.797%	0.559%	0.000%	0.000%	0.000%	6.062%
ESE	2.032%	1.918%	0.594%	0.000%	0.000%	0.000%	4.543%
SE	2.740%	2.717%	0.628%	0.000%	0.000%	0.000%	6.084%
SSE	2.169%	0.833%	0.080%	0.000%	0.000%	0.000%	3.082%
S	1.553%	0.308%	0.000%	0.000%	0.000%	0.000%	1.861%
SSW	1.610%	0.537%	0.034%	0.000%	0.000%	0.000%	2.180%
SW	4.384%	2.158%	0.365%	0.000%	0.000%	0.000%	6.906%
WSW	6.301%	2.626%	0.833%	0.057%	0.000%	0.000%	9.817%
W	5.525%	2.283%	1.142%	0.434%	0.000%	0.000%	9.384%
WNW	3.710%	1.986%	1.130%	0.194%	0.000%	0.000%	7.021%
NW	2.637%	0.422%	0.137%	0.000%	0.000%	0.000%	3.196%
NNW	2.226%	0.137%	0.000%	0.000%	0.000%	0.000%	2.363%
SUM	53.037%	21.815%	5.799%	0.685%	0.000%	0.000%	81.336%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,718; Calm wind periods = 1,593; Calm winds: 18.185 %;							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	39.6	6.8	100.3	359.7	8.5
Minimum	0.0	0.0	0.0	0.0	0.0
Average	17.3	0.0	73.2	164.7	1.6

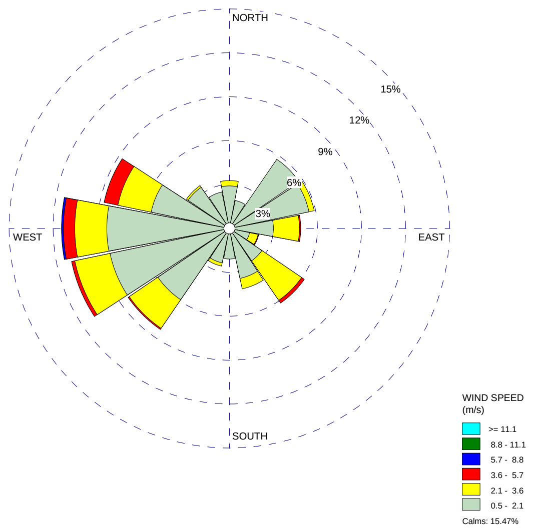
Annual 2014



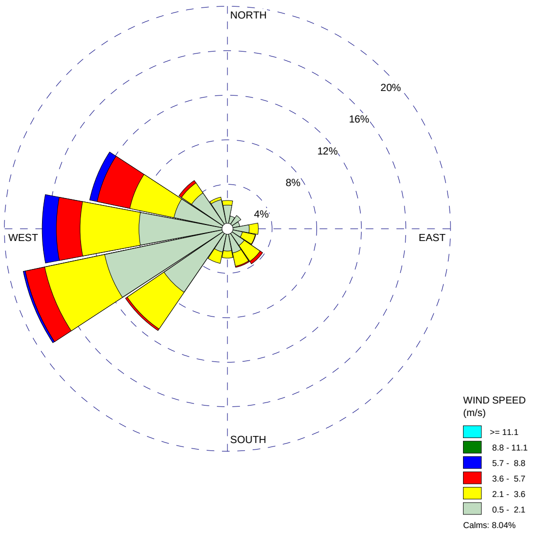
Summer 2014



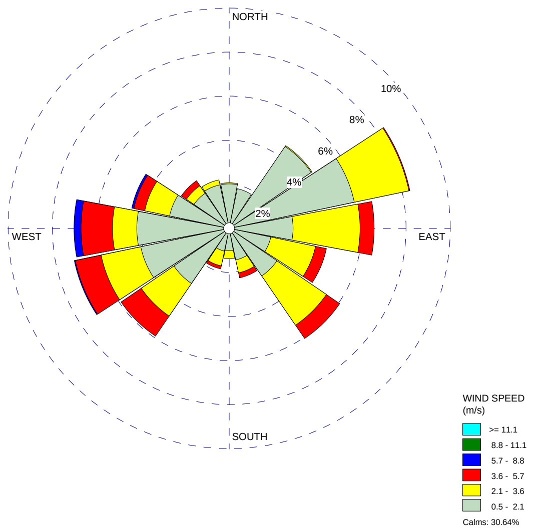
Autumn 2014



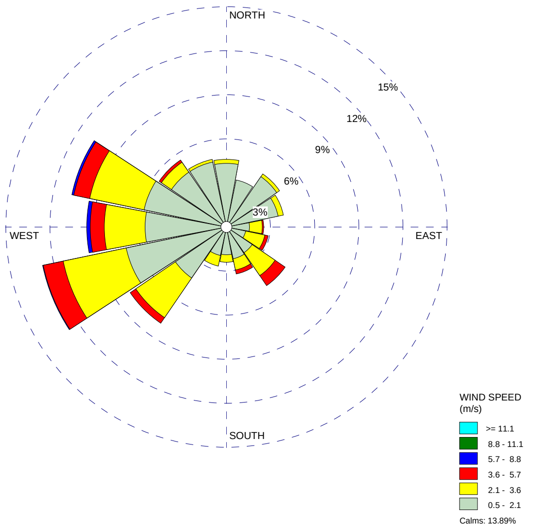
Winter 2014



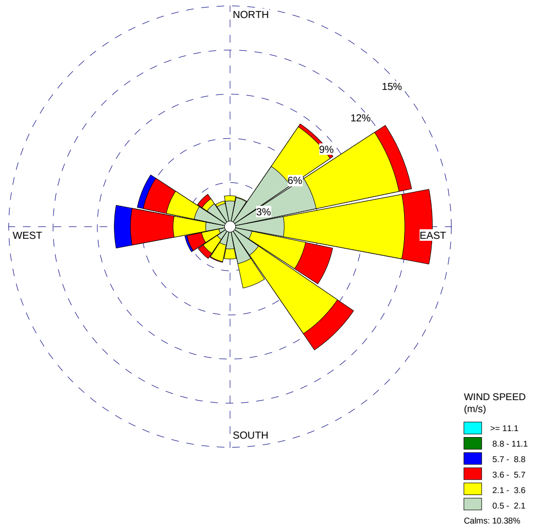
Spring 2014



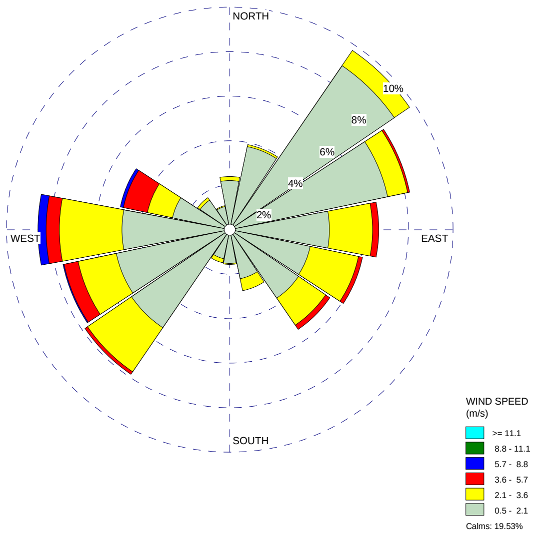
Morning (07h – 12h)



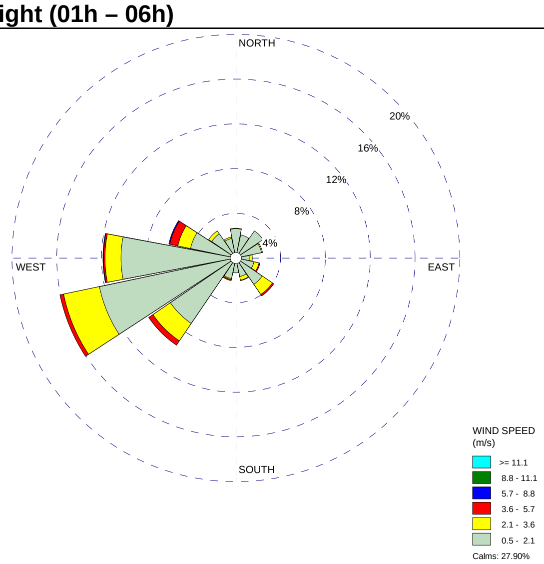
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Brickpit Park

Brickpit Park monitoring station is located approximately 3 kilometres south of Hornsby Quarry. The monitoring station is sited between tall vegetation approximately 10 metres to the east and west. Data from this station are summarised below.

Aerial view of Brickpit Park. Location of the monitoring station is marked with a red cross (image from Google Earth 2015).

View of monitoring station from Pennant Hills Road facing north (image from Google Earth street view 2015).

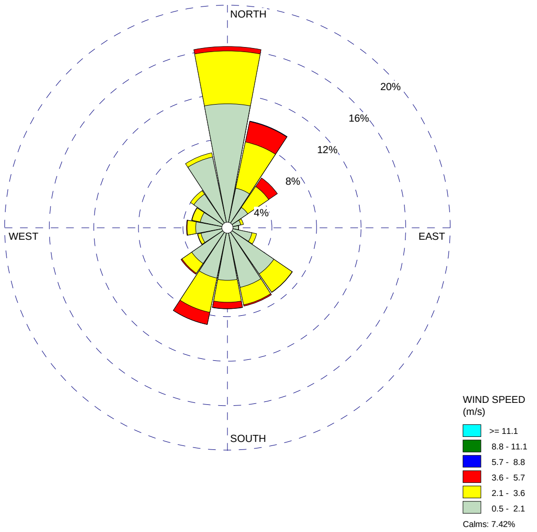
View of monitoring station from Pennant Hills Road facing northeast (image from Google Earth street view 2015).

View of monitoring station from Pennant Hills Road facing northwest (image from Google Earth street view 2015).

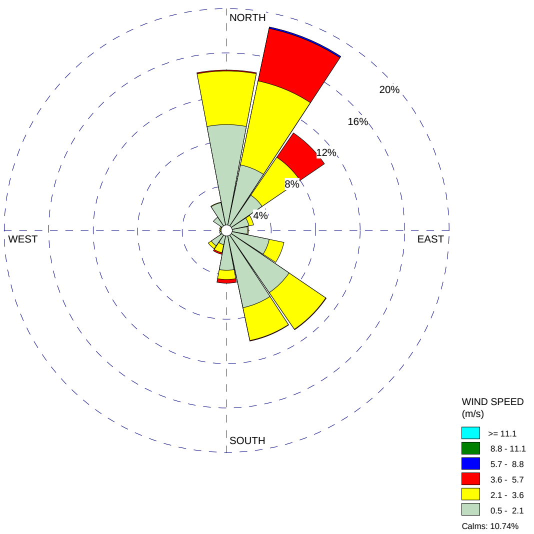
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	11.107%	4.737%	0.400%	0.000%	0.000%	0.000%	16.244%
NNE	3.619%	4.235%	1.861%	0.046%	0.000%	0.000%	9.760%
NE	2.203%	2.272%	0.925%	0.000%	0.000%	0.000%	5.400%
ENE	1.221%	0.240%	0.000%	0.000%	0.000%	0.000%	1.461%
E	0.993%	0.023%	0.000%	0.000%	0.000%	0.000%	1.016%
ESE	2.237%	0.422%	0.000%	0.000%	0.000%	0.000%	2.660%
SE	5.023%	1.986%	0.023%	0.000%	0.000%	0.000%	7.032%
SSE	5.468%	1.598%	0.114%	0.000%	0.000%	0.000%	7.180%
S	4.715%	1.975%	0.571%	0.023%	0.000%	0.000%	7.283%
SSW	4.623%	3.139%	1.096%	0.011%	0.000%	0.000%	8.870%
SW	3.881%	1.062%	0.103%	0.000%	0.000%	0.000%	5.046%
WSW	2.420%	0.297%	0.023%	0.000%	0.000%	0.000%	2.740%
W	2.842%	0.776%	0.057%	0.000%	0.000%	0.000%	3.676%
WNW	2.489%	0.753%	0.034%	0.000%	0.000%	0.000%	3.276%
NW	3.642%	0.377%	0.000%	0.000%	0.000%	0.000%	4.018%
NNW	6.473%	0.388%	0.000%	0.000%	0.000%	0.000%	6.861%
SUM	62.957%	24.281%	5.205%	0.080%	0.000%	0.000%	92.523%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,755; Calm wind periods = 650; Calm winds: 7.420 %							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	39.8		99.3	360.0	6.4
Minimum	0.0		0.0	0.0	0.0
Average	17.5		71.2	183.3	1.6

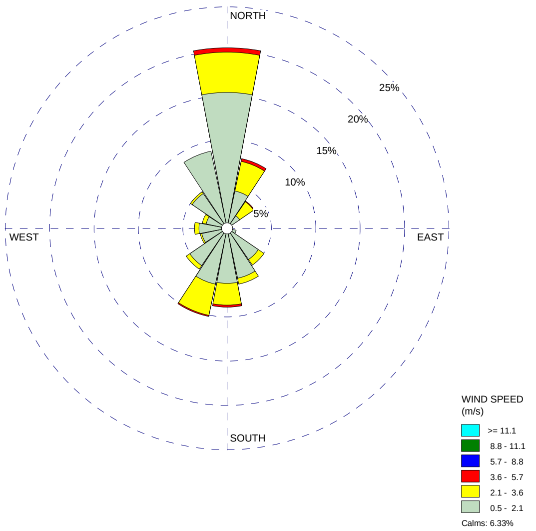
Annual 2014



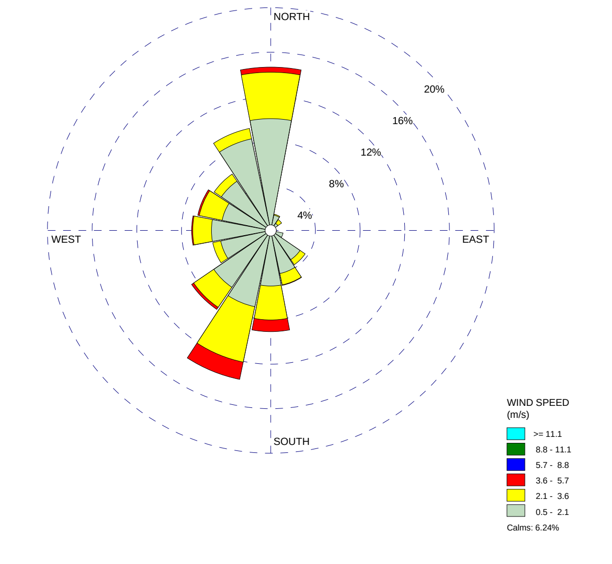
Summer 2014



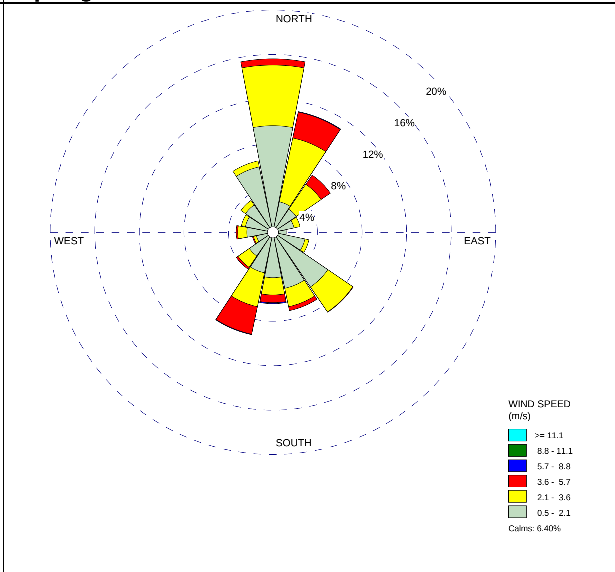
Autumn 2014



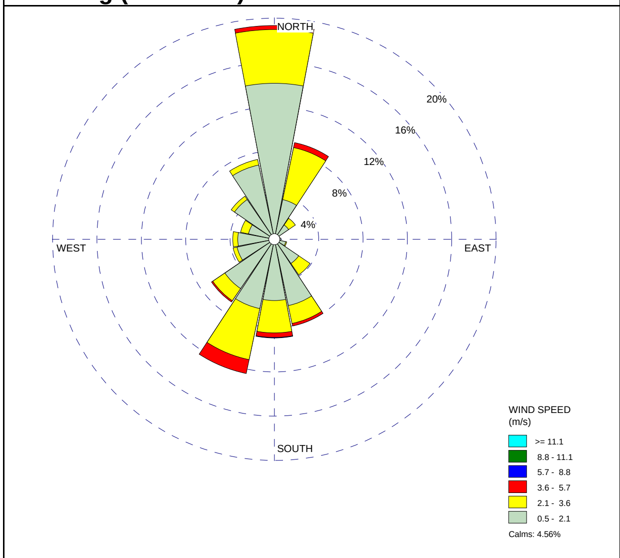
Winter 2014



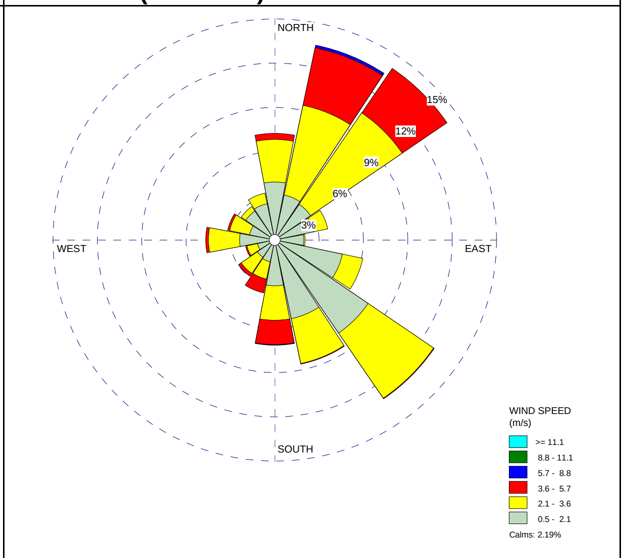
Spring 2014



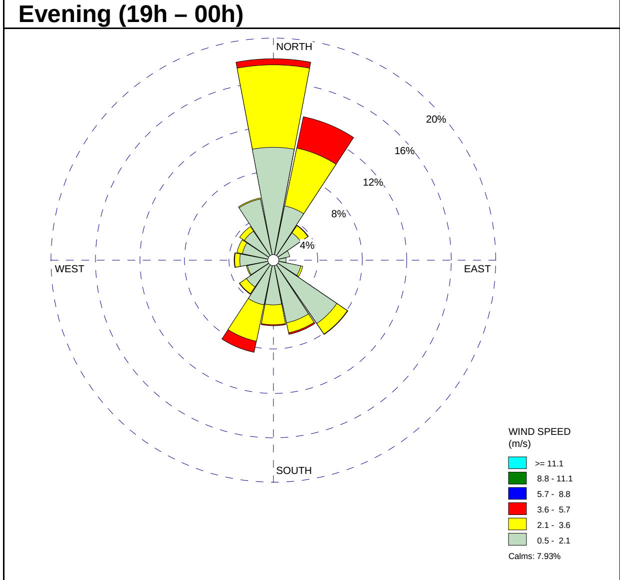
Morning (07h – 12h)



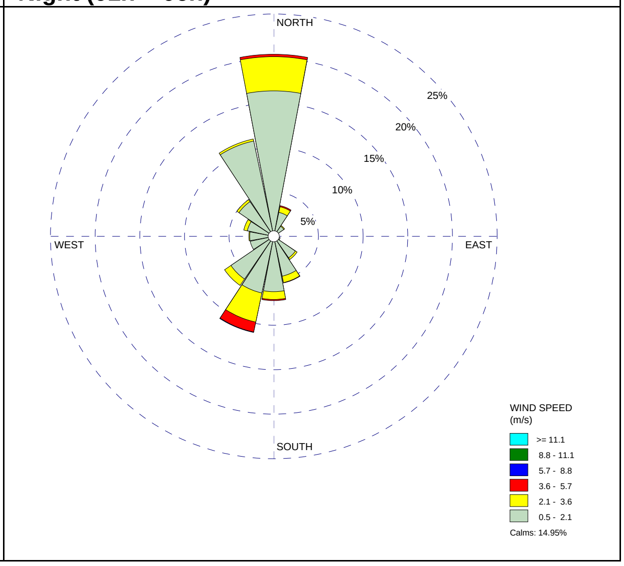
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Observatory Park

Observatory Park Monitoring Station is approximately 5 kilometres southwest of Hornsby Quarry. The monitoring station is located on the corner of Pennant Hills Road and Beecroft Road fronting onto tall vegetation in the southwest. The land slopes south from 192 metres above MSL at the site, dropping 37 metres in elevation to 155 metres above MSL 350 metres to the south. The nearby road follows a distinct ridgeline.

All winds from the dominant direction (southwest) are missing due to the positioning of the monitoring station. Data measured at the station are summarised below.

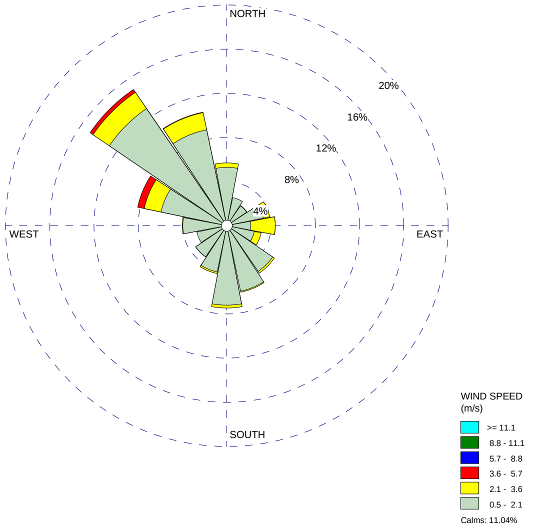
Aerial view of Observatory Park. The location of the monitoring station is marked with a red cross (image from Google Earth 2015).

View of the monitoring station from Beecroft Road facing south west (image from Google Earth street view 2015).

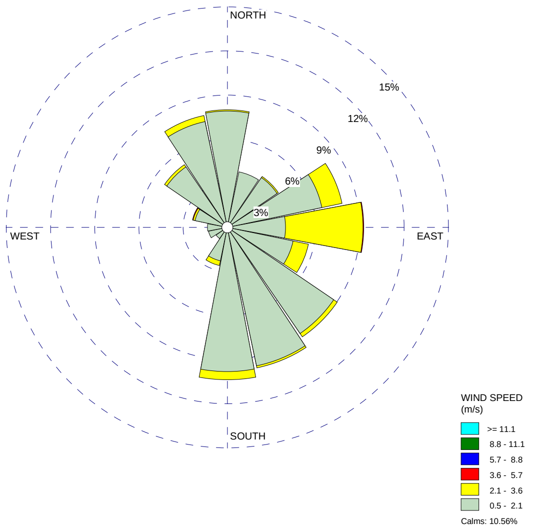
Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	5.274%	0.400%	0.000%	0.000%	0.000%	0.000%	5.674%
NNE	2.591%	0.000%	0.000%	0.000%	0.000%	0.000%	2.591%
NE	2.169%	0.034%	0.000%	0.000%	0.000%	0.000%	2.203%
ENE	3.356%	0.594%	0.000%	0.000%	0.000%	0.000%	3.950%
E	2.158%	2.203%	0.011%	0.000%	0.000%	0.000%	4.372%
ESE	2.534%	0.628%	0.000%	0.000%	0.000%	0.000%	3.162%
SE	5.000%	0.194%	0.000%	0.000%	0.000%	0.000%	5.194%
SSE	6.050%	0.091%	0.000%	0.000%	0.000%	0.000%	6.142%
S	7.180%	0.251%	0.000%	0.000%	0.000%	0.000%	7.432%
SSW	4.269%	0.137%	0.000%	0.000%	0.000%	0.000%	4.406%
SW	3.390%	0.011%	0.000%	0.000%	0.000%	0.000%	3.402%
WSW	2.763%	0.000%	0.000%	0.000%	0.000%	0.000%	2.763%
W	3.961%	0.057%	0.000%	0.000%	0.000%	0.000%	4.018%
WNW	6.050%	1.553%	0.605%	0.000%	0.000%	0.000%	8.208%
NW	12.820%	1.769%	0.320%	0.000%	0.000%	0.000%	14.909%
NNW	8.858%	1.575%	0.046%	0.000%	0.000%	0.000%	10.479%
SUM	78.425%	9.498%	0.982%	0.000%	0.000%	0.000%	88.904%
Annual(Jan to Dec) Calm Winds: 11.039% Total Periods = 8760; Valid Periods = 8755; Calm Wind Periods = 967							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

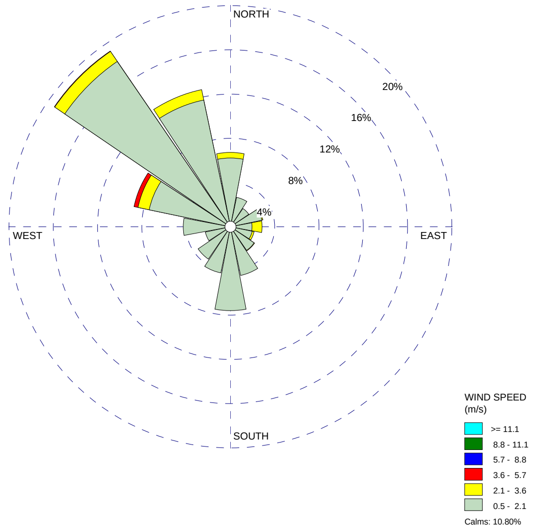
Annual 2014



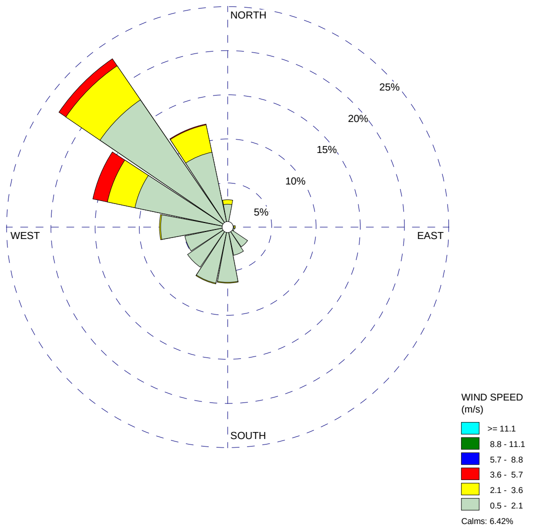
Summer 2014



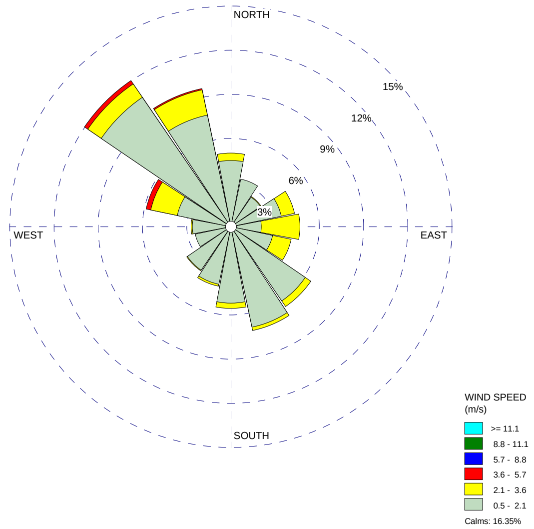
Autumn 2014



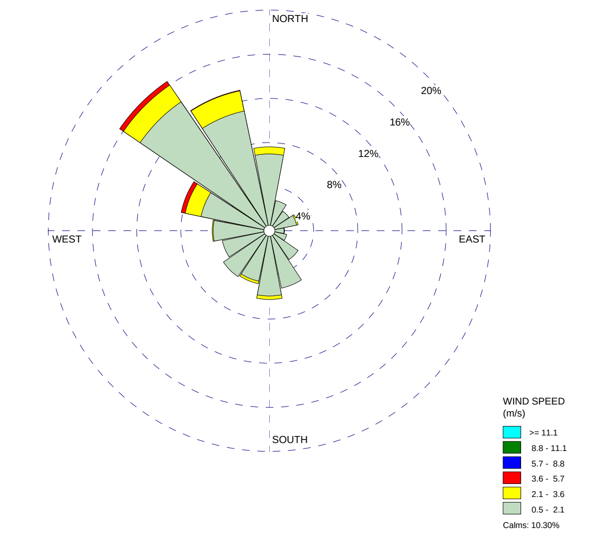
Winter 2014



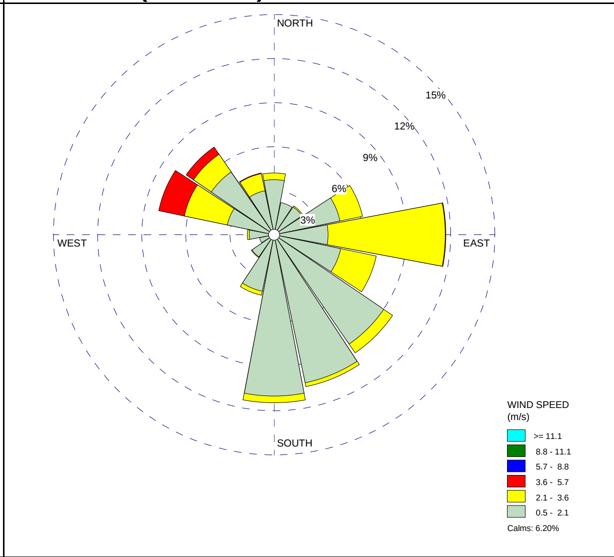
Spring 2014



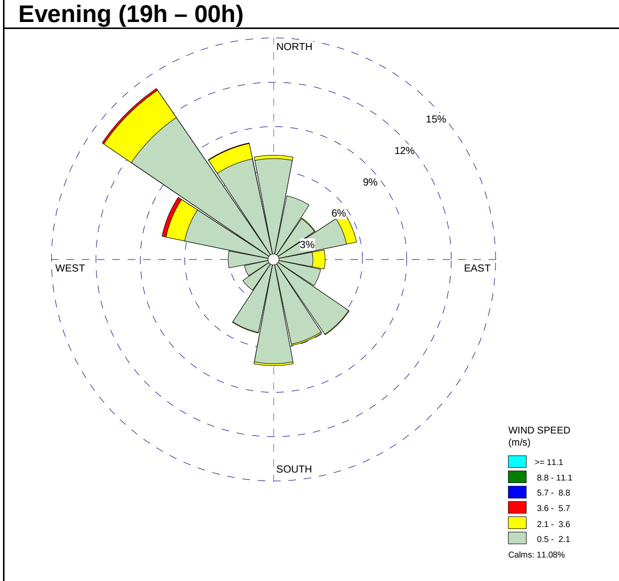
Morning (07h – 12h)



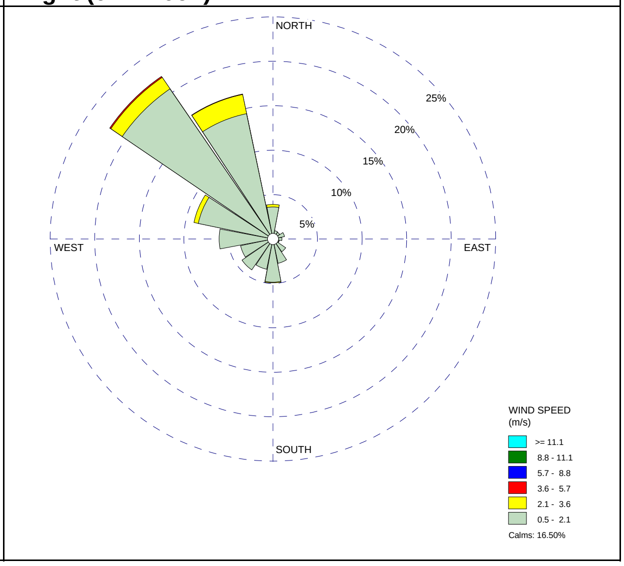
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Rainbow Farm

The monitoring station at Rainbow Farm is located approximately 8 kilometres south west of Hornsby Quarry. The meteorological station fronts both vegetation and residential properties to the southwest. Data collected by this station are summarised below.

Aerial view of Rainbow Farm. Location of the monitoring station is marked with a red cross (image from Google Earth 2015).

View of monitoring station from Coral Tree Drive facing south. (image from Google Earth street view 2015).

Wind Direction	Wind Speed Category (m/s)						
	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
N	3.539%	1.233%	0.148%	0.000%	0.000%	0.000%	4.920%
NNE	2.374%	0.639%	0.000%	0.000%	0.000%	0.000%	3.014%
NE	2.432%	0.331%	0.000%	0.000%	0.000%	0.000%	2.763%
ENE	1.701%	0.000%	0.000%	0.000%	0.000%	0.000%	1.701%
E	3.836%	0.582%	0.000%	0.000%	0.000%	0.000%	4.418%
ESE	3.699%	1.781%	0.114%	0.000%	0.000%	0.000%	5.594%
SE	2.911%	3.037%	1.735%	0.046%	0.000%	0.000%	7.728%
SSE	2.740%	2.911%	0.970%	0.011%	0.000%	0.000%	6.632%
S	1.861%	0.468%	0.023%	0.000%	0.000%	0.000%	2.352%
SSW	1.598%	0.240%	0.000%	0.000%	0.000%	0.000%	1.838%
SW	2.226%	0.605%	0.023%	0.000%	0.000%	0.000%	2.854%
WSW	3.265%	1.199%	0.502%	0.000%	0.000%	0.000%	4.966%
W	3.619%	0.845%	0.422%	0.011%	0.000%	0.000%	4.897%
WNW	4.783%	0.947%	0.594%	0.023%	0.000%	0.000%	6.347%
NW	7.180%	1.336%	0.434%	0.000%	0.000%	0.000%	8.950%
NNW	4.053%	1.233%	0.354%	0.000%	0.000%	0.000%	5.639%
SUM	51.815%	17.386%	5.320%	0.091%	0.000%	0.000%	74.612%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,333; Calm wind periods = 1,797; Calm winds: 20.514%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

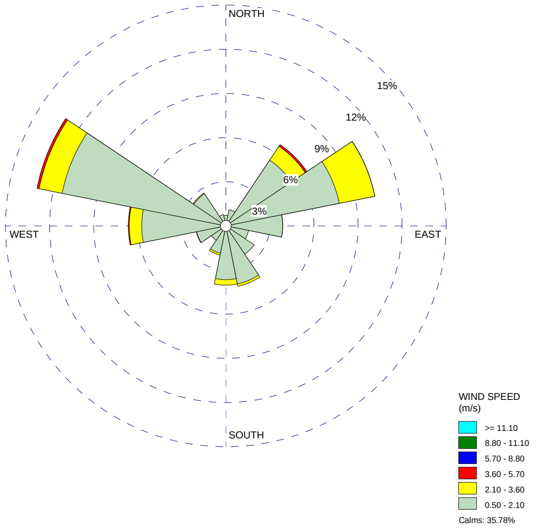
Lindfield

High frequency of calms unusual when compared to 2009-2011 data from Lindfield due to the large amount of calms recorded in the data and criticism received from using this meteorological station in the NorthConnex meteorological modelling. Data collected by this station are summarised below.

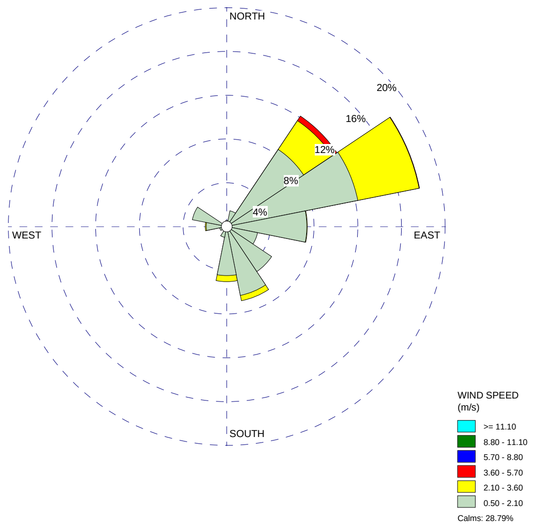
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	0.727%	0.000%	0.000%	0.000%	0.000%	0.000%	0.727%
NNE	1.143%	0.000%	0.000%	0.000%	0.000%	0.000%	1.143%
NE	5.413%	1.143%	0.139%	0.000%	0.000%	0.000%	6.694%
ENE	7.941%	2.482%	0.012%	0.000%	0.000%	0.000%	10.434%
E	3.901%	0.012%	0.000%	0.000%	0.000%	0.000%	3.913%
ESE	1.593%	0.000%	0.000%	0.000%	0.000%	0.000%	1.593%
SE	2.332%	0.000%	0.000%	0.000%	0.000%	0.000%	2.332%
SSE	4.051%	0.162%	0.000%	0.000%	0.000%	0.000%	4.213%
S	3.682%	0.381%	0.000%	0.000%	0.000%	0.000%	4.063%
SSW	1.904%	0.127%	0.000%	0.000%	0.000%	0.000%	2.031%
SW	1.189%	0.000%	0.000%	0.000%	0.000%	0.000%	1.189%
WSW	2.043%	0.012%	0.012%	0.000%	0.000%	0.000%	2.066%
W	5.783%	0.854%	0.058%	0.000%	0.000%	0.000%	6.694%
WNW	11.461%	1.616%	0.150%	0.000%	0.000%	0.000%	13.227%
NW	2.655%	0.058%	0.000%	0.000%	0.000%	0.000%	2.712%
NNW	0.796%	0.000%	0.000%	0.000%	0.000%	0.000%	0.796%
SUM	6.844%	0.369%	0.000%	0.000%	0.000%	63.128%	6.844%
Annual(Jan to Dec) Calm Winds: 36.17% Total Periods = 8760; Valid Periods = 8664; Calm Wind Periods = 3134							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

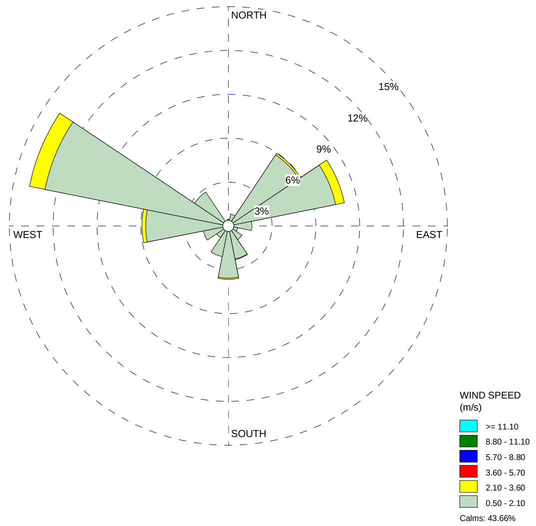
Annual 2014



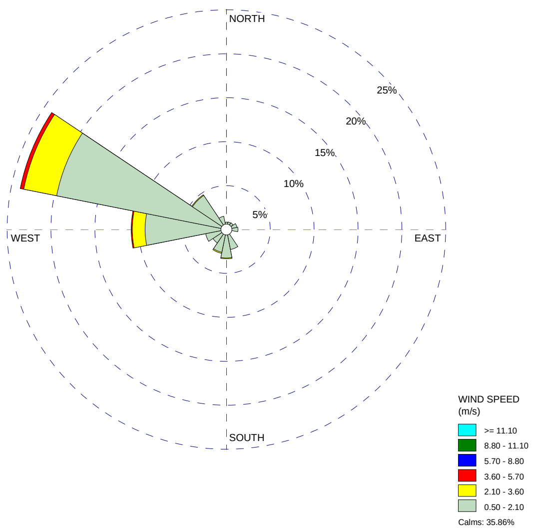
Summer 2014



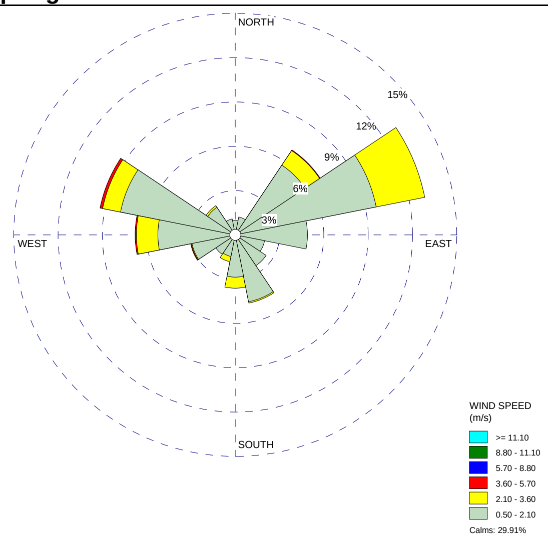
Autumn 2014



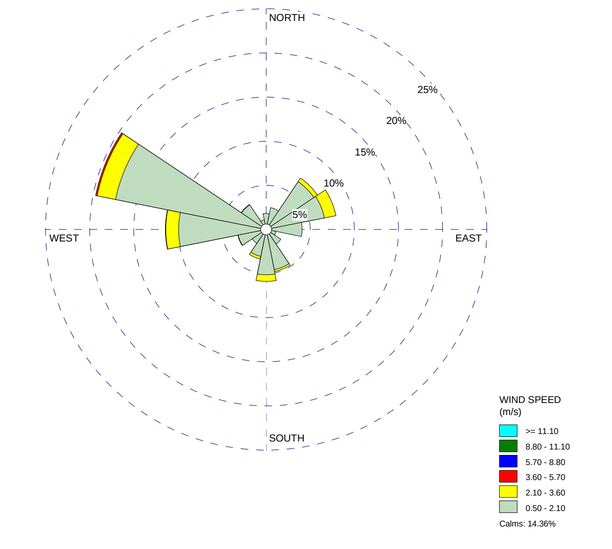
Winter 2014



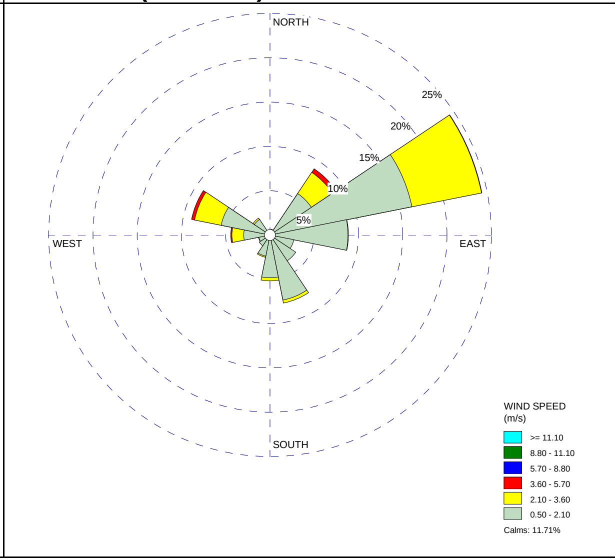
Spring 2014



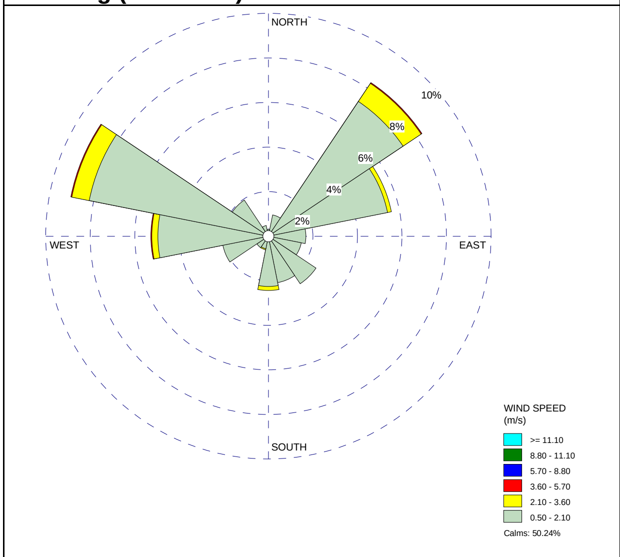
Morning (07h – 12h)



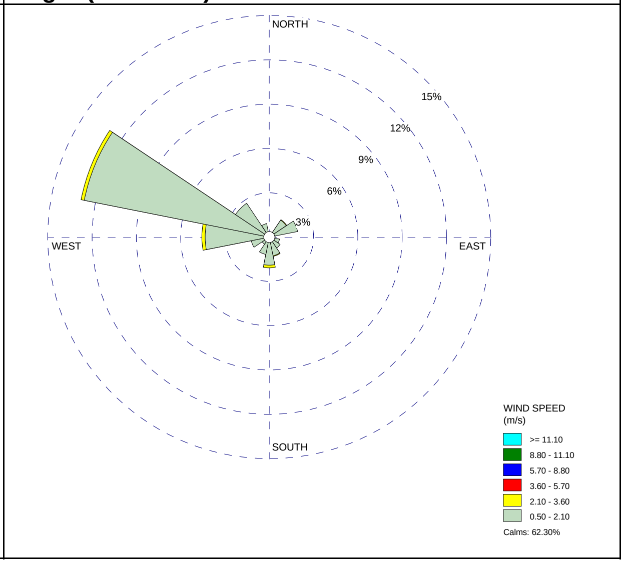
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



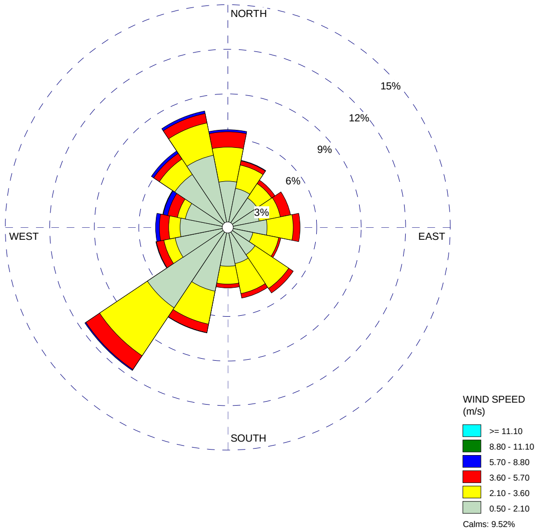
Prospect

Data collected by this station are summarised below.

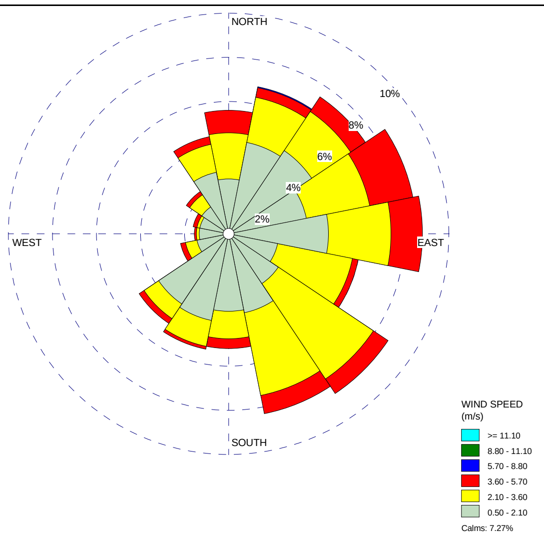
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	3.146%	2.325%	1.041%	0.139%	0.000%	0.000%	6.651%
NNE	2.718%	1.608%	0.289%	0.035%	0.000%	0.000%	4.650%
NE	2.418%	1.180%	0.278%	0.000%	0.000%	0.000%	3.875%
ENE	2.186%	1.469%	0.706%	0.000%	0.000%	0.000%	4.361%
E	2.684%	1.781%	0.463%	0.000%	0.000%	0.000%	4.928%
ESE	1.747%	1.793%	0.150%	0.000%	0.000%	0.000%	3.690%
SE	2.233%	2.765%	0.370%	0.000%	0.000%	0.000%	5.367%
SSE	2.510%	2.082%	0.312%	0.000%	0.000%	0.000%	4.905%
S	2.649%	1.215%	0.255%	0.000%	0.000%	0.000%	4.118%
SSW	4.430%	2.279%	0.590%	0.023%	0.000%	0.000%	7.322%
SW	6.582%	3.921%	1.134%	0.069%	0.000%	0.000%	11.706%
WSW	3.655%	0.787%	0.521%	0.035%	0.000%	0.000%	4.997%
W	3.250%	0.775%	0.636%	0.255%	0.000%	0.000%	4.916%
WNW	2.950%	0.544%	0.683%	0.312%	0.035%	0.000%	4.523%
NW	4.338%	1.272%	0.463%	0.185%	0.000%	0.000%	6.258%
NNW	5.009%	2.244%	0.659%	0.174%	0.000%	0.000%	8.086%
SUM	52.504%	28.039%	8.548%	1.226%	0.035%	0.000%	89.167%
Annual (Jan to Dec 2014). Total periods = 8,760; Valid periods = 8,645; Calm wind periods = 834; Calm winds: 9.521%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

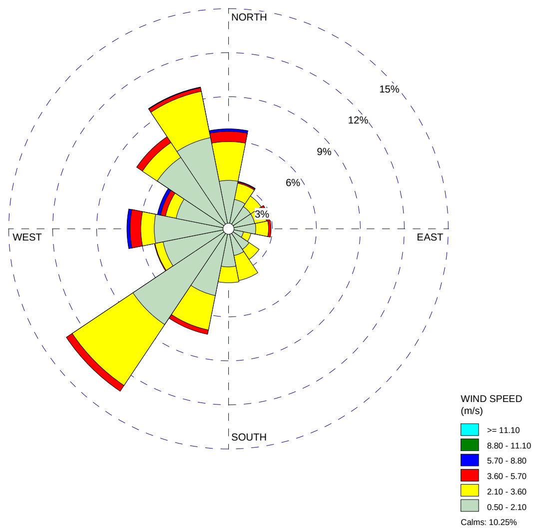
Annual 2014



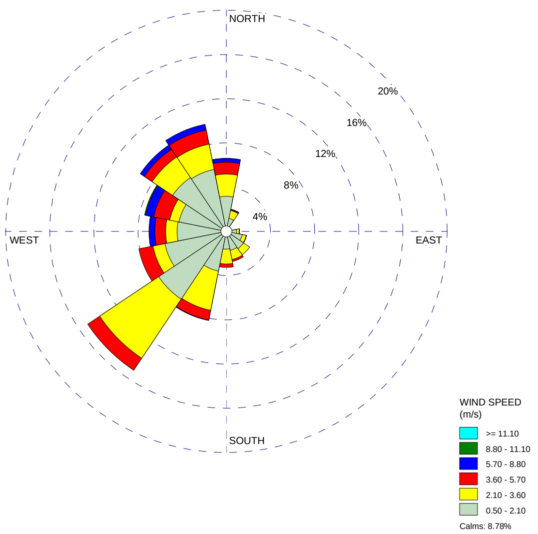
Summer 2014



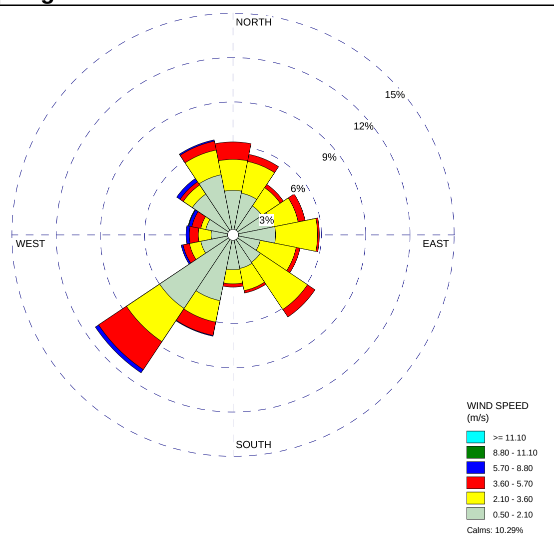
Autumn 2014



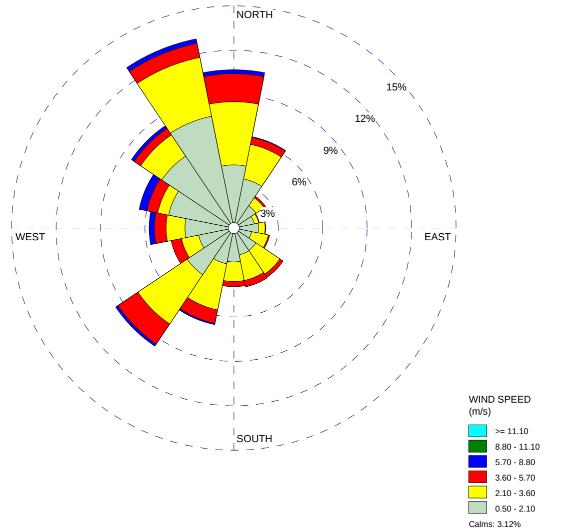
Winter 2014



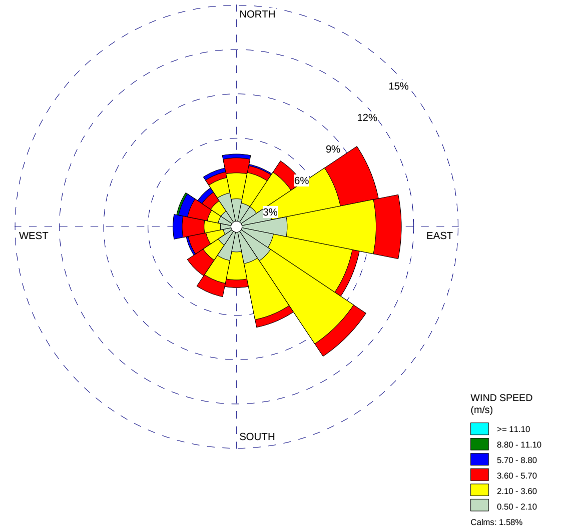
Spring 2014



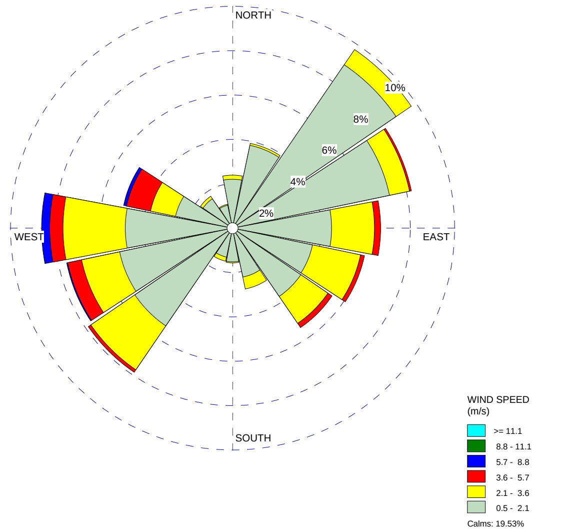
Morning (07h – 12h)



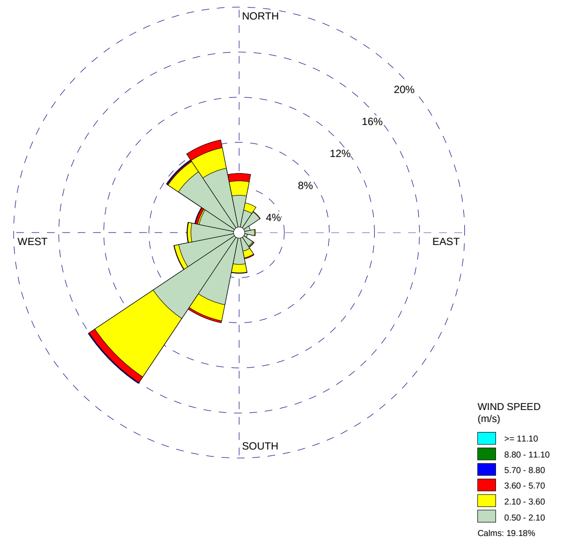
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



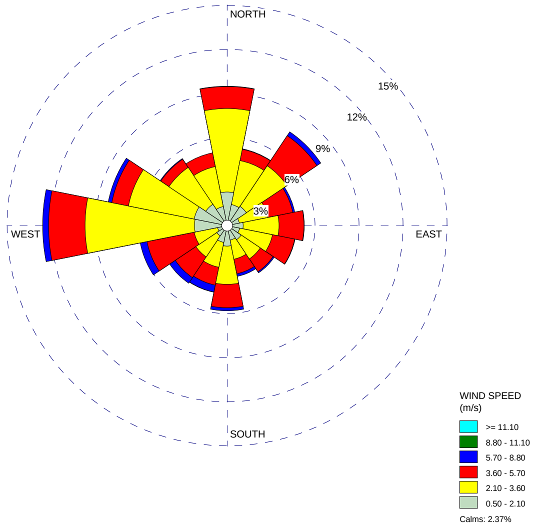
Terrey Hills

Data collected by this station are summarised below.

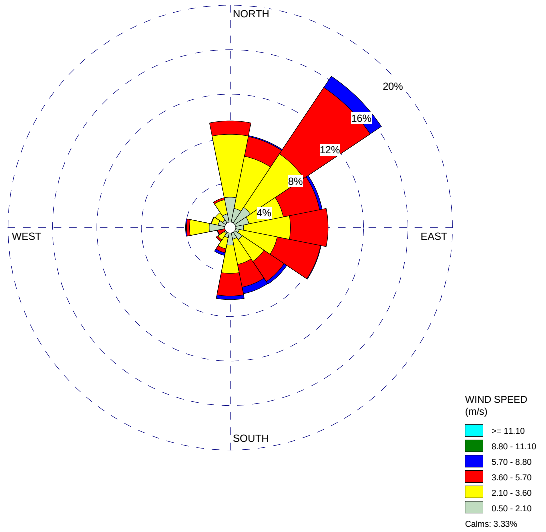
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	2.299%	5.713%	1.506%	0.023%	0.000%	0.000%	9.541%
NNE	1.471%	3.069%	0.793%	0.023%	0.000%	0.000%	5.357%
NE	1.586%	3.345%	2.472%	0.310%	0.000%	0.000%	7.714%
ENE	0.862%	1.989%	1.736%	0.138%	0.000%	0.000%	4.725%
E	1.104%	2.449%	1.713%	0.023%	0.000%	0.000%	5.288%
ESE	0.874%	2.299%	1.552%	0.023%	0.000%	0.000%	4.748%
SE	1.161%	1.575%	1.058%	0.092%	0.000%	0.000%	3.886%
SSE	1.012%	1.334%	1.012%	0.184%	0.000%	0.000%	3.541%
S	1.403%	2.621%	1.598%	0.207%	0.000%	0.000%	5.828%
SSW	1.173%	1.736%	1.242%	0.483%	0.012%	0.000%	4.644%
SW	0.851%	1.724%	1.701%	0.460%	0.000%	0.000%	4.736%
WSW	0.667%	1.632%	3.299%	0.471%	0.000%	0.000%	6.070%
W	2.230%	7.507%	2.495%	0.402%	0.000%	0.000%	12.634%
WNW	2.299%	4.598%	1.161%	0.241%	0.000%	0.000%	8.300%
NW	1.759%	3.035%	0.678%	0.046%	0.000%	0.000%	5.518%
NNW	1.334%	2.782%	0.966%	0.000%	0.000%	0.000%	5.081%
SUM	22.083%	47.408%	24.980%	3.127%	0.012%	0.000%	96.929%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,699; Calm wind periods = 61; Calm winds: 2.39%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum					
Minimum					
Average					

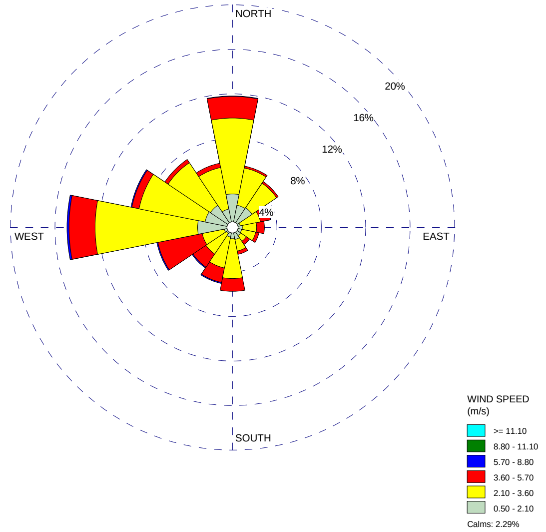
Annual 2014



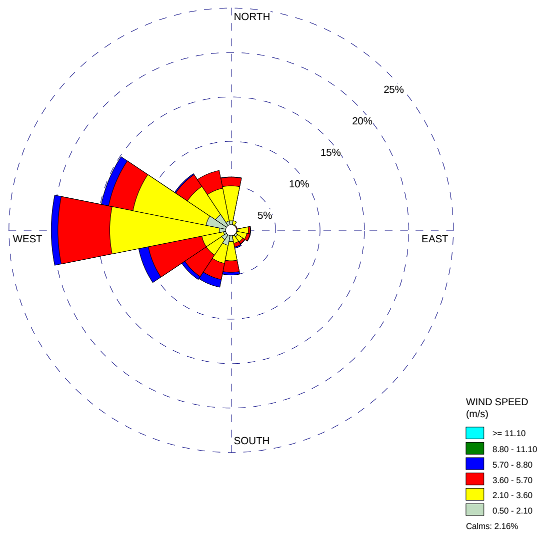
Summer 2014



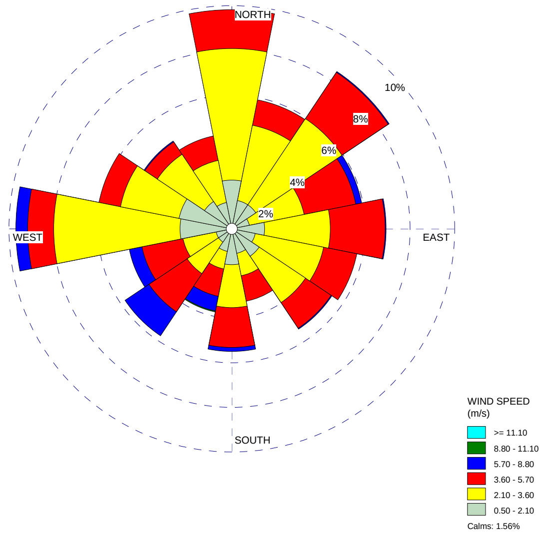
Autumn 2014



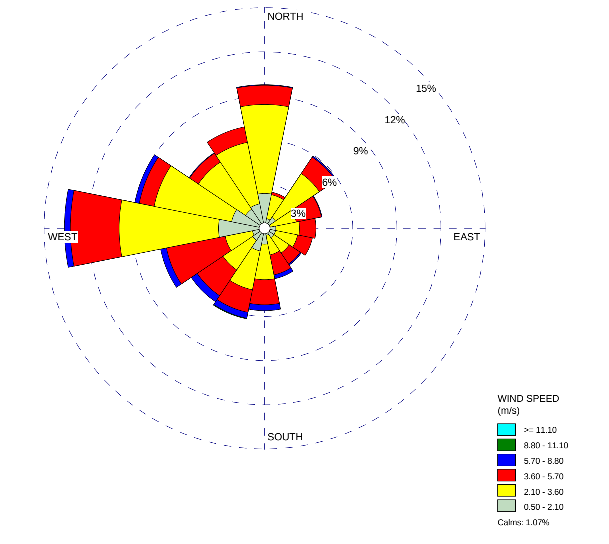
Winter 2014



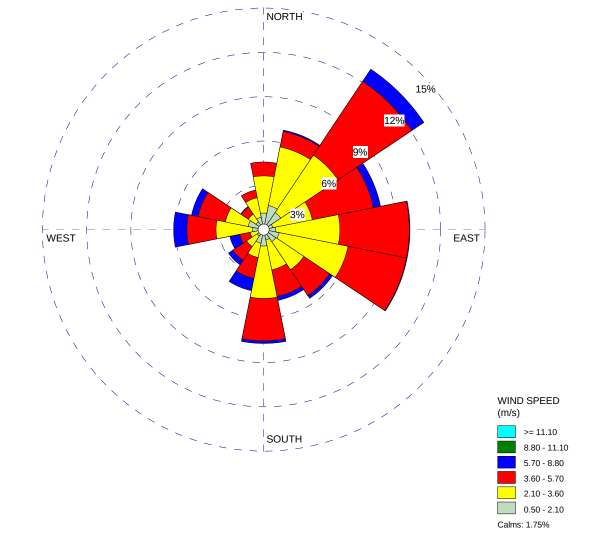
Spring 2014



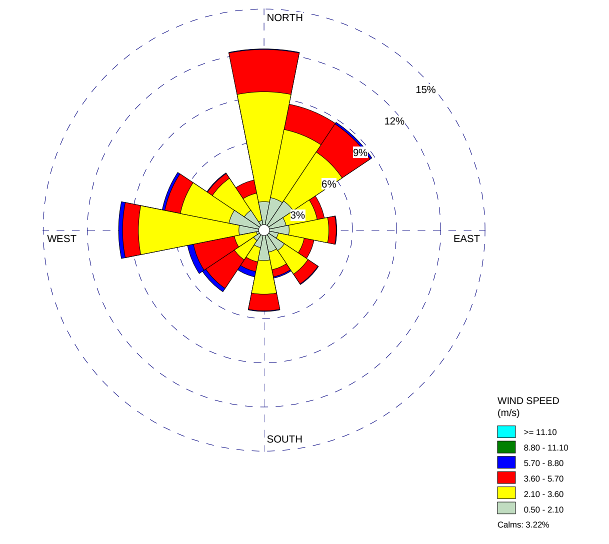
Morning (07h – 12h)



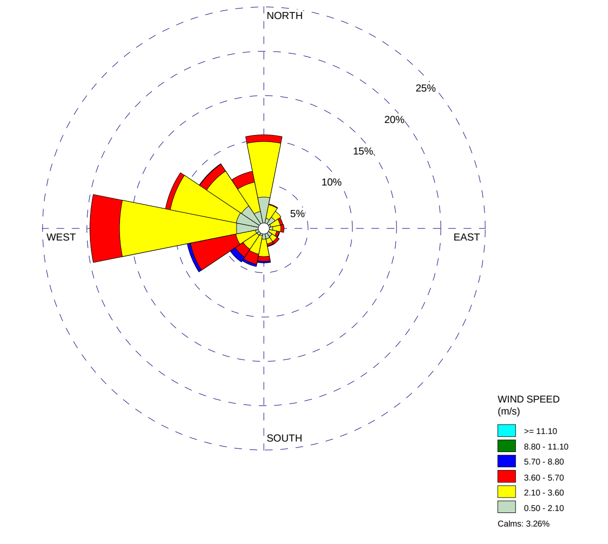
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



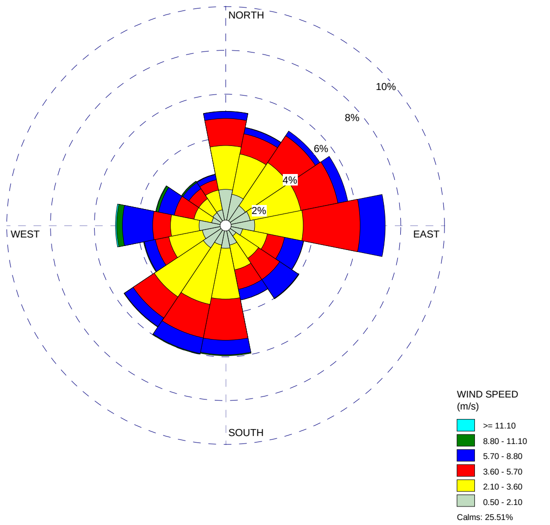
Richmond RAAF

Data collected by this station are summarised below.

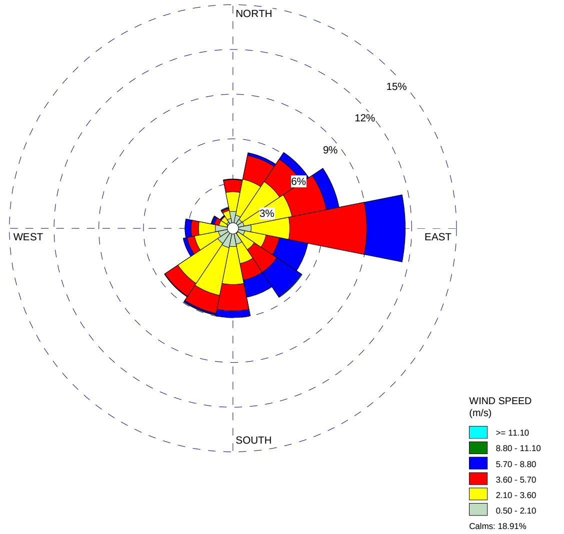
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	1.662%	2.020%	1.247%	0.323%	0.012%	0.000%	5.205%
NNE	1.466%	1.893%	0.946%	0.289%	0.012%	0.000%	4.555%
NE	1.096%	2.389%	1.489%	0.254%	0.000%	0.000%	5.171%
ENE	1.154%	2.378%	1.743%	0.462%	0.000%	0.000%	5.674%
E	1.339%	2.239%	2.620%	1.154%	0.000%	0.000%	7.272%
ESE	0.796%	1.166%	0.808%	0.889%	0.012%	0.000%	3.630%
SE	0.577%	1.247%	1.177%	1.039%	0.012%	0.012%	4.018%
SSE	0.923%	1.166%	0.912%	0.496%	0.012%	0.000%	3.470%
S	1.050%	2.343%	1.893%	0.669%	0.046%	0.000%	5.936%
SSW	0.923%	2.782%	1.570%	0.739%	0.035%	0.000%	5.982%
SW	1.235%	2.724%	1.166%	0.485%	0.023%	0.000%	5.571%
WSW	1.096%	1.570%	0.635%	0.519%	0.012%	0.023%	3.813%
W	1.223%	1.316%	0.819%	1.397%	0.265%	0.058%	5.023%
WNW	0.658%	0.831%	0.923%	0.739%	0.115%	0.023%	3.253%
NW	0.704%	0.785%	0.554%	0.335%	0.058%	0.023%	2.432%
NNW	0.739%	0.923%	0.485%	0.242%	0.012%	0.012%	2.386%
SUM	16.461%	27.466%	18.779%	9.920%	0.616%	0.148%	73.390%
Annual (Jan to Dec, 2014). Total periods = 8,760; Valid periods = 8,664; Calm wind periods = 2,235; Calm winds: 25.514%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	**43.5**	**38.0**	**101**	**360**	**18.0**
Minimum	**-3.0**	**0.0**	**9**	**0**	**0.0**
Average	**17.4**	**1.1**	**72**	**125**	**2.4**

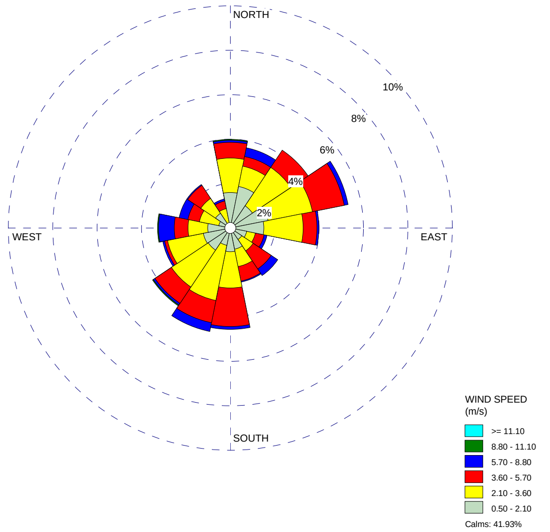
Annual 2014



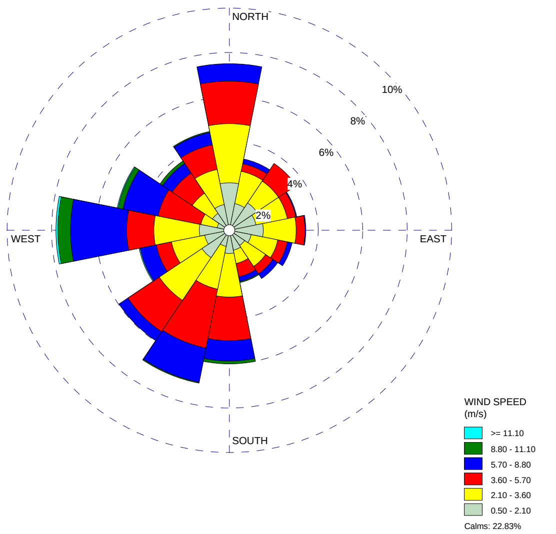
Summer 2014



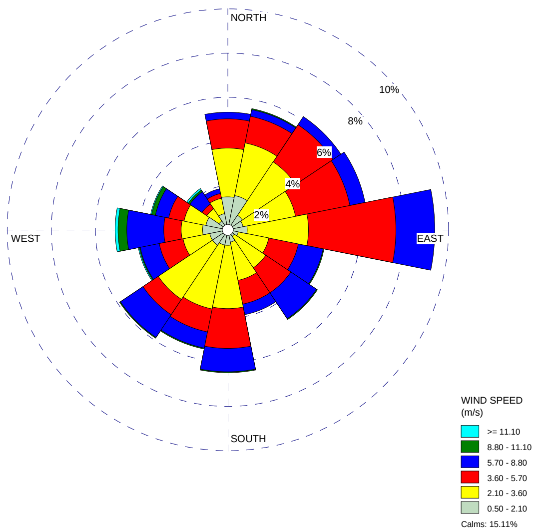
Autumn 2014



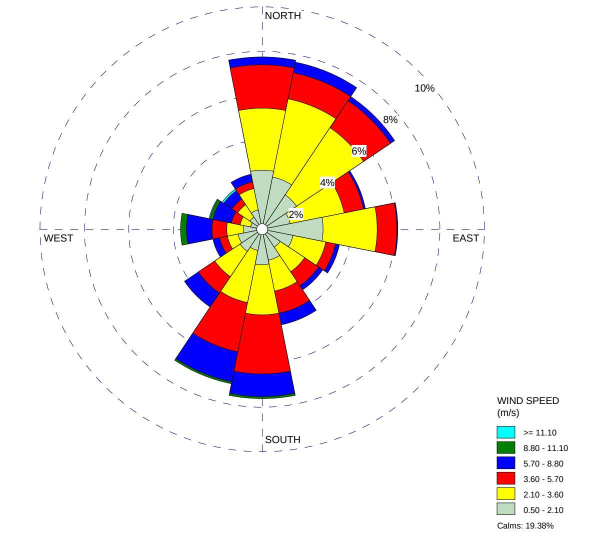
Winter 2014



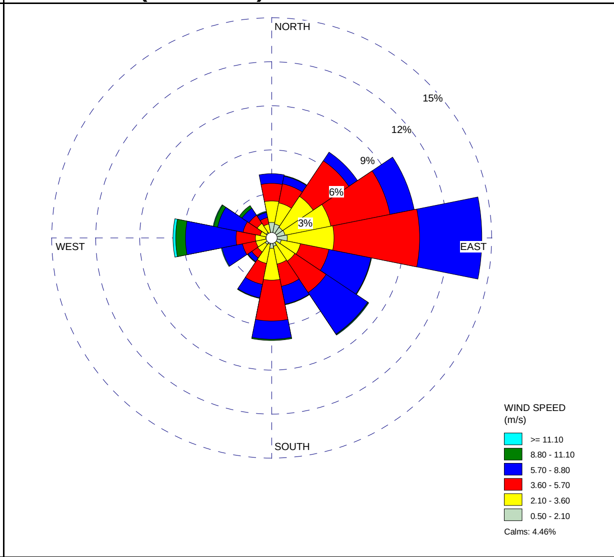
Spring 2014



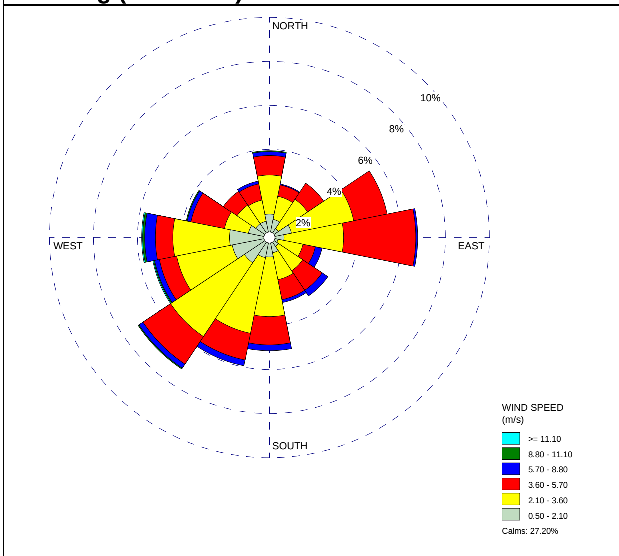
Morning (07h – 12h)



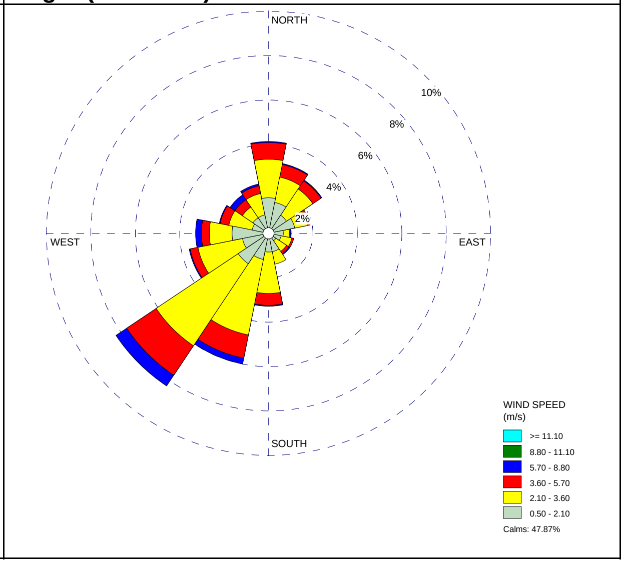
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



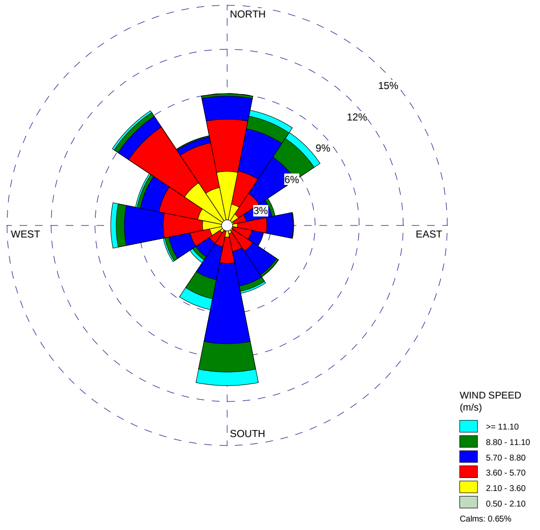
Sydney Airport

Data collected by this station are summarised below.

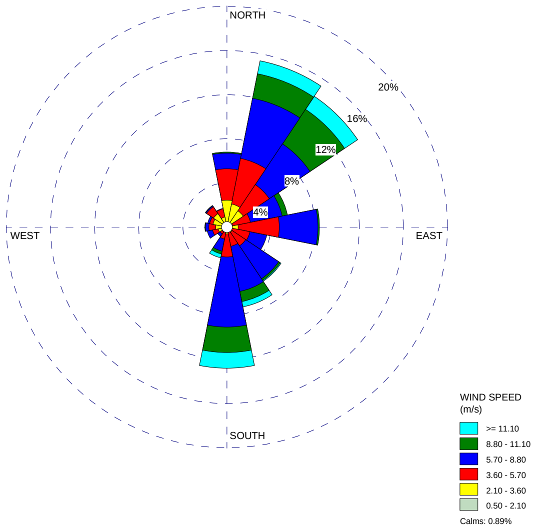
Wind Direction	Wind Speed Category (m/s)						
	0.5-2.1	2.1- 3.6	3.6- 5.7	5.7- 8.8	8.8-11.1	> 11.1	Total
N	0.394%	3.336%	3.602%	1.587%	0.162%	0.012%	8.961%
NNE	0.104%	1.390%	2.328%	2.977%	0.892%	0.405%	7.979%
NE	0.116%	0.822%	1.714%	3.012%	1.552%	0.498%	7.603%
ENE	0.035%	0.429%	0.880%	1.807%	0.220%	0.000%	3.322%
E	0.081%	0.626%	2.039%	1.807%	0.046%	0.000%	4.532%
ESE	0.070%	0.359%	1.309%	0.811%	0.012%	0.000%	2.523%
SE	0.046%	0.417%	1.668%	1.969%	0.151%	0.023%	4.212%
SSE	0.081%	0.498%	1.263%	2.433%	0.359%	0.139%	4.703%
S	0.093%	0.707%	1.819%	5.548%	1.946%	0.938%	10.890%
SSW	0.035%	0.382%	1.089%	2.317%	1.332%	0.765%	5.833%
SW	0.035%	0.568%	0.880%	1.124%	0.255%	0.232%	3.048%
WSW	0.070%	1.158%	1.367%	1.506%	0.278%	0.116%	4.429%
W	0.162%	1.541%	2.711%	2.676%	0.568%	0.371%	7.911%
WNW	0.127%	1.934%	2.734%	1.309%	0.220%	0.116%	6.347%
NW	0.151%	3.382%	4.633%	0.880%	0.324%	0.151%	9.384%
NNW	0.139%	2.525%	3.151%	0.405%	0.070%	0.023%	6.221%
SUM	1.712%	19.783%	32.705%	31.701%	8.265%	3.733%	97.900%
Annual (Jan to Dec 2014) .Total periods = 8,760; Valid periods = 8,633; Calm wind periods = 57; Calm winds: 0.651%							

	Temp (°C)	Precipitation (mm)	Relative Humidity (%)	Wind Direction	Wind speed (m/s)
Maximum	**37.4**	**101.0**	**100**	**360**	**19.0**
Minimum	**5.0**	**0.0**	**9**	**0**	**0.0**
Average	**18.8**	**1.3**	**63**	**193**	**5.5**

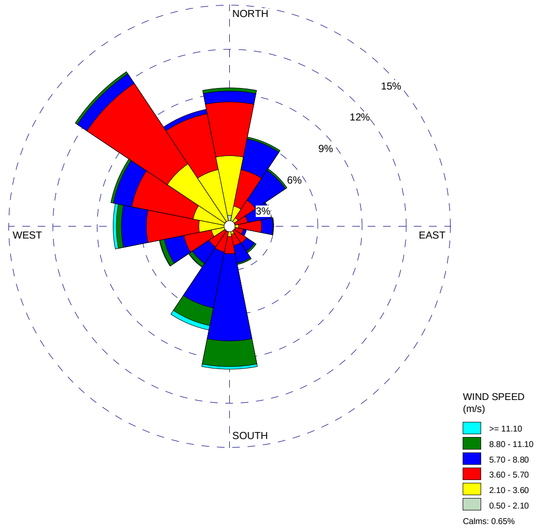
Annual 2014



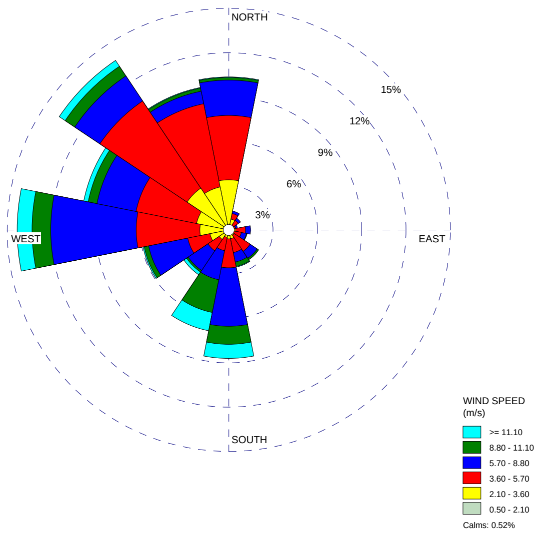
Summer 2014



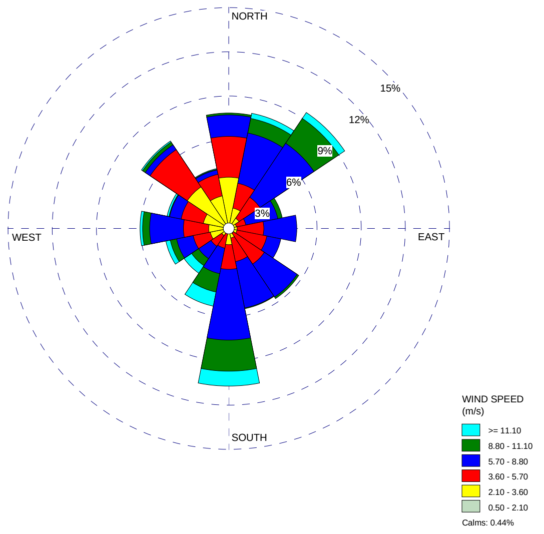
Autumn 2014



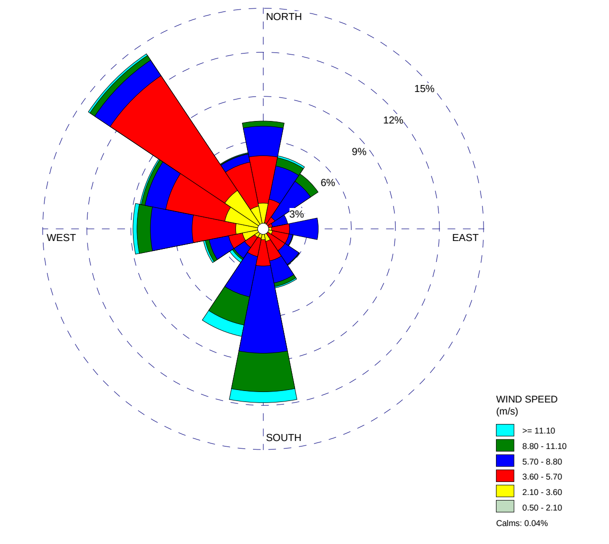
Winter 2014



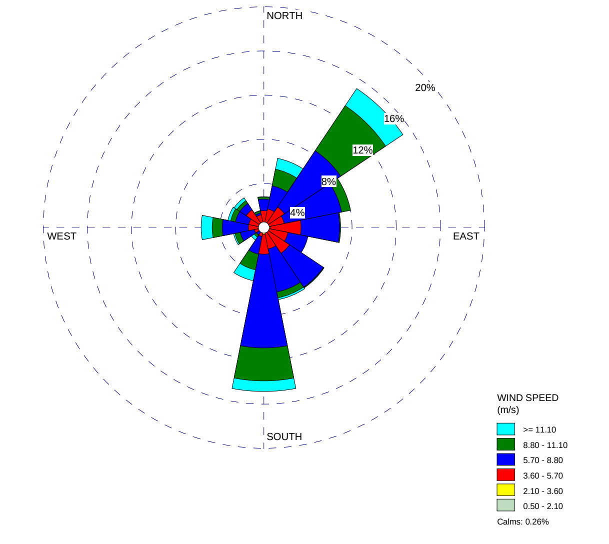
Spring 2014



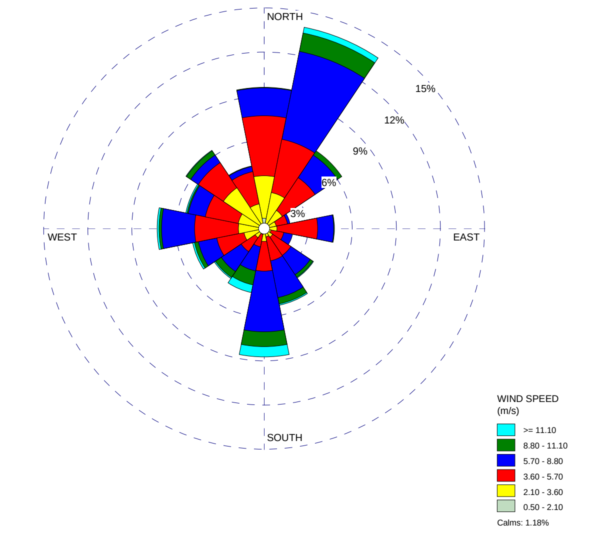
Morning (07h – 12h)



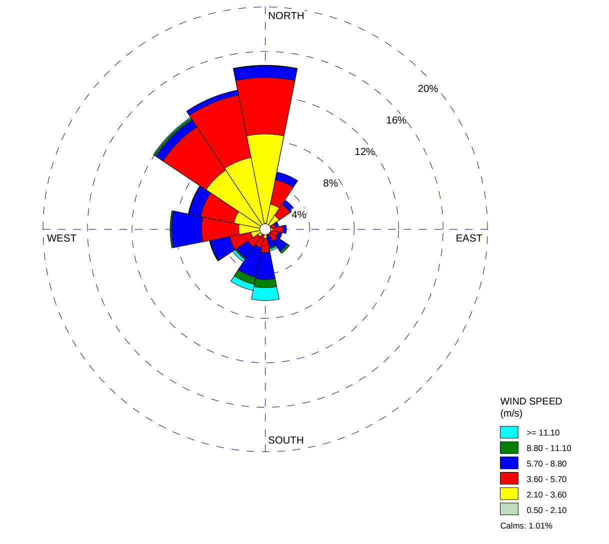
Afternoon (13h – 18h)



Evening (19h – 00h)



Night (01h – 06h)



Appendix C

Dispersion Model Details

Appendix C Dispersion Model Details

Dispersion modelling uses mathematical equations to characterise atmospheric processes, which disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, dispersion models can be used to predict concentrations at selected downwind receiver locations. Air quality models are used to determine compliance with air quality standards. Two well-known and internationally used US EPA guideline models were used in this assessment - CALPUFF and CALROADS. Details of both these models can be found on the US EPA SCRAM (Support Centre for Regulatory Atmospheric Modeling) Bulletin board. The models are addressed in Appendix A of the US EPA's Guideline on Air Quality Models (also published as Appendix W.pdf) of 40 CFR Part 51.

Dispersion models

Two dispersion models are recommended for regulatory assessments in Australia and New Zealand, which are CALPUFF and AERMOD. AERMOD has recently replaced AUSPLUME as the guideline model for all near-field, steady state modelling applications in Victoria. CALPUFF is recommended for use for all modelling applications where the steady state assumption does not apply; this includes complex terrain and coastal environments. A major difference between AERMOD and CALPUFF is in the models' treatment of meteorology. AERMOD is a 2-dimensional model where the effects of one single surface station and one single upper air station are assumed to be spatially uniform across the entire modelling region in its meteorological processor. In contrast, CALMET (CALPUFF's meteorological module) is a 3-dimensional model and is able to use the output of numerical prognostic meteorological models as well as multiple observation sites to assist in the development of three-dimensional wind fields.

Overview of the CALPUFF suite of models

The CALPUFF modelling system provides a non-steady state modelling approach, which evaluates the effects of spatial changes in the meteorological and surface characteristics. It offers the ability to treat stagnation, multiple-hour pollutant build-up, recirculation and causality effects, which are beyond the capabilities of steady-state models. The CALPUFF modelling system was adopted by the U.S. EPA as a guideline model for long range transport applications and, on a case-by-case basis, for near-field applications involving complex flows (Federal Register, April 15, 2003, pp 18,440-18,482). CALPUFF is also recommended by both the Federal Land Managers Air Quality Workgroup (FLAG, 2000, 2008) and the Interagency Workgroup on Air Quality Modelling (IWAQM, 1998). It was adopted for world-wide use by the United Nations International Atomic Energy Agency (IAEA). CALPUFF is widely used in many countries (over 100 countries) throughout the world, and has been incorporated as a regulatory model in several countries.

The CALPUFF modelling system includes three main components - CALMET, CALPUFF and CALPOST - and a large set of pre-processing programs designed to interface the model to standard, routinely-available meteorological and geophysical datasets. In simple terms, CALMET is a meteorological model, which develops hourly wind and temperature fields on a three-dimensional gridded modelling domain. CALPUFF is a transport and dispersion model, which advects 'puffs' of material emitted from modelled source, simulating dispersion and transformation processes along the way. In doing so, it uses the fields generated by CALMET. The primary output files from CALPUFF contain either hourly concentrations or hourly deposition fluxes evaluated at selected receiver locations. CALPOST is used to process these files, producing summaries of the results of the simulation.

CALMET overview

CALMET is a diagnostic meteorological model, which produces three-dimensional wind fields based on parameterised treatments of terrain effects such as slope flows and terrain blocking effects. Meteorological observations are used to determine the wind field in areas of the domain within which the observations are representative. Fine scale terrain effects are determined by the diagnostic wind module in CALMET.

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers (Scire et al., 2000a). When using large domains, the user has the option to adjust input winds to a Lambert Conformal Projection coordinate system to account for the Earth's curvature. The diagnostic wind field module uses a two-step approach to the computation of the wind fields (Douglas and Kessler, 1988). In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field in order to produce a final wind field.

An option is provided to allow gridded prognostic wind fields to be used by CALMET, which may better represent regional flows and certain aspects of sea breeze circulations and slope/valley circulations. The prognostic data (as a 3D.DAT file) can be introduced into CALMET in three different ways;

- As a replacement for the initial guess wind field
- As a replacement for the Step 1 field
- As observations in the objective analysis procedure

The techniques used in the CALMET model are briefly described below.

Step 1 wind field

Kinematic effects on terrain: CALMET uses the approach of Liu and Yocke (1980) to evaluate kinematic terrain effects. The domain-scale winds are used to compute a terrain-forced vertical velocity, subject to an exponential stability-dependent decay function. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence-minimisation scheme to the initial guess wind field. The divergence minimisation scheme is applied iteratively until the three dimensional divergence is less than a threshold value.

Slope flows. Slope flows are computed based on the shooting flow parameterisation of Mahrt (1982). Shooting flows are buoyancy-driven flows, balanced by advection of weaker momentum, surface drag and entrainment at the top of the slope flow layer. The slope flow is parameterised in terms of the terrain slope, distance to the crest and local sensible heat flux. The thickness of the slope flow layer varies with the elevation drop from the crest.

Blocking effects. The thermodynamic blocking effects of terrain on the wind flow are parameterised in terms of the local Froude number (Allwine and Whiteman 1985). If the Froude number at a particular grid point is less than a critical value and the wind has an uphill component, the wind direction is adjusted to be tangential to the terrain.

Step 2 wind field

The wind field resulting from the adjustments of the initial guess wind described above is the Step 1 wind field. The second step of the procedure involves the introduction of observational data into the Step 1 wind field through an objective analysis procedure. An inverse-distance squared interpolation scheme is used, which weighs observational data heavily in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The resulting wind field is subject to smoothing, an optional adjustment of vertical velocities based on the O'Brien (1970) method, and divergence minimisation to produce final Step 2 wind fields.

Overview of CALPUFF

CALPUFF is a non-steady-state puff dispersion model. It accounts for spatial changes in the meteorological fields, variability in surface conditions such as (elevation, surface roughness, vegetation type, etc.), chemical transformation, wet removal due to rain and snow, dry deposition and terrain influences on plume interaction with the surface. CALPUFF can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF contains algorithms for near-source effects, such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as longer range effects, such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, overwater transport and coastal interaction effects. It can accommodate arbitrarily-varying point source and gridded area source emissions. The major features of CALPUFF model are detailed below (after Scire et al., 2002).

Major features of the CALPUFF model

- Source types
  - Point sources (constant or variable emissions)
  - Line sources (constant or variable emissions)
  - Area sources (constant or variable emissions)
  - Volume sources (constant or variable emissions)
- Non-steady-state emissions and meteorological conditions
  - Gridded 3D fields of meteorological variables

    - Spatially variable 3D fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
    - Vertically and horizontally-varying turbulence and dispersion rates
    - Time-dependent source and emissions data
- Efficient sampling functions
    - Integrated puff formulation
    - Elongated puff (slug) formulation
- Dispersion coefficient options
    - Direct measures of sigma v and sigma w
    - Estimated values of sigma v and sigma w based on similarity theory
    - PG dispersion coefficients (rural areas)
    - McElroy Pooler dispersion coefficients (urban areas)
    - CTDM dispersion coefficients (neutral/stable)
- Vertical wind shear
    - Puff Splitting
    - Differential advection and dispersion
- Plume Rise
    - Partial penetration
    - Buoyant and momentum rise
    - Stack tip downwash effects
    - Vertical wind shear
    - Building downwash effects
- Building downwash
    - Huber-Snyder method
    - PRIME downwash
    - Schulman Scire method
- Dry deposition
    - Gases and particulate matter
    - Three options
        - Full treatment of space and time variations of deposition with a resistance model
        - User-specified diurnal cycles for each pollutant
        - No dry deposition
- Overwater and coastal interaction effects
    - Overwater boundary layer parameters
    - Abrupt change in meteorological conditions, plume dispersion at coastal boundary
    - Plume fumigation
    - Option to introduce sub grid scale TIBLs into coastal grid cells
- Chemical transformation options
    - Pseudo-first-order chemical mechanism for SO_2, SO_4, NO_x HNO_3 and NO_3 (MESOPUFF II method)

- User specified diurnal cycles of transformation rates
- No chemical conversion
- Wet Removal
- Scavenging coefficient approach
- Removal rate a function of precipitation intensity and precipitation type

Overview of CAL3QHCR

CAL3QHCR is a CALINE3-based model with queuing and hot spot calculations and with a traffic model to calculate delays and queues that occur at signalised intersections. The CALINE3 model on which it is based is a steady-state Gaussian dispersion model designed to determine air pollution concentrations at receiver locations downwind of highways located in relatively uncomplicated terrain.

The CAL3QHC model can predict carbon monoxide and other inert pollutant concentrations from motor vehicles at roadway intersections. The model includes the CALINE-3 line source dispersion model and a traffic algorithm for estimating vehicular queue lengths at signalised intersections. CALINE-3 was designed to predict air pollutant concentrations near highways and arterial streets due to emissions from motor vehicles operating under free flow conditions. CALINE-3, however, does not permit the direct estimation of the contribution of emissions from idling vehicles. CAL3QHC was developed to enhance CALINE-3 by incorporating methods for estimating queue lengths and the contributions of emissions from idling vehicles. The model permits the estimation of total air pollution concentrations from both moving and idling vehicles. CAL3QHC requires details on roadway geometries, receiver locations, meteorological conditions and vehicular emission rates. In addition, the model requires other parameters such as signal timing data and information describing the configuration of the intersection being modelled.

The CAL3QHCR model is an enhanced version of CAL3QHC, which can process up to a year of hourly meteorological data. Vehicular emissions, traffic volume, and signalisation data can be specified for each hour of a week. Further, the latest version also accommodates up to 5,000 receivers and 5,000 sources (previously 60 receivers and 120 sources). In order to accommodate the large number of receivers associated with this assessment, the CAL3QHCR model was considered to be the most appropriate choice for modelling the traffic movements on roadways external to the tunnels. The line source model predicts pollutant concentrations based on the Gaussian diffusion equation. CAL3QHCR was used to predict concentrations of carbon monoxide, nitrogen dioxide and particulate matter in this assessment.

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Appendix D

Sensitive Receivers

Appendix D Sensitive Receivers

The receiver locations included in the modelling are provided below.

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
1	313936.0	6273136.2	100.4	**141**	323349.5	6270489.2	189.5	**281**	322651.0	6269311.7	83.0
2	322768.4	6269869.6	158.1	**142**	323340.6	6270473.5	190.0	**282**	322638.3	6269278.9	80.3
3	322749.0	6269856.1	159.5	**143**	323324.4	6270481.2	188.0	**283**	322623.9	6269270.4	86.0
4	322732.8	6269844.9	159.5	**144**	323294.0	6270496.8	185.4	**284**	322931.0	6269266.3	186.2
5	322716.3	6269836.4	160.3	**145**	323252.5	6270503.8	183.4	**285**	322927.0	6269221.0	192.7
6	322697.3	6269822.1	159.1	**146**	323233.1	6270506.6	184.1	**286**	322949.6	6269240.5	192.7
7	322664.7	6269804.6	153.8	**147**	323211.8	6270512.4	184.2	**287**	322968.3	6269268.6	188.6
8	322616.3	6269828.4	150.9	**148**	323275.7	6270499.5	184.3	**288**	323023.0	6269259.5	196.7
9	322684.2	6269838.4	163.8	**149**	323329.8	6270522.5	186.6	**289**	323010.7	6269196.4	199.4
10	322657.6	6269841.5	162.8	**150**	323302.0	6270526.5	184.4	**290**	322999.6	6269178.9	199.3
11	322624.2	6269866.1	160.5	**151**	323280.9	6270530.0	182.8	**291**	323059.9	6269249.2	199.4
12	322619.5	6269889.6	162.4	**152**	323261.0	6270533.1	181.8	**292**	323086.9	6269250.0	199.1
13	322802.8	6269949.6	154.4	**153**	323240.2	6270535.8	181.5	**293**	323102.0	6269248.0	198.9
14	322774.3	6269995.7	171.2	**154**	323224.8	6270538.4	181.5	**294**	323143.3	6269241.7	196.4
15	322794.1	6270011.3	166.3	**155**	323214.3	6270539.7	181.7	**295**	323173.8	6269236.9	194.1
16	322823.7	6269964.4	141.4	**156**	323198.5	6270570.8	179.9	**296**	323200.2	6269233.1	192.6
17	322821.6	6270012.3	157.6	**157**	323196.9	6270542.6	182.0	**297**	323124.2	6269199.6	196.9
18	322841.2	6270033.5	160.7	**158**	323176.3	6270545.1	182.6	**298**	323084.9	6269200.4	199.2
19	322865.0	6270038.8	155.1	**159**	323185.0	6270562.6	181.0	**299**	323067.9	6269203.2	199.5
20	322884.9	6270047.0	154.1	**160**	323170.7	6270564.7	180.9	**300**	323151.6	6269189.3	194.1
21	322628.6	6269911.3	170.6	**161**	323149.3	6270549.6	182.7	**301**	323113.0	6269190.7	197.7
22	322639.3	6269934.7	176.5	**162**	323138.4	6270550.9	182.4	**302**	323173.8	6269188.2	192.7
23	322698.9	6269933.1	178.5	**163**	323142.3	6270580.6	180.4	**303**	323197.9	6269181.0	190.6
24	322723.1	6269907.7	173.3	**164**	323121.4	6270553.7	182.5	**304**	323223.1	6269231.4	191.4
25	322700.0	6269891.4	171.6	**165**	323122.7	6270580.3	180.8	**305**	323246.2	6269227.3	188.5
26	322687.5	6269904.6	175.9	**166**	323104.1	6270584.7	180.8	**306**	323244.7	6269167.0	187.2
27	322748.9	6269910.1	170.7	**167**	323090.6	6270558.1	182.8	**307**	323261.2	6269163.8	187.5
28	322744.5	6269947.8	176.4	**168**	323171.7	6270466.5	188.2	**308**	323278.3	6269215.9	186.1
29	322692.1	6269951.7	179.7	**169**	323191.2	6270492.7	185.6	**309**	323291.2	6269221.4	185.1
30	322725.4	6269943.8	177.6	**170**	323198.8	6270473.4	187.0	**310**	323304.4	6269218.9	184.5
31	322731.4	6269972.0	178.4	**171**	323216.4	6270460.6	187.7	**311**	323318.8	6269217.6	185.0
32	322757.2	6269968.0	172.3	**172**	323204.5	6270435.6	189.3	**312**	323335.1	6269215.3	185.5
33	322774.7	6269910.1	163.0	**173**	323233.6	6270432.7	189.4	**313**	323350.3	6269212.7	185.2
34	322609.2	6269974.0	167.0	**174**	323249.3	6270418.2	190.5	**314**	323366.4	6269210.6	185.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
35	322660.0	6269989.8	180.2	**175**	323280.9	6270410.8	191.4	**315**	323381.6	6269208.7	183.9
36	322650.8	6270010.5	180.2	**176**	323313.6	6270406.5	192.8	**316**	323396.9	6269205.5	182.4
37	322639.3	6270026.8	179.1	**177**	323238.1	6270457.7	187.1	**317**	323411.9	6269204.3	181.1
38	322626.6	6270042.6	176.8	**178**	323261.6	6270454.0	187.2	**318**	323434.1	6269200.2	180.3
39	322615.1	6270057.7	175.4	**179**	323286.2	6270450.8	188.2	**319**	323477.9	6269193.7	180.1
40	322605.2	6270075.2	168.8	**180**	323313.7	6270446.8	189.7	**320**	323513.5	6269188.8	179.7
41	322575.0	6270096.2	162.2	**181**	323336.8	6270443.4	191.1	**321**	323544.8	6269184.8	180.7
42	322603.2	6270114.9	163.2	**182**	323334.3	6270428.0	191.8	**322**	323697.6	6269321.7	183.6
43	322631.8	6270080.3	175.3	**183**	323269.0	6270239.1	197.2	**323**	323693.7	6269291.6	183.6
44	322651.6	6270037.1	179.7	**184**	323086.4	6270282.2	183.9	**324**	323697.9	6269276.2	183.6
45	322682.6	6270004.9	181.3	**185**	323213.8	6270087.3	168.2	**325**	323704.0	6269279.8	183.5
46	322737.7	6270042.6	177.8	**186**	323220.1	6270132.5	180.6	**326**	323717.4	6269290.2	182.8
47	322760.8	6270058.9	175.8	**187**	323243.0	6270128.4	183.1	**327**	323560.7	6269670.4	149.6
48	322781.8	6270073.6	173.9	**188**	323266.2	6270126.2	185.3	**328**	323637.8	6269676.9	175.5
49	322727.8	6270092.6	171.1	**189**	323302.3	6270104.0	172.4	**329**	323733.6	6269698.3	186.0
50	322718.3	6270108.9	167.2	**190**	323325.3	6270132.1	178.6	**330**	323732.7	6269681.0	186.0
51	322715.9	6270082.7	175.2	**191**	323300.3	6270046.8	153.0	**331**	323727.0	6269663.6	186.1
52	322682.6	6270113.3	170.5	**192**	323337.1	6270046.6	148.2	**332**	323724.1	6269646.9	186.1
53	322706.8	6270124.0	164.1	**193**	323401.6	6269982.5	116.0	**333**	323733.1	6269611.5	185.6
54	322690.1	6270056.5	179.5	**194**	323460.4	6269964.6	135.2	**334**	323731.2	6269596.1	185.6
55	322811.1	6270091.4	172.2	**195**	323372.9	6270218.0	189.9	**335**	323739.2	6269718.0	186.9
56	322823.6	6270096.8	172.4	**196**	323434.8	6270199.4	171.9	**336**	323753.5	6269639.3	184.0
57	322809.0	6270129.5	162.4	**197**	323457.4	6270189.0	158.7	**337**	323747.3	6269693.5	185.4
58	322844.7	6270105.1	172.5	**198**	323589.7	6270188.6	179.8	**338**	323832.3	6269695.2	181.6
59	322697.3	6270012.9	181.2	**199**	323590.5	6270171.2	179.5	**339**	323814.8	6269611.7	181.1
60	322713.5	6270024.4	180.4	**200**	323606.1	6270137.3	185.9	**340**	323805.7	6269567.9	181.8
61	322856.4	6270168.0	163.1	**201**	323601.1	6270102.1	183.0	**341**	323793.9	6269536.3	182.3
62	322869.9	6270114.8	172.9	**202**	323592.1	6270025.9	177.4	**342**	323715.1	6269548.8	186.7
63	322889.8	6270121.5	173.1	**203**	323615.1	6270179.7	187.9	**343**	323724.5	6269526.9	186.2
64	322915.2	6270127.9	173.5	**204**	323599.5	6270049.0	182.8	**344**	323721.3	6269510.1	184.8
65	322938.9	6270134.0	174.3	**205**	323579.1	6269984.4	172.0	**345**	323756.7	6269526.4	184.4
66	322935.9	6270176.6	165.0	**206**	323571.1	6270003.7	171.7	**346**	323666.4	6269497.8	188.6
67	322960.9	6270058.9	152.8	**207**	323571.5	6269949.0	166.3	**347**	323794.4	6269490.2	181.3
68	322878.9	6270161.1	165.6	**208**	323432.2	6270028.4	128.0	**348**	323789.6	6269446.5	181.3
69	322917.3	6270063.0	161.3	**209**	323326.3	6269985.2	131.0	**349**	323778.1	6269406.4	181.5
70	323023.7	6270084.1	161.7	**210**	323613.6	6269852.2	170.8	**350**	323753.9	6269346.9	181.8
71	322987.0	6270151.0	175.3	**211**	323629.5	6269862.5	172.9	**351**	323755.4	6269327.4	182.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
72	323019.4	6270157.7	177.0	**212**	323642.6	6269875.6	183.0	**352**	323754.7	6269292.5	181.8
73	323049.5	6270179.1	178.8	**213**	323693.8	6269886.3	190.8	**353**	323756.7	6269271.9	182.3
74	323071.0	6270194.9	181.9	**214**	323689.4	6269863.3	188.7	**354**	323655.1	6269903.2	188.1
75	323086.1	6270144.6	178.8	**215**	323686.2	6269842.3	187.3	**355**	323697.4	6269931.8	192.7
76	323103.5	6270152.0	179.1	**216**	323681.9	6269818.9	184.8	**356**	323660.9	6269937.3	190.0
77	323138.2	6270130.5	166.6	**217**	323667.2	6269787.9	182.4	**357**	323631.5	6269959.3	179.2
78	323157.8	6270152.8	174.2	**218**	323653.9	6269766.6	180.8	**358**	323633.9	6269973.5	180.9
79	323137.9	6270186.5	181.4	**219**	323617.2	6269714.1	169.1	**359**	323639.8	6270011.3	188.5
80	323099.8	6270220.6	184.9	**220**	323650.1	6269687.5	180.9	**360**	323637.0	6269994.9	185.7
81	323182.6	6270173.8	183.6	**221**	323643.0	6269613.7	181.3	**361**	323756.3	6269807.3	187.4
82	323205.7	6270172.3	184.8	**222**	323637.8	6269587.1	182.5	**362**	323760.7	6269854.4	188.4
83	323196.8	6270117.7	171.1	**223**	323566.4	6269501.0	183.2	**363**	323695.3	6269945.3	193.2
84	323017.9	6270260.6	162.9	**224**	323648.8	6269435.6	188.5	**364**	323693.9	6269956.1	193.4
85	323026.4	6270279.2	164.2	**225**	323646.2	6269419.3	187.7	**365**	323688.8	6269974.0	194.0
86	323026.2	6270299.1	165.8	**226**	323644.9	6269382.7	186.6	**366**	323686.3	6269988.6	193.9
87	323030.6	6270317.3	171.3	**227**	323646.9	6269347.4	186.3	**367**	323706.4	6269985.5	194.4
88	323037.6	6270335.9	174.0	**228**	323647.7	6269312.8	185.1	**368**	323740.8	6269740.8	186.8
89	323035.7	6270357.1	173.9	**229**	323553.3	6269251.7	177.2	**369**	323734.5	6269760.7	186.6
90	323035.0	6270374.9	174.3	**230**	323537.8	6269253.7	174.4	**370**	323767.1	6269750.6	186.9
91	323003.5	6270378.0	168.4	**231**	323467.9	6269264.8	166.6	**371**	323840.0	6269747.9	184.5
92	323064.0	6270302.5	178.4	**232**	323437.0	6269269.6	165.4	**372**	323806.4	6269799.0	186.1
93	323124.6	6270352.6	191.1	**233**	323399.3	6269251.3	174.6	**373**	323842.1	6269837.7	186.8
94	323121.8	6270313.5	189.7	**234**	323375.5	6269254.1	173.8	**374**	323841.1	6269796.0	186.0
95	323104.6	6270266.6	186.3	**235**	323334.6	6269276.8	171.0	**375**	322753.6	6269254.2	117.0
96	323165.4	6270259.1	191.6	**236**	323314.4	6269285.9	170.3	**376**	322698.4	6269260.2	89.4
97	323402.6	6270709.9	189.9	**237**	323292.3	6269289.6	172.6	**377**	322692.0	6269241.1	91.3
98	323359.2	6270698.2	185.0	**238**	323273.1	6269292.2	175.0	**378**	322670.6	6269244.8	87.9
99	323342.8	6270709.2	184.4	**239**	323225.8	6269300.9	176.7	**379**	322655.9	6269235.8	91.3
100	323328.3	6270711.6	183.2	**240**	323244.5	6269279.5	181.5	**380**	322621.1	6269241.4	92.5
101	323383.4	6270694.8	187.5	**241**	323219.9	6269283.5	180.4	**381**	322625.2	6269220.2	94.8
102	323375.7	6270679.3	187.5	**242**	323202.0	6269303.3	176.8	**382**	323281.3	6269169.1	188.3
103	323373.7	6270664.9	188.7	**243**	323183.8	6269307.3	176.5	**383**	323295.4	6269167.9	188.6
104	323348.0	6270668.3	187.0	**244**	323163.5	6269310.1	178.0	**384**	323308.3	6269166.3	189.3
105	323333.9	6270676.9	184.9	**245**	323142.5	6269313.2	180.1	**385**	323316.5	6269165.0	189.3
106	323306.8	6270681.1	182.6	**246**	323121.5	6269316.4	184.3	**386**	323323.5	6269163.6	189.4
107	323293.4	6270674.1	181.3	**247**	323288.2	6269266.8	177.1	**387**	323331.4	6269162.7	189.4
108	323345.3	6270653.6	187.2	**248**	323105.6	6269318.0	189.7	**388**	323342.7	6269160.7	189.2

ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)	ID	X (m)	Y (m)	Z (m)
109	323381.5	6270648.1	190.1	**249**	323091.7	6269320.4	191.1	**389**	323373.1	6269156.0	188.2
110	323372.7	6270634.6	190.4	**250**	323075.8	6269323.6	193.2	**390**	323396.9	6269153.1	186.9
111	323354.9	6270616.1	190.9	**251**	323060.7	6269325.5	193.2	**391**	323424.0	6269149.7	185.2
112	323382.5	6270711.3	188.0	**252**	323047.3	6269327.1	193.2	**392**	323361.7	6269160.3	188.3
113	323321.8	6270678.8	183.8	**253**	323008.4	6269333.5	184.4	**393**	323465.1	6269142.2	182.3
114	323326.5	6270591.2	186.9	**254**	322831.0	6269312.2	156.1	**394**	323475.8	6269140.3	182.3
115	323312.9	6270603.4	185.3	**255**	322744.4	6269372.5	98.2	**395**	323493.8	6269139.7	182.1
116	323301.1	6270606.4	183.3	**256**	322744.8	6269286.0	109.4	**396**	323514.2	6269136.1	182.1
117	323293.4	6270608.0	182.9	**257**	322813.9	6269253.2	155.8	**397**	323543.2	6269132.7	182.0
118	323281.1	6270609.6	181.6	**258**	322887.7	6269275.6	174.5	**398**	323563.7	6269129.5	182.2
119	323265.9	6270611.7	180.3	**259**	322838.1	6269253.0	163.8	**399**	323622.5	6269120.8	185.6
120	323358.4	6270599.3	191.4	**260**	322710.3	6269377.2	90.2	**400**	323633.3	6269119.4	186.2
121	323369.9	6270571.9	191.5	**261**	322637.7	6269388.0	82.1	**401**	323617.2	6269178.9	184.1
122	323279.3	6270685.2	180.1	**262**	322611.1	6269369.9	80.1	**402**	323614.7	6269153.6	185.2
123	323252.5	6270613.8	179.2	**263**	322561.3	6269376.6	73.4	**403**	323640.7	6269133.0	187.1
124	323236.5	6270616.3	178.4	**264**	322563.6	6269346.4	78.6	**404**	323633.5	6269153.3	186.5
125	323222.6	6270618.3	177.8	**265**	322547.1	6269341.7	79.4	**405**	323580.8	6269223.6	180.5
126	323208.2	6270620.6	177.3	**266**	322533.1	6269332.6	80.9	**406**	323641.9	6269236.9	184.6
127	323169.9	6270626.4	176.9	**267**	322517.5	6269325.8	80.0	**407**	323704.1	6269227.5	184.2
128	323146.8	6270629.6	176.9	**268**	322500.1	6269322.0	81.4	**408**	323642.6	6269275.5	184.7
129	323153.1	6270663.5	174.5	**269**	322489.1	6269330.5	78.4	**409**	323693.1	6269310.0	183.6
130	323129.6	6270632.3	177.0	**270**	322464.8	6269333.7	76.8	**410**	323775.3	6269933.5	190.3
131	323112.0	6270634.8	177.0	**271**	322444.0	6269324.1	76.8	**411**	323778.5	6269954.1	190.9
132	323119.3	6270669.9	174.5	**272**	322406.1	6269299.6	79.7	**412**	323768.2	6270001.2	191.8
133	323169.4	6270659.2	175.3	**273**	322656.1	6269364.6	83.8	**413**	323644.9	6270031.6	190.6
134	323160.9	6270702.3	172.8	**274**	322639.0	6269354.6	82.6	**414**	323646.2	6270047.2	190.8
135	323142.1	6270705.5	171.6	**275**	322623.5	6269345.3	81.4	**415**	323688.8	6270024.5	194.9
136	323206.2	6270695.7	175.7	**276**	322601.9	6269330.9	80.2	**416**	323692.3	6270039.6	195.2
137	323284.5	6270720.2	179.6	**277**	322580.8	6269319.1	82.2	**417**	323376.1	6270132.6	170.4
138	323382.9	6270542.3	192.1	**278**	322571.7	6269296.0	85.4	**418**	323558.9	6270180.7	173.7
139	323349.0	6270519.7	188.4	**279**	322680.0	6269329.4	89.8	**419**	322695.2	6270135.4	163.6
140	323371.5	6270500.9	191.3	**280**	322692.9	6269307.2	92.9	**420**	322840.0	6270164.6	161.2

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Appendix E

Emission Calculations

Appendix E Emission Calculations

The following subsections provide a detailed description of all emission calculations and assumptions used in the dispersion modelling. These values have been based on the operation of Hornsby Quarry filling at its peak operational capacity to ensure that prediction of maximum impacts. Site operations have been assumed to under maximum capacity for all hours to ensure that worst case operating conditions coincided with worst case meteorological conditions. As such predicted annual average concentrations for all pollutants are likely to be overestimated.

All emission sources were assigned a base level height using LPI LiDAR 2011 data with a grid resolution of 1m, with the exception to sources within the void. The modelling has been undertaken for the year 2017 were the pit is presumed to be largely filled as such a pit height of 100m above MSL was assigned, equating to approximately 25-30m below the surrounding flats.

Onsite Haul Truck Combustion Emissions

Onsite haul truck combustion emissions were calculated using PIARC emission rates for heavy vehicles. It was assumed that a total of 6 haul trucks would be present onsite at any one time.

Combustion Emissions from Mobile Sources

Combustion emissions for mobile plant equipment were calculated using the following equation, specified in the NPI Emissions Estimation Technique (EET) Manual for Combustion Engines (DEWHA, 2009):

$$E_i = P \times OpHrs \times LF \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
P	=	Power output (kW)
OpHrs	=	Operational hours (h/y)
LF	=	Load factor
EF_i	=	Emissions factor (kg/kWh)

Emission factors for mobile plant equipment were classified in accordance with Table 5 under Section 5.4 of the NPI EET Manual for Mining (DSEWPC, 2012). All mobile plant equipment was assumed to be operating at 80 percent utilisation rate between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays with the exception to haul trucks which would be operational for 100 percent of the time during the confined work hours..

Combustion Emissions for Stationary Combustion Engines

Combustion emissions for onsite generators were calculated using the equation for stationary combustion engines specified in the NPI Emissions EET Manual for Combustion Engines (DEWHA, 2009):

$$E_i = P \times OpHrs \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
P	=	Power output (kW)
OpHrs	=	Operational hours (h/y)
EF_i	=	Emissions factor (kg/kWh)

Emission factors from US EPA Tier 3 non-road diesel engine emission standards (37-75 kW and 225-450 kW) (Environ 2014) were used for carbon monoxide, oxides of nitrogen, particulates and volatile organic compounds. Emission factors from Table 49 (stationary diesel engines < 450kW) of the EET manual (DEWHA, 2009) were used for polycyclic aromatic hydrocarbons. Two onsite generators of 40 kW (50 kVA) were assumed to be used for site compounds, amenities. The generator used for the conveyor was assumed to have a power output of 400 kW (500 kVA). An additional 40 kW generator to be used for pumping water out of the void was excluded for the assessment as sight preparation works would be outside the timeframe of maximum haulage volumes conducted in 2017.

Generators for site compounds, amenities and the conveyor would be operational between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays. Generators for onsite amenities and site compound would 100 percent operational, while the generator for the conveyor would be operational for 80 percent of the time.

Dust Emissions from Excavators and Front-End Loaders.

Dust emissions rates for excavators and front-end loaders moving spoil were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

The emission factors for excavators and front-end loaders transfer points were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[5], provided by Lend Lease, was used.

The excavators and front-end loaders were assumed to be operating at 80 percent utilisation between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays. An activity rate of 720t/h (at 80 percent utilisation) was applied to all excavators and front-end loaders with the exception to those loading to arterial dump trucks in the pit which had an activity rate of equates to 216t/h at 80 percent utilisation.

A control efficiency of 30 percent was applied to all sources by reducing the drop height from 3m to 1.5m (Katestone Environmental 2011)

Dust Emissions from Bulldozers

Dust emissions from bulldozers shaping spoil stockpiles were calculated using the following equation:

$$E_i = OP \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y/vehicle)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

Bulldozers would be operating at 80 percent utilisation between 7 am and 6 pm on weekdays and 8 am to 1 pm on Saturdays.

[5] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Emission factors were based on the following US EPA AP-42 equation (Chapter 11.9)

$$EF_{TSP} = 2.6 \times s^{1.2} / M^{1.3}$$

$$EF_{PM10} = 0.45 \times s^{1.5} / M^{1.4} \times 0.75$$

$$EF_{TSP} = 2.6 \times s^{1.2} / M^{1.3} \times 0.105$$

Where:

EF_{TSP}/EF_{PM10} = Emission rate (kg/h/vehicle)
s = Silt content by weight (%)
M = Moisture content by weight (%)

Moisture and silt contents of 10 % and 12 % respectively (provided by Lend Lease) were used to calculate the emission factors for particulates.

A control efficiency of 50% has been applied to bulldozer emissions; ensuring that all material handled by bulldozers is kept moist with the use of water sprays (Katestone Environmental 2011).

Dust Emissions from Trucks Dumping Spoil

Dust emissions from haul trucks dumping spoil to temporary stockpiles were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i = Emission rate (kg/y)
A = Activity rate (t/h)
OP = Operational hours (h/y)
EF_i = Uncontrolled emissions factor (kg/t)
CE_i = Overall control efficiency (kg/t)

An activity rate of 1155 t/h was calculated based on a total of 35 trucks per hour delivering 12 bcm/truck (information provided by Lend Lease) and a spoil density of 2.65 t/bcm (information provided by Transurban). Haul truck deliveries would occur between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays.

The emission factors for excavators and front-end loaders transfer points were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i = Uncontrolled emissions factor (kg/t/transfer point)
k_i = Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U = Mean wind speed (m/s)
M = Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[6], provided by Lend Lease, was used.

An emission reduction efficiency of 70 % was applied for unloading trucks using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012).

[6] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Dust Emissions from Articulated Dump Trucks in Pit

Dust emissions from articulated dump trucks dumping spoil within the pit were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i = Emission rate (kg/y)
A = Activity rate (t/h)
OP = Operational hours (h/y)
EF_i = Uncontrolled emissions factor (kg/t)
CE_i = Overall control efficiency (kg/t)

Articulated dump trucks would be active in the pit between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays and operate 80 percent of the time. An activity rate of 30 percent of all spoil entering the pit would be moved by arterial dump trucks. This equates to 216t/h at 80 percent utilisation.

The emission factors for arterial dump trucks were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i = Uncontrolled emissions factor (kg/t/transfer point)
k_i = Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U = Mean wind speed (m/s)
M = Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[7], provided by Lend Lease, was used.

An emission reduction efficiency of 70 % was applied for unloading trucks using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012).

Dust Emissions from Roller in Void

Dust emissions from the roller were calculated using the following NPI EET manual for mining (DSEWPAC, 2012) equation:

$$E_i = VKT \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i = Emission rate (kg/y)
VKT = Vehicle kilometres travelled per year
EF_i = Uncontrolled emissions factor (kg/VKT)
CE_i = Overall control efficiency (kg/t)

Roller activities be conducted between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays and would operate at 80 percent utilisation during this time. The roller was assumed to operate at a speed of 5 km/h. Emission factors for TSP and PM_{10} were calculated using the equations below, while a particle size ratio for $PM_{2.5}/PM_{10}$ of 0.1 was applied to calculate the $PM_{2.5}$ emission rate based on Cowherd et.al (2006).

$$EF_{TSP} = 0.0034 \times S^{2.5}$$

[7] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

$$EF_{PM10} = 0.0034 \times S^{2.0}$$

Where:

EF_{TSP}/EF_{PM10}	=	Uncontrolled emissions factor (kg/VKT)
S	=	Mean vehicle speed (km/h)

An emission reduction efficiency of 75 % was applied for rollers using Level 2 watering of exposed surfaces (> 2 litres/m^2/h) based on Table 4 of the EET Manual for Mining (DSEWPAC, 2012).

Dust Emissions from Conveying Spoil

Dust emissions from conveyor transfer points were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = [A \times OP] \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i	=	Emission rate (kg/y/transfer point)
A	=	Activity rate (t/h)
OP	=	Operational hours (h/y)
EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
CE_i	=	Overall control efficiency (kg/t)

The temporary stockpiles on the flats were assumed to have two loading points with a capacity of up to 450t/h each. The southernmost conveyor would drop the spoil onto the other conveyor, which would transfer it to the pit at a maximum capacity of 900 t/h. The activity rate of the conveyors is assumed to be operating at an 80 percent utilisation rate, which equates to 720 t/h. It was, therefore, assumed that each transfer point on the flats would have an activity rate of 360 t/h (i.e. each taking half the load), while the activity rate for the conveyor leading into the pit would be 720 t/h (the total combined throughput). The conveyor would be operational between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays.

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for batch drops (Chapter 13.2.4.3). The equation can be seen here:

$$EF_i = k_i \times 0.0016 \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/t/transfer point)
k_i	=	Constant; where k = 0.74 for TSP, k= 0.35 for PM_{10} and k = 0.053 for $PM_{2.5}$
U	=	Mean wind speed (m/s)
M	=	Moisture content by weight (%)

A mean wind speed of 1.96 m/s (extracted from the CALMET data set for the project site location) was used to calculate the emission factors. A moisture content of 10 percent[8], provided by Lend Lease, was used.

An emission reduction efficiency of 50 % was applied for using water sprays based on *Table 4: Estimated control factors for various mining operations for coal mines* of the EET manual for Mining (DSEWPAC, 2012). Conveyor emissions from the base of the pit were assumed to be uncontrolled.

Wind Erosion from Stockpiles and Exposed Areas

Dust emissions from exposed areas were calculated using the following NPI EET Manual for Mining (DSEWPAC, 2012) equation:

$$E_i = A \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

[8] The moisture content is outside the correction parameter range tested in developing the equation as such the emission factor rating would be reduced.

Where:

E_i	=	Emission rate (kg/y)
A	=	Area (ha)
EF_i	=	Uncontrolled emissions factor (kg/t)
CE_i	=	Overall control efficiency (kg/t)

The exposed surface areas of the flats and pit were estimated to be approximately 4.3 ha and 7.5 ha respectively. The AP-42 (US EPA, 1988) equation referenced in the NPI EET Manual for Mining (DSEWPAC, 2012) was used to calculate the emission factor equation for TSP, and factors of 50 % (US EPA, 1988) and 15 % (Cowherd *et al*., 2006) were used to calculate the emission rates for PM_{10} and $PM_{2.5}$ respectively.

$$\mathrm{EF}_{\boldsymbol{TSP}} = \left(\frac{s}{1.5}\right) \times 365 \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right)$$

Where:

EF_{TSP}	=	Emission rate (kg/y)
s	=	Silt content by weight (%)
p	=	Number of days per year when rainfall is greater than 0.25 mm
f	=	Time that wind speed is greater than 5.4 m/s

A silt content of 12 % was used to calculate the emission factor for TSP (provided by Lend Lease). The 2014 CALMET data from the site were used to calculate the meteorological input parameters. There were 229 days in the year 2014 where the precipitation exceeded 0.25 mm, and winds higher than 5.4 m/s only occurred 0.23 % of the time.

An emission reduction efficiency of 50 % was applied for exposed areas within the pit using water sprays based on Table 4 of DSEWPAC (2012). For the temporary stockpiles on the flats, it was assumed that both water sprays and wind breaks would be used, resulting in an emission reduction efficiency of 85 %.

Wheel Generated Dust on Paved Roads

Dust emissions from haul trucks on paved roads were calculated using the following equation:

$$E_i = VKT \times EF_i$$

Where:

E_i	=	Emission rate (kg/y)
VKT	=	Vehicle kilometres travelled per year
EF_i	=	Uncontrolled emissions factor (kg/VKT)

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for paved roads (Chapter 13.2.2.2). The equation can be seen here:

$$EF_i = k_i \times (sL)^{0.91} \times (W)^{1.02} \times 1000$$

Where:

EF_i	=	Uncontrolled emissions factor (kg/VKT)
k_i	=	Constant; where k = 3.23 for TSP, k= 0.62 for PM_{10} and k = 0.015 for $PM_{2.5}$
sL	=	Road surface silt loading (g/m^2)
W	=	Average weight of vehicles travelling the road (t)

A silt loading content of 0.6 was assumed based on Table 13.2 1-2 of the US EPA AP-42 document. Haul trucks were assumed to have an empty vehicle mass of 15 tonnes, and a full load mass of 48 tonnes. Based on a roundhouse trip of 0.45km, and 35t/h between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays a total of 49140 VKT was used.

Wheel Generated Dust on Unpaved Roads

Dust emissions from both haul trucks and articulated dump trucks on unpaved roads were calculated using the following equation:

$$E_i = VKT \times EF_i \times \left[1 - \frac{CE_i}{100}\right]$$

Where:

E_i = Emission rate (kg/y)
VKT = Vehicle kilometres travelled per year
EF_i = Uncontrolled emissions factor (kg/VKT)
CE_i = Overall control efficiency (kg/t)

The emission factor conveying material were calculated using the US EPA AP-42 Predictive Emission Factor Equation for unpaved roads (Chapter 13.2.1.3). The equation can be seen here:

$$EF_i = \frac{0.4536}{1.6093} \times k_i \times \left(\frac{s}{12}\right)^a \times \left(\frac{W}{3}\right)^b$$

Where:

EF_i = Uncontrolled emissions factor (kg/VKT)
k_i = Constant (lb/VMT); where k = 4.9 for TSP, k= 1.5 for PM_{10} and k = 0.15 for $PM_{2.5}$
s = Silt content by weight (%)
a = Constant where a = 0.7 for TSP and a = 0.9 for PM_{10} and $PM_{2.5}$.
W = Average weight of vehicles travelling the road (t)
b = Constant where b = 0.45 for all particulates fractions.

A silt content of 7.1 was assumed based on Table 13.2 2-1 of the US EPA AP-42 document for both haul trucks and articulated dump trucks.

Haul trucks were assumed to have an empty vehicle mass of 15 tonnes, and a full load mass of 48 tonnes. Based on a round trip of 0.05km around temporary stockpile areas, and 35t/h between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays a total of 5460 VKT was used.

Articulated dump trucks were assumed to have an empty vehicle mass of 22.95 tonnes, and a full load mass of 23.6 tonnes based on a based on CAT 725C tree axle articulated truck. Thirty percent of material transferred into the void would be transported by articulated dump truck, accounting for a round trip of 0.3km and articulated dump trucks operating 80 percent of the time between 7 am and 6 pm on weekdays and from 8 am to 1 pm on Saturdays this equates to 8566 VKT/y.

External Haul Route Emissions

Onsite haul truck combustion emissions were calculated using PIARC emission rates for heavy vehicles. A total of 70 vehicles per hour were modelled (35 inbound trucks and 35 outbound trucks). Expected haulage routes used in the CALROADS model are identified below:

- **In:** Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.
- **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road.
- **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

All vehicle emissions have been modelled at grade as heavy vehicles with a speed of 60km per hour with exception to vehicles entering and exiting the site (links 25 to 29) which are assumed to have a speed of 10km per hour. The mixing width was assumed to be 20m for all road links. The location of all links, vehicles per hour and road grades are shown in the table below.

Link	Endpoint 1 Coordinate		Endpoint 2 Coordinate		Peak hours (7am-9am and 3am-5pm)			Non-Peak hours (9am-3pm)		
	X1	Y1	X2	Y2	Direction	VPH	Grade	Direction	VPH	Grade*
1	324873	6267434	324717	6267471	Inbound	35	2	Bi-Directional	70	2 / -2
2	324717	6267471	324721	6267522	Inbound	35	2	Bi-Directional	70	2 / -2
3	324721	6267522	324753	6267722	Inbound	35	0	Bi-Directional	70	0 / 0
4	324753	6267722	324741	6267808	Inbound	35	-4	Bi-Directional	70	-4 / 4
5	324741	6267808	324657	6268036	Inbound	35	-4	Bi-Directional	70	-4 / 4
6	324657	6268036	324624	6268096	Inbound	35	-4	Bi-Directional	70	-4 / 4
7	324624	6268096	324568	6268157	Inbound	35	-4	Bi-Directional	70	-4 / 4
8	324568	6268157	324516	6268193	Inbound	35	-4	Bi-Directional	70	-4 / 4
9	324516	6268193	324312	6268299	Inbound	35	-4	Bi-Directional	70	-4 / 4
10	324312	6268299	324180	6268335	Inbound	35	0	Bi-Directional	70	0 / 0
11	324180	6268335	324117	6268370	Inbound	35	0	Bi-Directional	70	0 / 0
12	324117	6268370	324063	6268425	Inbound	35	0	Bi-Directional	70	0 / 0
13	324063	6268425	324001	6268459	Inbound	35	0	Bi-Directional	70	0 / 0
14	324001	6268459	323832	6268534	Inbound	35	0	Bi-Directional	70	0 / 0
15	323832	6268534	323796	6268558	Inbound	35	0	Bi-Directional	70	0 / 0
16	323796	6268558	323830	6268790	Inbound	35	0	Bi-Directional	70	0 / 0
17	323830	6268790	323838	6268890	Inbound	35	0	Bi-Directional	70	0 / 0
18	323838	6268890	323802	6268970	Inbound	35	0	Bi-Directional	70	0 / 0
19	323802	6268970	323857	6269235	Inbound	35	-2	Bi-Directional	70	-2 / 2
20	323857	6269235	323950	6269673	Inbound	35	-2	Bi-Directional	70	-2 / 2
21	323950	6269673	323948	6269709	Inbound	35	2	Bi-Directional	70	2 / -2
22	323948	6269709	323940	6269761	Inbound	35	2	Bi-Directional	70	2 / -2
23	323940	6269761	323652	6269807	Inbound	35	0	Bi-Directional	70	0 / 0
24	323652	6269807	323607	6269736	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
25	323607	6269736	323586	6269741	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
26	323586	6269741	323578	6269800	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
27	323578	6269800	323563	6269836	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
28	323563	6269836	323528	6269837	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
29	323528	6269837	323496	6269692	Bi-Directional*	35	-6 / 6	Bi-Directional	70	-6 / 6
30	325619	6271882	325324	6271921	Outbound	35	2			
31	325324	6271921	325042	6271881	Outbound	35	2			
32	325042	6271881	325080	6272091	Outbound	35	2			
33	325080	6272091	325006	6272101	Outbound	35	2			
34	325006	6272101	324997	6272021	Outbound	35	2			
35	324997	6272021	324975	6271952	Outbound	35	2			
36	324975	6271952	324897	6271801	Outbound	35	2			
37	324897	6271801	324883	6271740	Outbound	35	2			
38	324883	6271740	324877	6271369	Outbound	35	2			
39	324877	6271369	324859	6271286	Outbound	35	4			
40	324859	6271286	324799	6271111	Outbound	35	4			
41	324799	6271111	324768	6271040	Outbound	35	0			
42	324768	6271040	324696	6270901	Outbound	35	0			
43	324696	6270901	324581	6270730	Outbound	35	0			
44	324581	6270730	324540	6270675	Outbound	35	0			

45	324540	6270675	324070	6270156	Outbound	35	0			
46	324070	6270156	324031	6270114	Outbound	35	0			
47	324031	6270114	323984	6270042	Outbound	35	0			
48	323984	6270042	323948	6269984	Outbound	35	0			
49	323948	6269984	323910	6269897	Outbound	35	0			
50	323910	6269897	323871	6269780	Outbound	35	0			

* Inbound grade / outbound grade

Appendix F

NO_X to NO_2 Conversion

Appendix F NO_X to NO_2 Conversion

One of the challenges of modelling NOx emissions is determining the amount of NO_2 at a receiver, due to uncertainties in the conversion rates. Early studies (Hegg et al., 1977) showed that the rate of oxidation is controlled by the rate of plume mixing rather than by gas reaction kinetics. Ozone is usually the chemical that is responsible for most of the oxidation, but other reactive atmospheric gases can also oxidise NO.

Several methods were proposed for evaluating the amount of NO_2 that is formed from NO. These include:

1) Total conversion;
2) The Ambient Ratio Method (ARM), (0.75 is the US default value) when no measured nearby NOx/NO_2 ratios are available;
3) Ozone Limiting Method (OLM);
4) Jansenn's equations (which assume approximately 10 per cent of all NOx is NO_2) – used in Australia and New Zealand; and
5) Plume Volume Molar Ratio method.

All of these methods are referenced in the Federal Guideline on Air Quality Models (GAQM) and DEC (2005).

NOx to NO2 conversion in NSW

In NSW, the oxidation of NO to NO_2 is assessed by three methods (Method 1, the most simple, to Method 3, the most complex). Method 1, which assumes 100 per cent conversion of NO to NO2, can be used in one of two ways. A Level 1 assessment uses maximum predicted NO_X concentrations (assuming NOx = NO_2) and maximum ambient NO_2 concentrations to determine a cumulative NO_2 concentration. If the facility fails to meet the NO_2 impact assessment criteria, a Level 2 assessment is conducted, which again assumes 100 per cent conversion but with contemporaneous assessment of model predictions and ambient concentrations.

Method 2 is the OLM, where NO to NO_2 conversion is limited by the amount of ozone available. The OLM uses a simple approach to the reaction chemistry; it assumes that O_3 and NO react to form NO_2 in proportion to their ground level concentrations. That is, for each hour,

- if $O_3 < NO_{plume}$,
    - $NO_{2\ plume} = NO_{2\ initial} + O_3$, and if
- $O_3 \geq NO_{plume}$, $NO_{2\ plume} = NO_{x\ plume}$

Method 3 uses an empirical relationship to convert NO to NO_2 based on the equation developed by Janssen et al. (1988). The conversion is based on the distance of the receiver downwind from the source, and can be used with various levels of refinement (i.e. using maxima or contemporaneous data).

NOx to NO_2 assessment in the United States

In the United States, the first level recommended technique in the Guideline on Air Quality Models (GAQM) is to assume the total conversion of NO to NO_2. This is the same first tier level as DEC (2005). It is a conservative, first-level technique, which may lead to unnecessary control in areas where the predicted impacts are close to ambient air quality criteria.

The Ambient Ratio Method (ARM) is the second-level technique recommended in the GAQM. The ARM is defined as the ratio of the average NO_2 and NOx ambient concentrations measured at a representative site. It uses local monitoring or a default 75per cent ratio to find the ambient equilibrium NO_2/NOx ratio (annual average). Theoretically, equilibrium occurs when the rate of NO_2 formation equals the rate of dissociation of NO_2 by sunlight. Chu and Meyer (1991), who developed this technique, recommended that this monitoring be performed far away so that true equilibrium would occur. Unfortunately, ambient monitoring is usually insufficient for determining this ratio because ambient concentrations are frequently below the minimum monitoring threshold for NOx (20 ppb). Further, if the monitoring is performed too close to an existing source, the ARM's assumption of equilibrium is violated and the monitoring results are not applicable to receivers further downwind.

The third-level tier is the OLM (stated above) and a Plume Volume Molar Ratio method (PVMRM). The PVMRM method better simulates the NO to NO_2 conversion chemistry during plume expansion and is particularly well suited for the receivers located close to sources where maximum modelled NO concentrations are usually predicted. The PVMRM method follows the chemistry of the main forward reaction of NO with O_3 as it occurs during expansion of a plume segment travelling downwind:

NO + O3 → NO2 + O2

This is accomplished by computing the number of moles of NOx and O_3 that are contained within a plume segment as it reaches a receiver. Although the PVMRM follows the same chemical reactions as those used in the OLM, it uses both plume size and O_3 concentration to derive the amount of O_3 available for the reaction. NOx moles are determined by emission rate and travel time through the plume segment. The number of O_3 moles is determined by the size of the plume segment and the measured background O_3 concentration. This plume segment always contains the same amount of primary NOx emissions as it travels downwind. The amount of O_3 available for reaction, however, increases as the plume segment enlarges downwind. The last approach, which is not yet included in any US Guideline criteria, is based on an empirical approach of some 3,000 co-located NOx and NO_2 monitors in Europe. The approach uses a scaled approach to NOx bins of concentration levels. This method was developed by the Atmospheric Studies Group and is included in the US EPA guideline model CALPOST. It has been used on a case-by-case basis when all other methods fail.

Concerns with and likely conservatism of the OLM

The OLM employed by the EPA (DEC, 2005) was taken from the US EPA OLM, originally developed by Cole and Summerhays (1979) and Tikvart (1996). The method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O_3 or all the NO is used up. The approach is known to be conservative. Some of the reasons for its lack of robustness and conservatism are listed below:

- The OLM approach assumes that the atmospheric reaction is instant, whereas in reality the reaction takes place over a number of hours.
- The actual reactions of NO to NO_2 occur in proportion to the moles of each reactant rather than in proportion to the concentration assumed by the OLM. At constant volume, 1 ppm of a gas is proportional to 1 mole of a gas. This assumption is not valid in the open atmosphere, as there is virtually unlimited amount of O_3 available for reaction. As plumes expand downwind, more O_3 is available for reaction, and even lower concentrations of O_3 can react with NO in the plume.
- The OLM is further complicated as some of the NOx is already converted to NO_2 upstream in the plume before it reaches the receiver.
- Studies have shown that the NOx emission rates are extremely important with respect to the rate of conversion to NO_2. The size of the plume is not affected by the NOx emission rate, which means that there is the same amount of O_3 available for chemical conversion regardless of the NOx emission rate. Larger NOx emission rates lead to lower predicted ratios of NO_2/NOx. Maximum impacts that occur at receivers located further away have high predicted NO_2/NOx ratios. Further emissions emitted into stable (narrow) plumes will have less conversion to NO_2 compared to those emissions emitted into less stable (wider) plumes. The OLM does not take the NOx emission rate or plume size into consideration.
- The OLM can only be used on one plume at a time. The US EPA states that the OLM should be used with a 'plume-by-plume' approach. This is a big limitation to a facility with lots of different plumes. The OLM will therefore be very conservative for close in NO_2 impacts for large multi plume sources. The OLM may not be conservative for single plumes downwind, where low concentrations of O_3 can still react with the plume.

The OLM is expected to be conservative during daylight hours when the photochemical equilibrium reverses the oxidation of NO by O_3. It is also expected to be conservative during stable and night conditions when both NO_2 and O_3 are removed by reaction with vegetation and other surfaces.

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Appendix G

Pollutant Concentrations Along Haul Routes

Appendix G Pollutant Concentrations Along Haul Routes

ID	Predicted ground level concentration (µg/m^3)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_001	1.6	0.0	0.00050	0.00002	0.0838	0.0215	0.0797	0.0205	0.00018	0.00000011	Ku-Ring-Gai Chase Rd
R_002	1.5	0.0	0.00049	0.00002	0.0711	0.0222	0.0677	0.0211	0.00017	0.00000011	Ku-Ring-Gai Chase Rd
R_003	2.1	1.2	0.00063	0.00003	0.1174	0.0335	0.1117	0.0319	0.00024	0.00000015	Ku-Ring-Gai Chase Rd
R_004	1.7	1.2	0.00057	0.00003	0.0914	0.0336	0.0869	0.032	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_005	1.7	1.2	0.00057	0.00003	0.1079	0.0335	0.1026	0.0319	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_006	2.2	1.2	0.00072	0.00003	0.1106	0.0398	0.1052	0.0378	0.00026	0.00000016	Ku-Ring-Gai Chase Rd
R_007	1.7	1.2	0.00097	0.00007	0.0899	0.0402	0.0855	0.0382	0.00020	0.00000012	Ku-Ring-Gai Chase Rd
R_008	2.8	1.2	0.00103	0.00005	0.1568	0.0508	0.1492	0.0483	0.00031	0.00000020	Ku-Ring-Gai Chase Rd
R_009	3.5	1.2	0.00147	0.00009	0.1695	0.0674	0.1612	0.0641	0.00040	0.00000025	Pacific Hwy
R_010	5.5	1.2	0.00300	0.00006	0.2332	0.0314	0.2218	0.0299	0.00063	0.00000039	Pacific Hwy
R_011	6.0	2.3	0.00329	0.00020	0.3887	0.0988	0.3697	0.094	0.00068	0.00000042	Pacific Hwy
R_012	3.9	2.3	0.00214	0.00012	0.1541	0.0659	0.1466	0.0626	0.00044	0.00000027	Pacific Hwy
R_013	2.9	1.2	0.00160	0.00011	0.1225	0.0544	0.1165	0.0518	0.00033	0.00000020	Pacific Hwy
R_014	6.5	2.3	0.00359	0.00017	0.326	0.0822	0.31	0.0782	0.00075	0.00000046	Pacific Hwy
R_015	3.0	1.2	0.00158	0.00010	0.1311	0.0501	0.1247	0.0476	0.00034	0.00000021	Pacific Hwy
R_016	5.0	2.3	0.00272	0.00012	0.3151	0.0614	0.2997	0.0584	0.00057	0.00000035	Pacific Hwy
R_017	4.4	1.2	0.00243	0.00012	0.2433	0.0588	0.2314	0.0559	0.00051	0.00000031	Pacific Hwy
R_018	4.2	1.2	0.00222	0.00012	0.182	0.0602	0.1731	0.0573	0.00048	0.00000030	Pacific Hwy
R_019	3.5	1.2	0.00182	0.00010	0.1497	0.0513	0.1424	0.0488	0.00040	0.00000025	Pacific Hwy
R_020	4.2	1.2	0.00232	0.00012	0.235	0.0585	0.2235	0.0557	0.00048	0.00000030	Pacific Hwy
R_021	3.4	1.2	0.00184	0.00008	0.1902	0.0435	0.1809	0.0414	0.00038	0.00000024	Pacific Hwy
R_022	2.3	1.2	0.00105	0.00005	0.1565	0.0404	0.1488	0.0385	0.00026	0.00000016	Pacific Hwy
R_023	2.0	1.2	0.00086	0.00005	0.1552	0.038	0.1476	0.0361	0.00023	0.00000014	Pacific Hwy
R_024	2.1	1.2	0.00079	0.00005	0.1515	0.0399	0.1441	0.038	0.00024	0.00000015	Pacific Hwy
R_025	1.2	0.0	0.00052	0.00002	0.0554	0.0165	0.0527	0.0157	0.00013	0.00000008	Pacific Hwy
R_026	3.0	1.2	0.00111	0.00006	0.195	0.0528	0.1855	0.0502	0.00034	0.00000021	Pacific Hwy
R_027	2.6	1.2	0.00096	0.00006	0.1578	0.0462	0.1501	0.044	0.00029	0.00000018	Pacific Hwy
R_028	0.9	0.0	0.00040	0.00002	0.0398	0.0125	0.0379	0.0119	0.00011	0.00000007	Pacific Hwy
R_029	1.3	0.0	0.00055	0.00002	0.0485	0.0176	0.0462	0.0168	0.00015	0.00000009	Pacific Hwy

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_030	2.4	1.2	0.00088	0.00005	0.1377	0.0411	0.131	0.0391	0.00027	0.00000017	Pacific Hwy
R_031	2.0	1.2	0.00075	0.00004	0.1187	0.0341	0.1129	0.0324	0.00022	0.00000014	Pacific Hwy
R_032	1.4	1.2	0.00052	0.00003	0.096	0.0237	0.0913	0.0225	0.00016	0.00000010	Pacific Hwy
R_033	1.7	1.2	0.00064	0.00004	0.1118	0.0296	0.1063	0.0281	0.00019	0.00000012	Pacific Hwy
R_034	1.7	1.2	0.00066	0.00004	0.1157	0.0306	0.11	0.0291	0.00020	0.00000012	Pacific Hwy
R_035	1.1	1.2	0.00041	0.00002	0.0867	0.0176	0.0825	0.0167	0.00012	0.00000008	Jersey St North
R_036	2.4	1.2	0.00096	0.00005	0.1639	0.0411	0.1558	0.0391	0.00028	0.00000017	Jersey St North
R_037	2.4	1.2	0.00107	0.00005	0.1586	0.0382	0.1509	0.0363	0.00027	0.00000017	Jersey St North
R_038	2.6	1.2	0.00121	0.00007	0.1514	0.0486	0.144	0.0462	0.00030	0.00000019	Jersey St North
R_039	2.5	2.3	0.00095	0.00007	0.2572	0.0676	0.2446	0.0643	0.00029	0.00000018	Jersey St North
R_040	4.7	3.5	0.00194	0.00007	0.3587	0.0533	0.3411	0.0507	0.00054	0.00000033	George St
R_041	6.2	4.6	0.00258	0.00015	0.5384	0.1017	0.512	0.0967	0.00071	0.00000044	George St
R_042	5.6	4.6	0.00230	0.00012	0.4547	0.1038	0.4324	0.0987	0.00063	0.00000039	George St
R_043	5.8	4.6	0.00239	0.00012	0.4746	0.1072	0.4513	0.1019	0.00066	0.00000041	George St
R_044	4.7	3.5	0.00189	0.00010	0.3557	0.0873	0.3382	0.083	0.00054	0.00000034	George St
R_045	3.1	1.2	0.00119	0.00005	0.1585	0.0433	0.1507	0.0412	0.00035	0.00000022	George St
R_046	6.3	4.6	0.00259	0.00014	0.5246	0.1202	0.4988	0.1143	0.00072	0.00000044	George St
R_047	4.8	3.5	0.00200	0.00012	0.4011	0.1025	0.3815	0.0975	0.00055	0.00000034	George St
R_048	5.6	4.6	0.00231	0.00013	0.4692	0.1172	0.4462	0.1115	0.00064	0.00000040	Pacific Hwy
R_049	5.5	3.5	0.00225	0.00013	0.4287	0.1143	0.4076	0.1087	0.00062	0.00000039	Pacific Hwy
R_050	3.1	2.3	0.00123	0.00007	0.1995	0.0579	0.1897	0.0551	0.00035	0.00000022	Pacific Hwy
R_051	5.8	3.5	0.00217	0.00015	0.4081	0.1229	0.3881	0.1169	0.00066	0.00000041	Pacific Hwy
R_052	3.6	2.3	0.00134	0.00008	0.327	0.0653	0.3109	0.0621	0.00041	0.00000025	Pacific Hwy
R_053	5.9	4.6	0.00220	0.00014	0.5319	0.1175	0.5058	0.1117	0.00067	0.00000042	Pacific Hwy
R_055	4.1	3.5	0.00152	0.00011	0.364	0.0919	0.3461	0.0874	0.00046	0.00000029	Pacific Hwy
R_056	4.4	3.5	0.00164	0.00013	0.3601	0.1126	0.3425	0.1071	0.00050	0.00000031	Pacific Hwy
R_057	3.9	2.3	0.00149	0.00011	0.2998	0.0897	0.2851	0.0853	0.00045	0.00000028	Pacific Hwy
R_058	4.6	3.5	0.00175	0.00014	0.3814	0.1143	0.3627	0.1087	0.00052	0.00000033	Pacific Hwy
R_059	4.2	2.3	0.00158	0.00013	0.2774	0.1063	0.2638	0.1011	0.00048	0.00000030	Pacific Hwy
R_060	2.9	2.3	0.00111	0.00006	0.245	0.0472	0.233	0.0449	0.00033	0.00000021	Pacific Hwy
R_061	4.8	2.3	0.00183	0.00009	0.3048	0.0776	0.2899	0.0738	0.00055	0.00000034	Pacific Hwy
R_062	4.6	3.5	0.00174	0.00011	0.3567	0.0951	0.3393	0.0904	0.00053	0.00000033	Pacific Hwy

ID	Predicted ground level concentration (µg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_063	4.0	2.3	0.00152	0.00010	0.3147	0.0866	0.2993	0.0824	0.00046	0.00000029	Pacific Hwy
R_064	4.2	3.5	0.00158	0.00012	0.3473	0.0967	0.3303	0.092	0.00048	0.00000030	Pacific Hwy
R_065	4.0	3.5	0.00148	0.00011	0.3324	0.0947	0.3161	0.0901	0.00045	0.00000028	Pacific Hwy
R_066	5.9	3.5	0.00226	0.00013	0.4914	0.1093	0.4673	0.104	0.00067	0.00000042	Pacific Hwy
R_067	2.9	2.3	0.00111	0.00007	0.2528	0.0607	0.2404	0.0577	0.00034	0.00000021	Pacific Hwy
R_068	6.3	3.5	0.00249	0.00016	0.5179	0.1321	0.4925	0.1256	0.00071	0.00000044	Pacific Hwy
R_069	5.3	4.6	0.00199	0.00012	0.4598	0.1001	0.4373	0.0952	0.00061	0.00000038	Pacific Hwy
R_070	4.2	2.3	0.00157	0.00011	0.2964	0.0878	0.2819	0.0835	0.00048	0.00000030	Pacific Hwy
R_071	5.7	3.5	0.00268	0.00011	0.4205	0.0896	0.3999	0.0853	0.00065	0.00000041	Pacific Hwy
R_072	4.4	3.5	0.00217	0.00012	0.3609	0.0908	0.3432	0.0864	0.00051	0.00000031	Pacific Hwy
R_073	6.5	3.5	0.00327	0.00012	0.3646	0.0942	0.3467	0.0896	0.00074	0.00000046	Pacific Hwy
R_074	4.3	3.5	0.00209	0.00011	0.3147	0.0836	0.2993	0.0796	0.00049	0.00000030	Pacific Hwy
R_075	5.1	3.5	0.00248	0.00014	0.3802	0.1072	0.3615	0.1019	0.00058	0.00000036	Pacific Hwy
R_076	4.5	2.3	0.00219	0.00008	0.2815	0.0615	0.2677	0.0585	0.00051	0.00000032	Pacific Hwy
R_077	3.2	2.3	0.00161	0.00010	0.2389	0.0775	0.2272	0.0737	0.00037	0.00000023	Pacific Hwy
R_078	3.6	2.3	0.00177	0.00007	0.2545	0.0584	0.2421	0.0556	0.00041	0.00000026	Pacific Hwy
R_079	3.8	2.3	0.00189	0.00011	0.2403	0.082	0.2285	0.078	0.00043	0.00000027	Pacific Hwy
R_080	4.1	2.3	0.00194	0.00008	0.2847	0.0627	0.2707	0.0596	0.00047	0.00000029	Pacific Hwy
R_081	4.4	3.5	0.00214	0.00014	0.3163	0.1116	0.3008	0.1061	0.00050	0.00000031	Pacific Hwy
R_082	7.3	4.6	0.00363	0.00012	0.4843	0.0941	0.4606	0.0895	0.00084	0.00000052	Pacific Hwy
R_083	3.5	2.3	0.00132	0.00011	0.2369	0.0864	0.2253	0.0821	0.00039	0.00000024	Pacific Hwy
R_084	3.5	2.3	0.00153	0.00005	0.1983	0.0436	0.1886	0.0415	0.00040	0.00000025	Pacific Hwy
R_085	4.0	2.3	0.00155	0.00012	0.3253	0.1	0.3093	0.0951	0.00046	0.00000028	Pacific Hwy
R_086	2.8	1.2	0.00108	0.00007	0.1837	0.0547	0.1747	0.052	0.00032	0.00000020	Pacific Hwy
R_087	5.5	3.5	0.00228	0.00016	0.5032	0.1122	0.4785	0.1067	0.00063	0.00000039	Pacific Hwy
R_088	3.0	2.3	0.00125	0.00015	0.3107	0.0976	0.2954	0.0928	0.00035	0.00000021	Pacific Hwy
R_089	4.8	2.3	0.00201	0.00010	0.2734	0.067	0.26	0.0637	0.00055	0.00000034	Pacific Hwy
R_090	4.0	2.3	0.00162	0.00009	0.2624	0.0596	0.2495	0.0567	0.00045	0.00000028	Pacific Hwy
R_091	2.4	2.3	0.00100	0.00010	0.271	0.0661	0.2577	0.0629	0.00028	0.00000017	Pacific Hwy
R_092	4.8	3.5	0.00179	0.00013	0.3947	0.1089	0.3754	0.1035	0.00055	0.00000034	Bridge Rd
R_093	4.6	1.2	0.00168	0.00009	0.216	0.0724	0.2054	0.0688	0.00053	0.00000033	Bridge Rd
R_094	4.0	1.2	0.00142	0.00008	0.2155	0.0643	0.205	0.0611	0.00045	0.00000028	Bridge Rd
R_095	3.3	2.3	0.00117	0.00009	0.2965	0.0774	0.282	0.0736	0.00038	0.00000023	Bridge Rd
R_096	4.6	3.5	0.00175	0.00013	0.39	0.1088	0.3709	0.1035	0.00052	0.00000032	Bridge Rd
R_097	4.0	3.5	0.00156	0.00012	0.3703	0.1031	0.3521	0.0981	0.00046	0.00000029	Bridge Rd

ID	Predicted ground level concentration (μg/m³)										Description
	CO		NO_2		PM_{10}		$PM_{2.5}$		TVOC	TPAH	
	1 hr	8 hr	1 hr	Annual	24 hr	Annual	24 hr	Annual	1 hr	1 hr	
R_098	7.2	3.5	0.00298	0.00014	0.4682	0.1192	0.4453	0.1134	0.00082	0.00000051	Bridge Rd
R_099	7.9	3.5	0.00316	0.00018	0.3851	0.1441	0.3662	0.1371	0.00091	0.00000056	Bridge Rd
R_100	8.1	4.6	0.00254	0.00010	0.3857	0.0843	0.3668	0.0801	0.00092	0.00000057	Bridge Rd
R_101	8.8	4.6	0.00343	0.00014	0.3879	0.1129	0.3689	0.1074	0.00101	0.00000062	Bridge Rd
R_102	17.8	8.1	0.00589	0.00012	0.6573	0.0967	0.6251	0.092	0.00203	0.00000126	TAFE Entry Rd
R_103	5.5	3.5	0.00184	0.00007	0.3035	0.0606	0.2887	0.0576	0.00063	0.00000039	TAFE Entry Rd
R_104	6.9	5.8	0.00287	0.00014	0.5718	0.1244	0.5438	0.1183	0.00079	0.00000049	George St
R_105	5.0	3.5	0.00207	0.00011	0.41	0.096	0.3899	0.0913	0.00057	0.00000035	George St
R_106	8.6	6.9	0.00354	0.00019	0.7107	0.1542	0.6758	0.1466	0.00098	0.00000061	George St
R_107	9.8	8.1	0.00404	0.00029	0.8454	0.1965	0.8039	0.1868	0.00111	0.00000069	George St
R_108	3.7	1.2	0.00176	0.00008	0.2309	0.0596	0.2196	0.0567	0.00043	0.00000027	George St
R_109	2.3	1.2	0.00106	0.00005	0.1246	0.0326	0.1185	0.031	0.00027	0.00000017	Jersey St North
R_110	2.3	1.2	0.00093	0.00004	0.158	0.0359	0.1502	0.0342	0.00027	0.00000016	Jersey St North
R_111	2.1	1.2	0.00082	0.00004	0.1473	0.0363	0.14	0.0345	0.00024	0.00000015	Jersey St North
R_112	2.4	1.2	0.00093	0.00005	0.1551	0.0422	0.1475	0.0401	0.00028	0.00000017	Jersey St North
R_113	1.7	1.2	0.00065	0.00004	0.1188	0.0299	0.113	0.0285	0.00020	0.00000012	Jersey St North
R_114	1.9	1.2	0.00071	0.00004	0.1157	0.0336	0.11	0.032	0.00022	0.00000013	Pacific Hwy
R_115	3.3	1.2	0.00124	0.00007	0.1827	0.0544	0.1738	0.0517	0.00037	0.00000023	Pacific Hwy
R_116	2.3	1.2	0.00085	0.00005	0.134	0.04	0.1274	0.038	0.00026	0.00000016	Pacific Hwy
R_117	2.8	1.2	0.00106	0.00006	0.1616	0.0486	0.1537	0.0462	0.00032	0.00000020	Pacific Hwy
R_118	1.2	0.0	0.00048	0.00002	0.044	0.0155	0.0419	0.0147	0.00013	0.00000008	Pacific Hwy
R_119	1.0	0.0	0.00042	0.00002	0.0415	0.0141	0.0394	0.0134	0.00012	0.00000007	Pacific Hwy
R_120	1.2	0.0	0.00051	0.00002	0.055	0.0179	0.0523	0.017	0.00014	0.00000009	Pacific Hwy

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Appendix F

Technical working paper:
Health

Technical Working Paper: Human Health Risk Assessment – Hornsby Quarry

Prepared for: AECOM

28 July 2015

Document History and Status

Report Reference	ARM/15/HQR001
Revision	D - Final
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Previous Revisions	A, B and C – Drafts and Final Draft for internal review

Limitations

Environmental Risk Sciences has prepared this technical working paper for the use of AECOM and Roads and Maritime Services in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this technical working paper.

It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this technical working paper.

The methodology adopted and sources of information used are outlined in this technical working paper. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information contained in the reports for use in this assessment was false.

This report was prepared between May and July 2015 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this technical working paper in any other context or for any other purpose or by third parties. This technical working paper does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Appendices

Glossary of Terms

Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days).
absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems.
ANZECC	Australia and New Zealand Environment and Conservation Council
AQIA	Technical Working Paper: Air Quality (AECOM, 2014) for the NorthConnex project.
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).
Body burden	The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.
BTX	Benzene, toluene and total xylenes
Carcinogen	A substance that causes cancer.
Chronic exposure	Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure].
COPD	Chronic Obstructive Pulmonary Disease
DECCW	Department of Environment, Climate Change and Water
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
DGRs	Director General Requirements
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
EC	European Commission
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	Environment Protection Authority
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed) to it. An exposure pathway has five parts: a source of contamination (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receiver population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Guideline value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organisation (WHO)), that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines will have different names, such as investigation level, trigger value, ambient guideline etc.
HIA	Health Impact Assessment
HHRA	Human Health Risk Assessment
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Intermediate exposure Duration	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].
LGA	Local Government Area
LOAEL	Lowest-observed-adverse-effect-level - The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.
LOR	Limit of Reporting
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOAEL	No-observed-adverse-effect-level - The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.
NSW	New South Wales
OEH	Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA)
PAH	Polycyclic aromatic hydrocarbon
PM	Particulate matter
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 µm and less
PM_{10}	Particulate matter of aerodynamic diameter 10 µm and less
Point of exposure	The place where someone can come into contact with a substance present in the environment [see exposure pathway].
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

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

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Executive Summary

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the use of Hornsby Quarry as a site for handling, management and beneficial reuse of spoil generated by road construction (the project).

On 13 January 2015 Roads and Maritime received approval under Part 5.1 of the EP&A Act to construct and operate the NorthConnex project, a multi-lane tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at the Pennant Hills Road interchange at Carlingford in northern Sydney. The Environmental Impact Statement (EIS) exhibited for the NorthConnex project identified that approximately 2.6 million cubic metres of spoil would be generated during the construction of the project. The NorthConnex EIS also identified a number of potential spoil management location options, with the final option(s) to be determined at the construction stage.

Following design development, the Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnel excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portals could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of approximately one million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Council separately rehabilitating and developing the site for public recreation in the future.

This technical working paper was prepared to assess potential risks to human health associated with key aspects of the project, namely local air quality impacts, noise and vibration.

A human health risk assessment is a way of deciding now, what the consequences (to health) of some future action (such as this project) may be. In this case the technical working paper includes a detailed review of what impacts to air quality, noise and vibration may occur, who may be exposed to these impacts and whether there is potential for these impacts to result in adverse health effects within the local community. It has been conducted in accordance with national guidance available from enHealth (enHealth 2001, 2012a) and it has involved the following:

- review of predicted impacts to air quality, noise and vibration associated with the project;
- identification and characterisation of the community (including the presence of sensitive receivers such as childcare centres, aged care centres, schools and hospitals) who may be affected by these impacts;

- assessment of air quality impacts on health including:
  - review of the key pollutants to air that are predicted from the carrying out of the project;
  - identifying guidelines that are based on protection of the health of all members of the population for exposure to these pollutants all day, every day;
  - comparing the predicted impacts with the health based guidelines; and
  - a more detailed assessment of exposure to particulate matter utilising robust (published) associations between exposure to increased concentrations of particulates (as $PM_{2.5}$ or PM_{10}) and specific health effects (or health endpoints). The assessment conducted has evaluated the impact of the project on these health endpoints within the local community.
- assessment of noise and vibration impacts on health including:
  - review of the impacts that are predicted from the carrying out of the project;
  - identifying guidelines that are based on the protection of health and wellbeing of all members of the population;
  - comparing the predicted impacts with the health based guidelines. Where the health based guidelines cannot be met, consideration of the implementation of practical and feasible mitigation/management measures and the duration of the works to determine the potential for impacts on health.

Based on the assessment undertaken and presented in this technical working paper the following has been concluded:

Air Quality:

All predicted concentrations of carbon monoxide, nitrogen dioxide, key individual volatile organic compounds and polycyclic aromatic hydrocarbons in the local community are below health based guidelines.

For the assessment of potential impacts of $PM_{2.5}$ and PM_{10} the following has been determined:

- Potential concentrations of silica that may be present in $PM_{2.5}$ and PM_{10} dust emissions are not considered to be of concern for community health.
- Calculated risks associated with exposures to PM_{10} and $PM_{2.5}$ (including diesel particulate matter, DPM) from emissions from trucks on the haulage route roads are not considered to be of concern for community health.
- In relation to the proposed activities at the quarry site, where standard mitigation measures are considered, risks are considered to be tolerable.
- Where risks are determined to be tolerable, it is expected that mitigation measures be implemented to minimise exposures associated with the project. For this project, air impacts and hence health risks are proposed to be further minimised through the implementation of best industry practice dust management and mitigation measures, to be outlined in a comprehensive dust management plan for the project. Such measures would result in lower levels of exposure and risk at all receptors in the surrounding community. Where these measures are implemented no significant health impacts are expected in the local community.

Noise and Vibration:

In relation to noise and vibration, potential impacts associated with the project have been considered. The worst case assessment predicts that noise criteria would be exceeded at a number of properties without additional noise mitigation measures. Feasible and reasonable mitigation measures would be detailed within the Construction Noise and Vibration Management Plan (CNVMP) to manage and mitigate predicted noise levels at sensitive receivers. In addition the affected community would be notified of the complaint reporting mechanisms should they have any concerns. Where the proposed noise management and mitigation measures are adopted, no adverse health impacts are expected in the local community.

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Section 1. Introduction

1.1 Project background

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Following design development, the Hornsby Quarry site has now been identified as one of the preferred options for the management of spoil generated during tunnelling and excavation activities from late 2015, noting that it is not a standalone solution. The Hornsby Quarry site is located close to NorthConnex and would minimise the distance required for haulage. In particular, spoil from the northern interchange compound and northern portal could be solely handled and reused at the Hornsby Quarry site. The handling, management and reuse of up to 1.5 million cubic metres of spoil at the Hornsby Quarry site would also alleviate the need for an increased number of other sites accepting small spoil volumes, thus reducing overall potential impacts within the wider community and the environment.

Hornsby Shire Council has also been actively seeking opportunities for material to fill the quarry void, with the aim of future rehabilitation of the site and return to use for public recreation. Beneficially reusing spoil from NorthConnex would be an important first step towards preparing the site in anticipation of Council separately rehabilitating and developing the site for public recreation in the future.

The Hornsby Quarry site is not currently the subject of a development approval that would permit handling, management and beneficial reuse of spoil at that site. Therefore, assessment and approval is being pursued in accordance with the EP&A Act. The Secretary's environmental assessment requirements (SEARs) for the project were issued on 2 July 2015 and included a requirement to undertake an assessment of potential impacts on human health associated with emissions to air as well as noise and vibration from the project. This human health risk assessment has been prepared to inform the EIS being prepared for the Hornsby Quarry Road Construction Spoil Management Project.

1.2 Project location

The Hornsby Quarry site is located off Bridge Road on the western side of Hornsby town centre. The site covers about 35 hectares and is owned by Hornsby Shire Council (Council) (refer to **Figures 1-1 and 1-2**).

The site comprises the quarry void, internal access roads and a cleared area to the east which is likely to have been used as processing areas when the quarry was operational. Disused facilities associated with the previous quarrying operations remain on the site, including concrete office block buildings, a crushing and screening plant, a pipeline, security fencing and gates.

Whilst the site is zoned for public recreation (RE1) under the *Hornsby Local Environmental Plan 2013*, the quarry void itself is unsafe for public access given the steep sides and flooded nature of the void. Council currently maintains exclusion fencing around the void to prevent public access for public safety reasons. The areas outside of the void exclusion fencing are open to public access including mountain bike trails which have been established across the site by Council.

The site and surrounds are densely vegetated with some cleared areas comprising the void itself, internal access roads and areas to the east which were used as processing areas when the quarry was operational. Dense bushland comprising the Berowra Valley National Park lies directly to the west.

The general location and key features of the project are shown in **Figures 1-1, 1-2 and 1-3**.

1.3 Purpose of this report

The SEARs for the project were issued on 2 July 2015. The SEARs have informed the preparation of the EIS for the project. The SEARs include the requirements specific to potential impacts on air quality and noise and vibration and include a human health risk assessment (HHRA). Specifically, the SEARs states that the assessment should include:

> *An assessment of human health impacts with particular consideration of:*
>
> - *how the design of the proposal minimises adverse health impacts*
> - *human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal.*

This technical working paper presents a Human Health Risk Assessment (HHRA) associated with key aspects of the project, namely local air quality impacts, noise and vibration (as proposed in the design as outlined in **Section 2**).

Other aspects of the SEARS relating to air quality, noise and vibration and social impacts have been addressed in separate specific technical working papers.

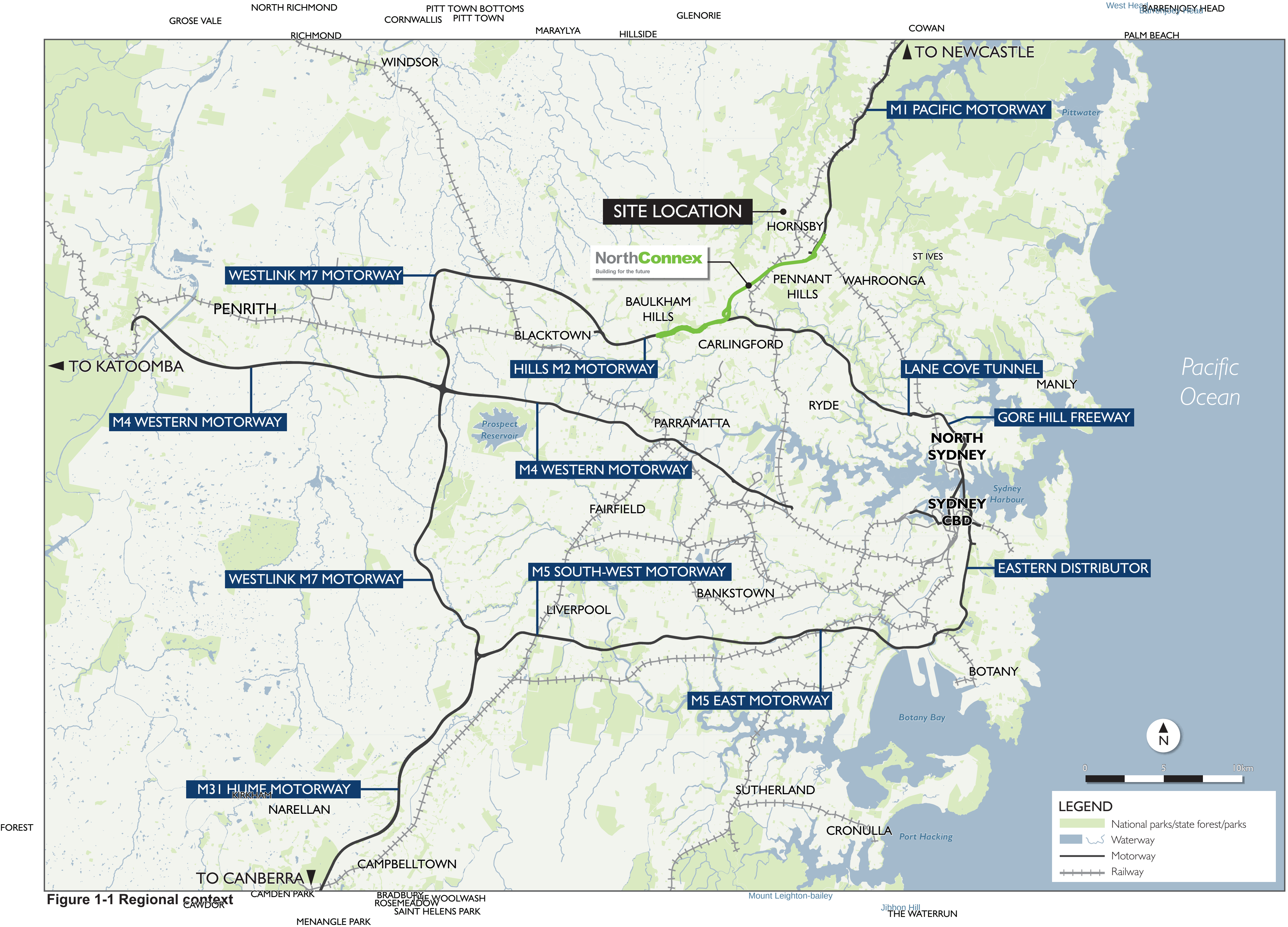

Figure 1-1 Regional context

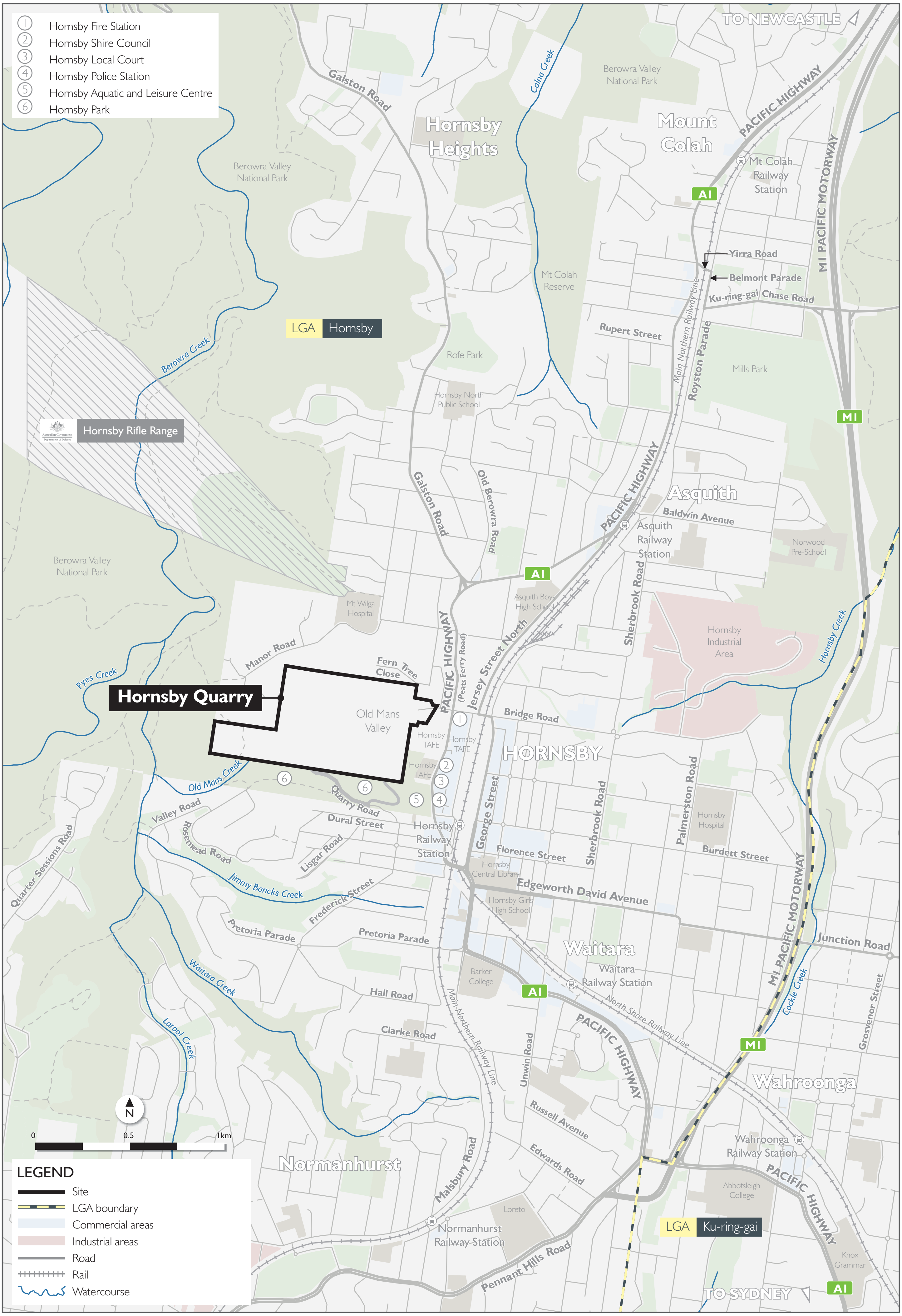

Figure 1-2 Local and site context

Figure 1-3 Indicative Site layout

1.4 Objectives

The overall objective of the HHRA presented in this technical working paper is to assess health risks associated with the following:

- Emissions to air and exposures in the local community (principally dust) as a result of the proposed project.
- Noise and vibration, as a result of the project.

The assessment presented has considered both short-term/acute and long-term/chronic risks to surrounding communities, based on outcomes presented in the air quality, noise and vibration technical working papers that have been completed as part of the environmental impact statement.

1.5 Approach to Human Health Risk Assessment

1.5.1 What is a risk assessment?

Risk

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

Voluntary risks are those associated with activities that we decide to undertake such as driving a vehicle, riding a motorcycle and smoking cigarettes.

Involuntary risks are those associated with activities that may happen to us without our prior consent or forewarning. Acts of nature such as being struck by lightning, fires, floods, tornados, etc, and exposures to environmental contaminants are examples of involuntary risks.

Defining risk

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

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

1.5.2 Overall approach

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

- EnHealth Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012 (enHealth 2012a);
- EnHealth Health Impact Assessment Guidelines: September 2001 (enHealth 2001);
- EnHealth Exposure Factors Guide, EnHealth Council, 2012 (enHealth 2012b);
- National Environment Protection Council (NEPC) Schedule B(8) Guideline on Community Consultation and Risk Communication, National Environment Protection (Assessment of Site Contamination) Measure, 1999 (NEPC 1999 amended 2013);
- NEPC National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure, 2003 (NEPC 2003); and
- United States Environment Protection Agency (USEPA) Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment), EPA-540-R-070-002, January 2009 (USEPA 2009a).

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

The methodology used for the conduct of the HHRA presented in this report is consistent with that undertaken for the assessment of the NorthConnex Project (the project from which materials being handled in this project are derived).

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

Data evaluation and issue identification

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

This aspect of the assessment also considers the available guidelines for air quality and noise, whether these guidelines are based on the protection of community health, and if a more detailed evaluation of specific impacts is required. The HHRA has considered a more detailed evaluation of exposures to particulate emissions within the surrounding community.

Exposure assessment

This involves the identification of populations located in the vicinity of the project that may be exposed to impacts from the project. The existing air and noise environments as well as the health of the existing population has been considered in relation to the key health endpoints, relevant to the assessment of exposures to particulate matter, that require further detailed consideration in this assessment. The assessment of potential particulate matter exposure has considered both short-term (acute) and chronic inhalation exposures relevant to the project.

Toxicity assessment

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

1. Identify the adverse health effects associated with exposure to particulate matter. Based on the available information, the most robust health endpoints (effects or outcomes) for the assessment of inhalation exposure to particulate matter (assessed over different size fractions) have been identified. The most robust health endpoints are where a relationship has been established between exposure to particulate matter and a specific health endpoint (effect/outcome).

2. Identify the most relevant and robust exposure-response relationship for the quantitative assessment of exposure to particulate matter. The exposure-response relationships are derived from published peer reviewed sources and relate to the identified health endpoints (effects/outcomes).

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

Risk characterisation

Risks have been characterised using quantitative and qualitative assessment methods. The quantitative assessment of potential exposure to particulate emissions from the project combined with information on exposure (i.e. what additional concentrations of particulate matter would be present in the community as a result of the project) and the exposure-response relationships relevant for the health-endpoints (effect) has been used. This enables an assessment of an increased annual risk and an increased incidence of the effect occurring within the population of concern.

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

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

The overall approach is outlined in **Figure 1-4.**

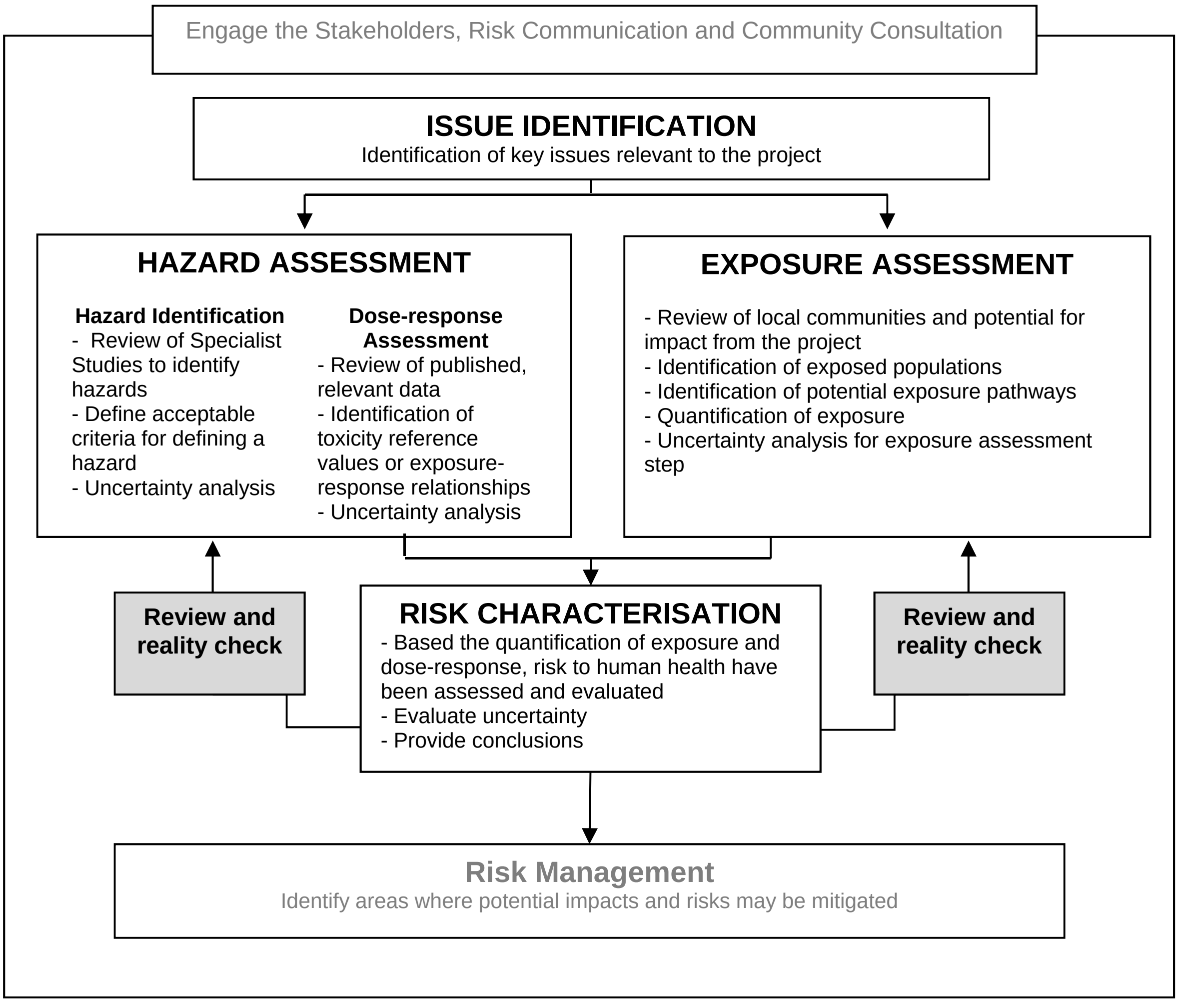

Figure 1-4 Overall human health risk assessment approach (modified from enHealth, 2012)

1.5.3 Features of the risk assessment

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

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

This assessment does not address all the health impacts, both positive and negative, associated with the project. Rather the assessment presented in this technical working paper has focused on key impacts (negative impacts) to air quality and noise/vibration as requiring detailed consideration within the EIS.

Section 2. Project description

2.1 General

This section presents an overview of the project being considered in this technical working paper. The details presented are only a summary. Full details are presented in the EIS.

The Hornsby Quarry site would receive up to 1.5 million cubic metres of excavated natural material (ENM) and/or virgin excavated natural material (VENM) from the approved NorthConnex construction sites. Only ENM and/or VENM would be received and reused at the Hornsby Quarry site.

Key features of the project would include:

- Widening and sealing of the quarry access road (Bridge Road and track) to facilitate all weather access.
- Clearing and grubbing, and establishment of erosion and sediment controls.
- Establishment of a compound site, security fencing and signage around the works area.
- Dewatering of the void (to be undertaken by Hornsby Council in accordance with its existing groundwater licence) to a suitable level that allows working within the void.
- Construction of a conveyor from the stockpile site to the rim of the quarry void.
- Spoil haulage by truck from the NorthConnex construction sites to the Hornsby Quarry site over a period of approximately 28 months.
- Stockpiling of spoil at stockpile sites within the Hornsby Quarry site using dozers.
- Transport of the spoil via the conveyor from the stockpiles to the rim of the quarry void, where the spoil would fall directly into the void.
- Spreading and grading of the spoil on the quarry floor.
- Site demobilisation and rehabilitation of the compound site, stockpile areas and the conveyer corridor.

The project is anticipated to commence in late 2015 and is expected to take around 33 months to complete.

Detailed descriptions of each activity can be found in Section 4.1 of the EIS for the project.

An indicative project program is provided in **Table 2-1.**

Table 2-1 Indicative program

Activity	Indicative timeframe															
	2015				2016				2017				2018			
Site establishment works				■												
Establishment of conveyer					■											
Spoil haulage and stockpiling					■	■	■	■	■	■	■	■	■	■		
Spoil emplacement (operation of conveyor)						■	■	■	■	■	■	■	■	■	■	
Site clean-up and demobilisation														■	■	

2.2 Project activities

Project activities would generally include:

- Site establishment.
- Maintenance pumping of the quarry void for the duration of the works.
- Conveyor construction works, involving construction of a conveyor from the stockpile site to the rim of the void.
- Spoil haulage from the NorthConnex project by truck and stockpiling at the Hornsby Quarry site.
- Spoil emplacement activities, following the completion of the conveyor construction works.
- Site demobilisation and rehabilitation at the completion of the emplacement activities.

An overview of the activities associated with the project is provided in **Table 2-2**. Detailed descriptions of each project activity can be found in section 4.1 of the EIS for the project.

Table 2-2 Overview of project works

Component	Typical activities
Site establishment (including preparatory works)	The following works would be completed: - Dewatering of the void to a suitable working level - Clearing and grubbing, and establishment of erosion and sediment controls - Establishment of a compound site - Establishment of security fencing and signage around the compound site - Widening and sealing of the currently unsealed quarry access road (Bridge Road) to facilitate all weather access.
Establishment of conveyor	The construction of the conveyor works would include establishment of footings and the conveyor and would occur concurrently with the establishment of the site.
Spoil haulage and stockpiling	Trucks would enter and leave via Bridge Road during standard work hours over a maximum period of 28 months. Spoil would be unloaded from the haulage trucks and stockpiled using dozers. It is expected that this activity would commence whilst the conveyer is still being constructed.
Spoil emplacement	Once the conveyer is constructed, these works would occur concurrently with spoil haulage and stockpiling activities, but would also continue for a period after the completion of spoil haulage onto the site. The activities include: - Placement of spoil from the stockpiles into the conveyor by front end loader - Transport of the spoil via overhead conveyor to the quarry void rim where the spoil would fall directly into the void - Front-end loaders and articulated trucks would move the spoil along the quarry floor and dozers and rollers would spread the material. Periodic maintenance pumping of water from the void would be conducted.

Component	Typical activities
Site demobilisation and rehabilitation	The compound and conveyor would be dismantled and removed from the site. Disturbed areas would be rehabilitated to a standard agreed with the Council. Security fencing would be removed, however would be retained around the quarry void if the void is deemed to remain an ongoing risk to public safety. Public access would then be reinstated to the areas outside the void exclusion zone.

2.3 Project hours

Works would be undertaken in accordance with the Interim Construction Noise Guideline (ICNG) recommended standard work hours, as presented below:

- 7am to 6pm Monday to Friday.
- 8am to 1pm Saturdays.
- No works on Sundays or Public Holidays.

Whilst no works are anticipated to occur outside of standard hours there may be circumstances where out-of-hours activities associated with the project are necessary. Activities which may be undertaken outside of standard daytime hours (in accordance with Section 2.3 of the ICNG) would include the following circumstances:

- The delivery of materials or oversized plant as required by the Police or other authorities for safety reasons.
- Where it is required to avoid the loss of lives, property and / or to prevent environmental harm in an emergency.
- Activities which are determined to comply with the relevant Noise Management Level (NML) at the most affected sensitive receiver.
- Where agreement is reached with affected receivers.

Out of hours work may also be undertaken where explicitly approved through an Environment Protection Licence.

2.4 Haulage routes

The expected haulage routes to and from the Hornsby Quarry site have been identified in consultation with the NorthConnex construction contractor, Hornsby Shire Council and Roads and Maritime with the aim of minimising potential impacts on the community. Expected haulage routes are identified below. These routes would be subject to further investigation as part of detailed design.

- Haulage from spoil locations south of Pennant Hills Road / M1 Motorway intersection:
    - **In:** Pacific Highway from the intersection with Pennant Hills Road, then along George Street and onto Bridge Road.
    - **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road.
    - **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

- Haulage from spoil locations north of Pennant Hills Road / M1 Motorway intersection:
  - **In:** From the Mt Colah M1 Pacific Motorway exit, a U-turn via Ku-ring-gai Chase Road back onto the M1 Pacific Motorway to travel south, then taking the exit onto the A1 (Pacific Highway), turning right and traveling along Pacific Highway as per the southern haulage route (Pacific Highway, George Street and into Bridge Road).
  - **Out (non-peak hours):** Bridge Road and south along George Street and the Pacific Highway onto Pennant Hills Road and back on the M1 Pacific Motorway.
  - **Out (peak hours):** out through Bridge Road and north along Jersey Street North, the Pacific Highway, Yirra Road, Belmont Parade, Ku-ring-gai Chase Road to connect with the M1 Pacific Motorway.

Vehicles during site preparation and establishment would also use the above traffic routes. Only light vehicles (for site personnel) and delivery trucks would access the site (in and out) via Quarry Road. There may be instances, however, when heavy vehicles would be required to access the site from Quarry Road, namely during an emergency and where entry and/or exit via Bridge Road is impeded due to vehicle breakdown.

2.5 Onsite activities

At the peak of site activities (year 2017) a total of 35 trucks per hour hauling 12 bank cubic metres (bcm) of spoil per load would be transported to the temporary stockpile area in the eastern portion of the Hornsby Quarry site. From the stockpiles on the flats, spoil would then be transported via conveyor to the void of the former Hornsby Quarry. A summary of the spoil handling activities onsite is presented in **Figure 2-1**.

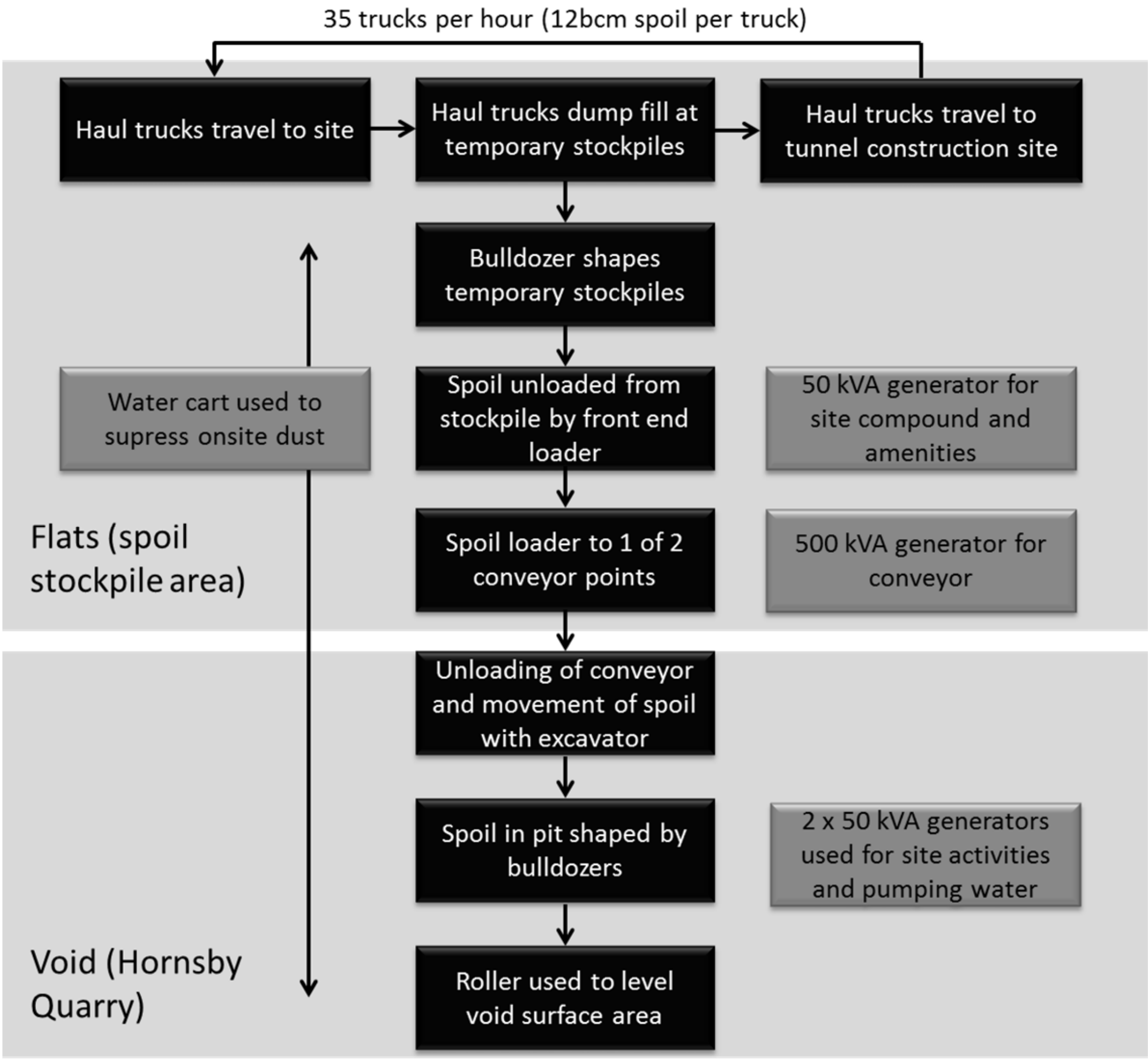

Figure 2-1 Onsite works at the Spoil Management Facility

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Section 3. Community profile

3.1 General

This section provides an overview of the community potentially impacted by the project. The key focus of the assessment presented is the local community, however some aspects of the assessment require consideration of statistics that are derived from larger populations, such as those within the Northern Area Health District and the greater Sydney Area. Hence, where relevant, information related to both the local community and other areas within Sydney (and NSW) have been presented.

3.2 Surrounding area and population

The Hornsby Quarry site is located in the suburb of Hornsby. The quarry is located in an area that is surrounded by bushland (immediately surrounding the quarry pit extending to the west) that is used for recreational purposes by the local community (including bushwalking and mountain biking), low density residential homes (to the northwest, north and south), Hornsby TAFE and other commercial/retail businesses (to the east). It is noted that Mt Wilga Private Hospital (rehabilitation hospital) is located to the north of the quarry.

Sensitive receivers

Sensitive receivers are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations comprise hospitals, child care facilities, schools and aged care homes/facilities. The assessment of potential impacts on the surrounding community, particularly in relation to air quality, has considered all impacts at all individual residential homes and business in the vicinity of the quarry as shown on **Figure 3-1**.

Figure 3-1 Location of sensitive receivers

3.3 Population profile

The population within the area surrounding the quarry has been assumed to be consistent with the statistics available for the population of the larger suburb of Hornsby. No data is available for smaller areas within the suburb of Hornsby.

Tables 3-1 and 3-2 present a summary of a selected range of demographic measures relevant to the suburb of Hornsby with comparison to the statistical area of Hornsby South, greater Sydney and the rest of NSW (excluding greater Sydney).

Table 3-1 Summary of population statistics

Location	Total Population		% Population by Key Age Groups				
	Male	Female	0-4	5-19	20-64	65+	30+
Hornsby	9694	10169	7.2	15.7	65.5	11.6	62
Larger Statistical Areas							
Hornsby South (Statistical Area)	43701	46404	6.2	19.4	59.6	14.7	62
Greater Sydney	2162221	2229453	6.8	18.7	61.7	12.9	60
Rest of NSW (excluding greater Sydney)	1239007	1273942	6.3	19.7	55.9	18	63

Ref: Australian Bureau of Statistics, Census Data 2011

Based on this general population data, the suburb of Hornsby is generally similar to Greater Sydney and NSW.

Table 3-2 Selected demographics of population of interest

Location	Median age	Median household income ($/week)	Median mortgage repayment ($/month)	Median rent ($/week)	Average household size	Unemployment rate (%)
Hornsby	35	1436	2167	380	2.5	5.7
Larger Statistical Areas						
Hornsby South (Statistical Area)	38	1730	2383	400	2.8	5.2
Greater Sydney	36	1447	2167	351	2.7	5.7
Rest of NSW (excluding greater Sydney)	41	961	1560	220	2.4	6.1

Ref: Australian Bureau of Statistics, Census Data 2011

The social demographics of an area have some influence on the health of the existing population. The population located in the suburb of Hornsby is generally similar to that in Greater Sydney.

3.4 Existing health of population

3.4.1 General

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

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

Most of the health indicators presented in this report are not available for each of the smaller suburbs/statistical areas surrounding the site. Health indicators are only available from a mix of larger areas (that incorporate the study area) - the Northern Sydney Area Health Service and/or the combined area of Northern Sydney and the Central Coast. The health statistics for these larger areas (and in some cases data for the Greater Sydney area) are assumed to be representative of the smaller population located in the vicinity of the Hornsby Quarry site, given the similarity of the demographics of these populations to Greater Sydney.

3.4.2 Health-related behaviours

Information in relation to health-related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) are available for large health population areas in Sydney and NSW. This includes risky alcohol drinking, smoking, consumption of fruit and vegetables, overweight and obesity and adequate physical activity. The study population is grouped in the larger population area of Northern Sydney and Central Coast. The incidence of these health-related behaviours generally indicates the population in the Northern Sydney and Central Coast area:

- Has similar rates of risky alcohol drinking, recommended consumption of vegetables and overweight and obesity compared with NSW.
- Has higher rates of recommended consumption of fruit and adequate physical activity compared with NSW.

3.4.3 Health indicators

In relation to some specific health indicators relevant for this assessment **Table 3-3** presents the available data for the slightly smaller population areas defined under the Northern Sydney Area Health and for the Hornsby, Ku-ring-gai and the Hills local government areas (or GP health areas). These have been compared with available data for Sydney and NSW. The health indicators include those that are specifically relevant to the quantification of exposure to particulate matter presented in **Section 4.4.**

Table 3-3 Summary of key health indicators

Health Indicator	Data available for Population (rate per 100,000 population)					
	Hornsby Shire	Ku-ring-gai Shire	The Hills Shire	Northern Sydney Area Health	Greater Sydney	NSW
Mortality						
All causes – all ages*	--	--	--	496.6[1]	586.9[1]	670#[2]
All causes ≥30 years*	--	--	--	--	--	1087#[2]
Cardiopulmonary ≥30 years*	--	--	--	--	--	490#[2]
Cardiovascular – all ages*	--	--	--	--	--	164#[2]
Respiratory – all ages*	--	--	--	--	--	57#[2]
Hospital admissions						
Coronary heart disease	539.5[3]	462.7[3]	597.5[3]	442.3[4]	391.6[4]	608.7[4]
COPD >65 years	647.9[3]	558.1[3]	735.6[3]	745.2[4]	1194.2[4]	1470.4[4]
Cardiovascular disease						
All ages	--	--	--	1642.3[5]	1582.6[5]	1949.9[5]
>65 years*	--	--	--			23352#[3]
Respiratory Disease						
All ages	--	--	--	1520.1[5]	1530.3[5]	1770.2[5]
>65 years*	--	--	--	--	--	8807#[3]
Asthma						
Asthma hospitalisations (ages 5-34 years)	--	--	--	85.7[4]	105.1[4]	133.6[4]
Current asthma for ages 16 and over	--	--	--	12.1%[4]	7.8%[4]	11.3%[4]

* Health indicators directly relevant to the characterisation of potential impacts associated with exposure to particulate matter as presented in **Section 4**
# Data provided by NSW Health (upon written request) for the purpose of this assessment.
All other data has been obtained from Health Statistics New South Wales
1 - Data from 2006-2007
2 – Data for 2005-2007
3 - Data for 2009-2011
4 – Data for 2010-2011
5 – Data for 2011-2012
-- No data available

In relation to asthma, **Figure 3-2** shows the general indicators reported for the larger population area of Northern Sydney and Central Coast compared with the data available for NSW.

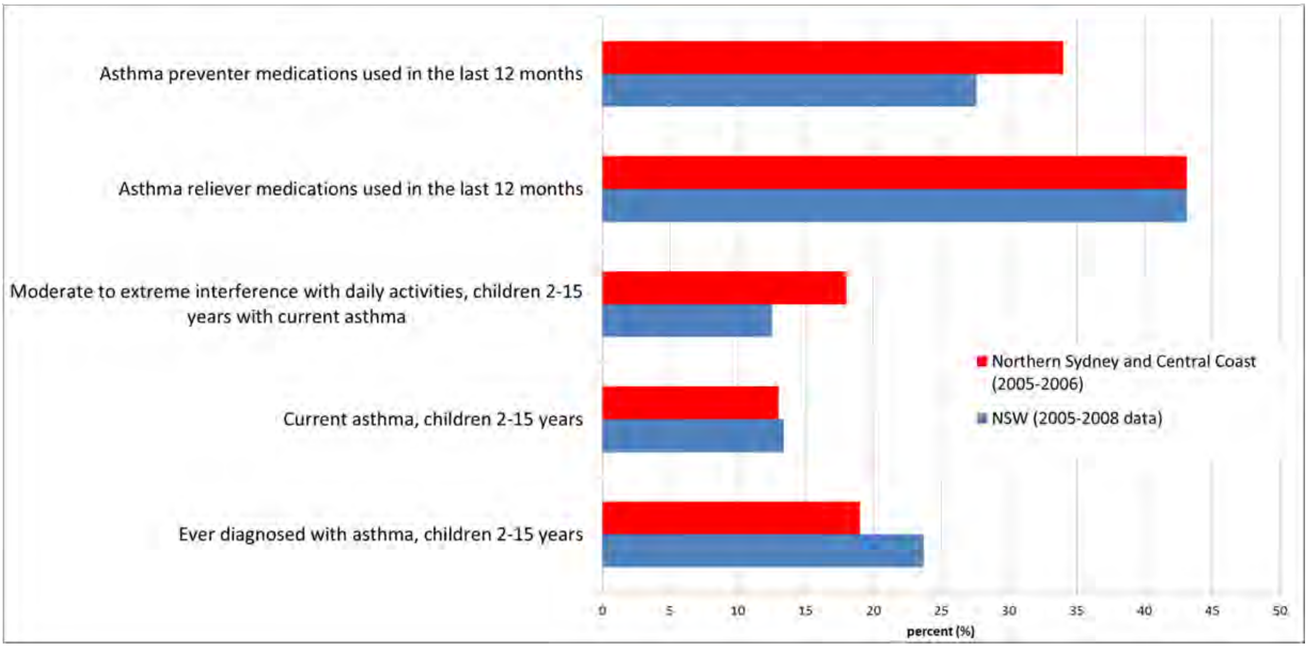

Figure 3-2 Summary of asthma prevalence and management (NSW and Northern Sydney/Central Coast)

Review of the available data generally indicates that for the population in the Northern Sydney area (including the Northern Sydney and Central Coast combined areas where relevant) the health statistics (including mortality rates and hospitalisation rates for most of these categories) are generally lower than compared with a number of other health areas and the whole of NSW.

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

Uncertainties

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

3.5 Existing environment

3.5.1 Existing air quality

The existing air quality in the study area is described in the technical working paper: air quality (AQIA) (AECOM, 2015). For this project the AQIA has used background air quality data collected as part of the NorthConnex Project for the year 2014 from the closest ambient air monitoring station at James Park.

It is noted that air quality in the greater Sydney area is most significantly affected by bushfires (including hazard reduction burns) and dust storms with transport-related emissions identified as the largest source of human-related pollution. In general, NSW is considered to have good air quality in relation to international standards. Review of $PM_{2.5}$ and PM_{10} in many countries by the WHO[1] identified that concentrations reported in Australia were low (amongst the lowest of all countries evaluated) compared with international levels.

Exceedances of the NEPC guidelines and advisory goals for particulate matter (PM) do occur in Sydney (as presented in the AQIA), primarily due to occasional bushfires, dust storms and hazard reduction burns rather than more every day conditions. In relation to $PM_{2.5}$, review of the sources (emissions) that contribute to the measured $PM_{2.5}$ reported in the Sydney area by the NSW EPA (based on emissions inventory data – for the year 2008, published 2012[2]), indicates that the most significant sources are household activities (including residential wood heaters – with peak emissions in the winter months from wood-smoke).

3.5.2 Existing noise environment

The existing noise environment in the area surrounding the Hornsby Quarry site is characterised by the local road network (including the Pacific Highway) and other transport infrastructure such as Hornsby railway station and the Northern rail line. Hence the main contributors to the existing noise environment are road traffic (including heavy vehicles using the existing road network) and passenger and freight rail movements. Commercial and light industrial areas along and around the Pacific Highway road corridor would also contribute to the local noise environment. Notwithstanding, the quarry site is located within a dense bushland area to the west of the Hornsby town centre and is surrounded by residential receivers to the south and north. It is expected that residential receivers in proximity to the quarry would experience a noise amenity consistent with a suburban setting (AECOM 2015).

Background noise monitoring has been undertaken at 6 locations in the study area that includes:

- 4 locations to establish background levels in areas considered representative of the local suburban area (with one of these locations also used to evaluate road noise); and

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[1] WHO, Ambient (outdoors) air pollution in cities database 2014, available from http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

[2] http://www.epa.nsw.gov.au/woodsmoke/index.htm

- an additional 2 locations to evaluate road noise.

The background noise data is used to define appropriate construction noise management limits consistent with the NSW EPA Interim Construction Noise Guideline and NSW Road Noise Policy.

Background noise levels in the suburban area (4 locations sampled) were as follows:

- Day (7am to 6pm): rating background levels ranged from 34 to 39 dB(A) as $LA_{90,15}$
- Evening (6pm to 10pm): rating background levels range from 33 to 37 dB(A) as $LA_{90,15}$
- Night (10pm to 7am): rating background levels ranged from 31 to 33 dB(A) as $LA_{90,15}$

Section 4. Review of air impacts

4.1 Air impact assessment

4.1.1 Summary

Emissions to air associated with the project have been evaluated in detail within the technical working paper: air quality (AECOM 2015) (AQIA). The AQIA has considered emissions to air that may occur during all activities associated with the project.

The AQIA has considered the following emissions:

- The generation of dust during spoil stockpiling and emplacement activities. Dust-generating activities include the handling of material from haul trucks dumping spoil, transfer of spoil from temporary stockpiles to the conveyor and the distribution of spoil within the quarry void. Haulage routes within the site would be paved therefore wheel generated dust has not been considered as part of this assessment.
- Diesel exhaust emissions from truck haulage activities, mobile equipment and onsite generators would also result in the emission of combustion products including oxides of nitrogen, carbon monoxide, particular matter (PM), polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs).

Two scenarios have been modelled in the AQIA for the carrying out of the project as outlined in **Table 4-1**. As the timing of stockpiling and void filling is likely to be staggered Scenario 1 accounts for only stockpiling activities while Scenario 2 takes into account both stockpiling and void filling consecutively.

Table 4-1: AQIA Modelling Scenarios

Scenario	Scenario Description
Scenario 1	- Movement of up to 4,620 m^3/day of spoil from NorthConnex project construction site to the Hornsby Quarry site. - Storage of 170,000 m^3 of spoil in temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site.
Scenario 2	- Movement of up to 4,620 m^3/day of spoil from NorthConnex project construction site to the Hornsby Quarry site. - Storage of 170,000 m^3 of spoil to temporary stockpiles located on the flats within the eastern part of the Hornsby Quarry site. - Transport of up to 7,920 t/day of spoil from the temporary stockpiles via conveyor to the quarry floor. A volume of 1,000,000 m^3 of spoil would be used to fill the void.

In addition to the above scenarios, emissions derived from trucks using haulage route roads to and from the site have been assessed at sensitive receptors located close to the haulage route roads.

Scenario 2 results in the more significant levels of emissions and potential for air quality and health impacts. Hence this scenario has been the focus of further evaluation in this assessment.

Emissions related to the project have been assessed using CALPUFF (for the modelling of emissions from stockpiling and filling activities at the quarry) and CAL3QHCR (for the modelling of emissions from vehicles on surface roads around the project). Meteorological data collected from

NorthConnex monitoring stations and from the BOM and OEH monitoring stations used in the NorthConnex EIS assessment and terrain information relevant for the area was used to predict pollutant concentrations at 420 sensitive receiver locations surrounding the site.

Emissions associated with the spoil management activities have been based on Australian Government Department of Environment's, National Pollution Inventory (NPI) Emission Estimation Technique Manuals.

Vehicle emission rates have been based on internationally-recognised emission factors coupled with emission source types (diesel trucks and other equipment) and projected traffic volumes.

The AQIA has evaluated the key pollutants that are relevant to emissions to air during the project, which include:

- Particulate matter (PM) including size fractions PM_{10} and $PM_{2.5}$ which are of importance for the assessment of potential health impacts from the movement and handling of soil/rock and emissions from trucks.
- Oxides of nitrogen (in particular NO_2).
- Carbon monoxide (CO).
- Volatile organic compounds (VOCs) as total VOCs.
- Polycyclic aromatic hydrocarbons (PAHs, as total PAHs) which are particularly associated with diesel emissions.

Background levels of key pollutants (particulate matter, carbon monoxide and nitrogen dioxide) levels have been determined from available data on from the James Park NorthConnex monitoring station. The background air quality data is relevant for the assessment of cumulative impacts from the project.

Predicted impacts at all sensitive receiver locations have been provided for consideration in this assessment. The impacts have been presented as incremental impacts (i.e. the project only) and cumulative impacts (i.e. the project plus background air quality).

4.1.2 Mitigation measures

Given the proximity of the materials handling activities to the surrounding sensitive receptors and the quantity of material being transported onto the site, source based mitigation designed to reduce dust emissions through the application of specific measures, have been applied. The best practice measures that were assumed to be undertaken were:

- All site haul roads will be sealed.
- Water sprays will be used on the spoil stockpiles and conveyor transfer points.
- Water carts will wet down the material being worked by the roller and bulldozers.
- Wind barriers, such as shade cloth on boundary fencing, will be erected around the stockpile site perimeter.
- Management of speed limits on internal site haul roads.

4.1.3 Vehicle emissions

Diesel vehicles/equipment (considered in this project) emit a range of air pollutants that are known to be associated with adverse health impacts. Common air pollutants emitted from these vehicles include (DEH 2003):

- nitrogen oxides, in particular nitrogen dioxide;
- carbon monoxide;
- fine particulates;
- volatile organic compounds (in particular benzene, toluene and total xylenes [BTX] and 1,3-butadiene) and aldehydes (formaldehyde and acetaldehyde); and
- polycyclic aromatic hydrocarbons where the toxicity will vary depending on the presence of individual polycyclic aromatic hydrocarbons.

The assessment of emissions from vehicles requires consideration of key urban air pollutants (nitrogen oxides, carbon monoxide), the individual compounds likely to be present in the more general measures of volatile organic compounds (which include BTX, 1,3-butadiene and the aldehydes) and polycyclic aromatic hydrocarbons, and particulates. These are further discussed in the following sections.

4.2 Review of key air pollutants

4.2.1 Oxides of nitrogen

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

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

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen of concern (WHO 2000c). Nitrogen dioxide is a colourless and tasteless gas with a sharp odour. Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (Morgan et al. 1998). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide (NEPC, 2010). The health effects associated with exposure to nitrogen dioxide depend on the duration or exposure as well as the concentration; hence guidelines have been developed in Australia (and internationally) that reflect both acute and chronic exposures.

Guidelines are available from the NSW EPA and NEPC (NEPC 2003) that are based on protection from adverse health effects following short-term (acute) and longer-term (chronic) exposure. Review of these guidelines by NEPC (2010) identified additional supporting studies for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available).

The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2010[3], specifically listed to be protective of exposures to sensitive populations including asthmatics, children and the elderly). On this basis the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

Assessment of acute exposures:

The NEPC ambient air quality guideline for the assessment of acute (short-term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) 1-hour average concentration in air. The guideline of 246 µg/m^3 (or 120 ppbv) is based on a lowest observed adverse effect level (LOAEL) of 409 to 613 µg/m^3 derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma. An uncertainty factor of two to protect susceptible people (i.e. asthmatic children) was applied to the LOAEL (NEPC 1998). On this basis the NEPC (and Environment Protection Authority) acute guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The maximum 1-hour average concentration of nitrogen dioxide (cumulative concentration) predicted at the surrounding receptors is 139.8 µg/m^3, below the health based guideline of 246 µg/m^3. Hence there are no adverse health effects expected in relation to acute exposures to nitrogen dioxide in the local area surrounding the project. Hence no further detailed assessment of these exposures is warranted.

Assessment of chronic exposures:

The NEPC ambient air quality guideline for the assessment of chronic (long-term or lifetime) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) annual average concentration in air. The guideline of 62 µg/m^3 (or 30 ppbv) is based on a lowest observed adverse effect level (LOAEL) of the order of 40 – 80 ppbv (around 75-150 µg/m^3) during early and middle childhood years which can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school. An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20-40 ppbv (38-75 µg/m^3) (NEPC 1998). On this basis the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The maximum annual average concentration of nitrogen dioxide (cumulative concentration) predicted at the surrounding receptors is 22.7 µg/m^3, below the health based guideline of 62 µg/m^3. Hence there are no adverse health effects expected in relation to long-term/chronic exposures to nitrogen dioxide in the local area surrounding the project. Hence no further detailed assessment of these exposures is warranted.

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[3] Most recent review of the Primary National Ambient Air Quality Standards for Nitrogen Dioxide published by the USEPA in the Federal Register Volume 75, No. 26, 2010, available from: http://www.gpo.gov/fdsys/pkg/FR-2010-02-09/html/2010-1990.htm

4.2.2 Carbon monoxide

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

Guidelines are available in Australia from NEPC (NEPC 2003) and NSW EPA (OEH) that are based on the protection of adverse health effects associated with carbon monoxide. Review of these guidelines by NEPC (2010) identified additional supporting studies[4] for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2011[5], specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

The NEPC ambient air quality guideline for the assessment of exposures to carbon monoxide has considered LOAEL (lowest observed adverse effect level) and NOAELs (no observed adverse effect level) associated with a range of health effects in healthy adults, people with ischemic heart disease and foetal effects. In relation to these data, a guideline level of carbon monoxide of nine ppmv (or 10 mg/m^3 or 10 000 µg/m^3) over an 8-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population. An additional 1.5 fold uncertainty factor to protect more susceptible groups in the population was included. On this basis the NEPC (and the Environment Protection Authority) guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The Environment Protection Authority has also established a guideline for 15-minute average (100 mg/m^3) and 1-hour average (30 mg/m^3) concentrations of carbon monoxide in ambient air. These guidelines are based on criteria established by the WHO (WHO 2000b) using the same data used by the NEPC to establish the guideline (above) with extrapolation to different periods of exposure on the basis of known physiological variables that affect carbon monoxide uptake.

The maximum 1-hour average concentration of carbon monoxide (cumulative concentration) predicted at the surrounding receptors is 1983 µg/m^3, below the health based guideline of 30,000 µg/m^3. The maximum 8-hour average concentration of carbon monoxide (cumulative concentration)

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

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

predicted at the surrounding receptors is 1086 µg/m^3, below the health based guideline of 10,000 µg/m^3. Hence there are no adverse health effects expected in relation to long-term/chronic exposures to carbon monoxide in the local area surrounding the project. Hence no further detailed assessment of these exposures is warranted.

4.3 Review of volatile organic compounds and polycyclic aromatic hydrocarbons

4.3.1 General

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

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

Volatile organic compounds and polycyclic aromatic hydrocarbons from the project are associated with emissions from trucks and equipment used in the project. The makeup of the volatile organic compounds and polycyclic aromatic hydrocarbons emissions would depend on the mix of vehicles considered as these pollutants will be emitted in different proportions from petrol and diesel powered vehicles. In addition, the age and the fuel used by the vehicle fleet would affect these emissions. For the purpose of this assessment emissions are all assumed to be derived from heavy duty diesel vehicles.

4.3.2 Volatile organic compounds

Volatile organic compounds have been modelled in the AQIA based on emissions from all vehicles considered. The proportion of each of the individual volatile organic compounds that may be present in the air is then estimated based on the assumed composition of the vehicle fleet and the type of fuel used. Most of the VOC emissions comprise a range of hydrocarbons that are of low toxicity (such as methane, ethylene, ethane, butenes, butanes, pentenes, pentanes, heptanes etc) (EPA 2012). From a toxicity perspective the key volatile organic compounds that have been considered for the vehicle emissions are BTX, 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions) (DEH 2003; EPA 2012).

The proportion of each of the key volatile organic compounds considered are derived from the 2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW (EPA 2012), for heavy duty diesel vehicles, where the following mass fractions have been adopted (as % of total) VOCs):

- 1,3-Butadiene = 0.4%
- Acetaldehyde = 3.81%
- Benzene = 1.07%
- Formaldehyde = 9.86%
- Xylenes = 0.38%
- Toluene = 0.47%

4.3.3 Polycyclic aromatic hydrocarbons

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

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

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

On the basis of this approach the speciation of individual polycyclic aromatic hydrocarbons (as per cent of total polycyclic aromatic hydrocarbons) has been calculated based on the data from DEH (2003) assuming most of the diesel vehicles will be operating in the local area under stop/start conditions (relevant for diesel equipment on the site and stop/start activity of trucks driving on-site, unloading soil/rock and leaving the site. For the PAHs considered in this assessment the following mass fractions for each individual PAH have been adopted (as % total PAHs):

- Carcinogenic PAHs as benzo(a)pyrtene equivalents = 4.6%
- Naphthalene = 70%
- Acenaphthalene = 4.9%
- Acenaphthene = 2%
- Fluorene = 5%
- Phenanthrene = 3.4%
- Anthracene = 0.49%
- Fluoranthene = 0.45%
- Pyrene = 0.71%

4.3.4 Review of health impacts

The predicted (incremental) concentrations of individual volatile organic compounds and polycyclic aromatic hydrocarbons associated with the project (based on the speciation as outlined above) have been reviewed against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures that may occur to all members of the general public (including sensitive individuals) with no adverse health effects. The guidelines available relate to the duration of exposure and the nature of the health effects considered where:

- Acute guidelines are based on exposures that may occur for a short period of time (typically between an hour and up to 14 days). These guidelines are available to assess peak exposures (based on the modelled 1-hour maximum concentration) that may be associated with volatile organic compounds in the air;
- Chronic guidelines are based on exposures that may occur all day, every day for a lifetime. These guidelines are available to assess long-term exposures (based on the modelled annual average concentration) that may be associated with volatile organic compounds and polycyclic aromatic hydrocarbons in the air.

Table 4-2 and **Table 4-3** present a summary of the maximum predicted 1-hour or annual average concentration with comparison against acute (**Table 4-2**) and chronic (**Table 4-3)** health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all the volatile organic compounds and polycyclic aromatic hydrocarbons considered. The total HI is a sum of the potential hazards associated with all the volatile organic compounds and polycyclic aromatic hydrocarbons together assuming the health effects are additive, and is evaluated as follows:

- A total HI ≤ 1 means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern.

- A total HI > 1 means that the predicted concentrations (for at least one individual compound) are above the health based guidelines, or that there are at least a few individual volatile organic compounds or polycyclic aromatic hydrocarbons where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

The following evaluation is based on the maximum predicted (incremental) concentration in air at any of the modelled receptor locations for Scenario 2 (which results in the highest maximum impact from any of the scenarios evaluated, including emissions from haulage roads). Concentrations at other receptors are lower and hence the tables present a worst-case evaluation only.

Table 4-2 Evaluation of potential acute impacts in local area (Scenario 2)

Key VOC	Proportion of total VOCs*	Health based acute guideline and basis ($\mu g/m^3$)	Maximum predicted 1-hour average concentration from Project** and Calculated HI	
			Maximum Concentration ($\mu g/m^3$)	HI
		Total VOCs	**64.3**	
Benzene	1.1%	**29^{A1} to 170^{T1}** (lower value adopted) A1: Acute guideline (1hr to 14 day exposure), based on immunological effects in mice. T1: Acute 1 hour health based guideline, based on depressed peripheral lymphocytes and depressed mitogen-induced blastogenesis (mice study)	0.69	0.024
Toluene	0.5%	**4500^{T2}** Acute 1 hour health based guideline, based on eye and nose irritation, increased occurrence of headache and intoxication in human male volunteers	0.30	0.000067
Xylenes	0.4%	**2200^{T3}** Acute 1 hour health based guideline, based on mild respiratory effects and subjective symptoms of neurotoxicity in human volunteers	0.24	0.00011
1,3-Butadiene	0.4%	**660^{O1}** Acute 1 hour health based guideline, based on developmental effects	0.26	0.00039
Formaldehyde	9.9%	**15^{T4}** Acute 1 hour health based guideline, based on eye and nose irritation in human volunteers	6.3	0.42
Acetaldehyde	3.8%	**470^{O2}** Acute 1 hour health based guideline, based on effects on sensory irritation, bronchoconstriction, eye redness and swelling	2.4	0.0052
			Total HI	0.45

Notes:

* Percentage of each individual volatile organic compound is based on a heavy diesel vehicles (refer to discussion above table)

** Concentrations presented for the maximum 1 hour average (as provided from the AQIA)

A1: Acute inhalation guideline (for exposures from 1 hour to 14 days) from review by ATSDR 2008 for benzene

T1: TCEQ 2007, Benzene, Development Support Document. Texas Commission of Environmental Quality, 1 hour average guideline value (include additional 3.3 fold safety factor). This acute guideline is lower than that derived by the OEHHA (based on older studies)

T2: TCEQ 2008, Toluene, Development Support Document. Texas Commission of Environmental Quality, 1 hour average guideline value (include additional 3.3 fold safety factor)

T3: TCEQ 2009, Xylenes, Development Support Document. Texas Commission of Environmental Quality, 1 hour average guideline value (include additional 3.3 fold safety factor)

T4: TCEQ 2008, Formaldehyde, Development Support Document. Texas Commission of Environmental Quality, 1 hour average guideline value (include additional 3.3 fold safety factor). This guideline is noted to be lower than the acute guideline available from the WHO (2000a, 2010) of 100 µg/m^3 for formaldehyde

O1: OEHHA 2013, Acute (1 hour average) guideline derived by the California Office of Environmental Health Hazard Assessment. The guideline developed is lower than developed by TCEQ (2008) based on the same critical study

O2: OEHHA 2008, Acute (1 hour average) guideline derived by the California Office of Environmental Health Hazard Assessment

Table 4-3 Evaluation of potential chronic impacts in local area (Scenario 2)

Key VOC	Proportion of total VOCs/ PAHs*	Health based chronic guideline and basis (µg/m^3)	Maximum predicted annual average concentration from Project** and Calculated HI	
			Max Conc. (µg/m^3)	HI
Total VOCs			**0.84**	
Benzene	1.1%	**1.7**[W1] Benzene is classified as a known human carcinogen by IARC. Chronic guideline based on excess risk of leukaemia	0.0090	0.0053
Toluene	0.5%	**5000**[U1] Chronic guideline based on neurological effects in an occupational study (converted to public health value using safety factors)	0.0039	7.9E-07
Xylenes	0.4%	**220**[A1] Chronic guideline based on mild subjective respiratory and neurological symptoms in an occupational study (converted to public health value using safety factors)	0.0032	0.000015
1,3-Butadiene	0.4%	**0.3**[U2] 1,3-Butadiene is classified by IARC as a probable human carcinogen. Chronic air guideline based on an excess risk of leukaemia	0.00336	0.011
Formaldehyde	9.9%	**3.3**[T1] Formaldehyde is classified by IARC as carcinogenic to humans. The guideline developed is based on the protection of all adverse effects including cancer and non-cancer (including short term effects)	0.0828	0.025
Acetaldehyde	3.8%	**9**[U3] Chronic guideline based on nasal effects (in a rat study) (converted to a public health value using safety factors)	0.0320	0.0036
Total PAHs			**2.1×10^{-4}**	
Naphthalene	70.0%	**3**[U4] Chronic guideline based on nasal effects (in a mouse study) (converted to a public health value using safety factors)	1.5×10^{-4}	5.0×10^{-5}
Acenaphthylene	4.9%	200[U5S]	1.0×10^{-5}	5.2E-08
Acenaphthene	2.0%	200[U5]	4.3×10^{-6}	2.1×10^{-8}
Fluorene	5.0%	140[U5]	1.1×10^{-5}	7.6×10^{-8}
Phenanthrene	3.4%	140[U5S] — Refer to notes for ref U5	7.2×10^{-6}	5.2×10^{-8}
Anthracene	0.5%	100[U5]	1.0×10^{-6}	1.0×10^{-8}
Fluoranthene	0.5%	140[U5]	9.6×10^{-7}	6.8×10^{-9}
Pyrene	0.7%	100[U5]	1.5×10^{-6}	1.5×10^{-8}
Benzo(a)pyrene TEQ	4.6%	**0.00012**[W2] BaP is classified by IARC as a known human carcinogen, which relates to BaP as well as all the other carcinogenic PAHs assessed as a BaP toxicity equivalent value. The chronic guideline is based on protection from lung cancer for an occupational study	9.8×10^{-6}	0.082
			Total HI for VOCs and PAHs	**0.13**

Notes for Table 4-3:

*	Percentage of each individual volatile organic compounds and polycyclic aromatic hydrocarbons is based on a weighted average of emissions from the range of vehicle types proposed to be used on the project in 2019 and 2029, and for normal traffic flow or congested traffic flow (refer to discussion above table)
**	Concentrations presented for the annual average are as provided from the AQIA
A	Polycyclic aromatic hydrocarbon speciation data for normal traffic conditions – utilised in the assessment of scenarios 2a and 2b
W1:	WHO 2000 Air Quality Guidelines, value for benzene is based on non-threshold carcinogenic effects (excess lifetime risk of leukaemia). Guideline value based on incremental cancer risk of $1x10^{-5}$, consistent with guidance provided by NEPM (1999 amended 2013) and enHealth (2012)
W2:	WHO 2010 Guidelines for Indoor Air Quality, value for BaP is based on non-threshold carcinogenic effects from occupational study of coke workers (lung cancer is critical effect). Guideline value based on incremental cancer risk of $1x10^{-5}$, consistent with guidance provided by NEPM (1999 amended 2013) and enHealth (2012)
T1:	TCEQ 2008, Formaldehyde, Development Support Document. Texas Commission of Environmental Quality. The air guideline is derived on the basis of irritation of the eyes and airway discomfort in humans, with review of carcinogenic and other non-carcinogenic effects found to be adequately protected by this guideline. The guideline is more conservative than derived by the WHO (2010)
A1:	ATSDR 2007, Toxicological Profile for Xylene, chronic inhalation guideline derived is the most current robust evaluation
U1:	USEPA evaluation for toluene (most recently reviewed in 2005). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NEPM (1999 amended 2013) health based guidelines
U2:	USEPA evaluation of 1,3-butadiene (most recently updated in 2002) with the chronic guideline adopted as the lower from the evaluation of non-threshold carcinogenic effects and non-cancer effects. This is the most conservative evaluation of this compound. A more recent review by TCEQ (2013) on the basis of the same critical studies as well as more current studies resulted in a higher chronic air guideline value.
U3:	USEPA evaluation of acetaldehyde (most recently updated in 1991). The guideline established is lower than more recent reviews undertaken by the WHO (2000) and the Californian OEHHA where less conservative evaluations are presented.
U4:	USEPA evaluation of naphthalene (most recently updated in 1998). The guideline established is and is consistent with the value used to derive the NEPM (1999 amended 2013) health based guidelines
U5:	Guideline available from the USEPA. Chronic guidelines for non-carcinogenic polycyclic aromatic hydrocarbons are based on criteria derived from oral studies (for critical effects on the liver, kidney and haematology) which are then converted to an inhalation value (relevant for the protection of public health, including the use of safety factors) for use in this assessment. The value presented in the above table has been converted from an acceptable dose in mg/kg/day to an acceptable air concentration assuming a body weight of 70kg and inhalation of 20 m^3/day (as per (USEPA 2009a))
U5S:	No guideline available for individual polycyclic aromatic hydrocarbon, hence a surrogate compound has been used for the purpose of screening. The surrogate compound is a polycyclic aromatic hydrocarbon of similar structure and toxicity. In relation to the surrogates adopted in this evaluation, acenaphthene has been adopted as a surrogate for acenaphthylene, fluoranthene has been adopted as a surrogate for phenanthrene

Review of the acute assessment presented in **Table 4-2** indicates that the maximum short-duration peak (1 hour average) concentrations of volatile organic compounds (assessed as the key individual volatile organic compounds and as a sum of all the individual volatile organic compounds) in air surrounding the site are below the relevant acute health based guidelines. On this basis no further detailed assessment of the peak emissions of volatile organic compounds from the project is warranted.

Review of the chronic assessment presented in **Table 4-3** indicates that the maximum long-term average (annual average) concentrations of volatile organic compounds and polycyclic aromatic hydrocarbons (assessed as the key individual volatile organic compound and polycyclic aromatic hydrocarbon compounds and as a sum of all the individual volatile organic compounds and polycyclic aromatic hydrocarbons) in air surrounding the site are below the relevant long-term (chronic) health based guidelines. These are guidelines that are based on the protection of public health for inhalation exposures all day (24 hours), every day (365 days per year) for a lifetime (at least 70 years). Hence comparison against these guidelines is conservative for a project that may occur for up to 3 years. On this basis no further detailed assessment of the emissions of individual volatile organic compounds and polycyclic aromatic hydrocarbons from the project is warranted.

4.4 Review of particulate matter

4.4.1 General

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

Numerous epidemiological studies[6] have reported significant positive associations between particulate air pollution and adverse health outcomes, in particular mortality as well as a range of adverse cardiovascular and respiratory effects.

4.4.2 Particulate size and composition

The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter.

The size of particulates is important as it determines how far from an emission source the particulates may be present in air (with larger particulates settling out close to the source and smaller particles remaining airborne for greater distances) and also the potential for adverse effects to occur as a result of exposure.

The common measures of particulate matter that are considered in the assessment of air quality and health risks are:

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

- **Total suspended particulates (TSP):** This refers to all particulates with an equivalent aerodynamic particle[7] size below 50 microns (µm) in diameter[8]. It is a fairly gross indicator of the presence of dust with a wide range of sizes. Larger particles (termed "inspirable", comprise particles around 10 microns (µm) and larger) are more of a nuisance as they will deposit out of the air (measured as deposited dust) close to the source and, if inhaled, are mostly trapped in the upper respiratory system[9] and do not reach the lungs. Finer particles (smaller than 10 µm, termed "respirable") tend to be transported further from the source and are of more concern with respect to human health as these particles can penetrate into the lungs. Hence not all of the dust characterised as total suspended particulates is relevant for the assessment of health impacts, and total suspended particulates as a measure of impact, has not been further evaluated in this assessment. The assessment has only focused on particulates of a size where significant associations have been identified between exposure and adverse health effects.
- **PM_{10}, particulate matter below 10 µm in diameter, $PM_{2.5}$, particulate matter below 2.5 µm in diameter and PM_1, particulate matter below 0.1 µm in diameter (termed ultrafine particles):** These particles are small and have the potential to penetrate beyond the body's natural clearance mechanisms of cilia and mucous in the nose and upper respiratory system, with smaller particles able to further penetrate into the lower respiratory tract[10] and lungs. Once in the lungs adverse health effects may result (OEHHA 2002). It is well accepted nationally and internationally that monitoring for PM_{10} is a good method of determining the community's exposure to potentially harmful dust (regardless of the source) and is most commonly measured in local and regional air quality monitoring programs. Smaller particulates such as $PM_{2.5}$ and PM_1, however, are of most significance with respect to evaluating health effects as a higher proportion of these particles penetrate deep into the lungs. Urban air, that has a significant contribution from combustion sources, tends to have a significant proportion of $PM_{2.5}$ and PM_1 in ambient air.

Evaluation of size alone as a single factor in determining the potential for particulate toxicity is difficult since the potential health effects are not independent of chemical composition. There are certain particulate size fractions that tend to contain certain chemical components, such as metals in fine particulates ($<PM_{2.5}$) and crustal materials (like soil) in the coarse mode (PM_{10} or larger).

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[7] The term equivalent aerodynamic particle is used to reference the particle to a particle of spherical shape and particle of density 1 g/cm^3

[8] The size, diameter, of dust particles is measured in micrometers (microns, µm).

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

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

In addition, different sources of particulates have the potential to result in the presence of other pollutants in addition to particulate matter. For example combustion sources, prevalent in urban areas, result in the emission of particulate matter (more dominated by $PM_{2.5}$) as well as gaseous pollutants (ozone, nitrogen dioxide, carbon monoxide and sulfur dioxide).

There is strong evidence to conclude (USEPA 2012; WHO 2003, 2013) that fine particles (< 2.5 µm, $PM_{2.5}$) are more hazardous than larger ones (coarse particles), primarily on the basis of studies conducted in urban air environments where there is a higher proportion (as a percentage of all particulates) of fine particulates and other gaseous pollutants present from fuel combustion sources, as compared to particulates derived from crustal origins. Toxicological and controlled human exposure studies indicate that primary particles generated from fossil fuel combustion processes may be a significant contributor to adverse health outcomes with several physical, biological and chemical characteristics of particles found to elicit cardiopulmonary responses. Amongst the characteristics found to be contributing to toxicity in epidemiological and controlled exposure studies are high organic carbon content, metal content, presence of polycyclic aromatic hydrocarbons, presence of other organic components or endotoxins and both small (< 2.5 µm) and extremely small size (< 1 µm) (USEPA 2009b; WHO 2003, 2006a). Where soil/rock is being handled the potential presence of and exposure to silica (as a fraction of particulates in air) also requires consideration.

A significant amount of research, primarily from large epidemiology studies, has been conducted on the health effects of particulates with causal effects relationships identified for exposure to $PM_{2.5}$ (acting alone or in conjunction with other pollutants) (USEPA 2012). A more limited body of evidence suggests an association between exposure to larger particles, PM_{10} and adverse health effects (USEPA 2009b; WHO 2003). The health effects identified from these studies has been specifically related to $PM_{2.5}$ or PM_{10} as these are the most commonly adopted robust and widespread measures of particulate matter available in urban air environments.

4.4.3 Health effects

Health effects that have been associated with exposure to PM_{10} and $PM_{2.5}$ relate to exposure over both the short term (hours or days where effects may occur on the same day or after a day or two) and long term (lifetime) and include (Anderson et al. 2004; NEPC 2010; OEHHA 2002; USEPA 2009b; WHO 2003, 2013):

- Respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions.
- Mortality from all causes, and specifically cardiovascular and respiratory diseases and from lung cancer.

There is good evidence of the effects of short-term exposure to PM_{10} on respiratory health, but for mortality and cardiovascular effects the evidence of effects for PM_{10} exposure is weaker. For these health effects $PM_{2.5}$ (particles in the 2.5-10 µm range) is a stronger risk factor (particles in the 2.5-10 µm range).

In short-term studies (based on 24-hour particulate levels), groups with pre-existing respiratory, lung or heart disease, as well as elderly people, were more susceptible to the morbidity and mortality effects of ambient particulate matter exposure (Esworthy 2013; WHO 2013). In longer term studies it has been suggested that the socially disadvantaged and poorly educated populations respond more strongly in terms of mortality (Esworthy 2013; WHO 2003, 2013).

Based on the available studies, there is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur (NEPC 2010; WHO 2013).

At present, at the population level, there is not enough evidence to identify differences in the effects of particles with different chemical compositions or emanating from various sources (NEPC 2010; WHO 2013). The evidence for the hazardous nature of combustion-related particulate matter (from both mobile and stationary sources that dominate urban air where most of the epidemiological studies are conducted) is more consistent than that for particulate matter from other sources, and dominate the epidemiological studies used to develop relationships between exposure and adverse health effects.

Particulates that are derived from specific sources, such as diesel emissions, are known to comprise other compounds such as volatile organic compounds and polycyclic aromatic hydrocarbons that are known to also be associated with adverse health effects. The presence of these other compounds has been addressed separately however the presence of these (and likely other compounds) compounds and other co-pollutants (also derived from combustion sources) adds to the complexity of utilising data from urban air epidemiological studies for assessing health effects from particulate matter.

Recently, outdoor air pollution has been classified by the International Agency for Research on Cancer (IARC 2013) as carcinogenic (Group 1) to humans based on sufficient evidence that exposure to outdoor air pollution causes lung cancer. Particulate matter, a major component of outdoor air pollution, was evaluated separately and also classified as carcinogenic to humans (Group 1).

In 2012, IARC evaluated exhaust from diesel engines (consisting mostly of particulate matter) and classified these emissions as carcinogenic (Group 1) to humans.

4.4.4 Assessment of potential health issues from exposure to particulate matter

General

For many of the key health effects associated with exposures to PM_{10} and $PM_{2.5}$ the exposure-response relationship is linear (where there is no threshold below which no adverse effects have been identified) (NEPC 2010). This means that any exposure to particulate matter has the potential to be associated with an effect. Guidelines have been established in Australia (and internationally) to determine a level at which cumulative exposure (i.e. exposure to particulates from all sources) are likely to minimise the potential for adverse impacts in a population. The available guidelines are discussed and further considered below.

However as there is no threshold for adverse effects it is also important that any incremental exposure to particulate matter derived from the project is also assessed.

Cumulative impacts

Air quality goals for PM_{10}, and advisory goal for $PM_{2.5}$, have been established by NEPC (NEPC 2002, 2003) that are based on the protection of human health and well-being. The goals apply to average or regional exposures by populations from all sources, not to localised "hot-spot" areas such as locations near industry, busy roads or mining. They are intended to be compared against ambient air monitoring data collected from appropriately sited regional monitoring stations.

In addition, the assessment of impacts from any development requires consideration of air quality goals/guidelines that are outlined in the Environment Protection Authority's "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (DEC 2005b). The guidelines are primarily derived from the NEPC, with the exception of an annual average PM_{10} guideline which is derived from older goals adopted by the Environment Protection Authority (EPA 1998). The air quality goals relate to total particulate matter burden in the air and not just the particulate matter from the project, hence use of these criteria requires consideration of background levels of particulate matter and other local sources. Similar to the NEPC criteria, these guidelines do not apply to localised "hot-spot" areas such as locations near industry, busy roads or mining. However, in the absence of alternative measures, Environment Protection Authority does apply these criteria to assess the potential for impacts to arise at such locations, particularly for new projects.

Table 4-4 presents a summary of the current NEPC and Environment Protection Authority's air quality goals and guidelines for particulate matter.

Table 4-4 Air quality goals for particulates

Pollutant	Averaging period	Criteria	Reference
PM_{10}	24-hour	50 µg/m^3 Maximum of 5 days exceedance per year	(DEC 2005b; NEPC 2003)
	Annual	30 µg/m^3	(DEC 2005b)
$PM_{2.5}$	24-hour	25 µg/m^3	Advisory goal [11] (NEPC 2003)
	Annual	8 µg/m^3	

The AQIA presents a detailed assessment of cumulative PM_{10} and $PM_{2.5}$ impacts associated with the project. The assessment undertaken concluded the following in relation to Scenario 2:

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

- For PM_{10}, one exceedance of the 24-hour average criteria is predicted, likely attributable to materials handling activities both on the flats and within the quarry void. No exceedances of the annual average PM_{10} criteria have been predicted.
- For $PM_{2.5}$, two exceedances of the 24-hour $PM_{2.5}$ advisory NEPM criterion were predicted, attributed to the high background concentration considered which exceeded the advisory level in isolation, as well as materials handling activities both on the flats and within the quarry void. In addition, exceedance of the annual average $PM_{2.5}$ advisory standard is predicted. It is noted that background concentrations contributed up to 95% of the advisory standards in the area.
- Both the predicted 24-hour and annual average PM_{10} and $PM_{2.5}$ concentrations could be minimised through a comprehensive dust management program to be implemented during the project.

Incremental impacts

Methodology

As there is no safe level for particulate matter in ambient air, the incremental impact of $PM_{2.5}$ and PM_{10} emissions to air from the project have been evaluated in more detail utilising the methodology outlined in **Appendix A**. The assessment of incremental impacts has addressed the following health endpoints:

Table 4-5 Health Impact Assessment Health Endpoints for Exposure to $PM_{2.5}$ and PM_{10}

Health Endpoint	Effect duration	Age group	Particulate fraction assessed
Primary health endpoints			
Mortality – all causes	Long-term	≥30 years	$PM_{2.5}$
Hospitalisations – Cardiovascular	Short-term	≥65 years**	$PM_{2.5}$
Hospitalisations – Respiratory	Short-term	≥65 years**	$PM_{2.5}$
Secondary health endpoints			
Mortality – all causes	Short-term	All ages	PM_{10}
Mortality all causes	Short-term	All ages	$PM_{2.5}$
Mortality – Cardiopulmonary	Long-term	≥30 years	$PM_{2.5}$
Mortality – Cardiovascular	Short-term	All ages	$PM_{2.5}$
Mortality – Respiratory	Short-term	All ages	$PM_{2.5}$
Lung cancer	Long-term	All ages	Diesel particulate matter (DPM)*

* Diesel particulate matter assumed to be 100% of $PM_{2.5}$ which is an overly conservative estimate as not all $PM_{2.5}$ will be derived from diesel emissions for this project for Scenario 2. Much of the $PM_{2.5}$ will be derived from dust generated from the handling and disposal of rock/soil. The emissions from haulage roads are assumed to all be from diesel trucks and hence the assumption adopted is less conservative.

** Not relevant for exposures in a workplace, only calculated for residential receptors and aged care facilities

Following this approach, the following information has been used to calculate an annual risk (on an individual basis) associated with specific primary and secondary health indicators (identified as robust associations related to exposure to $PM_{2.5}$ or PM_{10}):

- Estimates of the changes in particulate matter exposure levels (i.e. incremental impacts) due to the project (as provided by the AQIA). For the sensitive receivers considered in this assessment, the maximum incremental impacts associated with the project are as follows:
    - Scenario 2 – impacts from the site:

- the maximum annual average $PM_{2.5}$ incremental impact = 1.4 μg/m^3 which is located within Hornsby TAFE and 0.7 μg/m^3 for residential receptors with best practice mitigation measures
- the maximum annual average PM_{10} incremental impact = 2.4 μg/m^3 which is located within Hornsby TAFE and 1.1 μg/m^3 for residential receptors with best practice mitigation measures

  - Scenario 2 – impacts from trucks on haulage route roads to/from the site:
    - the maximum annual average $PM_{2.5}$ incremental impact = 0.14 μg/m^3
    - the maximum annual average PM_{10} incremental impact = 0.14 μg/m^3

- Baseline incidence of the key health endpoints that are relevant to the population exposed (refer to **Section 3.4.3**);
- Exposure-response relationships expressed as a percentage change in health endpoint per µg/m^3 change in particulate matter exposure, where a relative risk (RR) is determined (refer to **Appendix A**); and
- Consideration of the duration of exposure for the assessment of health effects associated with long-term exposures:
  - Long-term effects on health are assessed using annual average exposure concentrations as an estimation of a long-term (lifetime) population exposure. Where the duration of the exposure to the impacts from the project is less than lifetime (as is the case for this project where it is expected to occur over a 33 month period only) the calculated long-term annual risk is adjusted to reflect the less than lifetime exposure. The adjustment relates to long-term exposures for populations over 30 years of age. Assuming a lifetime average of 82 years (enHealth 2012b) the adjustment factor relevant to a 33 month exposure (2.75 years) out of 52 years (>30 years of age) is 0.053.
  - Long-term effects from exposure to diesel particulate matter relates to incremental lifetime risk of lung cancer, based on the use of an inhalation unit risk. This relates to increased lifetime risks (averaged over a 70 year period, the duration of a lifetime over which carcinogenic effects are of importance) and hence for exposures that are less than a lifetime in duration the incremental risk can be calculated by accounting for the duration of exposure. For this calculation the duration of exposure is 2.75 years which results in an adjustment factor of 0.039 (when compared to a 70 year lifetime considered in the cancer risk calculation).

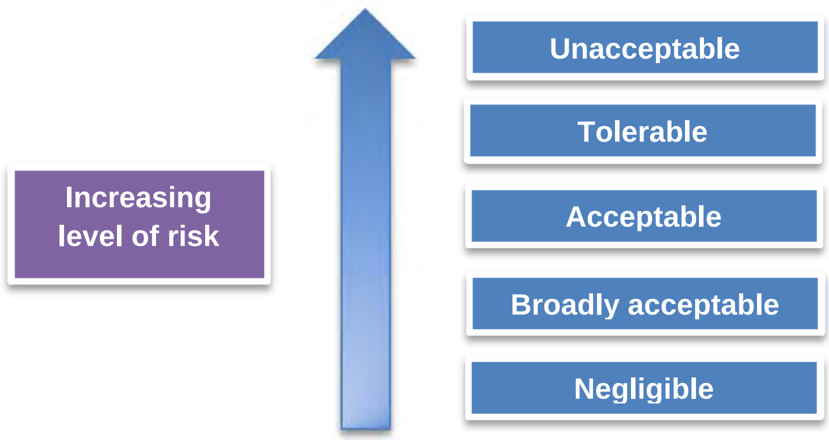
  It is noted that no adjustment for the exposure duration can be included where short-term effects of exposure to particulates is assessed. The short-term effects calculation relates to effects that may occur on the day or shortly after the short-term (daily) change in exposure. The calculation undertaken for these effects at any individual receptor is based on daily risks that are then summed over each day for a year to obtain an annual risk. This risk is relevant for the period of exposure.

The calculations undertaken provide an annual risk for individuals exposed to increased PM emissions from the project at specific locations (such as the maximum, or at specific sensitive receiver locations).

Acceptability of Risk

The acceptability of incremental risks associated with the impacts evaluated in this assessment is the subject of some discussion in relation to exposures to particulate matter. More specifically there are no guidelines available that relate to an acceptable level of risk for a small population (associated with impacts from a specific activity or project).

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



It is not always possible to provide a rigid definition of acceptable risk due to the complex and context-driven nature of any particular project. However for the purpose of this assessment the following have been considered:

- A level less than 10^{-6} (one chance in a million) is considered to be a level of increased risk that would be considered as a negligible risk in the community.
- A level in excess of 10^{-4} for increased risk (one chance in 10,000) is considered to be unacceptable. This level of risk has been generally adopted by health authorities as a point where risk is considered to be unacceptable in the development of drinking water guidelines (that impact on whole populations) (for exposure to carcinogens as well as for annual risks of disease (Fewtrell & Bartram 2001)) and in the evaluation of exposures from pollutants in air (DEC 2005a).
- Between an increased risk level considered negligible (10^{-6}) and unacceptable (10^{-4}) lie risks that may be considered to be tolerable or even acceptable. Tolerable risks are those that can be tolerated (and where the best available, and most appropriate, technology has been implemented to minimise exposure) in order to realise some benefit.

When considering the impacts associated with this project, it is important to consider the health effects being considered and the size of the population exposed. In addition it is important to note that there are a range of benefits associated with the project.

<u>Risk Calculations</u>

On the basis of the approach outlined above, and for the key health endpoints considered in relation to exposure to $PM_{2.5}$ and PM_{10} (derived from the project), incremental risks have been calculated based on data from the AQIA. The calculations have been undertaken for the maximum predicted concentrations at all the sensitive receivers considered.

Table 4-6 presents present a summary of the predicted increased annual risks relevant to the primary and secondary health indicators addressed in this assessment.

The calculations presented in these tables are considered accurate to one significant figure only due to the level of uncertainty within all aspects of the assessment presented.

Table 4-6 Incremental Annual Risks – Exposure to $PM_{2.5}$ and PM_{10}

Health Endpoint	Effect duration	Age group	PM fraction assessed	Risks for Scenario 2 – Best Practice Mitigation			
				Maximum impacts (TAFE)	Maximum impacts (residential)	Average over all sensitive receptors	Maximum Community exposures from haulage roads
Primary health endpoints							
Mortality – all causes	Long-term	≥30 years	$PM_{2.5}$	$5x10^{-6}$	$2x10^{-6}$	$7x10^{-7}$	$5x10^{-7}$
Hospitalisations – Cardiovascular	Short-term	≥65 years*	$PM_{2.5}$	NA	$1x10^{-4}$	$4x10^{-5}$	$3x10^{-5}$
Hospitalisations – Respiratory	Short-term	≥65 years*	$PM_{2.5}$	NA	$2x10^{-5}$	$7x10^{-6}$	$5x10^{-6}$
Secondary health endpoints							
Mortality – all causes	Short-term	All ages	PM_{10}	$1x10^{-5}$	$4x10^{-6}$	$2x10^{-6}$	$6x10^{-7}$
Mortality all causes	Short-term	All ages	$PM_{2.5}$	$9x10^{-6}$	$4x10^{-6}$	$1x10^{-6}$	$9x10^{-7}$
Mortality – Cardiopulmonary	Long-term	≥30 years	$PM_{2.5}$	$5x10^{-6}$	$2x10^{-6}$	$7x10^{-7}$	$5x10^{-7}$
Mortality – Cardiovascular	Short-term	All ages	$PM_{2.5}$	$2x10^{-6}$	$1x10^{-6}$	$3x10^{-7}$	$2x10^{-7}$
Mortality – Respiratory	Short-term	All ages	$PM_{2.5}$	$1x10^{-6}$	$8x10^{-7}$	$2x10^{-7}$	$1x10^{-7}$
Lifetime cancer risk							
Lung cancer	Long-term	All ages	DPM	$2x10^{-6}$	$9x10^{-7}$	$3x10^{-7}$	$2x10^{-7}$

* Not relevant for exposures in a workplace, only calculated for residential receptors and aged care facilities

Based on the calculations presented above the following can be noted:

- Calculated risks associated with exposures to PM_{10} and $PM_{2.5}$ (including DPM) from emissions from haulage route roads are considered to be tolerable and for many health endpoints the risks are considered to be negligible.

- For Scenario 2, where best practice mitigation measures have been considered for the project the following can be noted:
  - Maximum risks associated with exposure to PM_{10} and DPM are less than 1 x 10^{-5} and are considered to be low.
  - Maximum risks associated with exposure to $PM_{2.5}$ typically lie in the range of <$1x10^{-6}$ to $1x10^{-4}$ and are generally considered to be tolerable. It is noted that the maximum level of risk calculated related to potential cardiovascular hospitalisations for individuals aged 65 years and over associated with short-term changes in $PM_{2.5}$ exposures. For the maximum risk calculation this relates to the maximum at a specific residential receptor where the age and existing health status of the residents is not known. The calculated risk specifically relates to individuals aged 65 years of age and over residing at this location with pre-existing cardiovascular disease. As the population evaluated in this assessment is small (with the impacts limited to areas located immediately adjacent to the quarry and access road) the calculated impacts are not considered to be of significance (i.e. would not result in measurable effects in the population evaluated).

The calculated risks are in the range considered to be negligible to tolerable, where the available guidance requires that mitigation measures be implemented to minimise exposures associated with the project. For this project, air impacts and hence health risks are proposed to be minimised through the implementation of best practice mitigation measures and a comprehensive dust management plan. Such measures are described in detail in the AQIA and would result in lower levels of exposure and risk at all receptors in the surrounding community.

4.4.5 Silica Exposures

Silica is abundant in the earth's crust and is released as fine particulates whenever rock is disturbed. Silica can occur both in crystalline and amorphous forms. There are several crystalline forms: quartz, cristobalite and tridymite; while the amorphous form occurs mainly as diatomaceous earth resulting from deposition of the exoskeletons of living organisms. It is generally only the crystalline forms which are fibrogenic which can cause inflammation resulting in scarring and progressive reduction in lung capacity for which there is no effective treatment (silicosis). The risk and the severity of damage are related to the size and shape of the particles, the concentration of particles and the length of time the person is exposed. Silicosis can only be caused by exposure to crystalline silica particles which are in the respirable size range. This is why only PM_{10} and $PM_{2.5}$ impacts are further reviewed in relation to silica exposures. The International Agency for Research on Cancer (IARC) has classified crystalline silica as carcinogenic to humans.

In relation to this project an assessment of potential silica exposures has been undertaken. The assessment has first determined the likely percentage of crystalline silica that may be present in the PM_{10} and $PM_{2.5}$ impacts predicted. The assessment has then compared the potential silica air concentrations against criteria established that are based on the protection of community health.

The project involves the handling and placement of rock/soil extracted from the construction of the NorthConnex project. This material largely comprises sandstone materials that are rich in quartz and hence there is the potential for community exposures to crystalline silica that will be present in the dust generated. The silica content of Sydney sandstone is reasonably well studied, with published quartz contents between 60% and 70% for “yellow block” sandstone and 70% to 80% for quartz rich (whiter) sandstone which are the materials likely to be extracted during the construction of the tunnel. From these materials an average quartz content of 70% can be assumed.

A number of guidelines are available for occupational exposures to crystalline silica (which is where most exposure occurs and where adverse health effects have been identified). In relation to non-occupational exposures the WHO (WHO 2000a) states “there are no known adverse health effects associated with the non-occupational exposures to quartz”.

The guidelines that are available in relation to non-occupational exposures relate to concentrations of crystalline silica present in various particle fraction sizes, In relation to $PM_{2.5}$ and PM_{10} criteria based on the protection of community health are available from the WHO (WHO 2000a) and in guidance from the Victorian EPA (EPA Victoria 2007).

It is noted that these criteria relate to the total community exposure to crystalline silica in air and hence background levels (i.e. the levels normally found in air) also need to be considered. No data has been collected for the area evaluated in this assessment however data is available from the Hunter Valley which has been assumed to be representative (and conservative) for the study area.

Table 4-7 presents a summary of the maximum predicted incremental $PM_{2.5}$ and PM_{10} impacts from the project (for Scenario 2 at the TAFE as well as the maximum residential receptor), the calculated silica concentration in these fractions, the adopted background concentration of silica in air, the total silica concentration and the relevant guidelines.

Table 4-7 Assessment of Silica Impacts

Aspect of assessment	**Scenario 2 – Maximum (TAFE)**		**Scenario 2 – Maximum Residential**	
	$PM_{2.5}$	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**
Incremental dust impact (annual average) µg/m^3	1.4	2.4	0.7	1.1
Incremental silica concentration, µg/m^3	0.98	1.7	0.49	0.77
Background silica concentration#, µg/m^3	0.61	1.9	0.61	1.9
Total silica exposure concentration, µg/m^3	**1.6**	**3.6**	**1.1**	**2.7**
Guidelines				
Victoria EPA*, µg/m^3	3		3	
WHO**, µg/m^3		8		8

Background levels based on measured respirable crystalline silica levels (for the fraction sizes) in the Hunter Valley (potentially conservative for the Hornsby area where ambient particulates are expected to dominated by combustion sources rather than crustal sources [as may be the case for the Hunter Valley]) (Morrison et al)

* Guideline available in the Protocol for Environmental Management: Mining and Extractive Industries. The criteria relates to respirable crystalline silica as $PM_{2.5}$ fraction size and is derived from the California EPA Office for Environmental Health Hazard Assessment (OEHHA) Reference Exposure Level (REL) (OEHHA 2005). It is noted that the OEHHA REL was derived for PM_4 and has been adopted by the Victorian EPA for $PM_{2.5}$.

** Guideline for respirable crystalline quartz as PM_{10}, based on lifetime exposures resulting in silicosis risks of less than 3% in a healthy population, and considered to be consistent with ambient levels of risk. The use of such a guideline is highly conservative for the assessment of silica exposures over a 33 month period, rather than a lifetime (taken to be 70 years for the assessment of cancer risk).

Review of the above table indicates that the potential respirable silica concentrations in air derived from the project are below health based criteria.

<u>US EPA Silicosis Potency Estimates</u>

The US EPA (1996) examined the non-cancer epidemiological literature on crystalline silica induced diseases. From the extensive data available, which examined the medical histories of thousands of miners, they concluded that the cumulative risk of developing silicosis is zero for cumulative exposures of less than 1000 $\mu g/m^3$.years.

Cumulative exposure is the average respirable crystalline silica concentration a person is exposed to over a period of time, multiplied by the number of years exposed. For example, an exposure of 1000 $\mu g/m^3$.years, would be experienced by an individual exposed to 14.3 $\mu g/m^3$ per year for 70 years. For cumulative exposures less than 1000 $\mu g/m^3$.years, the US EPA concludes that the risk of developing silicosis is zero.

For this project, the following has been calculated:

- The total respirable crystalline silica concentration (as annual average $PM_{2.5}$) is 1.6 $\mu g/m^3$
- The duration of the project is 33 months, which is 2.75 years
- The total silica exposure associated with the project is calculated to be 4.4 $\mu g/m^3$.years
- Silica exposures relevant to the remaining 75.25 years (assuming a lifetime of 78 years) to ambient/background levels of 0.61 $\mu g/m^3$ is 46 $\mu g/m^3$.years
- Total lifetime exposure from background plus the project is calculated to be 50.4 $\mu g/m^3$.years

The total cumulative risk of silicosis is well below 1000 $\mu g/m^3$.years and is therefore considered to be zero.

<u>Overall assessment</u>

Hence no adverse health impacts are expected as a result of exposure to silica emissions from the project.

4.5 Uncertainties

The modelling of particulate impacts involves the use of a number of assumptions in relation to the carrying out of the project and activities that result in the emission of dust to air. In addition, determining the dispersion of particulate matter from the project to the surrounding environment has utilised air dispersion models. While the approach adopted in the AQIA utilised published peer-reviewed emission estimation techniques, the currently available site-specific data on the carrying out of the project, site-specific meteorology and terrain data and approved models for the quantification of impacts in the surrounding areas, the overall approach adopted is generally conservative to ensure that where uncertainties are present, the impact is overestimated.

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Section 5. Review of noise and vibration impacts

5.1 Overview of the noise and vibration assessment

5.1.1 General

This section presents a summary of the technical working paper: noise and vibration (AECOM, 2015) (NVTP) that relates to the project. The assessment has been reviewed to determine if the predicted impacts have the potential to affect the health of the surrounding community and, if impacts are predicted, if they can be effectively mitigated.

The NVTP provides a more detailed evaluation of all the activities, and the duration of those activities, that may give rise to noise or vibration impacts in the surrounding community.

To undertake the noise assessment required for the project, the existing background noise quality is required as the guidelines that relate to noise impacts from a specific project are based on levels allowable above background (refer to **Section 3.5.2** for further detail). Background noise levels were measured at 4 locations in the study area, at locations considered representative of the local suburban area. Two additional roadside locations were monitored to determine existing road traffic noise levels. Noise assessment criteria were then established addressing activities in the quarry as well as road traffic.

Noise levels that are measured, or modelled, refer to noise levels over a specified period of time and are presented as L_{A1}, L_{A10}, L_{A90}, L_{Amax} and L_{Aeq} levels of the noise environment. The L_{A1}, L_{A10} and L_{A90} levels are the levels exceeded for one percent, 10 per cent and 90 per cent of the sample period respectively. The L_{Amax} is indicative of maximum noise levels due to individual noise events. The L_{A90} is taken as the rating background noise level (RBL). The L_{Aeq} is the energy averaged noise level over a defined period.

5.1.2 Noise assessment criteria

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

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

Construction noise

The ICNG has been adopted for the assessment of noise generated by the project. In relation to these guidelines, noise impacts from the project are predicted at sensitive receivers and compared with the criteria, referred to as management levels, outlined in the ICNG. Where an exceedance occurs, the guidelines advise that the proponent apply all feasible and reasonable work practices to minimise impacts. The management levels are based on levels of noise above background that may result in reactions (or complaints) by the community. The levels are based on some reaction (noise affected) and a strong reaction (highly noise affected).

During standard work hours (Monday to Friday 7am to 6pm and Saturday 8am to 1pm) the construction noise management level is set at the background level plus 10 dB(A). Where construction noise levels reach 75 dB(A) residential receivers can be considered as 'highly noise affected' and the proponent should, in consultation with the community, consider restricting hours to provide respite periods.

Levels of noise allowable outside standard work hours, particularly at night, are lower. For works undertaken outside of standard work hours the construction noise management level is set at the background level plus 5 dB(A). It is noted that no works outside of standard work hours are proposed as part of the project.

For non-residential areas noise management levels are outlined in the ICNG.

The assessment of noise impacts from the project has been undertaken based on 4 noise catchment areas (assumed to have background noise levels consistent with the background noise monitoring location within that catchment area).

Construction Road Noise

The ICNG does not provide direct reference to an appropriate criterion to assess the noise arising from construction traffic on public roads. However, as the RNP is the current state policy document for assessing road traffic noise and in the absence of an alternative guidance it has been used to assess the noise arising from construction traffic movements generated by the project. The RNP does not require assessment of noise impact to commercial or industrial receivers. Based on this guidance the external noise criteria (applied 1 m from the external façade of a building) is set at:

- 60 dB(A) $LA_{eq,15hr}$ between 7 am and 10 pm and 55 dB(A) $LA_{eq,9hr}$ between 10 pm and 7 am for arterial/sub-arterial roads.
- 55 dB(A) $LA_{eq,15hr}$ between 7 am and 10 pm and 50 dB(A) $LA_{eq,9hr}$ between 10 pm and 7 am for local roads (including Bridge Road).

It is noted that as no works or haulage to the site is proposed outside of standard work hours the night time criteria (10 pm to 7 am) are not applicable to the project.

In cases where existing traffic noise levels are above the noise assessment criteria, the primary objective is to reduce these through feasible and reasonable measures to meet the assessment criteria. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

Vibration criteria

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

In relation to human comfort, intermittent vibration has been evaluated on the basis of the Environment Protection Authority guideline Assessing Vibration: A Technical Guideline (Department of Environment and Conservation, 2006), which is based on vibration dose values (VDV). The criteria for VDV are based on the potential for annoyance (based on the level of vibration over the assessment period). Guidelines for continuous and impulsive vibration are dependent on the time of day and the activity taking place. The criteria established for these vibration types are based on the potential for adverse comment (complaint) and disturbance to building occupants.

The structural damage guidelines adopted are the German Standard DIN 4150 (as there are no Australian Standards available).

Ground-borne noise

Noise from activities such as vibratory rolling or tunnelling are assessed on the basis of criteria outlined in the ICNG for the day-time and night-time. These criteria are based on amenity and sleep disturbance when people are at home.

5.2 Impacts

5.2.1 Noise impacts

The assessment of noise impacts has considered the activities proposed to be undertaken (and equipment to be used) as well as the work hours and overall duration of the activities.

During standard work hours the assessment has identified a number of sensitive receivers in the community (including some classrooms at Hornsby TAFE) where noise management levels (NML) are exceeded. No sensitive receivers are identified as highly noise affected. The exceedance of the NML is typical of a construction project and highlights the need for a detailed Construction Noise and Vibration Management Plan (CNVMP) to ensure that all feasible and reasonable noise management and mitigation measures are employed. The NVTP has outlined a range of management and mitigation measures to be considered in the project.

Cumulative noise impacts from the project as well as maintenance pumping of the quarry void (by council) have also been assessed. In general the predicted noise impacts are not changed by the additional consideration of pumping activities. The exception to this is during the conveyer construction phase where noise levels could increase, however the increase would be by less than 1dB(A), and the cumulative impacts are unlikely to affect sensitive receivers.

No out of hours work is proposed to be undertaken and hence no noise impacts are assessed for these periods of time.

Review of the impact of road traffic (for the initially proposed peak number of 50 movements per hour into the site) on noise levels has identified that the predicted increase for sub-arterial and arterial roads during the morning and afternoon peak periods (less than 2 dB) meets the recommended noise goal. However, noise level increase for Bridge Road, the only affected local road, is predicted to be exceeding the 2 dB(A) increase criterion.

A sensitivity analysis was undertaken to determine a more manageable number of movements that would achieve compliance. To achieve compliance, it was considered that a maximum of 10 movements per hour would be required. However this number of movements is not considered feasible to meet project requirements of efficient spoil disposal in line with the rate of spoil generation at the tunnel excavation sites. To ensure the potential traffic noise impact from the project is minimised as far as practicable, while still allowing a reasonable volume of material to be hauled in to the site, the maximum number of movements per hour into the site was decreased to 35. This decrease reduced the exceedance on bridge Road to 7 to 10 dB(A) depending on the time of day. Whilst these levels are still non-compliant, they are considered a realistic balance between the project's objectives and ensuring noise impacts are minimised as far as reasonably and feasibly possible.

Additional feasible and reasonable noise management and mitigation measures would be considered for all residual noise exceedances and recommendations have been provided in the NVTP. Further noise mitigation management measures, including hoarding would be investigated by the Contractor and presented in the CNVMP. Residents would also be consulted to ensure that the most appropriate combination of noise mitigation will be implemented to minimise the impacts on sensitive receivers.

As a result of the assessment undertaken a CNVMP would be prepared. The CNVMP would address the following:

- Identification of nearby residences and other sensitive land uses.
- Description of approved hours of work.
- Description and identification of all project activities, including work areas, equipment and duration.
- Description of what work practices (generic and specific) would be applied to minimise noise and vibration. This would include feasible and reasonable mitigation measures to manage predicted noise and vibration impacts.
- A complaints handling process.
- Noise and vibration monitoring procedures.
- Overview of community consultation required for identified high impact works.
- Cumulative noise impacts of the maintenance pumping of the quarry void.

5.2.2 Vibration impacts

The assessment undertaken considered that given the site layout and existing offset distances to sensitive receivers it is unlikely that the proposed activities would result in exceedance of vibration criteria relevant to structural damage or human comfort. Where work is required to be undertaken during the site establishment phase closer to sensitive receivers a review of the equipment proposed to be used, with alternative equipment (with lower potential for vibration impacts) would be implemented/used.

Impacts associated with vibration are to be addressed, mitigated or managed, using measures to be outlined in the Construction Noise and Vibration Management Plan.

5.3 Health outcomes relevant to noise

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

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

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

- Sleep disturbance.
- Annoyance.
- Hearing impairment.
- Interference with speech and other daily activities.
- Children's school performance (through effects on memory and concentration).
- Cardiovascular health.

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

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects).
- Effects on the performance of cognitive tasks.
- Some evidence of indirect effects such as impacts on the immune system.

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

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

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

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

In relation to the project, potential noise impacts have been assessed against Australian (more specifically New South Wales) criteria that have been established on the basis of the relationship between noise and health impacts. The criteria developed for use in the assessment for control of noise come from policy documents developed by the NSW Government including the NSW Interim Construction Noise Policy, and the NSW Road Noise Policy. These policies are based on the health effects of noise, and are based on guidance and reviews published in the following:

- World Health Organisation- Guidelines on Community Noise – Health effects of noise (WHO 1999).
- World Health Organisation – Night Noise Guidelines for Europe (WHO 2009).
- Environmental Health Council of Australia - The health effects of environmental noise – other than hearing loss (enHealth 2004).

Various attempts have been made to assess the effect (measured by average reported annoyance, sleep disturbance or a similar type of effect) from community noise (measured by long term average sound levels) to develop exposure-response relationships. As individual reactions to noise are so varied, these studies need large sample sizes to obtain reasonable correlation between the noise exposure and the response. Any dose-response relationship determined from large studies over a range of communities and cultures will not necessarily represent the reaction of individuals or small communities.

These exposure-response relationships are of value for macro-scale (i.e. whole urban environment scale) strategic assessment purposes where individual differences are not important, however they are not useful when considering potential impacts to a small population located close to a specific project/activity. Hence these macro-scale relationships cannot be applied (in any meaningful way) in this assessment.

As guidelines/criteria are available for noise and vibration impacts associated with this project, that are based on the protection of health (including annoyance), the assessment of potential health impacts has focused on whether the guidelines/criteria established can be met. Noise levels that do not comply with these guidelines/criteria may have the potential to have negative health outcomes for the community adjacent to the project. The guidelines in relation to construction noise provides management levels that require assessment of noise impacts and implementation of practical and feasible management measures to minimise impacts. Where this process is followed, and where project works are only expected to occur for a relatively short period of time (as is the case with the proposed project, when compared to permanent operations) no adverse health effects are expected to occur in the community.

Currently, the worst case assessment predicts that noise criteria would be exceeded at a number of properties without additional noise mitigation measures. Detailed consideration of feasible and reasonable mitigation measures will determine the suite of measures that will achieve the most effective outcome for affected receivers. These measures will be detailed within the CNVMP and implemented to manage predicted impacts at sensitive receivers. Consultation with the affected community would also occur prior to and during the project.

Where the proposed noise management and mitigation measures are adopted, no adverse health impacts are exposure in the local community.

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Section 6. Conclusions

An assessment of health impacts associated with emissions to air as well as noise and vibration resulting from the project has been undertaken.

In relation to impacts to air quality, potential health impacts have been evaluated on the basis of appropriate health based guidelines (that are protective of public health), or, in the case of exposure to $PM_{2.5}$ and PM_{10} conducting a detailed assessment of the impact of the emissions on key community health indicators. All predicted concentrations of carbon monoxide, nitrogen dioxide, key individual volatile organic compounds and polycyclic aromatic hydrocarbons are below health based guidelines.

For the assessment of potential impacts of $PM_{2.5}$ and PM_{10} the following has been determined:

- Potential concentrations of silica that may be present in $PM_{2.5}$ and PM_{10} dust emissions are not considered to be of concern for community health.
- Calculated risks associated with exposures to PM_{10} and $PM_{2.5}$ (including DPM) from emissions from trucks on the haulage route roads are not considered to be of concern for community health.
- In relation to the proposed activities at the Hornsby Quarry site, where best practice mitigation measures are considered, risks are considered to be tolerable.
- Where risks are determined to be tolerable, it is expected that mitigation measures would be implemented to minimise exposures associated with the project. For this project, air impacts and hence health risks are proposed to be further minimised through the implementation of best industry practice dust management and mitigation measures. Such measures would result in lower levels of exposure and risk at all receptors in the surrounding community.

In relation to noise and vibration, potential impacts associated with the project have been considered. The worst case assessment predicts that noise criteria would be exceeded at a number of properties without additional noise mitigation measures. Feasible and reasonable mitigation measures would be detailed within the CNVMP to manage and mitigate predicted noise levels at sensitive receivers. In addition consultation with the affected community would also occur prior to and during the project. Where the proposed noise management and mitigation measures are adopted, no adverse health impacts are expected in the local community.

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Appendix A Methodology for Detailed Assessment of Exposure to $PM_{2.5}$ and PM_{10}

A1 Summary of adverse health effects

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

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

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

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

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

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

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

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

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

The detailed assessment of potential health effects associated with exposure to emissions associated with the project has focused on health effects and exposure-response relationships[12] that are robust and relate to $PM_{2.5}$, being the more important particulate fraction size relevant for emissions from combustion sources. These health effects (or endpoints) have been identified and agreed with NSW Health and include the following:

- Primary health endpoints:
    - Long-term exposure to $PM_{2.5}$ on all-cause mortality (≥ 30 years of age).
    - Short-term exposure on the rate of hospitalisation with cardiovascular and respiratory disease (≥ 65 years of age).
- Secondary health endpoints (to supplement the primary assessment):
    - Long-term exposure to $PM_{2.5}$ on cardiopulmonary mortality (≥ 30 years of age).
    - Short-term exposure to $PM_{2.5}$ on mortality (all causes, cardiovascular and respiratory, all ages).
    - Short-term exposure to PM_{10} on mortality (all causes and all ages).

A2 Exposure-response relationships

Mortality and morbidity health endpoints

A quantitative assessment of risk for these endpoints uses a mathematical relationship between an exposure concentration (ie concentration in air) and a response (namely a health effect). This relationship is termed an exposure-response relationship and is relevant to the range of health effects (or endpoints) identified as relevant (to the nature of the emissions assessed) and robust. An exposure-response relationship can have a threshold, where there is a safe level of exposure,

[12] An exposure-response relationship is a quantitative relationship between an exposure concentration of particulate matter in air (what is inhaled) and the health effect evaluated.

below which there are no adverse effects; or the relationship can have no threshold (and is regarded as linear) where there is some potential for adverse effects at any level of exposure.

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

A range of exposure-response relationships are available from the many studies that have been undertaken and published. Review of the available studies has been undertaken in Australia for the purpose of developing the NEPC Air Quality Guidelines (Burgers & Walsh 2002; NEPC 2002, 2010), where a range of health endpoints and exposure-response relationships were identified and evaluated. Similar exposure-response relationships have been considered in the development and review of air guidelines established by the WHO (WHO 2005) and the USEPA (USEPA 2012). These organisations have identified which of the available relationships that have been identified are the most robust.

The exposure-response relationships adopted in this assessment have been identified on the basis of the studies considered in the development of the NEPC Air Quality Guidelines as well as updated supporting studies published in the literature.

The assessment of potential risks associated with exposure to particulate matter involves the calculation of a relative risk (RR). For the purpose of this assessment the shape of the exposure response function used to calculate the relative risk is assumed to be linear[13]. The calculation of a relative risk based on the change in relative risk exposure concentration from baseline/existing (ie based on incremental impacts from the project) can be calculated on the basis of the following equation (Ostro 2004):

$$RR = exp[\beta(X\text{-}X_0)] \qquad \text{…Equation 1}$$

Where:

$X\text{-}X_0$ = the change in particulate matter concentration to which the population is exposed (µg/m^3)

β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per 1 µg/m^3 increase in particulate matter exposure.

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[13] Some reviews have identified that a log-linear exposure response function may be more relevant for some of the health endpoints considered in this assessment. Review of outcomes where a log-linear exposure-response function has been adopted (Ostro 2004) for $PM_{2.5}$ identified that the log-linear relationship calculated slightly higher relative risks compared with the linear relationship within the range 10-30 µg/m^3,(relevant for evaluating potential impacts associated with air quality goals or guidelines) but lower relative risks below and above this range. For this assessment (where impacts from a particular project are being evaluated) the impacts assessed relate to concentrations of $PM_{2.5}$ that are well below 10 µg/m^3 and hence use of the linear relationship is expected to provide a more conservative estimate of relative risk.

Based on this equation, where the published studies have derived relative risk values that are associated with a 10 µg/m^3 increase in particulate matter exposure (as presented in **Table A-**1), the β coefficient can be calculated using the following equation:

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

Where:

RR = relative risk for the relevant health endpoint as published and listed in **Table 5-1** (µg/m^3)

10 = increase in particulate matter concentration associated with the RR (all the RR presented in **Table 5-1** are associated with a 10 µg/m^3 increase in particulate matter exposure).

Table A-1 presents a summary of the health endpoints considered in this assessment, the relevant health impact functions (from the referenced published studies) and the associated β value relevant to the calculation of a relative risk.

The health impact functions presented in this table have been discussed and agreed with NSW Health as the most current and appropriate for the quantification of potential health effects for the health endpoints considered in this assessment.

Table A-1 Adopted health impact functions and exposure-responses relationships

Health endpoint	Exposure period	Age group	Published relative risk [95% confidence interval] per 10 µg/m^3	Adopted β coefficient (as %) for 1 µg/m^3 increase in PM	Reference
Primary assessment health endpoints					
PM2.5: Mortality, all causes	Long-term	≥30yrs	1.06 [1.04-1.08]	0.0058 (0.58%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009). This study is an extension (additional follow-up and exposure data) of the work undertaken by Pope (2002), is consistent with the findings from California (1999-2002) (Ostro et al. 2006) and is more conservative than the relationships identified in a more recent Australian and New Zealand study (EPHC 2010).
PM2.5: Cardiovascular hospital admissions	Short-term	≥65yrs	1.008 [1.0059-1.011]	0.0008 (0.08%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 0 (exposure on same-day)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
PM2.5: Respiratory hospital admissions	Short-term	≥65yrs	1.0041 [1.0009-1.0074]	0.00041 (0.041%)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 2 (exposure 2 days previous)(strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
Secondary assessment health endpoints					
PM10: Mortality, all causes	Short-term	All ages*	1.006 [1.004-1.008]	0.0006 (0.06%)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
PM2.5: Mortality, all causes	Short-term	All ages*	1.0094 [1.0065-1.0122]	0.00094 (0.094%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
PM2.5: Cardiopulmonary Mortality	Long-term	≥30yrs	1.14 [1.11-1.17]	0.013 (1.3%)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500 000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009).
PM2.5: Cardiovascular mortality	Short-term	All ages*	1.0097 [1.0051-1.0143]	0.00097 (0.097%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
PM2.5: Respiratory mortality (including lung cancer)	Short-term	All ages*	1.0192 [1.0108-1.0278]	0.0019 (0.19%)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

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

Exposure to diesel particulate matter

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

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

Data from the USEPA (USEPA 2002) indicates that diesel exhaust as measured as diesel particulate matter made up about six per cent of the total ambient/urban air $PM_{2.5.}$ In this project, emissions to air from the carrying out of the project include a significant proportion of diesel powered vehicles (100 per cent of the HGVs and 49.9 per cent of the LDVs). Available evidence indicates that there are human health hazards associated with exposure to diesel particulate matter. The hazards include acute exposure-related symptoms, chronic exposure related non-cancer respiratory effects, and lung cancer.

In relation to non-carcinogenic effects, acute or short-term (eg episodic) exposure to diesel particulate matter can cause acute irritation (eg eye, throat, bronchial), neurophysiological symptoms (eg light-headedness, nausea), and respiratory symptoms (cough, phlegm). There also is evidence for an immunologic effect–exacerbation of allergenic responses to known allergens and asthma-like symptoms. Chronic effects include respiratory effects. The review of these effects (USEPA 2002) identified a threshold concentration for the assessment of chronic non-carcinogenic effects. The review conducted by the USEPA also concluded that exposures to diesel particulate matter also consider $PM_{2.5}$ goals (as these also address the presence of diesel particulate matter in urban air environments). The review found that the diesel particulate matter chronic guideline will also be met if the $PM_{2.5}$ guideline was met. Review of exposure to $PM_{2.5}$ has been assessed separately in relation to the current ambient air guidelines (refer to **Section 4.4.4**) where cumulative impacts of $PM_{2.5}$ for the project have been found to comply with the NEPC $PM_{2.5}$ advisory goal. Hence non-carcinogenic effects associated with exposure to diesel particulate matter are not considered to be of concern.

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

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

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

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

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

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

A3 Particulate impact assessment

Quantification of impact and risk

The assessment of health impacts for a particular population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004)[14] where the exposure-response relationships (presented in **Table A-1**) have been directly considered on the basis of the approach outlined below.

[14] For regional guidance, such as that provided for Europe by the WHO ((WHO 2006a)) regional background incidence data for relevant health endpoints are combined with exposure-response functions to present an impact function, which is expressed as the number/change in incidence/new cases per 100,000 population exposed per µg/m^3 change in particulate matter exposure. These impact functions are simpler to use than the approach adopted in this assessment, however in utilising this approach it is assumed that the baseline incidence of the health effects is consistent throughout the whole population (as used in the studies) and is specifically applicable to the sub-population group being evaluated. For the assessment of exposures in the areas evaluated surrounding the project it is more relevant to utilise local data in relation to baseline incidence rather than assume that the population is similar to that in Europe (where these relationships are derived).

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

- Estimates of the changes in particulate matter exposure levels (ie incremental impacts) due to the project for the relevant modelled scenarios (as provided by the AQIA);
- Estimates of the number of people exposed to particulate matter at a given location (ie population data);
- Baseline incidence of the key health endpoints that are relevant to the population exposed; and
- Exposure-response relationships expressed as a percentage change in health endpoint per µg/m^3 change in particulate matter exposure, where a relative risk (RR) is determined (refer to Equation 1).

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

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

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

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

$$E=AF \times B \times P \quad \text{… Equation 4}$$

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

The above approach (while presented slightly differently) is consistent with that presented in Australia (Burgers & Walsh 2002), US (OEHHA 2002; USEPA 2005, 2010) and Europe (Martuzzi et al. 2002; Sjoberg et al. 2009). Where a linear dose-response is assumed (as is the case in this assessment), the calculations are equivalent to the following:

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

- Equation 1 has been used to calculate a relative risk. The relative risk has been calculated for a population weighted annual average incremental increase in $PM_{2.5}$ concentrations. The population weighted average has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics within a suburb (i.e. mesh blocks – which are small blocks that cover an area of approximately 30 urban residences). For each mesh block in a suburb the average incremental increase in $PM_{2.5}$ concentration has been calculated and multiplied by the population living in the mesh block (data available from the ABS for the 2011 census year). The weighted average has been calculated by summing these calculations for each mesh block in a suburb and dividing by the total population in the suburb (i.e. in all the mesh block).
- Equation 3 has been used to calculate an attributable fraction.
- Equation 4 has been used to calculate the increased number of cases associated with the incremental $PM_{2.5}$ impact evaluated. The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered and the population (for the relevant age groups) present in the suburb.

The above approach can be simplified (mathematically, where the incremental change in particulate concentration is low, less than 1 µg/m^3) as follows:

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

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m^3 change in particulate matter exposure (as per **Table 5-1**)
B = baseline incidence of a given health effect per person (eg annual mortality rate)
ΔX_{mesh} = change (increment) in PM_{10} or $PM_{2.5}$ exposure concentration in µg/m^3 as an average within a small area defined as a mesh block (from the ABS – where many mesh blocks make up a suburb)
P_{mesh} = population (residential – based on data from the ABS) within each small mesh block

An additional risk can then be calculated as:

$$Risk=\beta \times \Delta X \times B \quad \text{… Equation 6}$$

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m^3 change in particulate matter exposure (as per **Table 5-1**)
ΔX = change (increment) in PM_{10} or $PM_{2.5}$ exposure concentration in µg/m^3 relevant to the project at the point of exposure
B = baseline incidence of a given health effect per person (eg annual mortality rate)

This calculation provides an annual risk for individuals exposed to increased PM emissions from the project at specific locations (such as the maximum, or at specific sensitive receiver locations).

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

Carcinogenic Risk (inhalation) = Exposure Concentration in Air x Inhalation Unit Risk

Quantification of short-and long-term effects

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

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

Short-term effects are also assessed on the basis of an exposure-response function that is expressed as a percentage change in endpoint per $\mu g/m^3$ change in particulate matter exposure. For short-term effects, the calculations relate to daily increases in particulate matter exposures and changes in daily effects endpoints. While it may be possible to measure daily incidence of the evaluated health endpoints in a large population study specifically designed to include such data, it is not common to collect such data in hospitals nor are effects measurable in smaller communities. Instead these calculations relate to a parameter that is measurable, such as annual incidence of hospitalisations, mortality or lung cancer risks. The calculation of an annual incidence or additional risk can be undertaken using two approaches (Ostro 2004; USEPA 2010):

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

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

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

Hence for the calculations presented in this technical working paper, for both long-term and short-term effects, annual average concentrations of particulate matter have been utilised.

A4 Uncertainties

Exposure-response function

The choice of exposure-response functions for the quantification of potential health impacts is important. For mortality health endpoints, many of the exposure-mortality functions have been replicated throughout the world. While many of these have shown consistent outcomes, the calculated relative risk estimates for these studies do vary. This is illustrated by **Figures A-1** to **A-3** that show the variability in the relative risk estimates calculated in published studies for the US (and Canadian) population that are relevant to the primary health endpoints considered in this assessment (USEPA 2012). A similar variability is observed where additional studies from Europe, Asia and Australia/New Zealand are considered.

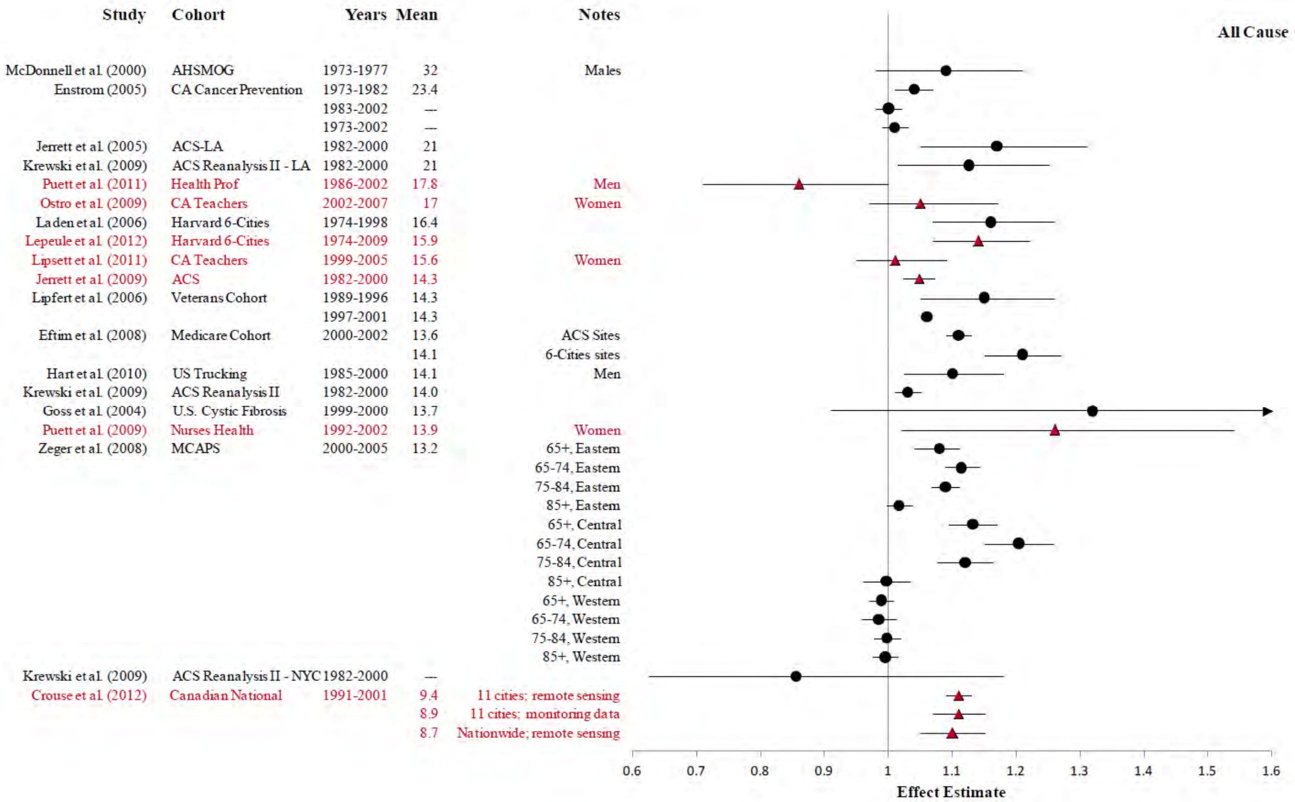

Figure A-1 **All-cause mortality relative risk estimates for long-term exposure to $PM_{2.5}$** (USEPA 2012, note studies in red are those completed since 2009)

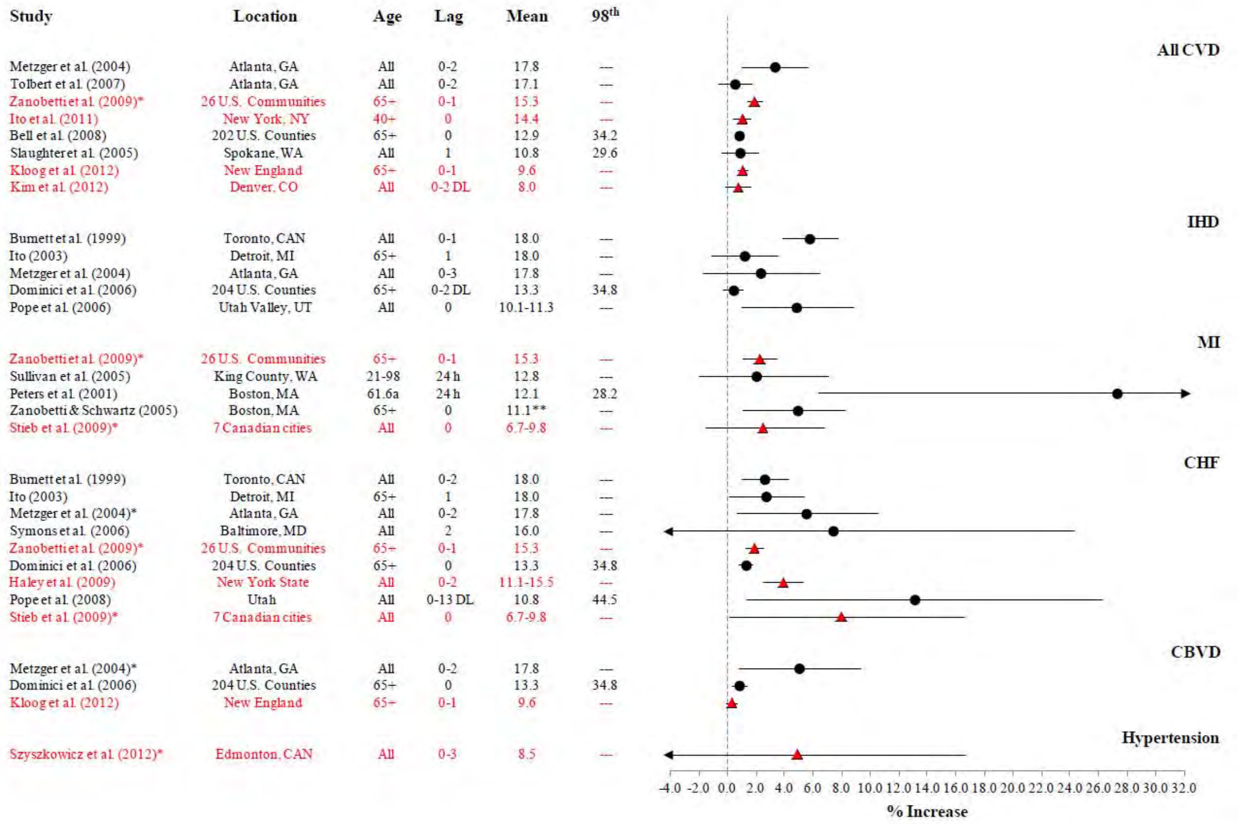

Figure A-2 Per cent increase in cardiovascular-related hospital admissions for a 10 µg/m³ increase in short-term (24-hour average) exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)

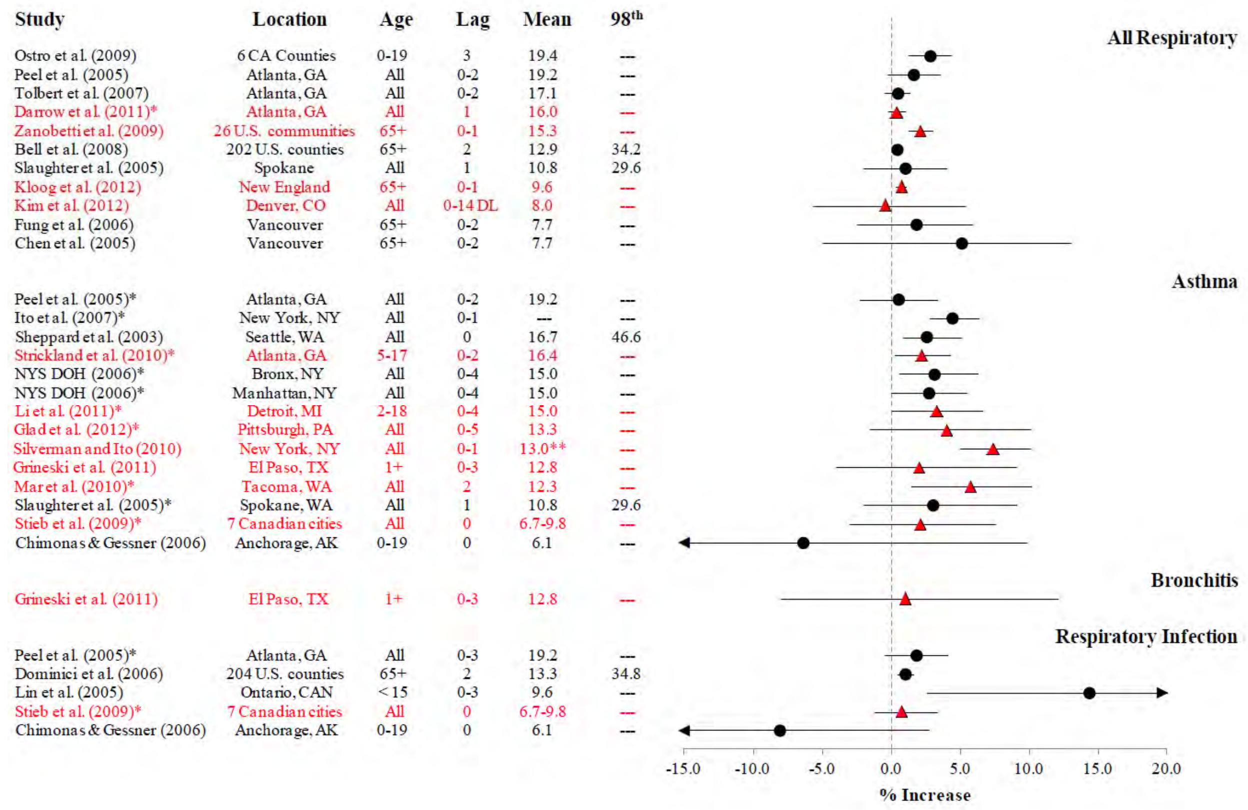

Figure A-3 **Per cent increase in respiratory-related hospital admissions for a 10 µg/m³ increase in short-term (24-hour average) exposure to $PM_{2.5}$** (USEPA 2012, note studies in red are those completed since 2009)

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

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

Shape of exposure-response function

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

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

Co-pollutants

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

Selected health outcomes

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

Application of exposure-response functions to small populations

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

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

Diesel particulate matter evaluation

The health hazard conclusions associated with exposure to diesel particulate matter are based on studies that are dominated by exhaust emissions from diesel engines built prior to the mid-1990s. With current engine use including some new and many older engines (engines typically stay in service for a long time), the health hazard conclusions, in general, are likely to be applicable to engines currently in use. However as new and cleaner diesel engines, together with different diesel fuels, replace a substantial number of existing engines; the general applicability of the health hazard conclusions may require further evaluation. The NEPC (NEPC 2009) has established a program to reduce diesel emissions from the Australian heavy vehicle fleet. This is expected to lower the potential for all diesel emissions over time.

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