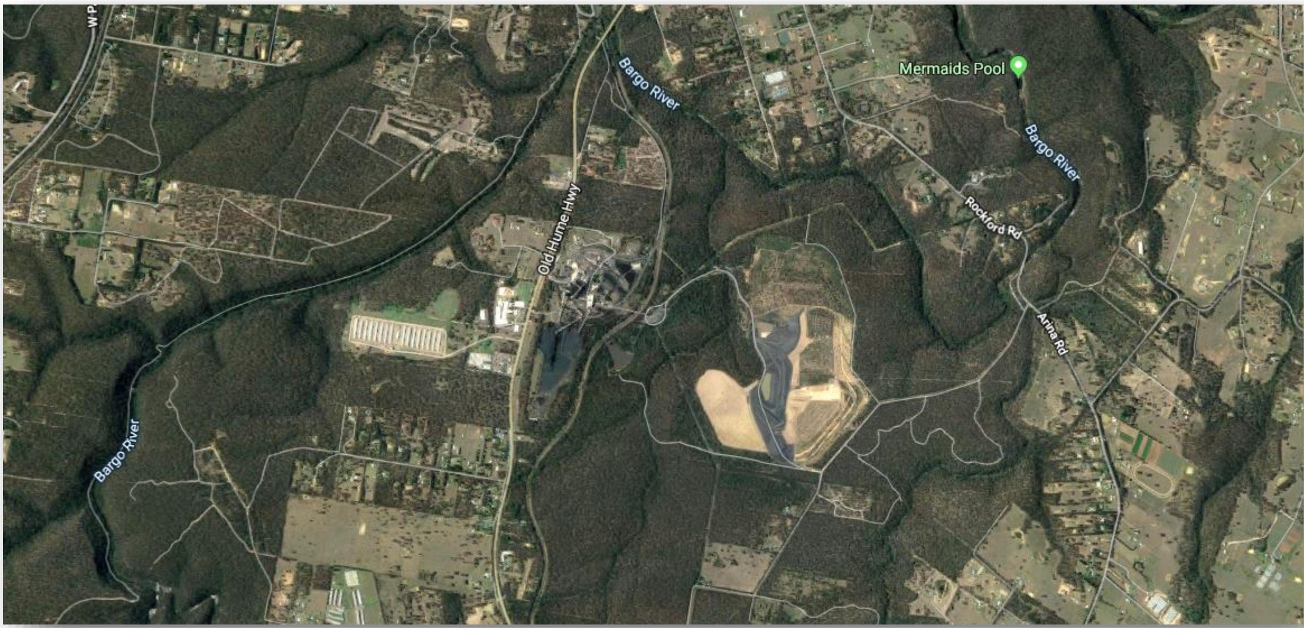
APPENDIX N

Health Impact Assessment



Tahmoor South Project: Health Impact Assessment

Prepared for: SIMEC Mining Division

19 February 2020

Document History and Status

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Limitations

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It is prepared in accordance with the scope of work and for the purpose outlined in the Section 1 of this report.

The methodology adopted, and sources of information used are outlined in this report. 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 provided for use in this assessment was false.

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Appendices

Glossary of Terms and Abbreviations

Term	Definition
ABS	Australian Bureau of Statistics.
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.
Aerodynamic diameter	Airborne particles have irregular shapes, their aerodynamic behaviour is expressed in terms of the diameter of an idealised spherical particle.
AIHW	Australian Institute of Health and Welfare.
ANZECC	Australia and New Zealand Environment and Conservation Council.
ATSDR	Agency for Toxic Substances and Disease Register.
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.
Carcinogen	A substance that causes cancer.
CCME	Canadian Council of Ministers of the Environment.
CHPP	Coal handling and preparation plant.
Chronic exposure	Contact with a substance or stressor that occurs over a long time (more than one year) [compare with acute exposure and intermediate duration exposure].
CL	Coal Lease.
COMEAP	Committee on the Medical Effects of Air Pollutants.
dB(A)	Decibels (A-weighted).
DEC	NSW Department of Environment and Conservation.
DECC	NSW Department of Environment and Climate Change.
DECCW	NSW Department of Environment, Climate Change and Water.
DEFRA	Department for Environment, Food & Rural Affairs.
DEH	Australian Department of Environment and Heritage (now DoEE, as below).
Detection limit	The lowest concentration of a substance that can reliably be distinguished from a zero concentration.
DoEE	Department of Environment and Energy.
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.
EIS	Environmental Impact Statement.
EL	Exploration Licence.
EPHC	Environment Protection and Heritage Council.
EU	European Union.

Term	Definition
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Also includes contact with a stressor such as noise or vibration. 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 endpoint (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 substance 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 receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Genotoxic carcinogen	These are carcinogens that have the potential to result in genetic (DNA) damage (gene mutation, gene amplification, chromosomal rearrangement). Where this occurs, the damage may be sufficient to result in the initiation of cancer at some time during a lifetime.
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 Organization (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 would have different names, such as investigation level, trigger value and ambient guideline.
HHRA	Human health risk assessment.
HI	Hazard Index.
IARC	International Agency for Research on Cancer.
ICNG	Interim Construction Noise Guideline.
I-INCE	International Institute of Noise Control Engineering.
Inhalation	The act of breathing.
Intermediate exposure	Contact with a substance that occurs for more than 14 days and less than a year [compared with acute exposure and chronic exposure].
LGA	Local Government Area.
LOAEL	Lowest-observed-adverse-effect level.
LOR	Limit of Reporting.
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism.
ML	Mining Lease.
Morbidity	This is the condition of being ill, diseased or unhealthy. This can include acute illness (which has a sudden onset and may improve or worsen over a short period of time) as well as chronic illness (which can present and progress slowly over a long period of time).
Mortality	This is the condition of being dead. It may be presented as the number of deaths in a population over time, either in general or due to a specific cause.
NCAs	Noise catchment areas.
NEPC	National Environment Protection Council.

Term	Definition
NEPM	National Environment Protection Measure.
NHMRC	National Health and Medical Research Council.
NO_2	Nitrogen dioxide.
NOx	Nitrogen oxides.
NSW	New South Wales.
NSW EPA	NSW Environment Protection Authority.
OEH	NSW Office of Environment and Heritage.
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA).
PM	Particulate matter.
PM_1	Particulate matter of aerodynamic diameter 1 micrometre (µm) and less (termed ultrafine particles).
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 micrometres (µm) and less.
PM_{10}	Particulate matter of aerodynamic diameter 10 micrometres (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).
RBL	Rating Background Level.
Receptor population	People who could come into contact with hazardous substances [see exposure pathway].
Risk	The probability that something would cause injury or harm.
ROM	Run-of-mine.
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].
SEARs	Secretary's Environmental Assessment Requirements.
SEIFA	Socio-Economic Index for Areas.
SIA	Social Impact Assessment.
TCEQ	Texas Commission on Environmental Quality.
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 substance 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, summarises, 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 particulates.
UK	United Kingdom.
US	United States of America.
USEPA	United States Environmental Protection Agency.
WHO	World Health Organization.
$\mu g/m^3$	Micrograms per cubic metre.
µm	Micrometre.

Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by SIMEC Mining Division (SIMEC) with a proposal to undertake a Health Impact Assessment (HIA) for the Tahmoor Coal Mine (Tahmoor Mine) located approximately 75 km south of Sydney in New South Wales. The mine is operated by Tahmoor Coal, which is a wholly owned entity within the SIMEC Mining Division of the GFG Alliance.

Tahmoor Mine has been operating as an underground coal mine since 1979, using longwall mining methods since 1987. The mine produces up to 3 Mt of Run-of-Mine (ROM) coal per annum. Operations in the current domain of Tahmoor North are expected to be complete around 2022. Without investment into other mining domains, the mine and operations at Tahmoor would close.

The proposed Project is the Tahmoor South project, which involves the development of coal resources to the south of the current mine infrastructure within the Bargo mining lease (CCL747). This Project would provide the opportunity to extend the life of the Central Domain for a further 13 years.

- The Tahmoor South Project will utilise existing mining infrastructure and assets, as well as the following:
    - Extract and process up to 4 Mt per annum of ROM coal from longwalls within the Central Domain;
    - Continue use of existing mine ventilation shafts and the construction of 2 additional mine ventilation shafts;
    - Transport product coal via rail to Port Kembla Coal Terminal and occasionally Newcastle Port Waratah using existing rail infrastructure;
    - Transport up to 200,000 tonnes per annum of either product coal or reject material via road;
    - Continue use of ancillary infrastructure and services until 2035;
    - Upgrade and augment existing surface facilities, amenities, equipment and infrastructure to accommodate the extension of mining; and
    - Rehabilitate the Surface Facilities Area and associated infrastructure following completion of mining.

Tahmoor Coal submitted the Environmental Impact Statement (EIS) for the Project to the Department of Planning and Environment (DPE) in December 2018. Responses to the EIS by South Western Sydney Local Health District (SWSLHD) recommended that a formal HIA, addressing impacts to air quality, noise, water and social issues, be undertaken for the Project. This report relates to the completion of the HIA, as requested by SWSLHD.

The conduct of a HIA is intended to provide a structured, solution-focused and action-oriented approach to maximising positive and minimise negative health impacts of the Project. The assessment involves identification and assessment of severity and likelihood of positive and negative impacts (either direct or indirect); identify ways in which the proposal can enhance or strengthen health; identify and address underlying social, economic and environmental impacts of the proposal on health; and communicate risks to stakeholders.

1.2 Objectives

The overall objective of the HIA presented in this report is to evaluate and assess health impacts from the Project that relate to changes to air quality, noise, water quality and social impacts.

This report addresses impacts relevant to community health. No assessment of impacts to on-site workers is presented. Workplace health and safety is expected to be managed separately through application of the NSW *Work Health and Safety Act 2011* and NSW *Work Health and Safety (Mines and Petroleum Sites) Act 2013*, and associated regulations.

1.3 Approach and scope of works

The HIA has been undertaken in accordance with the following guidance:

- Harris, P., Harris-Roxas, B., Harris, E. & Kemp, L., Health Impact Assessment: A Practical Guide, Centre for Health Equity Training, Research and Evaluation (CHETRE). Part of the UNSW Research Centre for Primary Health Care and Equity. University of New South Wales, Sydney, 2007;
- enHealth, 2012. Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards; and
- enHealth, 2017. Health Impact Assessment Guidelines.

In addition to the above, the following guidelines have also been utilised, where relevant:

- State Environmental Planning Policy No. 33 - Hazardous and Offensive Development (NSW Government 2014).
- National Environment Protection Council (NEPC) National Environment Protection (Ambient Air Quality) Measure (NEPM) (NEPC 2016).
- National Environmental Protection Measure – Assessment of Site Contamination including:
    - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013a).
    - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013b).
    - Schedule B6 Guideline on Risk Based Assessment of Groundwater Contamination (NEPC 1999 amended 2013c).
    - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013d).
    - Schedule B8 Guideline on Community Consultation and Risk Communication (NEPC 1999 amended 2013e).

- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA 2016b)[1].
- NSW Noise Policy for Industry (NSW EPA 2017).
- National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (NHMRC 2011 updated 2018).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).

Where relevant, additional guidance has been obtained from relevant Australian and International guidance, such as that available from the United States Environmental Protection Agency (USEPA) and the World Health Organisation (WHO), consistent with current industry best practice.

The above guidance requires the consideration of impacts that relate to a wider definition of health and well-being within the community. Health and health inequalities are affected by a wide range of factors, as illustrated in **Figure 1**. These factors may be affected by a specific Project in different ways. In some cases, the changes will result in negative impacts on health (and hence the HIA needs to determine what these impacts are and how they can be minimised) or positive impacts or benefits (and it is important that the HIA identified these and if these benefits can be enhanced).

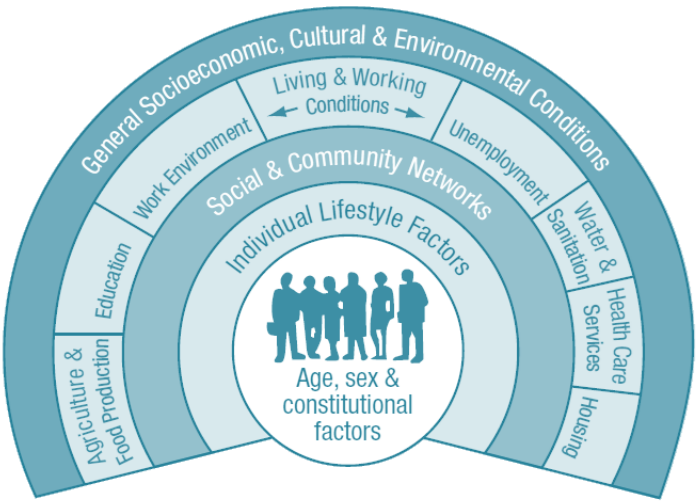

Figure 1: Wider determinants of health, as presented by Harris et al (2007)

1.4 Available information

The HIA has been prepared on the basis of information available in the EIS completed for the Project. More specifically the HIA has considered the information provided in the following specialist reports prepared for the EIS:

- ERM 2020, Tahmoor South Project, Air Quality Impact Assessment. Report dated February 2020 (AQIA).
- EMM 2018, Tahmoor South Project, Noise and vibration impact assessment. Report dated November 2018 and included as Appendix M to the EIS.

[1] NSW EPA – NSW Environment Protection Authority.

- EMM 2020, Tahmoor South Project, Noise and vibration impact assessment. Report dated February 2020.
- HEC 2020, Tahmoor South Project, Surface Water Baseline Study; Flood Study; Water Management System and Site Water Balance, and Surface Water Impact Assessment. Report issued as an update to the EIS.
- HydroSimulations, 2018. Tahmoor South Project EIS, Groundwater Assessment. Report dated December 2018 and included as Appendix I to the EIS.
- HydroSimulations 2020. Tahmoor South Amended Project Report: Groundwater Assessment. Report dated February 2020.
- AECOM 2018, Tahmoor South Project, Social Impact Assessment. Report dated 21 December 2018 and included as Appendix Q to the EIS.

Section 2. Project description

2.1 Site description and location

The Tahmoor South Project includes the extension of underground coal mining at Tahmoor Mine to the south of the existing Tahmoor Mine surface facilities area. The proposed development would be accessed via the existing Tahmoor Mine surface facilities, located between the towns of Tahmoor and Bargo (refer to **Figure 2.1**).

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal would enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas, providing an additional 13 years of operational life.

The proposed development would use established longwall mining methods, utilising existing ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project area and proposed mine plan is shown on **Figure 2.2** and covers the coal lease areas owned by Tahmoor Coal within the Wollondilly and Wingecarribee Local Government Areas (LGA), including the existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure, and the area immediately to the south of the existing Tahmoor Mine Approved Mining Area. Within the Project Area, the proposed development (including all longwall mining and surface development) would be confined to the Wollondilly LGA.

2.2 Overview of Project

Tahmoor Coal is seeking development consent for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south, within the Bargo area. The Project seeks to extend the life of underground mining at Tahmoor Mine for an additional 13 years until approximately 2035.

The Project would use longwall mining to extract coal from the Bulli seam within the bounds of Consolidated Coal Lease 716 (CCL716) and Consolidated Coal Lease 747 (CCL747). Coal extraction of up to 3.6 million tonnes of ROM coal per annum is proposed as part of the development with extraction of up to 43Mt of ROM coal over the life of the project. The project would consist of approximately:

- 30Mt coking product;
- 2Mt thermal product; and
- 11.6Mt rejects.

These approximate market mix volumes include moisture and are therefore an estimate only. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing CHPP and coal clearance facilities, and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets. Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road.

The Project would use the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension.

The Project also incorporates the planning for rehabilitation and mine closure once mining ceases.

The components of the Project in summary comprise:

- Longwall mining in the Central Domain mine development including underground redevelopment, vent shaft construction, pre-gas drainage and service connection;
- Upgrades to the existing surface facilities area including:
    - Upgrades to the CHPP;
    - Extension of the existing REA;
    - Additions to the existing bathhouses and associated access ways; and
    - Upgrades to onsite and offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla and Newcastle (from time to time);
- Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers by road;
- Mine closure and rehabilitation; and
- Environmental management.

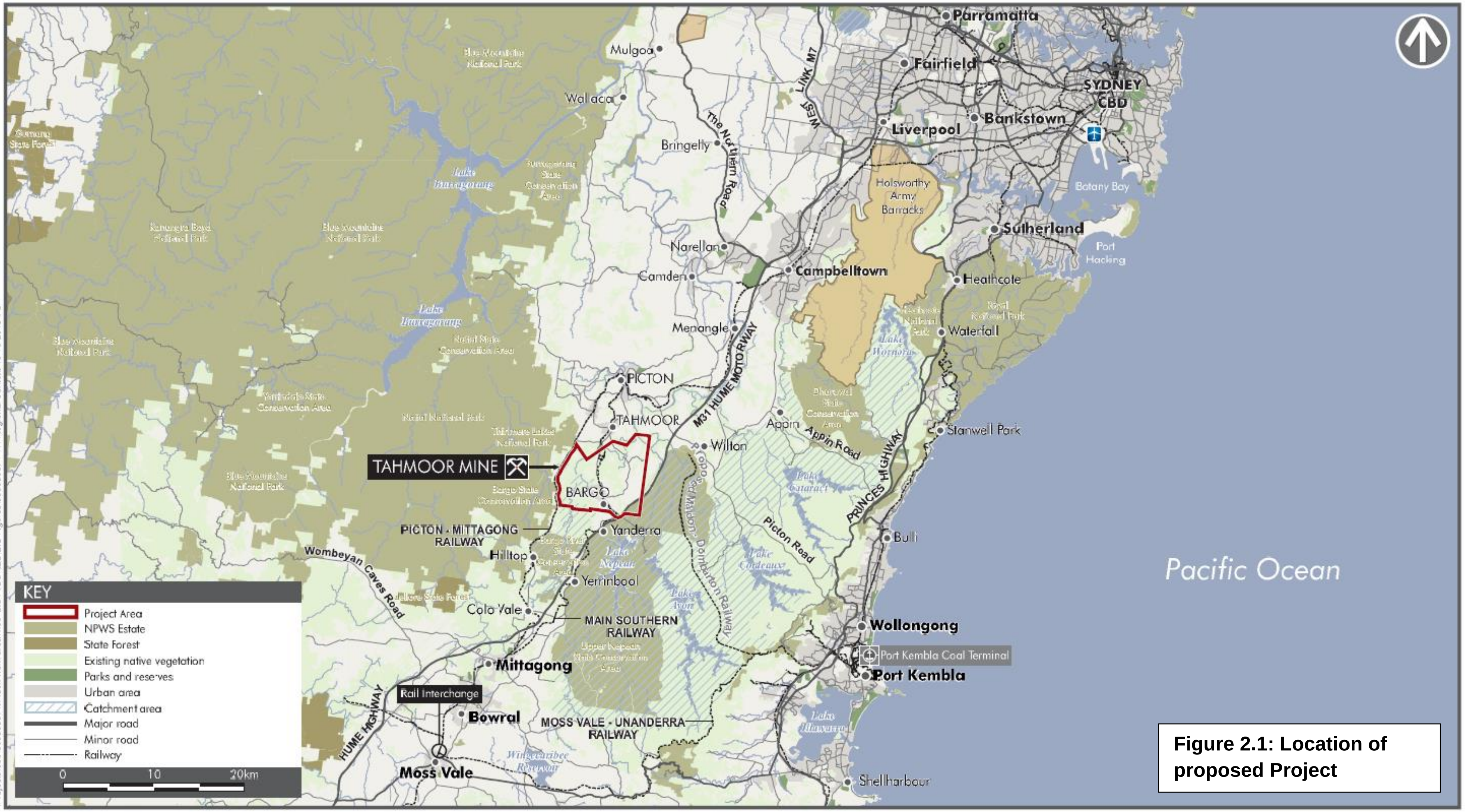

Figure 2.1: Location of proposed Project

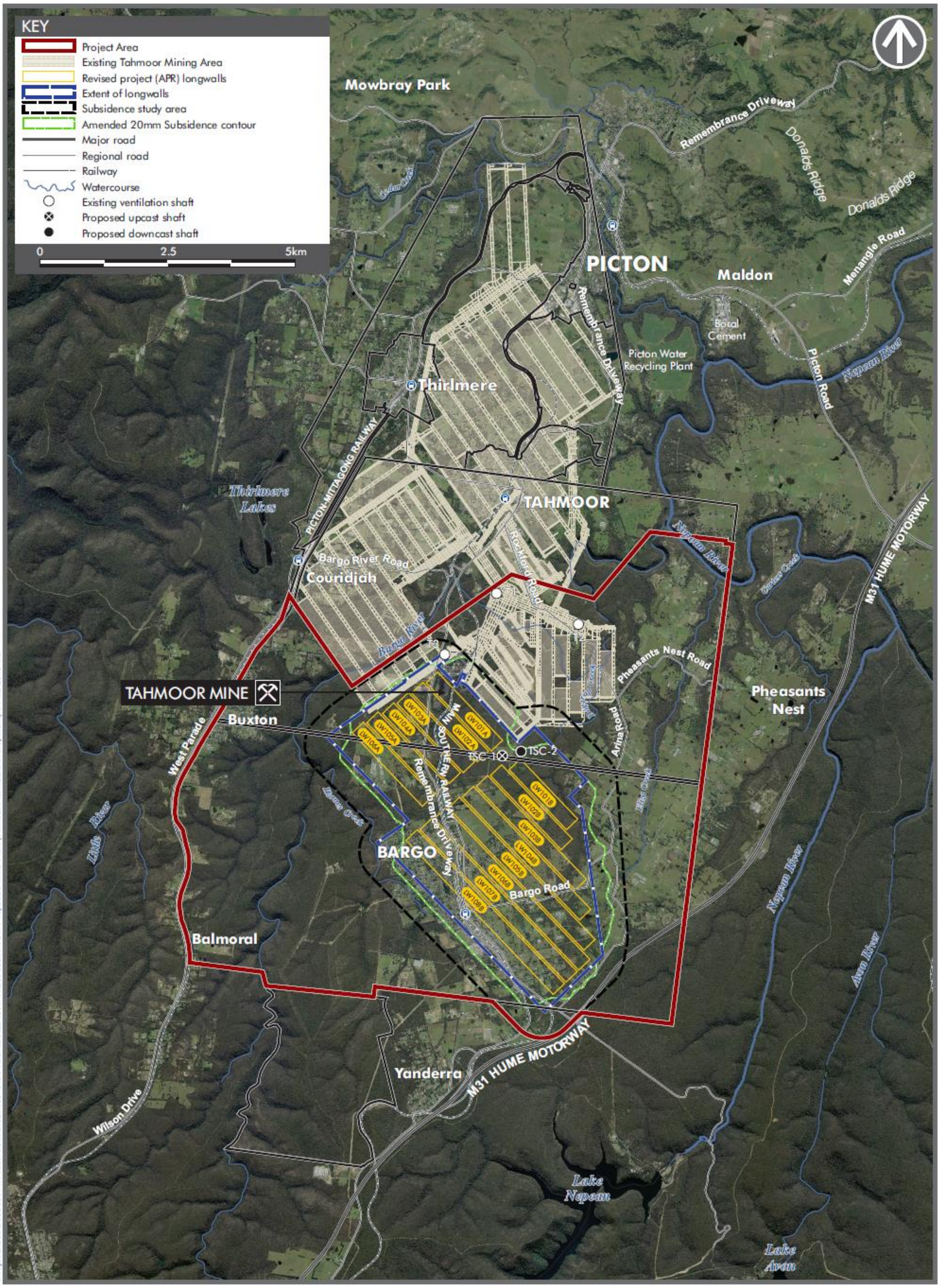

Figure 2.2: Proposed development (amended mine plan and ventilation shafts)

2.3 Regional setting

Tahmoor Mine is located within the Southern Coalfields of NSW. The Southern Coalfields is one of five major coalfields located within the Sydney-Gunnedah Basin. It is located south of Sydney and to the west of Wollongong with topography that is defined by the Illawarra and Woronora Plateau (**Figure 2.1**).

The geology of the Southern Coalfields includes the Illawarra Coal Measures and is the only NSW source of premium quality hard coking coals, which are primarily used for steel production. There are nine operational underground coal mines and one undergoing exploration in the Southern Coalfields.

Coal produced by the Tahmoor Mine is transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway, to Port Kembla for export. An upgrade to the Port Kembla Coal Terminal, to increase the throughput capacity to up to 27 million tonnes per annum, has been proposed in anticipation of continued growth in export market coal.

2.4 Local setting

Tahmoor Mine is located on the outer south western peri-urban fringe of Sydney, approximately 5 km south of Picton and 20 km northeast of Mittagong. The Project area for the proposed development is generally bounded by the Bargo and Nepean Rivers to the north, West Parade and the Picton-Mittagong Railway to the west, the Nepean River and Upper Nepean State Conservation Area to the east, and vegetated Crown land and the Hume Motorway to the south (refer to **Figure 2.2**). The mine infrastructure at the surface facilities area is surrounded by vegetated land and gullies, bounded by Remembrance Driveway (Old Hume Highway) to the west and bisected by the Main Southern Railway.

The existing Tahmoor Mine and proposed development are located within the Wollondilly LGA. The Project area also extends into the Wingecarribee LGA, as identified on **Figure 2.2**, however no activities associated with the proposed development will take place in Wingecarribee LGA. Land use in the region is characterised by a mix of village residential, rural residential, market gardens, agricultural and conservation areas.

The Project area exhibits a gently undulating landscape with generally low relief and small slopes. However, topography becomes steeper nearer to the valleys of the Bargo and Nepean Rivers which lie in the north and western portions of the Project Area, respectively. These areas, generally associated with the steeply incised sandstone embankments and escarpments, are more densely vegetated (undisturbed forest) and, in the case of the Nepean River, form part of designated protected areas. Approximately one third of the Project Area remains forested, in particular in the west of CCL 747, surrounding the surface facilities area and along the Bargo River.

The Project Area extends beneath semi-rural and partly forested landscapes, along with a mix of rural and environmental land uses. Rural uses in the area include small-scale agricultural activities such as farming produce, poultry, cattle grazing, trotting horse training, greyhound training and several horse studs.

Townships, villages and rural residences dot the landscape, the nearest of which include the township of Tahmoor and villages of Bargo, Yanderra, Pheasants Nest, Couridjah, Balmoral and

Buxton (refer to **Figure 2.2**). These localities are serviced by Picton Road, Remembrance Drive/Old Hume Highway, and Wilson Drive/Parade and the rail infrastructure corridors.

The region encompasses large areas dedicated to conservation and the protection of drinking water catchments. These are the Upper Nepean State Conservation Area to the east of the Old Hume Highway, and the Bargo River State Conservation Area, Nattai National Park, Thirlmere Lakes National Park and Blue Mountains National Park to the west (refer to **Figure 2.1**).

The Project area is also within the Greater Sydney Basin, with major drinking water catchments in the areas to the east, surrounding Lake Nepean, Lake Avon, Lake Cordeaux and Lake Cataract. The Project area is downstream of these areas, within the Bargo and Nepean catchments. The extent of proposed longwalls is not within the Metropolitan Special Area (i.e. the water supply catchment).

Section 3. Community profile

This section provides an overview of the community potentially impacted by the Project. It is noted that the key focus of this assessment is the local community surrounding the site.

The Project is situated in an area that includes existing agricultural and rural properties, as well as residential properties located on the larger towns of Bargo to the south and Picton to the north.

The extent of the community evaluated in this assessment has been determined based on modelling completed to evaluate key potential health impacts, specifically air quality and noise.

These assessments have focused on properties located within an area of 20 kilometres (km) x 20 km, which encompasses the Project along with rural residential and residential properties in areas surrounding the Project, as illustrated in **Figure 3.1** (also refer to further detail in **Sections 4 and 5**).

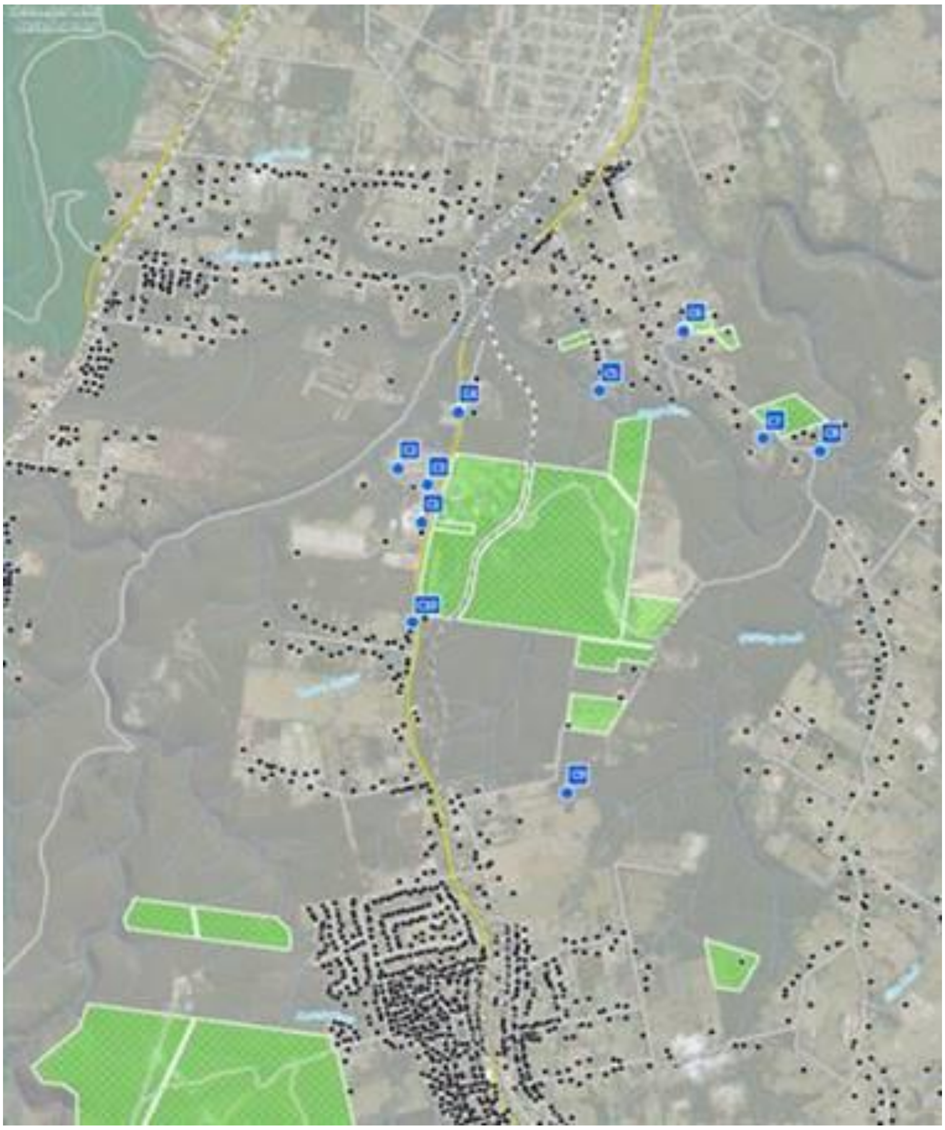

Figure 3.1: Study area (noise of which a subset is considered for air quality, refer to **Figure 5.2**)

These receptors are located within the Wollondilly LGA with the Wingacarribee LGA located just to the south.

Table 3.1 presents a summary of the population within the Wollondilly and Wingecarribee LGAs (based on 2016 Census and 2016 Socio-Economic data from the Australian Bureau of Statistics [ABS]) with comparison to NSW and Australia.

Table 3.1: Summary of populations surrounding the Project

Indicator	LGA		NSW	Australia
	Wollondilly	Wingecarribee		
Total population	48,519	47,882	7,480,231	23,401,892
Population 0 - 4 years	6.8%	4.9%	6.2%	6.3%
Population 5 - 19 years	22.2%	19.0%	18.3%	18.5%
Population 20 - 64 years	57.6%	50.2%	59.2%	59.6%
Population 65 years and over	13.3%	25.6%	16.3%	15.7%
Median age	37	47	38	38
Average household size	3	2.4	2.6	2.6
Unemployment (in 2016)	4%	3.8%	6.3%	6.9%
Unemployment (in March 2019)	2.5%	2.1%	4.4%	5.1%
Tertiary or technical institution	12.6%	20.3%	22.4%	22%
SEIFA IRSAD	1030	1022	--	--
SEIFA IRSAD rank	5	5	--	--
SEIFA IRSD	1043	1034	--	--
SEIFA IRSD rank	5	5	--	--
Indigenous	3.2%	2%	2.9%	2.8%
Born overseas	17.9%	34.6%	34.5%	26.3%

Most data presented in the table derived from the ABS 2016 Census (ABS 2016).
* Data presented for unemployment is based on available data (Australian Government 2018) to March 2019: https://docs.jobs.gov.au/documents/lga-data-tables-small-area-labour-markets-december-quarter-2018.
SEIFA IRSAD = index of socioeconomic advantage and disadvantage, rank relates to rank in Australia that ranges from 1 = most disadvantaged to 10 = least disadvantaged. Ranks lower than 5 are more disadvantaged than Australia on average.
SEIFA IRSD = index of socioeconomic disadvantage, rank relates to rank in Australia that ranges from 1 = most disadvantaged to 10 = least disadvantaged. Ranks lower than 5 are more disadvantaged than Australia on average.
Shading relates to comparison against NSW:

- statistic/data suggestive of a potential higher vulnerability within the population to health stressors.
- statistic/data suggestive of a potential lower vulnerability within the population to health stressors.
- statistics/data materially different to that of NSW and Australia, however this indicator is not a clear determinant of higher or lower vulnerability to health stressors.

Based on the population data available and presented in **Table 3.1**, the community of Wollondilly has a similar age distribution as NSW and Australia, with a lower level of tertiary education and percentage of people born overseas. Wingecarribee has a lower percentage of young people aged 4 years and younger and working aged people and a higher percentage of people aged 65 years and older. These communities are considered to be most advantaged and least disadvantaged, with a lower rate of unemployment.

The population demographics, employment status and index of socioeconomic advantage and disadvantage outlined in **Table 3.1** reflect the vulnerability of the population and its ability to adapt to environmental stresses. While it is not possible to provide more refined data for smaller pockets of these LGAs (in particular the properties evaluated in this assessment), in general the population in the community surrounding the Project has a lower level of social disadvantage relative to the rest of NSW.

The health of the community is influenced by a complex range of interactive 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. The health indicators available and reviewed in this report (**Table 3.2**) generally reflect a wide range of these factors.

The population adjacent to the proposed site is relatively small and health data is not available that specifically relates to this population.

The Project is located within the South Western Sydney Local Health District. This district covers a large area extending from Fairfield and Bankstown in the north and beyond Bowral in the south. There are approximately 966,450 people residing in the district, including residents in the major urban areas of the Greater Sydney area and regional communities. The populations considered in this Project comprise only a small fraction of the population within the South Western Sydney Local Health District.

Table 3.2 presents a summary of the general population health relevant to the area, based on currently available data. The table presents available information on health-related behaviours (i.e. key lifestyle and behaviours factors known to be important to health) and indicators for the burden of disease within the relevant LGAs (where available), the South Western Sydney Local Health District (SWSLHD) and NSW. Where available data is also included for the smaller areas of the Wollondilly LGA and Wingecarribee LGA. The values noted in bold are those utilised in this assessment.

Table 3.2: Summary of health indicators/data

Health indicator/data	South Western Sydney Local Health District	NSW
Health behaviours and asthma incidence (% population)		
Adults - compliance with fruit consumption guidelines (2017)[1]	45.8%	46.4%
Adults - compliance with vegetable consumption guidelines (2017)[1]	6.1%	6.6%
Children - compliance with fruit consumption guidelines (2017) [1]	60.5%	66.8%
Children - compliance with vegetable consumption guidelines (2017) [1]	5.7%	7.4%
Adults - increased lifetime risk of alcohol related harm (2017) [1]	24.7%	32.4%
Adults - body weight (overweight) (2018) [1]	33.2%	32.9%
Adults - body weight (obese) (2018) [1]	25.5%	21.4%
Adults – sufficient physical activity (2017-18) [1]	51.5%	58.4%
Children – adequate physical activity (2017-18) [1]	25.7%	24.2%
Current smoker (2018) [1]	16.2%	10.3%
Adult asthma – prevalence (2017)[1]	10.7%	10.9%
Adolescent (2015 years) – prevalence of current asthma (2016/2017)[1]	13.4%	12.9%
Burden of disease (rate per 100,000 population)		
Morbidity - cardiovascular disease hospitalisations (2017/2018)[1]	1570.3	1671.1
Cardiovascular disease hospitalisations (ages 65 years and older)[2]	--	**Sydney = 9,235**
Morbidity – respiratory disease hospitalisations (2017/2018)[1]	1868.2	1714.2
Respiratory disease hospitalisations (ages 65 years and older)[2]	--	**Sydney = 4,168**

Health indicator/data	South Western Sydney Local Health District	NSW
Mortality – all causes, all ages (2017)[1]	SWSLHD = 514.9 Wollondilly = **519.3** Wingecarribee = 563.9	508.8
Mortality (all causes, ages 30 years and older)[2]	--	**Sydney = 1,026**
Mortality – respiratory (all ages) (2017)	**52.4**	51.4
Asthma – emergency department admissions (1-14 years)2	--	**Sydney = 1209**

* Rate per 100,000 population.

1 Data from NSW Health (2010) Statistics: http://www.healthstats.nsw.gov.au/.

2 Data for Sydney Metropolitan area for 2010 based on hospital statistics as reported for 2010 and population data from the ABS for 2011 (relevant to each age group considered) used in review of exposure and risks to inform recommendations for updating the NEPM (Golder 2013).

Shading relates to comparison against NSW:

- statistic/data suggestive of a potential higher vulnerability within the population to health stressors.
- statistic/data suggestive of a potential lower vulnerability within the population to health stressors.
- statistics/data materially different to that of NSW and Australia, however this indicator is not a clear determinant of higher or lower vulnerability to health stressors.

As described above, the South Western Sydney Local Health District covers a large area and limited data is available for the smaller populations in the Wollondilly LGA and Wingecarribee LGA. These data indicate mixed statistics in relation to health. The data on health related behaviours indicate that some health related behaviours in the community (in general) may contribute to adverse health outcomes. Where the health data is evaluated there are lower rates of cardiovascular disease hospitalisations and higher levels of respiratory hospitalisations. This data does not suggest, overall, that the population would be significantly more vulnerable to health-related impacts related to the Project.

Section 4. Community engagement

The Social Impact Assessment (AECOM 2018) provides a summary of the community engagement undertaken for the Project, leading up to the EIS submission. This has included community surveys, community information days, newsletters and Tahmoor Colliery Community Consultative Committee (TCCCC) meetings. These activities have engaged with a wide variety of stakeholders who are likely to be affected or have an interest in the Project.

In relation to issues that directly or indirectly affect community health the community consultation undertaken identified the following:

- Positive impacts include increased employment opportunities, contribution to local economy and community support/funding;
- Negative impacts of concern included surface water (including potential for impact to Thirlmere Lakes) and groundwater impacts. In addition, general environmental/cumulative impacts were identified along with concerns over traffic on local roads.

Section 5. Health impacts: Air emissions

5.1 Approach

This section presents a review of impacts on health associated with predicted air emissions, relevant to the operation of the Project. The assessment presented has relied on the following:

- ERM 2020, Tahmoor South Project, Air Quality Impact Assessment. Report dated February 2020 (AQIA).

The estimation of risk follows the general principles outlined in the enHealth document Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012).

5.2 Background on particulate matter

The key focus of the AQIA and this assessment of potential health impacts is the emissions to air of dust or particulate matter.

Dust or Particulate Matter (PM) is a widespread air pollutant (that has and will always be present in air) 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 micrometres (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 formation of secondary particulates include: nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust; combustion sources; and agricultural, industrial and biogenic emissions).

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 (how far the particles can infiltrate into the respiratory system).

The common measures of particulate matter that are considered in the assessment of air quality and health risks are:

- **Total Suspended Particulates (TSP):** This refers to all particulates with an equivalent aerodynamic particle[2] size below 50 µm in diameter[3]. It is a gross indicator of the presence of dust with a wide range of sizes. The larger particles included in TSP (termed "inspirable", comprise particles around 10 µm and larger) are more of a nuisance as they will deposit out

[2] The term equivalent aerodynamic particle is used to reference the particle to a particle of spherical shape and particle of density 1 gram per cubic centimetre (g/cm^3)

[3] The size, diameter, of dust particles is measured in micrometers.

of the air (measured as deposited dust) close to the source and, if inhaled, are mostly trapped in the upper respiratory tract[4] and do not reach the lungs, hence, there is no potential for adverse health effects. Finer particles included in TSP (smaller than 10 µm, termed "respirable", as described below) 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. Not all of the dust characterised as TSP is relevant for the assessment of health impacts, and hence TSP as a measure of dust impact in the community, is difficult to directly include in this assessment. TSP can be used as a measure of dust that may give rise to nuisance impacts close to the source, where the heavier particles readily deposit out of the air causing dust to deposit onto surfaces (including vegetation and within homes). The deposition of dust is more often directly measured using dust deposition gauges, however, these data relate to an assessment of nuisance effects only. The assessment of potential health impacts relates to particles 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 filter mechanisms of cilia and mucous in the nose and upper respiratory system, with the smaller particles able to further penetrate into the lower respiratory tract[5] and lungs. Once in the lungs, adverse health effects may occur that include mortality and morbidity, which may be associated with a range of adverse cardiovascular and respiratory effects (OEHHA 2002)[6].

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. Reliable methods for the monitoring of PM_{10} concentrations has been available for a long time and hence these data are most widely available in urban and rural areas.

Smaller particles such as $PM_{2.5}$, however, are seen as more significant with respect to evaluating health effects, as a higher proportion of these particles penetrate deep into the lungs. Very fine particles, specifically ultrafine particles (PM_1 or $PM_{0.1}$), are also considered to be of importance for the assessment of health effects as these particles penetrate the deepest into the respiratory system.

Figure 5.1 provides a general illustration to provide some context in relation to the size of different particles (discussed above) and relevance/importance for the assessment of inhalation exposures.

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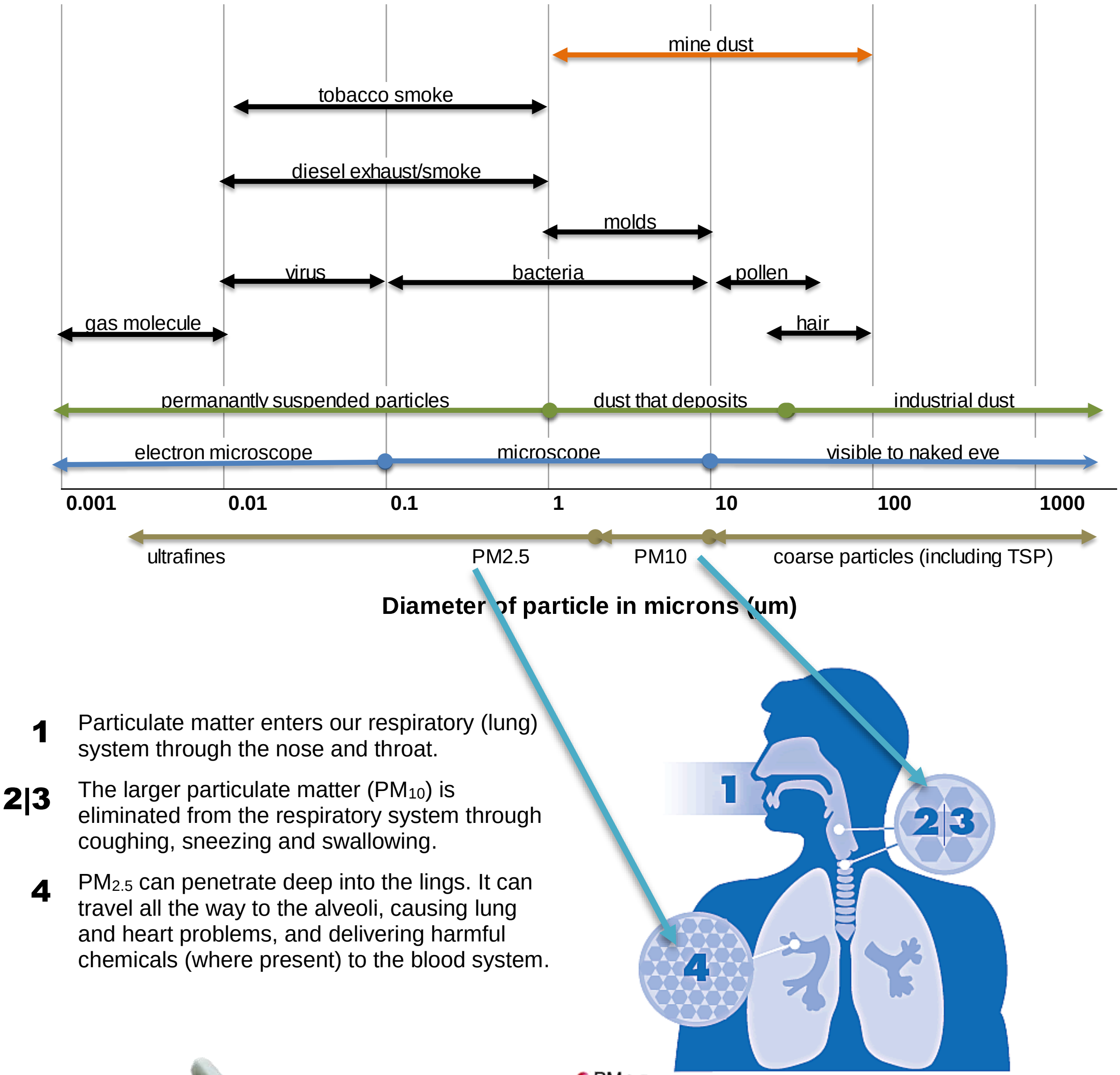
[4] The upper respiratory tract comprises the mouth, nose, throat and trachea. Larger particles are mostly trapped by the cilia and mucosa and swept to the back of the throat and swallowed.

[5] 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.

[6] OEHHA – Office of Environmental Health Hazard Assessment.



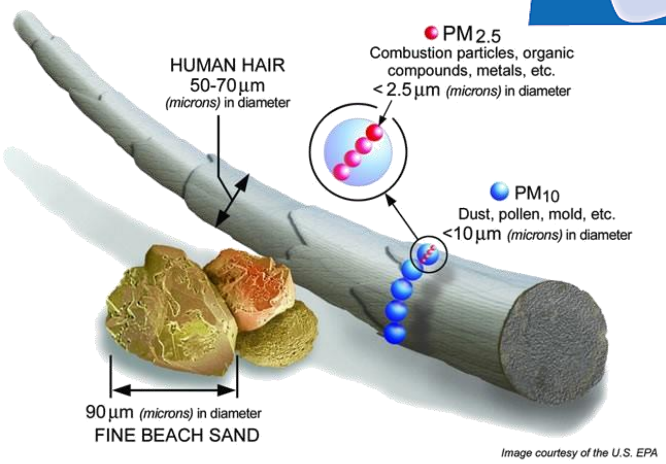


Figure 5.1: Illustrative Comparison of Relative Particle Sizes and Importance for Health

5.3 Summary of air modelling

5.3.1 Existing air quality

The main sources of particulate matter in the area surrounding the Project include mining, agriculture, urban activity and emissions from local anthropogenic activities such as motor vehicle exhaust, domestic wood heaters, dust storms and bushfires (including hazard reduction activities).

Data in relation to the existing air quality has been evaluated based on data from five NSW EPA monitoring stations as well as dust monitoring (using High Volume Air Sampling to sample TSP, measurements of PM_{10} and dust deposition) conducted in Tahmoor South. The existing Tahmoor mine also includes six dust deposition gauges.

Data from these monitoring stations indicate the following:

- In relation to dust:
    - Reported dust deposition levels showed some variability however all levels reported in Tahmoor South and off-site from the existing Tahmoor mine are well below the NSW EPA guideline (NSW EPA 2016b), suggesting dust deposition levels are generally good (or low) in the vicinity of the Project.
    - TSP monitoring in South Tahmoor, which includes all the large particulates which cannot be inhaled, reports levels well below the NSW EPA criteria (NSW EPA 2016b).
    - The PM_{10} data in the local area and the NSW EPA locations has some exceedances of the relevant 24-hour average guidelines (NEPC 2016; NSW EPA 2016b), primarily related to dust generated in dry conditions, including dust storm events, and hazard reduction activities. The NSW EPA monitors do not report any exceedance of the annual average guideline for PM_{10}.
    - $PM_{2.5}$ data for the NSW EPA monitoring stations do not exceed the annual average guidelines (NEPC 2016; NSW EPA 2016b), however there are some exceedances of the 24-hour average guideline noted to be associated with dust storms and wood smoke from fire activities.
- The regional NSW EPA monitors report low levels of nitrogen dioxide (NO_2), well below the current guideline (NEPC 2016; NSW EPA 2016b), with the available data showing little seasonal variability. In addition. These monitors report low levels of carbon monoxide (CO), well below the relevant guidelines (NEPC 2016; NSW EPA 2016b).

5.3.2 Modelling impacts from the Project

Modelling of air quality impacts requires consideration of the local area, specifically the local terrain and meteorological conditions, as well as emissions to air from the various activities relevant to the Project.

The local meteorological conditions have been evaluated on the basis of data collected from the Tahmoor South Meteorological Station, along with data from the Camden meteorological station. The influence of the local terrain of the Project areas and surrounding environments on meteorological conditions have also been taken into account.

Dust emissions from the Project have been estimated on the basis of emission factors for all the relevant activities, volumes to be handled and equipment proposed to be used. The emission factors have been locally developed and also derived from the USEPA. The assessment also considered emissions to air from the vent shafts and flares.

Modelling was undertaken using CALPUFF for a worst-case operational year, for TSP, PM_{10} and $PM_{2.5}$. Emissions to air from the flares, used to burn coal seam gases/methane, were modelled for products of combustion, specifically CO, NO_2 and volatile organic compounds (VOCs) (assumed to be hydrocarbons)

The modelling has also considered emissions to air from other nearby approved mining operations, and background (i.e. non-modelled) dust levels. Dust mitigation measures to be used within the Project have also been considered.

Impacts related to the Project have been evaluated at 40 receptors (R1-R40) as listed in **Table 5.1**, representing privately-owned properties, mine-owned properties (R5, R10, R16 and R37, noting that R12 is under negotiation) and also representative receptors within the local towns including schools at R25 and R26 (refer to **Figure 5.2** for the location of all receptors evaluated).

Table 5.1 Summary of receptors in the surrounding community

Receptor ID	Address	Lot Number and DP
R1	2 Olive Lane	Lot 1 DP877585
R2	4 Olive Lane	Lot 7 DP1029837
R3	2897 Remembrance Driveway	Lot 201 DP733965
R4	130 Stratford Road	Lot 8 DP3306
R5	7 Hodgson Grove	Lot 134 DP879762
R6	20 Dietrich Road - PO Box 119 Tahmoor	Lot 5 DP3306
R7	84 Stratford Road	Lot 14 DP3306
R8	250 Rockford Road	Lot 45 DP751270
R9	11 Kammer Place	Lot 22 DP777104
R10	215 Charlies Point Road	Lot 2231 DP787222
R11	3085 Remembrance Driveway	Lot 34 DP654711
R12	185 Charlies Point Road	Lot 216 DP751250
R13	30 Caloola Road	Lot 10 DP25735
R14	3092 Remembrance Driveway	Lot 14 DP656820
R15	3076 Remembrance Driveway	Lot 18 DP656823
R16	115 Charlies Point Road	Lot 217 DP751250
R17	60 Lyrebird Road, Pheasants Nest 2574	Lot 3 DP791071
R18	45 Knox Road, Pheasants Nest 2573	Lot 3 DP264153
R19	70 Warrobyn Road, Bargo	Lot 10 DP605241
R20	70 Hinkler Ave Bargo 2574	Lot 1 DP202891
R21	105 Dwyers Road, Pheasants Nest	Lot 9 DP 616757
R22	10 Pheasants Nest Rd, Pheasants Nest	Lot 7 DP243112
R23	Edge of Bargo township closest to site	-
R24	Edge of Tahmoor township closest to site	-
R25 (Anglical College)	Remembrance Driveway	Lot 12 DP1122904
R26 (Bargo Public School)	Great Southern Road	Lot 1 DP782052
R27	80 Charlies Point Road	Lot 228 DP751250
R28	3030 Remembrance Driveway	Lot 2 DP213596
R29	1 Olive Lane	Lot 2 DP877585
R30	5 Olive Lane	Lot 4 DP1010127
R31	7 Olive Lane	Lot 5 DP1010127
R32	6 Olive Lane	Lot 6 DP1029837
R33	4 Olive Lane	Lot 7 DP1029837
R34	2900 Remembrance Driveway	Lot 2063 DP1014538

Receptor ID	Address	Lot Number and DP
R35	230 Rockford Road	Lot 454 DP751270
R36	230 Rockford Road	Lot 454 DP751270
R37	260 Rockford Road	Lot 2 DP1037712
R38	280 Rockford Road	Lot 10 DP775465
R39	285 Rockford Road	Lot 1 DP725580
R40	5 Kammer Place	Lot 21 DP777104

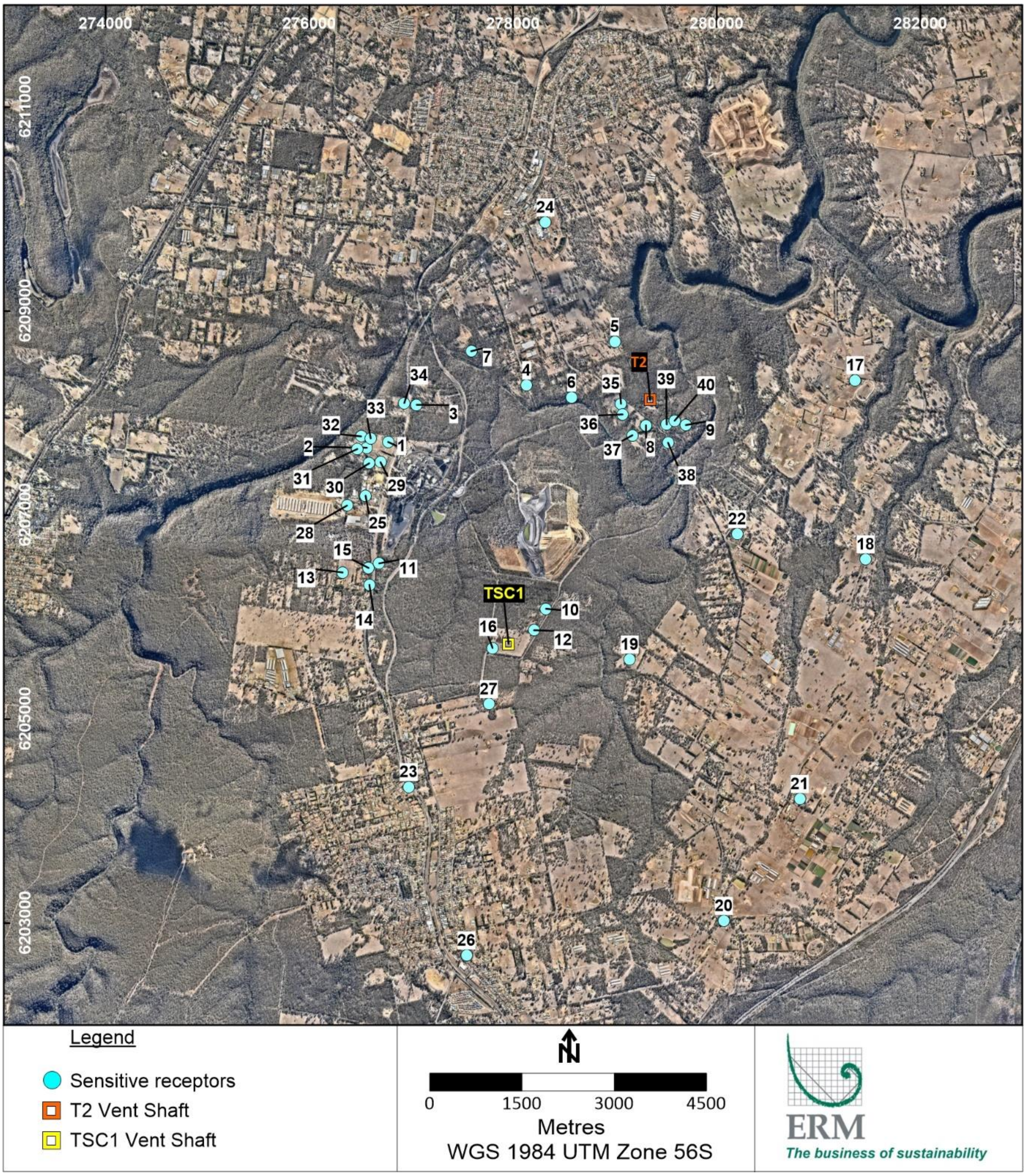


Figure 5.2: Location of air quality receptors

5.4 Assessment of health impacts – particulates

5.4.1 Health effects

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 particle size fractions that tend to contain certain chemical components, such as metals or other organic compounds.

There is strong evidence to conclude (USEPA 2012; WHO 2003, 2013b) 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 particles and other gaseous pollutants present from fuel combustion sources, as compared to particles derived from crustal origins.

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 2009; WHO 2003).

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 pre-existing (underlying) respiratory or cardiovascular disease. For long term exposures in a population, this relates to mortality rates over a lifetime (i.e. shortening the lifespan), 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 2009):

- 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 2009).

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 those shown with $PM_{2.5}$ (USEPA 2012).

There are a number of 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 (IARC 2013b, 2013a) has classified particulate matter as carcinogenic to humans based on data relevant to lung cancer.

Other studies have been reviewed to determine relationships/associations between particulate matter exposure (either PM_{10} or $PM_{2.5}$) and a wide range of other health effects and health measures including mortality (for different age groups), chronic bronchitis, medication use by adults and children with asthma, respiratory symptoms (including cough), restricted work days, work days lost, school absence and restricted activity days (Anderson et al. 2004; EC 2011; Ostro 2004; WHO 2006). 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.

5.4.2 Assessment of cumulative exposures to particulates

The assessment of cumulative exposures to $PM_{2.5}$ and PM_{10} is based on a comparison of the predicted cumulative concentrations to the current air quality standards and goals presented in the NEPM (NEPC 2016).

In relation to the current NEPM PM_{10} standard, the following is noted (NEPC 1998, 2010, 2014, 2016):

- The standard was derived through a review of appropriate health studies by a technical review panel of the NEPC where short term exposure-response relationships for PM_{10} and mortality and morbidity health endpoints were considered.
- Mortality health impacts were identified as the most significant and were the primary basis for the development of the standard.
- On the basis of the available data for key air sheds in Australia, the criterion of 50 micrograms per cubic metre (µg/m^3) was based on analysis of the number of premature

deaths that would be avoided and associated cost savings to the health system (using data from the US). The development of the standard is not based on any acceptable level of risk and hence simply meeting the standard does not cover all aspects that need to be considered in terms of health impacts.

- The assessment undertaken considered exposures and issues relevant to urban air environments that are expected to also be managed through the PM_{10} standard. These issues included emissions from vehicles and wood heaters.

A similar approach has been adopted by NEPC (Burgers & Walsh 2002; NEPC 2002, 2014) in relation to the derivation of the $PM_{2.5}$ air quality standards, with specific studies related to $PM_{2.5}$ and mortality and morbidity indicators considered. Goals for lower $PM_{2.5}$ standards to be met by 2025 are also outlined by NEPC (NEPC 2016).

Table 5.2 presents a comparison of the current NEPC standards and goals with those established by the WHO (WHO 2005), the European Union (EU) and the USEPA (2012). The 2025 goals established by the NEPM for $PM_{2.5}$ (and adopted in this assessment) are similar to but slightly more conservative (health protective) than those provided by the WHO, EU and the USEPA. The NEPM PM_{10} guidelines are also similar to those established by the WHO and EU, however the guidelines are significantly lower than the 24-hour average guideline available from the USEPA.

Table 5.2: Comparison of particulate matter air quality goals

Pollutant	Averaging period	Criteria/guidelines/goals			
		NEPC	**WHO (2005)**	**EU #**	**USEPA (2012)**
PM_{10}	24-hour	50 µg/m^3	50 µg/m^3	50 µg/m^3 as limit value to be met, with 35 exceedances permitted each year	150 µg/m^3 (not to be exceeded more than once per year on average over 3 years)
	Annual	25 µg/m^3	20* µg/m^3	40 µg/m^3 as limit value to be met	NA
$PM_{2.5}$	24-hour	25 µg/m^3 20 µg/m^3 (goal for 2025)	25 µg/m^3	NA	35 µg/m^3 (98th percentile, averaged over 3 years)
	Annual	8 µg/m^3 7 µg/m^3 (goal for 2025)	10* µg/m^3	25 µg/m^3 as target value to be met from 2010 and limit value to be met from 2015. 20 µg/m^3 as a 3 year average (average exposure indicator) from 2015 with requirements for ongoing percentage reduction and target of 18 µg/m^3 as 3 year average to be attained by 2020	12 µg/m^3 (annual mean averaged over 3 years)

Current EU Air Quality Standards (EU 2015) available from **http://ec.europa.eu/environment/air/quality/standards.htm**

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

The air quality standards and goals for $PM_{2.5}$ and PM_{10} relate to total concentrations in the air (from all sources including the Project). This has been modelled as part of the AQIA.

Table 5.3 summarises the maximum 24-hour average and annual average concentrations of $PM_{2.5}$ and PM_{10} estimated at any sensitive (privately-owned) receptor with comparison against the NEPC criteria.

Table 5.3: Review of cumulative PM concentrations

	Maximum 24-hour average concentration (µg/m^3)		Maximum annual average concentration (µg/m^3)	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Project only	6	46	1.1	8.4
Worst case operational scenario for Project + background	NA	NA (potential increase in number of days exceeding criteria from 1 (no Project) to 2 to 9 days)	7.1	21.5
Standards and goals	**25 (20 as goal for 2025)**	**50**	**8 (7 as goal by 2025)**	**25**

Review of **Table 5.2** indicates:

- The maximum annual average concentrations of PM_{10} and $PM_{2.5}$, for the cumulative scenario for the worst-case operational year, are below the relevant NEPC criteria.
- The maximum 24-hour average concentrations of PM_{10} and $PM_{2.5}$, for the Project for the worst-case operational year, are below the relevant NEPC criteria.
- In addition, the maximum 24-hour average concentrations of PM_{10}, for all scenarios considered, have been assessed separately in the AQIA, with the evaluation considering how the operation of the Project affects the number of days where exceedance of the criteria may occur. The assessment is conservative as it assumes that the worst-case background conditions may occur at the same time as worst-case emissions and dispersion conditions. The probability of exceeding the criteria was calculated to increase from the background of 1 day in a year to somewhere between 1 and 9 days in a year. The highest impacts are predicted at Receptor 10, which is a mine-owned receptor. The highest impacts at the privately-owned receptors are predicted for Receptor 1, where up to 5 days of exceedance are predicted. Receptor 1 is at the eastern end of Olive Lane and additional management may be required to reduce potential dust impacts. Where these management measures are implemented the AQIA concluded that these exceedances would be well managed. In addition, the AQIA concluded that it was unlikely there would be any additional exceedances of 24-hour $PM_{2.5}$.
- On this basis, there are no cumulative impacts of concern in relation to the Project.

5.4.3 Assessing incremental impacts associated with particulates

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

The available evidence does not suggest that there is a threshold below which health effects do not occur. Hence there are likely to be health effects associated with background levels of $PM_{2.5}$ and PM_{10}, even where the concentrations are below the current guidelines. Guidelines are currently available for the assessment of $PM_{2.5}$ and PM_{10} in Australia (NEPC 2002, 2003, 2016). These guidelines are not based on any acceptable level of risk, rather they are based on levels that are desirable in the community to balance background/urban sources with lowering impacts on health and cost savings in the health system.

A detailed assessment of potential health effects associated with exposure to a specific source, or a change in air quality as a result of a specific source has been undertaken. The assessment of impacts on health has utilised robust, published, quantitative relationships (exposure-response relationships) that correlate a change in $PM_{2.5}$ or PM_{10} concentration with a change in a health indicator. **Appendix A** presents an overview of the methodology adopted for using exposure-response relationships for the assessment of health impacts in a community.

This report presents an assessment of changes in localised risk (i.e. at an individual receptor) associated with predicted changes in air quality, as well as changes in population health impacts (as would be measured by changes in mortality statistics or hospital admissions) related to changes in exposures to particulates in the surrounding community.

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

- Long term exposure to $PM_{2.5}$ and PM_{10} and changes in all-cause mortality. This effect relates to exposures that may occur over all ages, however the most robust quantitative study used to calculate health risks and impacts relates to people aged 30 years and older.
- Short term exposure and changes to the rate of hospitalisations with cardiovascular and respiratory disease (equal or greater than 65 years of age). These effects have also been reported in other age groups, however the relationships between $PM_{2.5}$ and these effects are poor for younger age groups. The most robust relationships established are for people aged 65 years and older.

The above endpoints are robust and generally relate to $PM_{2.5}$. Exposure-response relationships are not as robust for PM_{10}, however, an assessment of PM_{10} has also been included for the key health endpoint (all-cause mortality), as particulate emissions derived from coal mining activities also include a significant proportion of particulates that are classified as PM_{10} but not $PM_{2.5}$.

The above endpoints are considered to be primary health indicators addressing the most significant health risks/impacts. Other effects and indicators reported in the literature are subsets of these and as a result have not been specifically presented. Notwithstanding, it is noted that in any community, asthma in children is typically of key concern and hence the following additional endpoint has also been considered:

- Short term exposure to $PM_{2.5}$ and changes in emergency department admissions for asthma in children aged 1–14 years. These effects have also been reported in other age groups, however it should be noted that the relationships between exposure to $PM_{2.5}$ and asthma effects are not as strong or robust for adults. The impact of air pollution on asthma has been the subject of a review by the Australian Institute of Health and Welfare (AIHW) (AIHW 2010). This review makes it clear there are multiple contributors to the exacerbation of asthma in any individual (including respiratory infections, weather, seasonal allergens, indoor allergens, household chemicals, dietary factors and presence of smoking) so that isolating any one single factor is very difficult. Regardless of these many other factors, the presence of air pollution and its impacts on children with asthma are a common key concern in communities.

Table 5.4 presents a summary of the health endpoints considered in this assessment, the relevant health impact functions (from the referenced published studies) and the associated β coefficient relevant to the calculation of the relative risk (refer to **Appendix A** for details on the calculation of a β coefficient from published studies).

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

It should be noted that the approach adopted for assessing health impacts associated with $PM_{2.5}$ and PM_{10} relates to $PM_{2.5}$ and PM_{10} from any source. All sources of $PM_{2.5}$ and PM_{10} have the potential to impact on the health of individuals and the community. In rural and urban areas these sources include wood smoke, industrial emissions, vehicle emissions and sea salt.

Table 5.4: Adopted health impact functions and exposure-responses relationships – $PM_{2.5}$ and PM_{10}

Health endpoint	Exposure period	Age group	Published relative risk [95 confidence interval] per 10 µg/m³	Adopted β coefficient (as per cent) for 1 µg/m³ increase in PM	Reference
$PM_{2.5}$: Mortality, all causes	Long term	≥30 years	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 et al. (Pope et al. 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)[7]
PM_{10}: Mortality, all causes	Short term	All ages	1.006 [1.004-1.008]	0.0006 (0.06)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
$PM_{2.5}$: Cardiovascular hospital admissions	Short term	≥65 years	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 2012; Bell et al. 2008)
$PM_{2.5}$: Respiratory hospital admissions	Short term	≥65 years	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 2012; Bell et al. 2008)
$PM_{2.5}$: Asthma (emergency department admissions)	Short term	1–14 years	–	0.00148 (0.148)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Jalaludin et al. 2008)

The assessment of health impacts for a population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004) (also outlined in **Appendix A**) where the exposure-response relationships (presented in **Table 5.4**) have been directly considered.

[7] EPHC – Environmental Protection and Heritage Council.

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

- Estimates of the changes in $PM_{2.5}$ and PM_{10} exposure levels or concentrations due to emissions from the Project.
- Baseline incidence of the key health endpoints that are relevant to the population exposed. This is specific to populations in the local area, or populations representative of the local area.
- Exposure-response relationships expressed as a percentage change in health endpoint per micrograms per cubic metre change in particulate matter exposure (see **Table 5.4**).

The change in incidence of each health endpoint relevant to changes in population exposure to $PM_{2.5}$ and PM_{10} has been calculated on the following basis:

- The average change in $PM_{2.5}$ and PM_{10} concentration over all receptors has been determined.
- A change in the number of cases associated with the change in $PM_{2.5}$ and PM_{10} impact evaluated in the population within the study area has been calculated (refer to **Appendix A** for details on the methodology). The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered and the population (for the relevant age groups) present in the area assuming the size of the population is represented by the population in the townships of Tahmoor and Bargo (which comprise the receptors modelled) and the age distribution is consistent with Wollondilly LGA.

Based on the above modelling and assumptions, health impacts associated with the Project for all three scenarios have been evaluated.

Table 5.5 presents a summary of the calculated impact of exposure to $PM_{2.5}$ and PM_{10} from the Project for the worst-case operational year. The calculated incremental risks presented relate to the maximum risk for all receptors evaluated. Calculations of incremental risk for each individual receptor are included in **Appendix B**.

The incremental risk relates to the maximum localised risk within the community or area evaluated and does not consider the size of the population. The calculated population incidence reflects the increased risks for all members of the population in terms of the number of cases.

Assessment of what constitutes an acceptable risk level (as a localised risk for members of the community) for changes in exposure to $PM_{2.5}$ and PM_{10} within a community is a complex issue. For new and expanding developments in NSW, NSW EPA (NSW EPA 2016b) states that the following should be considered in relation to carcinogenic risks, which is inferred to also apply to other non-threshold risks:

- Unacceptable risks are $\geq 1 \times 10^{-4}$, or 1 in 10,000 and where risk management measures are required to be implemented.
- Acceptable risks are in the range $<1\text{x}10^{-4}$ (1 in 10,000) and $>1\text{x}10^{-6}$ (1 in 1,000,000) and where best practice is required.
- Negligible risks are $\leq 1\text{x}10^{-6}$ or 1 in 1,000,000.

Table 5.5: Population health impacts associated with exposure to $PM_{2.5}$ and PM_{10}

Location	Population incidence (increase in number of cases in population per year) and calculated incremental risk				
	$PM_{2.5}$				PM_{10}
	Mortality (all causes, ≥30 years)	Cardiovascular hospitalisations (≥65 years)	Respiratory hospitalisations (≥65 years)	Asthma ED admissions (1-14 years)	Mortality (all causes, all ages)
Population incidence – population in study area					
Worst-case operational year	0.13	0.035	0.0081	0.013	0.097
Incremental risk – maximum from all receptors					
Worst-case operational year	$7x10^{-5}$	$8x10^{-5}$	$2x10^{-5}$	$2x10^{-5}$	$3x10^{-5}$

Review of **Table 5.5** and **Appendix B** indicates the following:

- The calculated population health incidence values are very low and would never be measurable within the population surrounding the Project.
- There are no incremental risks that would be considered to be unacceptable. The maximum localised risk (which is at Receptor 29) would not be considered to be unacceptable.
- Calculated risks for all individual receptors indicate population average risks in the order of $2x10^{-5}$ which are considered to be acceptable.
- On the basis of the above, there are no significant health impacts of concern in relation to potential emissions of $PM_{2.5}$ and PM_{10} from the Project.

5.4.4 Assessment of dust deposition

Dust deposition is generally considered to pose an aesthetic impact, as it relates to the deposition of predominantly coarse particles (i.e. particles too large to be of concern in relation to inhalation) onto surfaces. Dust deposition is measured in areas surrounding the site, with the existing levels all below the NSW EPA guideline of 4 g/m^2/month (as an annual average) (NSW EPA 2016b), which is an amenity-based guideline. This includes amenity issues related to rainwater tanks.

The monitoring of dust deposition reports the deposition of dust from all sources. While no specific study has been undertaken in the Southern coalfields area, the NSW EPA has conducted a dust deposition study in Newcastle (NSW EPA 2016a), to address concerns about the presence of black visible dust and to better understand the composition of dust deposited. Dust deposition levels in 2014-2015 were below the relevant guideline and principally comprised soil or rock (40% to 90%), with coal comprising an average of 10% (0% to 25%). The remainder comprised insects and plant debris, rubber dust, soot, salt, fly ash, alumina, paint and miscellaneous fibres. Although this study is not directly applicable to the Project, it indicates that the presence of black visible dust cannot be entirely attributed to the presence of coal dust.

The potential for any coal dust to contribute to, and impact on, the quality of water within rainwater tanks depends on the likelihood of coal dust depositing on the roof and being washed into the tank, the potential for leaching of trace elements into tank water and the quality of water at the point of use (i.e. as used from taps) (Lucas et al. 2009).

The AQIA considered dust deposition that may occur as a result of the Project. The maximum predicted total annual average dust deposition (from all sources including the Project) at all receptors considered is 1.8 g/m^2/month, well below the guideline of 4 g/m^2/month. The maximum increase in dust deposition as a result of the Project, at any of the receptors surrounding the Project is 0.4 g/m^2/month, which is considered to be a negligible contribution to existing dust deposition levels in the area. This represents a negligible impact to dust deposition and accumulation of dust in rainwater tanks.

The study conducted by Lucas et al. (2009) evaluated the potential for trace elements in coal dust (from an Australian coal terminal) to leach into rainwater. This study concluded that negligible amounts of trace elements from coal dust leached into rainwater, and the presence of coal dust resulted in the removal of trace elements present in the initial rainwater. Any concentrations leached were below the Australian Drinking Water Guidelines and were of no concern to human health. Hence if there were some coal dust deposited onto a roof (which will be negligible as per the discussion above), there would be negligible impacts to health where tank water was used for drinking water.

It should be noted that NSW Health's information on Rainwater Tanks (https://www.health.nsw.gov.au/environment/water/Pages/rainwater.aspx) provides advice on how to maintain water tanks for safe drinking for those landholders concerned about drinking water quality.

5.4.5 Impacts during construction

The AQIA presented a qualitative assessment of potential dust emissions during construction. The assessment concluded that where all construction activities were considered to occur at the same time and also at the same time as the worst-case operational year, which would not occur, dust generated from construction would increase the modelled dust impacts by 10% to 12%. Based on the assessment of health impacts from dust presented in **Section 5.4.3**, such an increase in dust would not change the outcomes assessment undertaken. On this basis there are no health impacts of concern in relation to dust generated during construction.

5.5 Assessment of health impacts – nitrogen dioxide

5.5.1 General

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 (e.g. gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In terms of health effects, nitrogen dioxide (NO_2) is the only oxide of nitrogen that may be of concern (WHO 2000). NO_2 is a colourless and tasteless gas with a sharp odour. NO_2 can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of NO_2 has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013a). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of NO_2 (Morgan, Broom & Jalaludin 2013; NEPC 2010). The health effects associated with exposure to NO_2 depend on the duration of exposure as well as the concentration.

In relation to potential exposures to NO_2, the following should be considered:

- Whether the evidence suggests that associations between exposure to NO_2 concentrations and effects on health are causal: The most current review undertaken by the USEPA (USEPA 2015) specifically evaluated evidence of causation. The review identified that a causal relationship existed for respiratory effects (for short term exposure, with long term exposures also likely to be causal). All other associations related to exposure to NO_2 (specifically cardiovascular effects, mortality and cancer) were considered to be suggestive.
- Whether the reported associations are distinct from, and additional to, those reported and assessed for exposure to particulate matter: Co-exposures to NO_2 and particulate matter complicates review and assessment of many of the epidemiology studies as both these air pollutants occur together in urban areas. There is sufficient evidence (epidemiological and mechanistic) to suggest that some of the health effect associations identified relate to exposure to NO_2 after adjustment/correction for co-exposures with particulate matter (COMEAP 2015)[8].
- Whether the assessment of potential health effects associated with exposure to different levels of NO_2 can be undertaken on the basis of existing guidelines, or whether specific risk calculations are required to be undertaken: The current guidelines in Australia for the assessment of NO_2 in air relate to cumulative (total) exposures and adopt criteria that are considered to be protective of short and long-term exposures. However, for the assessment of impacts from a specific emission source, where background is not being considered, the exposure-response relationships relevant to NO_2 require consideration.

The evidence base supports quantification of effects of short-term exposure to NO_2, using the averaging time as in the relevant studies. The strongest evidence is for respiratory effects, in particular exacerbation of asthma, with some support also for all-cause mortality.

For this assessment the source of NO_2 is the methane flares. The modelling undertaken in the AQIA has considered these emissions and assumed that 100% of the oxides of nitrogen (NOx) released during combustion are NO_2. This is highly conservative as not all the NOx will convert to NO_2.

5.5.2 Assessment of cumulative exposures to nitrogen dioxide

The NEPC ambient air quality guideline for the assessment of acute (short-term) exposures to NO_2 relates to the maximum predicted total (cumulative) 1-hour average concentration in air. The guideline of 246 $\mu g/m^3$ (or 0.12 parts per million [ppm]) is based on a lowest-observed-adverse-effect level (LOAEL) of 409–613 $\mu g/m^3$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 acute guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The NEPC ambient air quality standard for the assessment of chronic (long-term) exposures to NO_2 relates to the maximum predicted total (cumulative) annual average concentration in air. The

[8] COMEAP – Committee on the Medical Effects of Air Pollutants.

standard of 62 µg/m^3 (or 0.03 ppm) is based on a LOAEL of the order of 40–80 parts per billion by volume (around 75–150 µg/m^3). This relates to the early and middle childhood years when exposure can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school.

An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20-40 parts per billion by volume (38–75 µg/m^3) (NEPC 1998). On this basis, the NEPC standard is protective of adverse health effects in all individuals, including sensitive individuals.

Table 5.6 summarises the maximum predicted cumulative 1-hour average and annual average concentrations of NO_2, assuming 100% of NOx is NO_2. Background NO_2 monitoring data is based on monitoring data from Macarthur, which results in the highest 1 hour average levels from all the NSW EPA monitoring stations in the region (refer to the AQIA). The Macarthur area is a high population area that is likely to have a greater number of sources of NO_2, specifically vehicle emissions, than the local area. Hence use of this data is considered conservative. The annual average concentrations of NO^2 are from Bargo for 2017 and 2018[9].

Table 5.6: Review of potential acute and chronic health impacts – nitrogen dioxide

Location and scenario	Maximum 1-hour average concentration (µg/m^3)	Maximum annual average concentration (µg/m^3)
Background	166	11.3
Worst-case concentrations from Project	25	0.12
Cumulative concentrations	191	11.4
Standards and goals	**246**	**62**

Based on **Table 5.5**, there are no cumulative concentrations of NO_2 that exceed the relevant guidelines and hence there are no cumulative exposure issues for the local community.

To further address potential risks to human health that may be associated with population exposures and localised changes in NO_2 that relate to the Project, incremental risk calculations have been undertaken and are presented in **Section 5.5.3**.

5.5.3 Assessment of incremental impacts

The approach adopted for the assessment of exposures and impacts is consistent with that adopted for particulates as outlined above (and **Appendix A**). This involves the calculation of a change in relative risk, and the change in incidence, or the number of cases, that occur in the community.

Table 5.7 presents a summary of the health endpoints considered in this assessment, the β coefficient relevant to the calculation of a relative risk. The coefficients adopted for the assessment of impacts on mortality and asthma emergency department admissions are derived

[9] https://www.environment.nsw.gov.au/AQMS/search.htm

from the detailed assessment undertaken for the review of health impacts of air pollution undertaken by NEPC (Golder 2013) and are considered to be robust.

Table 5.7: Adopted exposure-responses relationships for assessment of changes in nitrogen dioxide concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (also as per cent) for 1 µg/m³ increase in NO_2	Reference
Mortality, all causes (non-trauma)	Short term	All ages*	0.00188 (0.19%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Mortality, respiratory	Short term	All ages*	0.00426 (0.43%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Asthma emergency department (ED) admissions	Short term	1–14 years	0.00115 (0.11%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Golder 2013; Jalaludin et al. 2008)

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

Table 5.8 presents a summary of the calculated impact of exposure to NO_2 from the Project for the scenarios considered. The calculated incremental risks presented relate to the maximum risk for all receptors evaluated. Calculations of incremental risk for each individual receptor are included in **Appendix C**. No population incidence has been calculated as the calculated risks are very low.

Table 5.8: Population health impacts associated with exposure to nitrogen dioxide

Location	Calculated incremental risk		
	Mortality (all causes, all ages)	Respiratory mortality (all ages)	Asthma ED admissions (1-14 years)
Incremental risk – maximum from all receptors			
Worst-case operational year	$1x10^{-6}$	$3x10^{-7}$	$2x10^{-6}$

Review of **Table 5.8** and **Appendix C** indicates the following:

- There are no incremental risks relevant to NO_2 impacts from the Project that would be considered to be unacceptable. The calculated risks are sufficiently low to be considered negligible.
- On the basis of the above there are no health impacts of concern in relation to potential emissions of NO_2 from the flares related to Project.

5.6 Assessment of health impacts – carbon monoxide

Combustion sources, including 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, an 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 from the NEPC (as standards) (NEPC 2016) that are based on the protection of adverse health effects associated with carbon monoxide. The air standards currently available from NEPC are consistent with health based guidelines currently available from the WHO (WHO 2005, 2010) and the USEPA (2011[10], specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis, the current NEPC standards are considered appropriate for the assessment of potential health impacts associated with the Project.

The NEPC ambient air quality standard for the assessment of exposures to carbon monoxide has considered the lowest observed adverse effect level (LOAEL) and the no observed adverse effect level (NOAEL) associated with a range of health effects in healthy adults, with people with ischemic heart disease and with foetal effects.

In relation to these data, a level of carbon monoxide of nine parts per million (ppm) by volume (or 10 milligrams per cubic metre or 10,000 micrograms per cubic metre) over an 8-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population (NEPC 2016). An additional 1.5-fold uncertainty factor to protect more susceptible groups in the population was included. On this basis, the NEPC (and the EPA Victoria) standard is protective of adverse health effects in all individuals, including sensitive individuals.

Table 5.9 summarises the maximum predicted cumulative (i.e. Project plus background) 1-hour average and 8-hour average concentrations of carbon monoxide related to emissions to air from the operation of the flares form the Project. Background concentrations of CO are the maximum 8-hour rolling average as reported in the AQIA. The background 1-hour average concentration of CO is not available.

Table 5.9 Review of potential acute and chronic health impacts – carbon monoxide (CO)

Scenario	Maximum 1-hour average concentration of CO (mg/m^3)	Maximum 8-hour average concentration of CO (mg/m^3)
Background	NA	2.3
Worst-case emissions from Project	0.14	0.026
Background plus Project	--	2.3
Relevant health based standard/ guideline	30	10

NA – it is not applicable or relevant to assess chronic exposures for the maximum emissions scenario

All the concentrations of carbon monoxide presented in **Table 5.9** are well below the relevant health based standards/guidelines listed at the base of the table. The contribution from the Project is negligible.

[10] 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

5.7 Assessment of health impacts – hydrocarbons

Assessment of air emissions from the operation of the flare also considered emissions of VOCs as hydrocarbons as a general group. From a health perspective it is not possible to properly assess such a general grouping of VOCs as each individual chemical has a different toxicity and the composition of the individual chemicals within the group is not known. For the assessment of inhalation exposures to hydrocarbons, it could be generally assumed that the group may comprise light aromatic hydrocarbons (which is a conservative assumption as less toxic aliphatic hydrocarbons would also be present) where a chronic health based inhalation criteria (TPHCWG 1999), protective of exposures by all members of the population, of 0.2 to 0.4 mg/m^3. The AQIA has predicted the maximum 1-hour average concentration of hydrocarbons at each receptor. The maximum predicted 1-hour average concentration is 0.052 mg/m^3. This is not representative of what any member of the population may be exposed to every hour of every day for a lifetime (which is what the chronic health based criteria is based on). There are no acute guidelines relevant to general hydrocarbon groups, hence if it were assumed that the maximum 1-hour average concentration was representative of a chronic exposure, the maximum concentration is well below the health based guidelines.

On the basis of the above, there are no health effects of concern in the community in relation to emissions to air of VOC form the operation of the flares.

5.8 Uncertainties

It is expected that the assessment of health impacts in relation to changes in air quality, associated with the Project, will be conservative. This is due to the incorporation of a number of conservative assumptions in the modelling of air quality impacts (specifically the continual operation of the proposed mine at maximum extraction rates, the use of conservative emission rates for the equipment proposed to be used, and the approach adopted for the estimation of nitrogen dioxide concentrations as a proportion of oxides of nitrogen).

In addition, the assessment of potential health impacts has assumed that the off-site community remains at home (or on their property) all day, every day for a lifetime. This will overestimate actual exposures where residents will spend time away from the home, and the changes in air quality evaluated remain the same for a lifetime.

As a result of the above, the risk calculations presented are considered to be conservative.

5.9 Outcomes of health risk assessment

Table 5.10 presents a summary of the outcomes of the assessment undertaken in relation to the impacts of changes in air quality, associated with the Project, on community health.

Table 5.10: Summary of health risks – air quality

Air emissions	
Impacts	Based on the available data and information in relation to emissions of dust, as well as emissions from the operation of the flare (nitrogen dioxide, carbon monoxide and VOCs as hydrocarbons) from the Project, potential impacts on the health of the community have been assessed. The impact assessment has concluded there are no health risk issues of concern relevant to the Project (including construction and operational phases).
Benefits	None identified
Mitigation	The current air quality management measures employed for the existing Tahmoor Mine, as described in the Tahmoor Air Quality & Greenhouse Gas Management Plan outlines relevant management measures to minimise dust generation. It is expected that these measures would apply to all activities associated with the Project.

Section 6. Health impacts: Noise

6.1 Background

This section presents a review and further assessment of impacts on health associated with noise, relevant to the Project. The assessment presented has relied on the information provided in the following report:

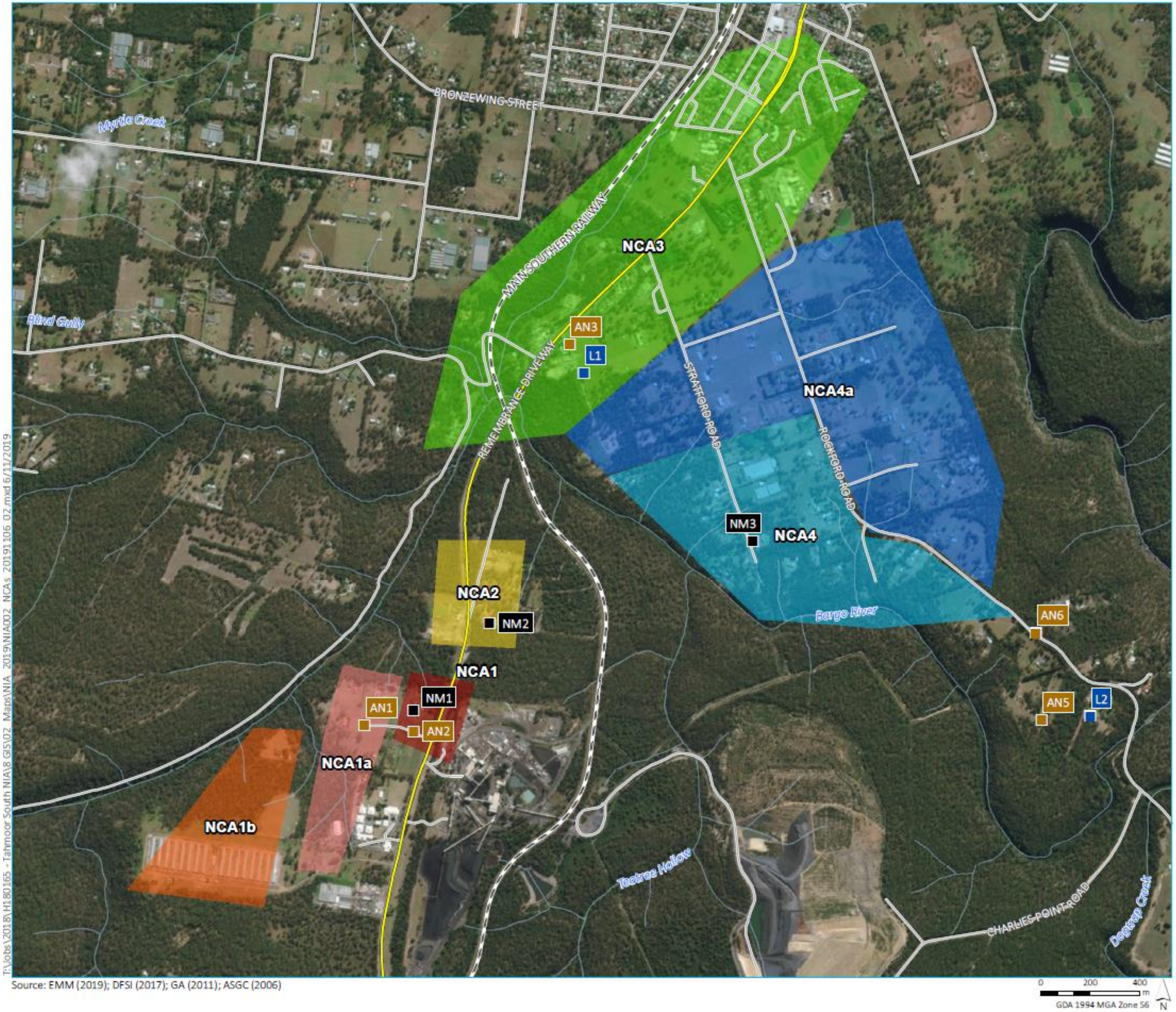
- EMM 2018, Tahmoor South Project, Noise and vibration impact assessment. Report dated November 2018 and included as Appendix M to the EIS.
- EMM 2020, Tahmoor South Project, Noise and vibration impact assessment. Report dated February 2020.

The noise impact assessment has considered impacts at a large number of locations within ten Noise Catchment Areas (NCA) (refer to **Figures 6.1a and 6.1b**). These NCAs cover a range of residential, semi-rural and agricultural areas that include the towns of Buxton, Bargo and Balmoral. Specific receptors modelled in the assessment include residential homes as well as noise-sensitive developments (such as the Anglican Church and College).

Existing, or background, noise levels in the community, at the receptors evaluated, have been determined on the basis of available noise monitoring data. Ambient monitoring data was collected at times when the existing mine was operational as well as when mining operations were limited.

The existing noise environment west of the site, in Olive Lane, is dominated by noise from Tahmoor mine and traffic on Remembrance Drive. North of the site the existing noise environment is dominated by local traffic and some commercial activity with some contribution from Tahmoor mine. Noise levels at residences south of the site are dominated by traffic noise from Remembrance Drive and trains. Noise levels in residential areas west of the site are dominated by typically rural sounds and local traffic.

The background noise levels adopted in the assessment, termed a Rating Background Level (RBL, which relates to noise over a 15-minute period) adopted for the NCAs ranged from 35 to 46 decibels (A-weighted) (dBA) during the day, from 30 to 46 dBA during the evening and from 30 to 42 dBA at night.



KEY

- Main road
- Local road
- Rail line
- Watercourse / drainage line

Noise monitoring locations

- EMM operator-attended noise surveys
- Unattended noise monitoring locations 2018
- Unattended noise monitoring locations 2019

Noise catchment area

- NCA1
- NCA1a
- NCA1b
- NCA2
- NCA3
- NCA4
- NCA4a
- NCA5
- NCA6
- NCA6a

Figure 6.1a

Assessment, monitoring locations and NCA

Tahmoor South Project
Noise impact assessment
Figure 4.1
Map 1 of 2

creating opportunities

Source: EMM (2019); DFSI (2017); GA (2011); ASGC (2006)

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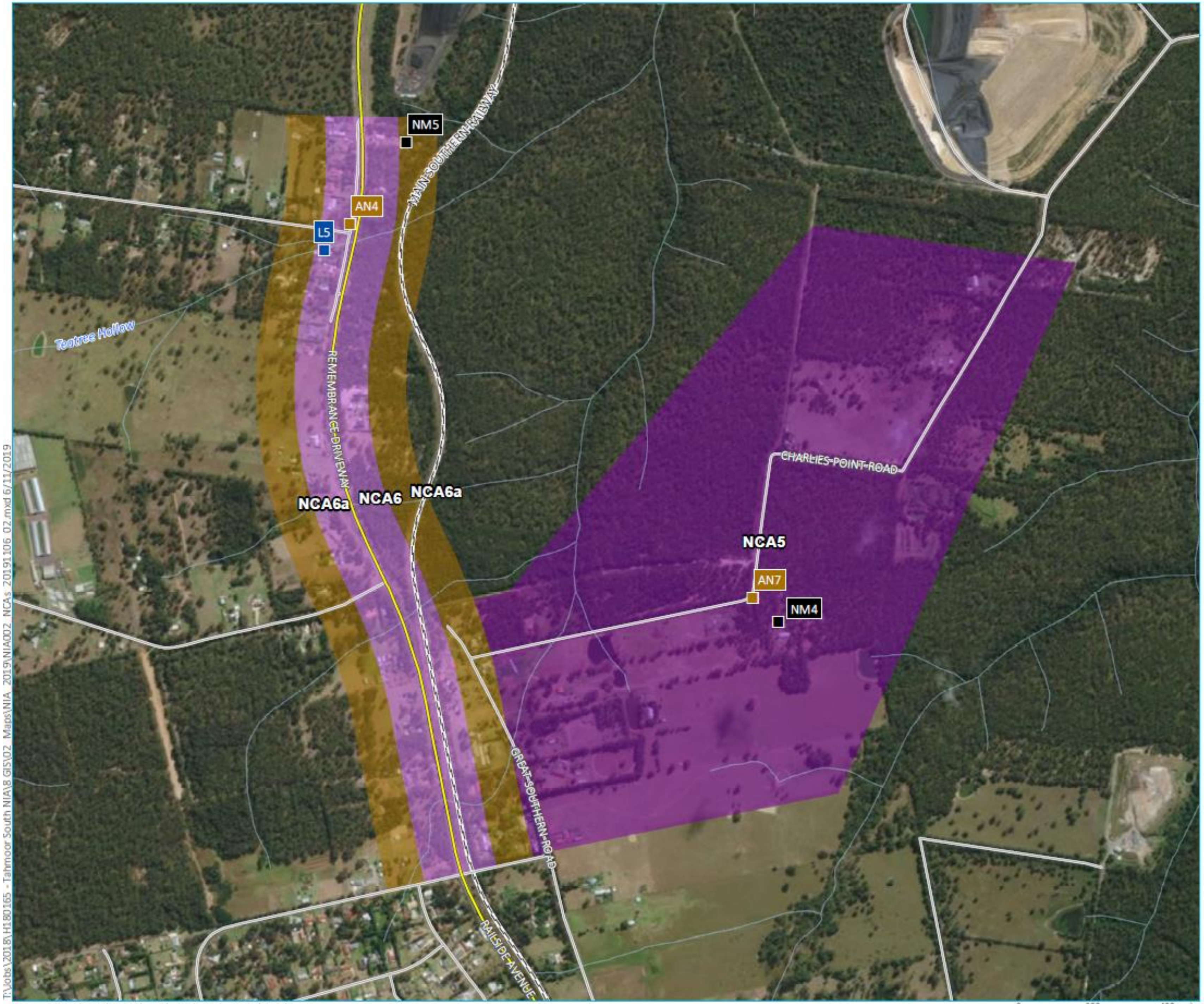

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Source: EMM (2019); DFSI (2017); GA (2011); ASGC (2006)

KEY

- Main road
- Local road
- Rail line
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Noise monitoring locations

- EMM operator-attended noise surveys
- Unattended noise monitoring locations 2018
- Unattended noise monitoring locations 2019

Noise catchment area

- NCA1
- NCA1a
- NCA1b
- NCA2
- NCA3
- NCA4
- NCA4a
- NCA5
- NCA6
- NCA6a

Figure 6.1b

Assessment, monitoring locations and NCA

Tahmoor South Project
Noise impact assessment
Figure 4.1
Map 2 of 2

EMM creating opportunities

6.2 Health impacts associated with noise

Environmental noise has been identified (I-INCE 2011; WHO 2011, 2018)[11] as a growing concern because it has negative effects on quality of life and wellbeing and has the potential for causing harmful physiological health effects. With increasingly urbanised or developed societies, impacts of noise on communities have the potential to increase over time.

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, 2018):

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, promote risk-taking behaviour and increase risk of accidents).
- Annoyance.
- Cardiovascular health.
- Hearing impairment and tinnitus.
- Cognitive impairment (effects on reading and oral comprehension, short and long-term memory deficits, attention deficit).

Other effects for which evidence of health impacts exists, and are considered to be important, but for which the evidence is weaker, include:

- Effects on quality of life, well-being and mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects).
- Adverse birth outcomes (pre-term delivery, low birth weight and congenital abnormalities).
- Metabolic outcomes (type 2 diabetes and obesity).

Within a community the severity of the health effects of exposure to noise and the number of people who may be affected are schematically illustrated in **Figure 6.2**.

[11] I-INCE – International Institute of Noise Control Engineering.

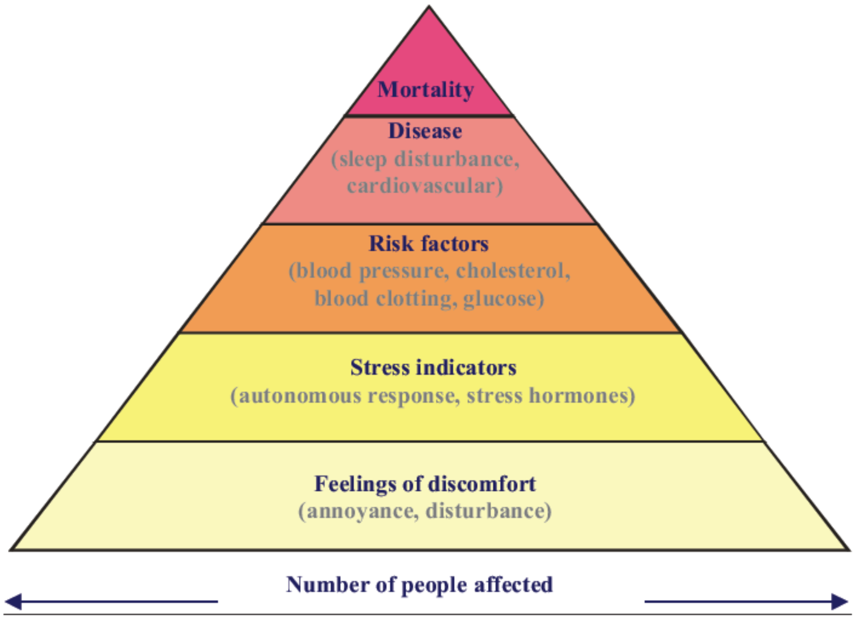


Figure 6.2: Schematic of severity of health effects of exposure to noise and the number of people affected (WHO 2011)

Often, annoyance is the major consideration because it reflects the community's dislike of noise and their concerns about the full range of potential negative effects, and it affects the greatest number of people in the population (I-INCE 2011; WHO 2011, 2018).

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 has the potential to lead to other 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 (I-INCE 2011; WHO 2011, 2018).

Different individuals have different sensitivities to types of noise and this reflects differences in expectations and attitudes more than it reflects any differences in underlying auditory physiology. A noise level that is perceived as reasonable by one person in one context (e.g. in their kitchen when preparing a meal) may be considered completely unacceptable by that same person in another context (e.g. 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 considered to be completely unacceptable by one person, may be of little consequence to another even if they are in the same room. In this case, the annoyance depends almost entirely on the personal preferences, lifestyles and attitudes of the listeners concerned (I-INCE 2011; WHO 2011, 2018).

Perceptible vibration (e.g. from construction activities) also has the potential to cause annoyance or sleep disturbance and adverse health outcomes in the same way as airborne noise. However, the health evidence available relates to occupational exposures or the use of vibration in medical treatments. No data is available to evaluate health effects associated with community exposures to perceptible vibrations (I-INCE 2011; WHO 2011, 2018).

It is against this background that an assessment of potential noise impacts of the Project on health was undertaken.

In relation to the available noise guidelines, the most recent review of noise by the WHO (WHO 2018) provided an update in relation to environmental noise guidelines (and targets) that more specifically relate to transportation (road, rail and air), wind turbines and leisure noise sources. The more comprehensive guideline levels for noise (related to all sources) remain the older WHO guidelines (WHO 1999) and night noise guidelines (WHO 2009).

Based on the relevant WHO guidelines for noise, **Table 6.1** presents thresholds that have been determined to be protective of health effects. These noise levels relate to levels outside a home/building as the modelling of noise impacts presented by EMM (2018 and 2020) are outside of a home (not inside). The guidelines for outside assume windows are left open, which may be the case during at least some of the year in the area evaluated. Where windows are closed the noise criteria will include an additional level of protection.

Table 7.1: Health protective noise thresholds from WHO (noise levels outside) (WHO 1999, 2009)

Environment and exposure time (T)	Critical (most sensitive health effect)	$LA_{eq,T}$ (dB(A))	LAmax (dB)
Residents			
Day and evening – 16 hours	Annoyance, cardiovascular effects and disturbance of conversation	50	NA
Night – 8 hours	Sleep disturbance	42	60
Schools			
Day – during class (6 hours)	Speech intelligibility, communication	50	NA

6.3 Review of the noise guidelines adopted

Noise guidelines adopted in the Noise and Vibration Impact Assessment (EMM 2020) are those outlined in the Noise Policy for Industry (NPfI) (NSW EPA 2017), which indicate that intrusive noise from a specific industrial source should not exceed the RBLs by more than 5 dBA. To address intrusive noise, the noise trigger levels adopted were $LA_{eq,15\text{-minute}}$ of 40 to 51 dBA during the day, 35 to 51 dBA during the evening and 35 to 47 dBA at night.

In addition, consideration has also been made to noise amenity, with the Project noise trigger levels adopted based on the lower noise criteria relevant to intrusiveness and amenity.

Noise amenity criteria (noted above) as $LA_{eq,15\text{-minute}}$ are 53 to 58 dBA during the day, 48 dBA during the evening and 43 dBA during the night-time period. The noise amenity criteria are more specifically used to evaluate cumulative noise from a number of industrial sources. These criteria will remain protective of health, including annoyance and sleep disturbance where they relate to outside noise levels (WHO 1999, 2009).

Adopting the lower of the intrusive noise and noise amenity guidelines results in the following: $LA_{eq,15\text{-minute}}$ of 40 to 51 dBA during the day, 35 to 48 dBA during the evening and 35 to 43 dBA at night. These noise trigger levels are generally sufficiently low to be protective of health, based on available guidance from the WHO (WHO 1999, 2011).The NPfI provides guidance on the interpretation of noise impacts in relation to these trigger levels, particularly in relation to predicted/estimated changes in noise levels. These noise criteria are the lowset of those to protect intrusive noise and noise amenity and have been adopted as the Project specific noise criteria.

Maximum noise levels were also established based on the NPfI guidance (NSW EPA 2017). The maximum noise criteria are set to protect residence from sleep disturbance and for this Project, an LA_{max} of 52 to 57 dBA is relevant to the night-time period. This maximum noise level is sufficiently low to be protective of health, based on available guidance from the WHO (WHO 1999).

Road traffic noise was assessed on the basis of the NSW Road Noise Policy (NSW DECCW 2011)[12], as it applies to existing residence affected by additional traffic. This provides a guideline of 60 dBA as $LA_{eq,15\ hour}$ (day and evening) and 55 dBA as $LA_{eq,9\ hour}$ (night). These guidelines are higher than the health based goals relevant to road noise traffic from the WHO (WHO 2018) but consistent with the upper end of noise criteria established in previous WHO guidelines for outdoor noise predictions (WHO 1999, 2009).

Construction noise criteria have been adopted from the Interim Construction Noise Guideline (ICNG) (NSW DECC 2009)[13] which provide management levels relevant to the assessment of noise impacts above the RBL during standard hours[14] (guideline of 40 dBA adopted for the Project) and outside standard hours (guideline 35 dBA adopted for the Project), with noise levels (total noise from all sources) above 75 dBA during standard hours considered to be highly noise affected. While these criteria may result in some construction noise being noticeable, the noise criteria adopted for the Project will be protective of health, including annoyance and sleep disturbance, where they relate to outside noise levels (WHO 1999, 2009).

6.4 Review and assessment of health impacts from noise

6.4.1 Construction noise

Assessment of noise impacts during construction involved consideration of the relevant construction activities (equipment used, hours of use and location of use).

In relation to the assessment of noise generated during a range of construction activities assuming these operate at the same time during construction hours, noting that ventilation shaft drilling would be continuous for 24 hours of the day, 7 days of the week.

The assessment of construction noise was undertaken using a noise model (Brüel & Kjær Predictor software, 'Predictor'), which provides noise predictions at each individual receptor – as an outdoor noise level.

[12] DECCW – NSW Department of Environment, Climate Change and Water.

[13] DECC – NSW Department of Environment and Climate Change.

[14] Standard hours outlined in the ICNG (NSW DECC 2009) are Monday to Friday 7 am to 6 pm; Saturday 8 am to 1 pm. No construction work is to take place on Sundays or public holidays.

Assessment of construction noise impacts during standard operating hours identified some areas where exceedance of the guidelines is predicted, however no noise levels exceed the criteria for highly noise affected. While such outcomes are not uncommon for construction Projects noise mitigation measures have been identified to minimise impacts during construction. Where these mitigation measures are implemented, it is expected that potential impact on community health are minimised. It should be noted that even where noise mitigation measures are implemented, noise levels during construction may be noticeable at times.

For works outside of standard operating hours, impacts in equal to or in excess of the adopted criteria were identified at the two nearest properties on Charles Point Road. Noise during these activities is likely to be below the relevant sleep disturbance criteria at all locations and hence at night-time is unlikely to result in health impacts. It is understood that Tahmoor Coal has commenced discussions/ negotiations with the owners of the property potentially affected by out of hours noise properties.

6.4.2 Operational noise

Approach

The operational noise assessment has considered noise impacts from the existing Tahmoor mine and the Project operations (unmitigated). The noise assessment has utilised a noise model (Brüel & Kjær Predictor software, 'iNoise') that provides predictions of noise impacts from multiple noise sources at each modelled receptor as an outdoor noise level.

Activities that are proposed to be undertaken during Project operations, including the location of operation, and sound power levels generated by these equipment/activities, have been considered in the noise model, along with terrain and meteorological conditions. The model assumed that all noise sources operated continuously during all periods of the day.

The noise modelling undertaken has been conducted in an iterative manner, incorporating and evaluating various combinations of feasible and reasonable noise management and mitigation measures. As a result, a range of specific mitigation measures have been identified in the noise impact assessment to reduce noise emissions from the Project. The assessment has also considered the use of a range of mitigation measures, with modelling being done with and without these measures.

Noise impacts

The assessment has evaluated noise impacts associated with the existing Tahmoor mine, the Project unmitigated and the Project with mitigation measures. Under all these scenarios there are a number of locations where there is predicted to be an exceedance of the Project specific noise level by varying levels (no more than 2 dB, 3 to 5 dB and more than 5 dB) under worst-case meteorological conditions described as either noise enhancing or calm.

Based on the assessment undertaken, where the Project is operational and mitigation measures are implemented:

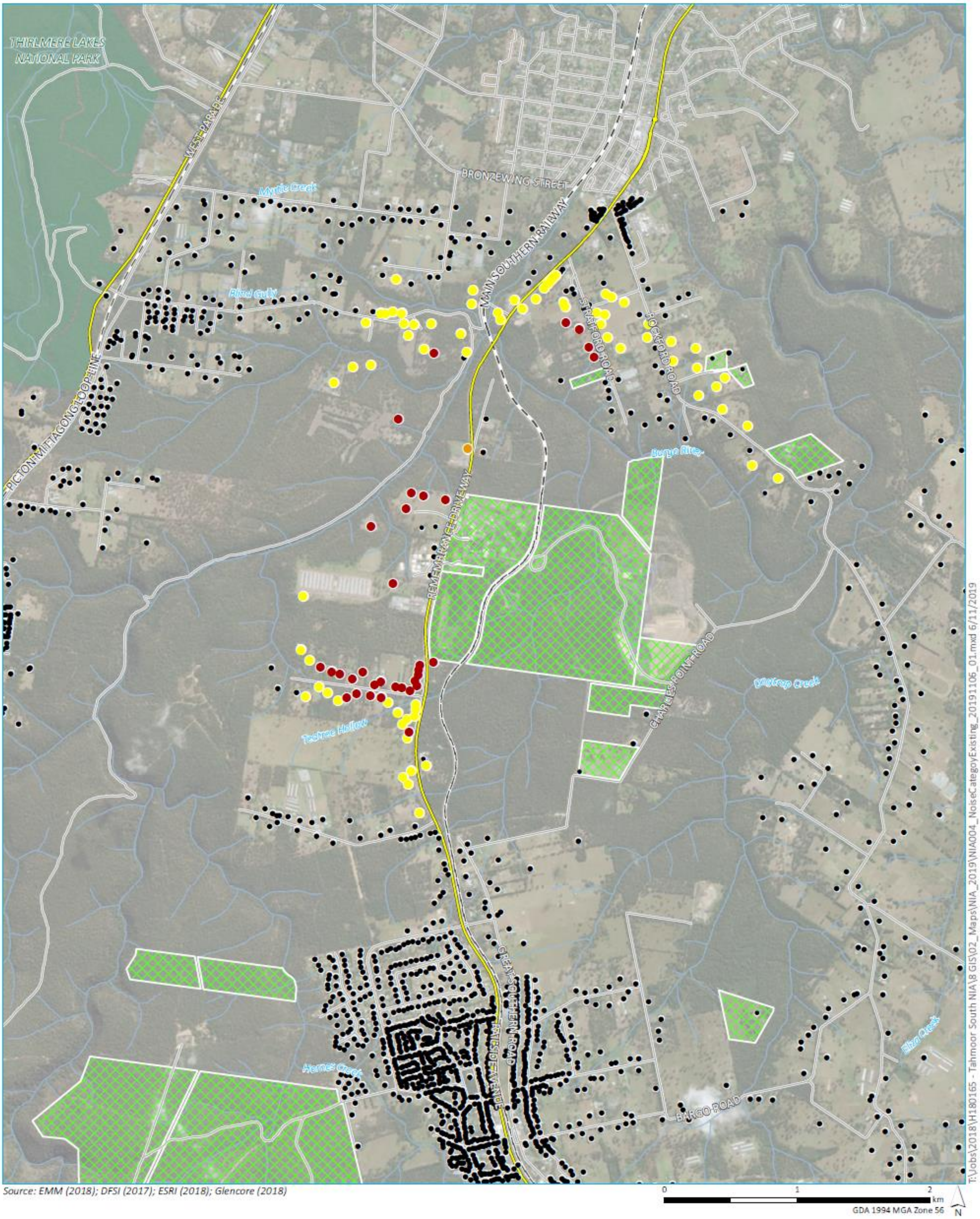
- there would be a significant reduction in the number of private dwellings affected by night-time noise, under noise enhancing conditions, that exceed the criteria by more than 5 dB (reduction from 33 dwellings for the existing Tahmoor mine to 6 dwellings);
- night time noise levels at the community receptors are expected to be reduced by 2 to18 dB; and
- day and evening noise levels are expected to be reduced by up to 7 dB at most community receptors.

Exceedances of the noise criteria that are categorised as negligible, marginal, moderate or significant are illustrated on **Figure 6.3** (for the existing Tahmoor mine) **and Figure 6.4** (for the Project). These figures highlight that these exceedances principally relate to the existing Tahmoor mine operations, with the operation of the Project (mitigated) expected to result in a reduction in noise at most community receptors. Where noise levels exceed the health based criteria adopted, where there are reductions in noise at community receptors, this has the potential for some health benefits. Tahmoor Coal will continue to investigate options for further noise reductions.

Predicted $L_{Aeq,15\text{-}minute}$ noise predictions in the Noise and Vibration Impact Assessment have been converted to represent $LA_{eq,day}$, $LA_{eq,evening}$ or $LA_{eq,night}$[15]. Using these noise levels, all predicted noise levels during the day (maximum $LA_{eq,day}$ = 48 dBA) and night (maxim $LA_{eq,night}$ = 42 dBA) (taken to be outdoor noise predictions at each receptor) are around or below health based noise guidelines for sleep disturbance and annoyance (WHO 1999).

The assessment of potential impacts on sleep disturbance determined that the operation of the Project was unlikely to result in maximum noise events that would result in sleep awakening.

[15] Conversion of $LA_{eq,15\text{-}minute}$ to $LA_{eq,period}$ is outlined in the NPfI NSW EPA 2017, Noise Policy for Industry (and in the Noise Impact Assessment), where $LA_{eq,period}$ = $LA_{eq,15\text{-}minute}$ - 3 dB.



Source: EMM (2018); DFSI (2017); ESRI (2018); Glencore (2018)

Figure 6.3: Noise impact categories - Existing

KEY

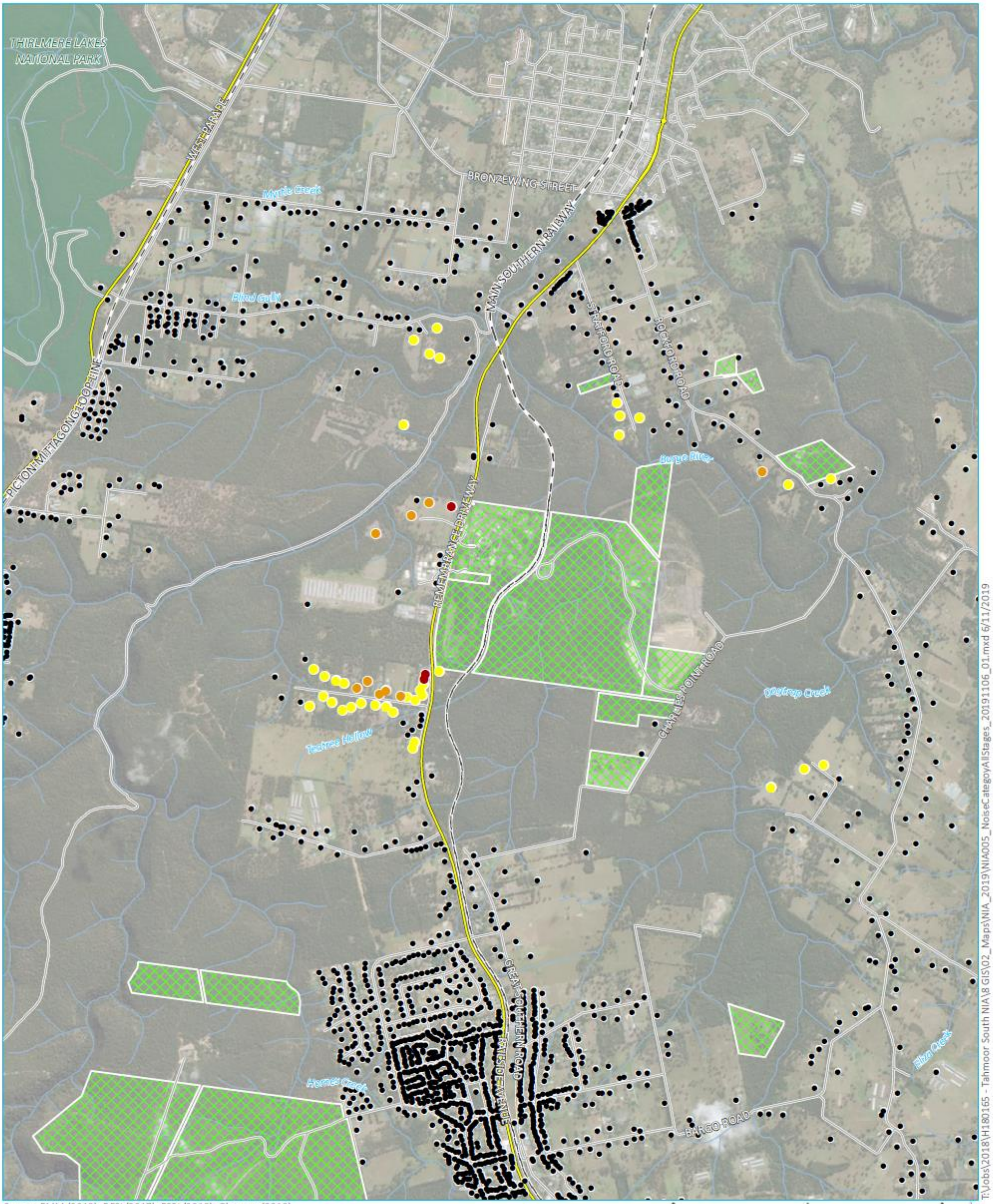
- Tahmoor-owned land
- Rail line
- Main road
- Local road
- Watercourse / drainage line
- NPWS reserve

Noise impact category (existing)

- Negligible
- Marginal
- Moderate
- Significant

Tahmoor South Project
Noise impact assessment
Figure X.1

EMM
creating opportunities



Source: EMM (2018); DFSI (2017); ESRI (2018); Glencore (2018)

KEY

- Tahmoor-owned land
- Rail line
- Watercourse / drainage line
- Main road
- Local road
- NPWS reserve

Noise impact category (all stages)

- Negligible
- Marginal
- Moderate
- Significant

Figure 6.4: Noise impact categories - Tahmoor South Project (all stages)

Tahmoor South Project
Noise impact assessment
Figure X.2

EMM creating opportunities

Road noise

Assessment of road traffic noise identified that existing road traffic resulted in noise levels in excess of the relevant criteria, particularly along Remembrance Drive. Where the Project is considered the change in noise levels is <1 dB along Remembrance Drive, 1 dB along Rockford Road and 8 dB on Charles Point Road. Changes in noise that are <1 or 1 dB are not considered to be of significance in relation to health. The increase of 8 dB does not result in noise levels that exceed the adopted criteria and are therefore not considered to be of concern in relation to health.

Overall

Based on the available information, the potential for noise impacts to result in adverse health impacts within the community is considered to be low, where proposed noise mitigation measures are implemented.

6.5 Uncertainties

The assessment presented in relation to potential noise impacts, and the potential for impacts on community health as a result of changes in noise as a result of the Project are considered to be conservative. There are a number of areas within the noise impact assessment where conservative assumptions and approaches have been adopted. This includes the selection of RBLs relevant to the off-site areas, consideration of the worst-case meteorological conditions and assuming these occur on a regular ongoing basis and use of the upper end of noise impacts for comparison with relevant guidelines.

On the basis of the above, conclusions in relation to potential impacts on community health are expected to be conservative.

6.6 Outcomes of health risk assessment: noise

Table 6.2 presents a summary of the outcomes of the assessment undertaken in relation to the impacts of changes in noise, associated with the Project, on community health.

Table 6.2: Summary of health risks - noise

Noise emissions	
Impacts	Based on the predicted noise levels and potential mitigation measures, the potential for adverse health impacts within the off-site community associated with noise generated during construction and operations is considered to be low
Benefits	Implementation of the proposed noise mitigation measures associated with the Project is expected to reduce site related noise impacts at most receptor locations in the community, providing some health benefit
Mitigation	The current noise management plan is expected to be revised to include the noise mitigation measures relevant to the Project, including any additional mitigation measures identified by Tahmoor to address operational noise levels from the existing mine and proposed Project.

Section 7. Health impact assessment: Water

7.1 Approach

Health impacts associated with potential impacts of the Project on water access and quality relevant to the local community have been evaluated on the basis of information provided in the following reports:

- HEC 2020, Tahmoor South Project, Surface Water Baseline Study; Flood Study; Water Management System and Site Water Balance, and Surface Water Impact Assessment.
- HydroSimulations, 2018. Tahmoor South Project EIS, Groundwater Assessment. Report dated December 2018 and included as Appendix I to the EIS Maxwell Project.
- HydroSimulations 2020. Tahmoor South Amended Project Report: Groundwater Assessment. Report dated February 2020.

The assessment undertaken in relation to water, has involved a qualitative review of the available information to determine if there is the potential for the Project to result in changes to surface water or groundwater quality or quantity, and where such changes may occur, if these may adversely affect the health of the community who may access and use these water resources.

7.2 Existing surface water and groundwater

Water Sharing Plans (WSPs) have been adopted and cover much of the State, and these, along with the *Water Management Act 2000*, establish rules for sharing and trading both groundwater and surface water between competing needs and users.

The WSP covering the Tahmoor South Project is the 'Greater Metropolitan Region Groundwater Sources' Plan. This WSP comprises several Groundwater Sources. These Groundwater Sources are used to manage the average long-term annual volume of water extracted. The source directly relevant to the Tahmoor South Project is:

- Sydney Basin – Nepean Sandstone, with the Project more specifically located within Nepean Management Zone 2

Other relevant Groundwater Sources include:

- Sydney Basin – Central, located some 10 km to the east and northeast;
- Sydney Basin – South, located around 15-20 km east and southeast; and
- Goulburn GMA, located more than 25 km to the west and south

The Greater Metropolitan Region Unregulated Water Sources WSP is the relevant plan for surface waters for the Project. Within this WSP the Upper Nepean River source is the relevant management area, of which the following Management Zones (MZ) cover the Project site:

- Pheasants Nest Weir to Nepean Dam MZ;
- Stonequarry Creek MZ; and
- Maldon Weir MZ.

The existing Tahmoor Mine and the Project Area are located within the Bargo River catchment. From its headwaters near the townships of Hill Top and Yerrinbool, the Bargo River flows in a generally north-easterly direction through incised valleys and gorges to its confluence with the Nepean River, near the Pheasants Nest Weir (refer **Figure 7.1**).

The Bargo River has intermittent flow in its upstream reaches. In its upper reaches flows are, to some degree, regulated by the Picton Weir which is located approximately 14 km upstream of the Nepean River confluence. Downstream of the Tahmoor Mine pit top (i.e. downstream of the Tea Tree Hollow confluence) flow is perennial due to persistent licensed discharges from Tahmoor Mine. The Bargo River flows into the Nepean River 9 km downstream of the Tea Tree Hollow confluence.

The Project Area major streams and associated monitoring sites are shown in **Figure 7.1**. Topography in the Project Area is varied, ranging from gently undulating plateaux, ridges and low hills in the upland areas, to a rugged landscape of deeply dissected valleys and gorges in Hawkesbury Sandstone. The upland areas, including Bargo Township, are drained by headwater streams of Hornes Creek, Tea Tree Hollow, Dog Trap Creek, Eliza Creek and Carters Creek. The lower reaches of Tea Tree Hollow and Dog Trap Creek, as well as the lower reaches of the Bargo River have previously been affected by mining-induced subsidence associated with the Tahmoor Mine.

To the west of Tahmoor Mine are Blue Gum Creek and Little River. Blue Gum Creek is a tributary to Little River, and this in turn is a tributary to the Nattai River and Lake Burragorang.

To the west of Tahmoor Mine are the Thirlmere Lakes, lying along the upper reaches of Blue Gum Creek. The lakes are, in order from upstream to downstream, Lake Gandagarra, Lake Werri Berri, Lake Couridjah, Lake Baraba and Lake Nerrigorang.

There are five major water storage reservoirs in the Study Area, the closest being Lake Nepean (3 km south of the Project), with Lake Avon (6 km southeast), Lake Cordeaux (14 km east-southeast), Lake Cataract (18 km east) and Lake Burragorang (Warragamba Dam) (18 km northwest). These are operated by WaterNSW and are designed to capture and store water for Sydney's drinking water supply.

National Parks, State Forests and 'drinking water catchments' (WaterNSW's 'Special Areas') are all present on land adjacent to Tahmoor Mine Leases areas.

A high priority groundwater dependant ecosystems (GDE) has been identified close to the Project, namely the Thirlmere Lakes. Other high priority GDEs are located more than 20 km from the Project.

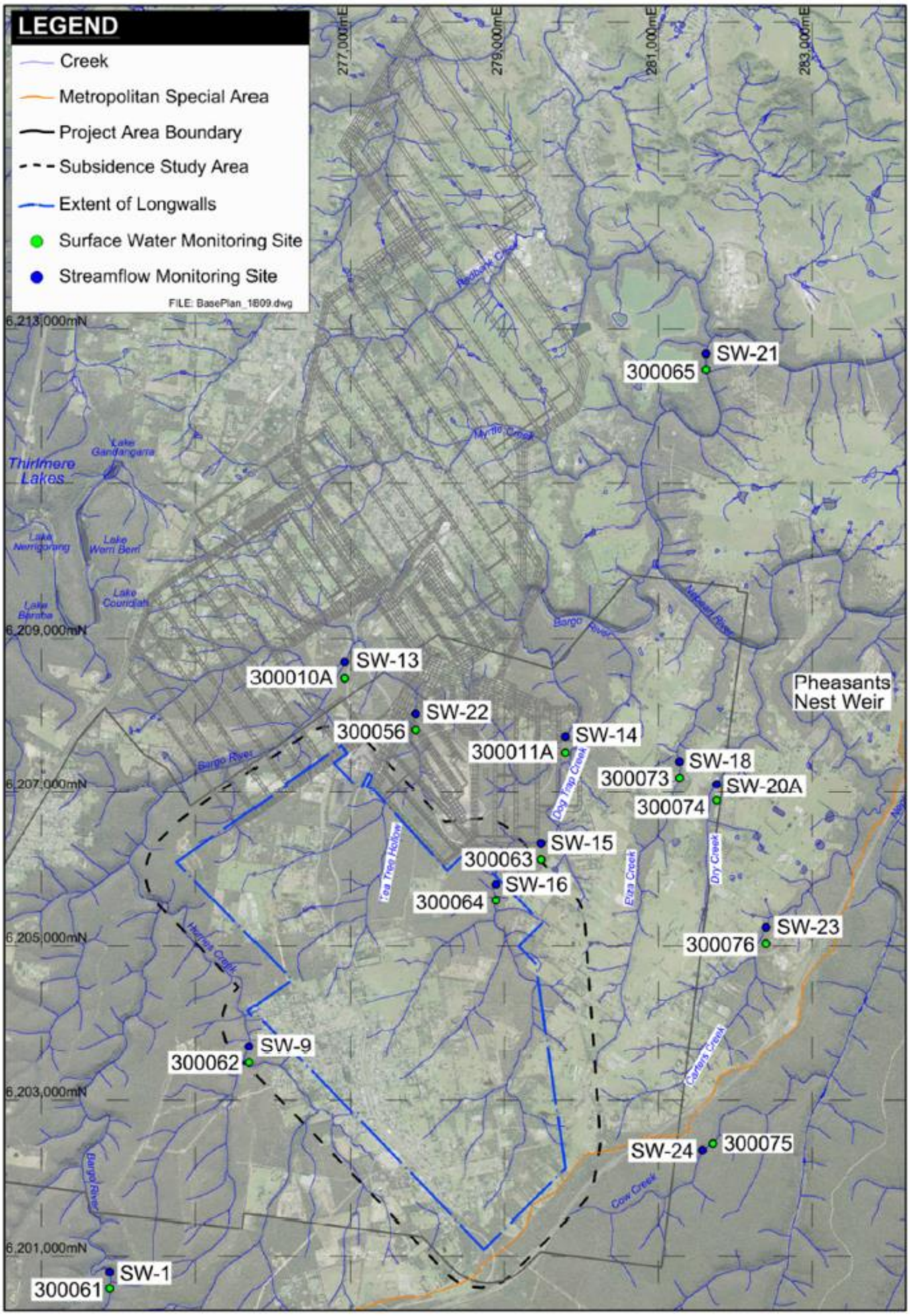


Figure 7.1: Project Area drainages and surface water monitoring sites

The major groundwater aquifers within the Study Area are the Sydney Basin Permian and Triassic rock units, and within the Nepean GMA these aquifers are classified as 'Highly Productive'. This classification is based on aquifer yield and groundwater quality. Within this broad classification of Permian and Triassic rock units the primary aquifer is the Hawkesbury Sandstone.

Smaller quantities of water can be extracted from parts of the Narrabeen Group, such as the Bulgo Sandstone, or from the Illawarra Coal Measures. The whole sequence comprises interlayered sandstone, claystone, siltstone, and, within the Permian strata, coal seams, to significant depth (>400-500 m).

Minor groundwater aquifers at Tahmoor include the Thirlmere Lakes alluvium and Wianamatta Formation shales.

There are 982 groundwater bores located within the Study Area, of which 791 could be matched with Water Access Licences which were reported to be used for private or small scale government use, most likely stock and domestic purposes. Most of the groundwater is extracted from the Hawkesbury Sandstone or from surficial alluvium and basalt aquifers, with around 10% from the Bulgo Sandstone.

7.3 Project management and use of water

A water management system is already in place for the existing Tahmoor Coal Mine (HEC 2020). The plan manages the movement of water onto and off the site, with one licensed discharge point and three licensed overflow points.

The proposed Project water management system for the mine will be based on the existing water management system with most aspects remaining unchanged. The proposed changes are (HEC 2020):

- Development and expansion of the stormwater drainage management and runoff control;
- Upgrading of water supply and water reticulation infrastructure
- Changes to underground mine water supply and mine dewatering reticulation
- Development of an underground storage within areas of the Tahmoor North underground to store water pumped from a sediment dam in excess of the wastewater treatment plant capacity.

The main water sources for the operation are (HEC 2020):

- Rainfall runoff;
- Sydney Water supply;
- Underground mine water extraction, including groundwater inflow; and
- Moisture entering the underground mine via the ventilation system.

Water would be required for: Coal Handling and Preparation Plant (CHPP) operation; underground mining operations (e.g. for cooling and underground dust suppression); dust suppression; washdown usage; and other minor non-potable uses. Water losses would also occur via evaporation.

7.4 Review of Project impacts on surface water and groundwater

7.4.1 Surface water

The assessment of impacts to surface water involved the conduct of baseline surface water monitoring for watercourses in the Study Area, catchment modelling of surface water over 129 years, assessment of the likelihood and potential scale of flooding as a result of the Project and assessment of surface water impacts relevant to the Project including the consideration of subsidence for watercourses and surface water discharges related to the Project (HEC 2020).

The surface water impact assessment identified that there may be some impacts to flow, specifically reduced flow in the immediate area of the Project and as a result of localised subsidence induced fracturing, and increased flow for Tea Tree Hollow and Bargo River Catchments immediately downstream as a result of increased discharges. Overall it was determined (HEC 2020) that there would be no net loss of water from the catchment.

Modelling of surface water impacts considered the proposed water management system for the mine. Based on the modelling undertaken it was concluded that the Project would not result in additional water quality impacts due to releases and overflows from the site (compared with the existing situation) (HEC 2020).

Subsidence fracturing of bed rock is predicted to occur and upsidence related buckling of stream beds is predicted along some sections of creeks. Based on past experience in the Southern Coalfields, including experience at the existing Tahmoor operation, it is expected that upsidence induced fracturing may lead to releases of aluminium, iron, manganese and zinc. It is likely that there may be transient, localised spikes in metal concentrations at Tea Tree Hollow, Dog Trap Creek and downstream watercourses, while subsidence is active. The extent of these impacts is expected to be similar to impacts observed in similar streams in the Southern Coalfields, and management measures have been identified to address these issues (HEC 2020).

While there have been some occurrences of gas release within the Southern Coalfields, studies have shown that gas flows do not impact water quality due to the low solubility of methane and the short residence time in the water column.

It has been determined (HEC 2020) that the proposed development would have negligible groundwater and surface water impacts on the Thirlmere Lakes that would be comparable to levels of natural variability (i.e. changes to lake levels of 0.01 m and 0.06 m on average) and would be imperceptible in many circumstances.

On the basis of the above there are no impacts identified to surface water quantity or quality that would be of significance to the health of the community that may access and use surface water bodies in the local area for any purpose (including recreational water and drinking water).

7.4.2 Groundwater

Assessment of potential impacts of the proposed Project on groundwater resources was undertaken on the basis of baseline monitoring data from existing Tahmoor Coal's groundwater monitoring program, establishing a groundwater assessment study area, developing a hydrogeological conceptual site model and numerical modelling to assess impacts (HydroSimulations 2018 and 2020).

The assessment of groundwater impacts conducted by HydroSimulations (2018 and 2020) concluded the following:

- **Aquifer interference** – the modelling identified that the Project, post closure, may affect groundwater influxes within the Sydney Basin – Nepean Sandstone Management Zone 1 and Sydney Basin-Central. The impacts, however, would not represent a significant component of these groundwater resources.
- **Baseflow impacts** – no significant impacts on baseflow loses as a result of depletion and enhanced leakage due to cracking were identified for key surface water bodies that include waterways, dams (including the surface water management zones), water storage reservoirs or special areas (i.e. Warragamba Dam)
- **Drawdown**
    - No significant impacts were predicted in relation to the GDEs, including Thirlmere Lakes.
    - Some drawdown impacts have been predicted for Wirrimbirra Sanctuary located above proposed longwalls, which include depressurisation and cracking. Drawdown of approximately 5 to 10 m is predicted in this area.
    - Some impacts have been identified in relation to drawdown impacting on groundwater bores, with approximately 50 bores predicted to experience drawdown greater than 2 m, 30 of which are in the deeper Hawkesbury Sandstone. Tahmoor Coal would manage potential bore impacts through the existing process to 'make good' on impacted users' water sources. Groundwater would be monitored during mining using manual and data logger based standing water level monitoring. Tahmoor Coal has been operating this process during the life of Tahmoor North. In addition, the process allows for bore owners to apply to Tahmoor Coal if they believe the level or water quality has declined in their groundwater bore. If it is deemed that the mine in responsible, then remedial actions could involve deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users.
- **Groundwater quality** - it is considered that mining-induced mixing of groundwater would result in changes to the salinity of the Hawkesbury Sandstone and Bulgo Sandstone, the two most commonly utilised aquifers. Any changes in salinity or specific nutrients (e.g. iron, manganese) are unlikely to alter or impact on the beneficial uses of groundwater in the Permo-Triassic rock aquifers in or around the mine lease. The risk of these impacts decreases with distance from the active mining area and enhanced rock mass deformation and fracturing. There are no anticipated risks of reduced beneficial uses of the Nepean Ground Water Management Area (GMA) porous rock aquifer as a result of the Tahmoor South mine. Where these impacts affected water quality in groundwater bores, Tahmoor Coal would 'make good' any impacts as described above.

The proposed development would require risk mitigation, prevention or avoidance strategies (including the 'make good' measures) to be implemented so that groundwater impacts are managed and minimised. These management measures are outlined by HydroSimulations (2018 and 2020). Where these risk management and mitigation measures are adopted there are no Project related impacts that would affect the quantity and quality of groundwater that the community may access or interact with, where water may be used for domestic or recreational purposes. Hence there are no impacts of concern to community health.

7.5 Uncertainties

The assessment presented in relation to potential surface water and groundwater impacts, and the potential for impacts on community health as a result of surface water and groundwater impacts as a result of the Project are considered to be conservative. There are a number of areas within the surface water and groundwater assessments where conservative assumptions and approaches have been adopted. The conclusions of these assessments have also been informed by sensitivity and uncertainty analysis.

On the basis of the above, conclusions in relation to potential impacts on community health are expected to be conservative.

7.6 Outcomes of health risk assessment: water

Table 7.1 presents a summary of the outcomes of the assessment undertaken in relation to the impacts of changes in surface water and groundwater, associated with the Project, on community health.

Table 7.1: Summary of health risks - water

Water	
Impacts	Based on the assessments undertaken, the potential for adverse health impacts within the off-site community associated with impacts to surface water and groundwater as a result of the Project is considered to be negligible.
Benefits	None identified
Mitigation	Implementation of the water management system that addresses surface water and groundwater management and mitigation measures.

Section 8. Health impact assessment: Social

Health impacts associated with potential impacts of the Project on social determinants that may affect community health have been evaluated on the basis of information provided in the following report:

- AECOM 2018, Tahmoor South Project, Social Impact Assessment (SIA). Report dated 21 December 2018 and included as Appendix Q to the EIS.

The SIA did not identify any impacts relating to community identity or cohesion. Some minor visual impacts were noted (from limited viewpoints), however these are not considered to be of relevance to community health.

The SIA considered the impacts the Project on private property (including homes). Mine-induced subsidence may result in structural and/or cosmetic damage to houses over and near the proposed longwalls. Impacts to bores as a result of the proposed development would potentially comprise impacts to their structural integrity, or from drawdown of the aquifer. These impacts as a result of the Project would be managed, monitored and remediated in accordance with the recommendations from the Southern Coalfields Inquiry. Affected property owners would be addressed through the repair, restoration and rehabilitation of these impacts in conjunction with Subsidence Advisory NSW.

The key impact identified in relation to the Project relates to beneficial employment opportunities.

Unemployment has a significant impact on physical and mental health and results in increased rates of overall mortality, including mortality from cardiovascular disease and suicide; poorer general health; poorer physical health including increased rates of cardiovascular disease, lung cancer and susceptibility to respiratory infections; poorer mental health and psychological well-being; somatic complaints; long-standing illness; disability and higher rates of medical consultation, medication consumption and hospital admission. For young people unemployment leads to a range of psychological problems including depression, anxiety and low self-esteem (Royal Australasian College of Physicians 2014).

Employment offers a range of health benefits including (Royal Australasian College of Physicians 2014, 2015):

- Work improves general health and wellbeing including self-esteem, self-rated health, self-satisfaction, physical health and financial concerns
- Work is an effective way of reducing poverty and social exclusion
- Reduces psychological distress and minor psychiatric morbidity
- Leads to lower morbidity rates
- Improves physical functioning and mental health in older people
- improvements in mental health, in particular decreased risk of depression.

The employment opportunities related to the Project have the potential to be of benefit to community health.

Section 9. Conclusions

The HHRA presented in this report has considered potential impacts on community health in relation to air quality, noise, water and social determinants.

Based on the available information, and with consideration of the uncertainties identified no significant health risk issues of concern have been identified for the off-site community. More specifically, **Table 9.1** presents a summary of the health impact assessment and mitigation measures relevant to ensuring impacts are minimised or mitigated.

Table 9.1: Summary of health risks

Air emissions	
Impacts	Based on the available data and information in relation to emissions of dust, as well as emissions from the operation of the flare (nitrogen dioxide, carbon monoxide and VOCs as hydrocarbons) from the Project, potential impacts on the health of the community have been assessed. The impact assessment has concluded there are no health risk issues of concern relevant to the Project (including construction and operational phases).
Benefits	None identified
Mitigation	The current air quality management measures employed for the existing Tahmoor Mine, as described in the Tahmoor Air Quality & Greenhouse Gas Management Plan outlines relevant management measures to minimise dust generation. It is expected that these measures would apply to all activities associated with the Project.
Noise emissions	
Impacts	Based on the predicted noise levels and potential mitigation measures, the potential for adverse health impacts within the off-site community associated with noise generated during construction and operations is considered to be low
Benefits	Implementation of the proposed noise mitigation measures associated with the Project is expected to reduce site related noise impacts at most receptor locations in the community, providing some health benefit
Mitigation	The current noise management plan is expected to be revised to include the noise mitigation measures relevant to the Project, including any additional mitigation measures identified by Tahmoor to address operational noise levels from the existing mine and proposed Project.
Water	
Impacts	Based on the assessments undertaken, the potential for adverse health impacts within the off-site community associated with impacts to surface water and groundwater as a result of the Project is considered to be negligible
Benefits	None identified
Mitigation	Implementation of the water management system that addresses surface water and groundwater management and mitigation measures.
Social determinants	
Impacts	No impacts on health identified
Benefits	Employment opportunities associated with the Project have the potential for a range of health benefits
Mitigation	NA

Section 10. References

Project specific references:

ERM 2020, Tahmoor South Project, Air Quality Impact Assessment. Report dated February 2020 (AQIA).

EMM 2018, Tahmoor South Project, Noise and vibration impact assessment. Report dated November 2018 and included as Appendix M to the EIS.

EMM 2020, Tahmoor South Project, Noise and vibration impact assessment. Report dated February 2020.

HEC 2020, Tahmoor South Project, Surface Water Baseline Study; Flood Study; Water Management System and Site Water Balance, and Surface Water Impact Assessment.

HydroSimulations, 2018. Tahmoor South Project EIS, Groundwater Assessment. Report dated December 2018 and included as Appendix I to the EIS Maxwell Project.

HydroSimulations 2020. Tahmoor South Amended Project Report: Groundwater Assessment. Report dated February 2020.

AECOM 2018, Tahmoor South Project, Social Impact Assessment. Report dated 21 December 2018 and included as Appendix Q to the EIS.

Other references:

ABS 2016, *2016 Census, including Community Profiles (accessed online)*, Australian Bureau of Statistics. <https://www.abs.gov.au/websitedbs/censushome.nsf/home/2016; https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/communityprofile/036?opendocument>.

AIHW 2010, *Monitoring the impact of air pollution on asthma in Australia, A methods paper*, Australian Institute of Health and Welfare, Canberra.

Anderson, CH, Atkinson, RW, Peacock, JL, Marston, L & Konstantinou, K 2004, *Meta-analysis of time-series studies and panel studies of Particulate Matter (PM) and Ozone (O3), Report of a WHO task group*, World Health Organisation.

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, A joint initiative of the Australian and New Zealand Governments in partnership with the Australian state and territory governments, Online. viewed August 2018, <http://www.waterquality.gov.au/anz-guidelines>.

Australian Government 2018, *LGA Data tables — Small Area Labour Markets, Data to December 2018 (online data)*, Department of Employment, Skills, Small and Family Business <https://docs.jobs.gov.au/documents/lga-data-tables-small-area-labour-markets-december-quarter-2018>.

Bell, ML, Ebisu, K, Peng, RD, Walker, J, Samet, JM, Zeger, SL & Dominici, F 2008, 'Seasonal and Regional Short-term Effects of Fine Particles on Hospital Admissions in 202 US Counties, 1999–2005', *American Journal of Epidemiology,* vol. 168, no. 11, December 1, 2008, pp. 1301-10.

Bell, ML 2012, 'Assessment of the health impacts of particulate matter characteristics', *Research report*, no. 161, Jan, pp. 5-38.

Burgers, M & Walsh, S 2002, *Exposure Assessment and Risk Characterisation for the Development of a PM2.5 Standard*, NEPC. <http://www.nepc.gov.au/system/files/resources/9947318f-af8c-0b24-d928-04e4d3a4b25c/files/aaq-pm25-rpt-exposure-assessment-and-risk-characterisation-final-200209.pdf>.

COMEAP 2015, *Statement on the Evidence for the Effects of Nitrogen Dioxide on Health*, Committee on the Medical Effects of Air Pollutants. <https://www.gov.uk/government/publications/nitrogen-dioxide-health-effects-of-exposure>.

EC 2011, *Final report on risk functions used in the case studies*, Health and Environment Integrated Methodology and Toolbox for Scenario Development (HEIMTSA).

enHealth 2012, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra. <http://www.health.gov.au/internet/main/publishing.nsf/content/804F8795BABFB1C7CA256F1900045479/$File/DoHA-EHRA-120910.pdf >.

EPHC 2010, *Expansion of the multi-city mortality and morbidity study, Final Report*, Environment Protection and Heritage Council.

EU 2015, *Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe*, European Parliament, Council of the European Union <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0050>.

Golder 2013, *Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2*, Golder Associates for National Environment Protection Council Service Corporation. <https://www.environment.gov.au/system/files/pages/dfe7ed5d-1eaf-4ff2-bfe7-dbb7ebaf21a9/files/exposure-assessment-risk-characterisation.pdf>.

I-INCE 2011, *Guidelines for Community Noise Impact Assessment and Mitigation, I-INCE Publication Number: 11-1*, International Institute of Noise Control Engineering (I-INCE) Technical Study Group on Community Noise: Environmental Noise Impact Assessment and Mitigation.

IARC 2013a, *Air Pollution and Cancer, IARC Scientific Publication No. 161*, International Agency for Research on Cancer. <http://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Air-Pollution-And-Cancer-2013>.

IARC 2013b, *Outdoor air pollution a leading environmental cause of cancer deaths*, International Agency for Research on Cancer. <http://www.iarc.fr/en/media-centre/iarcnews/pdf/ pr221_E.pdf>.

Jalaludin, B, Khalaj, B, Sheppeard, V & Morgan, G 2008, 'Air pollution and ED visits for asthma in Australian children: a case-crossover analysis', *Int Arch Occup Environ Health,* vol. 81, no. 8, Aug, pp. 967-74.

Krewski, D, Jerrett, M, Burnett, RT, Ma, R, Hughes, E, Shi, Y, Turner, MC, Pope, CA, 3rd, Thurston, G, Calle, EE, Thun, MJ, Beckerman, B, DeLuca, P, Finkelstein, N, Ito, K, Moore, DK, Newbold, KB, Ramsay, T, Ross, Z, Shin, H & Tempalski, B 2009, 'Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality', *Research report*, no. 140, May, pp. 5-114; discussion 15-36.

Lucas, SS, Coombes, PJ, Planner, J & Welschman, S 2009, 'Rainfall Harvesting and Coal Dust: The Potential Health Impacts of Trace Elements in Coal Dust in Rainwater', *Air Quality and Climate Change,* vol. 43, no. 2, pp. 23-30.

Martuzzi, M, Galasso, C, Ostro, B, Forastiere, F & Bertollini, R 2002, *Health Impact Assessment of Air Pollution in the Eight Major Italian Cities*, World Health Organisation, Europe.

Morawska, L, Moore, MR & Ristovski, ZD 2004, *Health Impacts of Ultrafine Particles, Desktop Literature Review and Analysis*, Australian Government, Department of the Environment and Heritage.

Morgan, G, Broom, R & Jalaludin, B 2013, *Summary for Policy Makers of the Health Risk Assessment on Air Pollution in Australia*, Prepared for National Environment Protection Council by the University Centre for Rural Health, North Coast, Education Research Workforce, A collaboration between The University of Sydney, Southern Cross University, The University of Western Sydney, The University of Wollongong, Canberra.

NEPC 1998, *National Environment Protection (Ambient Air Quality) Measure - Revised Impact Statement*, National Environment Protection Council.

NEPC 1999 amended 2013a, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council. <https://www.legislation.gov.au/Details/F2013L00768/Download>.

NEPC 1999 amended 2013b, *Schedule B4, Guideline on Health Risk Assessment Methodology, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council. <https://www.legislation.gov.au/Details/F2013L00768/Download>.

NEPC 1999 amended 2013c, *Schedule B6 Guideline on Risk Based Assessment of Groundwater Contamination, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council. <https://www.legislation.gov.au/Details/F2013L00768/Download>.

NEPC 1999 amended 2013d, *Schedule B7, Guideline on Health-Based Investigation Levels, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council. <https://www.legislation.gov.au/Details/F2013L00768/Download>.

NEPC 1999 amended 2013e, *Schedule B8 Guideline on Community Engagement and Risk Communication, National Environment Protection (Assessment of Site Contamination) Measure* National Environment Protection Council. <https://www.legislation.gov.au/Details/F2013L00768/Download>.

NEPC 2002, *National Environment Protection (Ambient Air Quality) Measure, Impact Statement for PM2.5 Variation Setting a PM2.5 Standard in Australia*, National Environment Protection Council.

NEPC 2003, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council.

NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure, Discussion Paper, Air Quality Standards*, National Environmental Protection Council.

NEPC 2014, *Draft Variation to the National Environment, protection (Ambient Air Quality) Measure, Impact Statement*, National Environment Protection Council.

NEPC 2016, *National Environment Protection (Ambient Air Quality) Measure*, Federal Register of Legislative Instruments F2016C00215.

NHMRC 2011 updated 2018, *Australian Drinking Water Guidelines 6, Version 3.5 Updated August 2018, National Water Quality Management Strategy*, National Health and Medical Research Council, National Resource Management Ministerial Council, Canberra.

NSW DECC 2009, *Interim Construction Noise Guideline*, NSW Department of Environment and Climate Change. <www.environment.nsw.gov.au/resources/stormwater/0801soilsconststorm2a.pdf>.

NSW DECCW 2011, *NSW Road Noise Policy*, NSW Department of Environment, Climate Change and Water, Sydney.

NSW EPA 2016a, *Lower Hunter Dust Deposition Study*, Report prepared by AECOM for the New South Wales Environment Proection Authority. <https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/air/lower-hunter-dust-study-report.ashx>.

NSW EPA 2016b, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*, State of NSW and Environment Protection Authority, Sydney.

NSW EPA 2017, *Noise Policy for Industry*, NSW Environment Protection Authority, Sydney. <https://www.epa.nsw.gov.au/your-environment/noise/industrial-noise/noise-policy-for-industry-(2017)>.

NSW Government 2014, *State Environmental Planning Policy No 33—Hazardous and Offensive Development*, NSW Government under Environmental Planning and Assessment Act 1979. <http://www.legislation.nsw.gov.au/inforce/e5ebfcd2-5ebc-11dd-8fae-00144f4fe975/1992-129.pdf>.

OEHHA 2002, *Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates*, Office of Environmental Health Hazard Assessment.

Ostro, B 2004, *Outdoor Air Pollution: Assessing the environmental burden of disease at national and local levels.*, World Health Organisation.

Ostro, B, Broadwin, R, Green, S, Feng, WY & Lipsett, M 2006, 'Fine particulate air pollution and mortality in nine California counties: results from CALFINE', *Environmental health perspectives,* vol. 114, no. 1, Jan, pp. 29-33.

Pope, CA, 3rd, Burnett, RT, Thun, MJ, Calle, EE, Krewski, D, Ito, K & Thurston, GD 2002, 'Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution', *JAMA : the journal of the American Medical Association,* vol. 287, no. 9, Mar 6, pp. 1132-41.

Royal Australasian College of Physicians 2014, *Australian and New Zealand Consensus Statemet on the Health Benefits of Work, Position Statement: Realising the Health Benefits of Work*, The Australasian Faculty of Occupational & Environmental Medicine, The Royal Australasian College of Physicians. <https://www.racp.edu.au/docs/default-source/advocacy-library/realising-the-health-benefits-of-work.pdf>.

Royal Australasian College of Physicians 2015, *Realising the health benefits of work - An evidence update*, The Australasian Faculty of Occupational & Environmental Medicine, The Royal Australasian College of Physicians. <https://www.racp.edu.au/docs/default-source/advocacy-library/pa-health-benefits-of-work-evidence-update.pdf?sfvrsn=4>.

Sjoberg, K, Haeger-Eugensson, M, Forsberg, B, Astrom, S, Hellsten, S, Larsson, K, Bjork, A & Blomgren, H 2009, *Quantification of population exposure to PM2.5 and PM10 in Sweden 2005*, Swedish Environmental Research Institute.

TPHCWG 1999, *Human Health Risk - Based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach, Volume 5*, Total Petroleum Hydrocarbon Criteria Working Group, Amhurst, Massachusetts.

USEPA 2005, *Particulate Matter Health Risk Assessment For Selected Urban Areas*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

USEPA 2009, *Integrated Science Assessment for Particulate Matter*, United States Environmental Protection Agency. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546#Download>.

USEPA 2010, *Quantitative Health Risk Assessment for Particulate Matter*, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency.

USEPA 2012, *Provisional Assessment of Recent Studies on Health Effects of Particulate Matter Exposure*, National Center for Environmental Assessment RTP Division, Office of Research and Development, U.S. Environmental Protection Agency.

USEPA 2015, *Integrated Science Assessment for Oxides of Nitrogen–Health Criteria, Second External Review Draft*, National Center for Environmental Assessment-RTP Division, Office of Research and Development, U.S. Environmental Protection Agency.

WHO 1999, *Guidelines for Community Noise*, World Health Organisation, Geneva.

WHO 2000, *WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version)*, World Health Organisation.

WHO 2003, *Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide, Report on a WHO Working Group*, World Health Organisation.

WHO 2005, *WHO air quality guidelines global update 2005, Report on a Working Group meeting, Bonn, Germany, 18-20 October 2005*, World Health Organisation.

WHO 2006, *Health risks or particulate matter from long-range transboundary air pollution*, World Health Organisation Regional Office for Europe.

WHO 2009, *Night Noise Guidelines for Europe* World Health Organisation Regional Office for Europe.

WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.

WHO 2011, *Burden of disease from environmental noise, Quantification of healthy life years lost in Europe*, World Health Organisation and JRC European Commission.

WHO 2013a, *Review of evidence on health aspects of air pollution - REVIHAAP Project, Technical Report*, World Health Organization, Regional Office for Europe.

WHO 2013b, *Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia*, WHO Regional Office for Europe.

WHO 2018, *Environmental Noise Guidelines for the European Region*, World Health Organization Regional Office for Europe. <http://www.euro.who.int/en/publications/abstracts/environmental-noise-guidelines-for-the-european-region-2018>.

Appendix A Calculation of risks from particulates and nitrogen dioxide

A1 Mortality and morbidity health endpoints

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

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

A2 Quantification of impact and risk

The assessment of health impacts for a particular population associated with exposure to particulate matter or nitrogen dioxide has been undertaken utilising the methodology presented by the WHO (Ostro 2004)[16] where the exposure-response relationships identified have been directly considered on the basis of the approach outlined below.

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

- Estimates of the changes in particulate matter exposure levels or nitrogen dioxide levels (i.e. incremental impacts) due to the Project for the relevant modelled scenarios.
- Estimates of the number of people exposed to particulate matter or nitrogen dioxide at a given location.
- Baseline incidence of the key health endpoints that are relevant to the population exposed.
- Exposure-response relationships expressed as a percentage change in health endpoint per µg/m^3 change in particulate matter or nitrogen dioxide exposure, where a relative risk (RR) is determined.

From the above, the increased incidence of a health endpoint corresponding to a particular change in exposure has been calculated using the approach outlined below.

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

The attributable fraction/portion (AF) of health effects from air pollution can be calculated from the relative risk as:

Equation 1 $$AF_{air} = \frac{RR-1}{RR}$$

The assessment of potential risks associated with these exposures 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 (RR) is assumed to be linear[17]. The calculation of a RR based on the change in relative risk exposure concentration from baseline/existing (i.e. based on incremental impacts from the Project) can be calculated on the basis of the following equation (Ostro 2004):

Equation 2 $$RR = \exp[\beta(X-X0)]$$

Where:
X-X0 = the change in particulate matter concentration to which the population is exposed (µg/m³)
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/m³ increase in particulate matter exposure

Based on this equation, where the published studies have derived relative risk values that are associated with a 10 µg/m³ increase in exposure, the β coefficient can be calculated using the following equation:

Equation 3 $$\beta = \frac{\ln(RR)}{10}$$

Where:
RR = relative risk for the relevant health endpoint as published (µg/m³)
10 = increase in particulate matter concentration or noise level associated with the RR (where the RR is associated with a 10 µg/m³ increase in concentration

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

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

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

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

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

The calculation of an increased incidence (i.e. 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 areas surrounding the Project.

When considering the potential impact of the Project on the population for changes in air quality, the calculation has been undertaken using the following:

- The relative risk has been calculated for a population weighted annual average incremental increase in concentrations. The population weighted average has been calculated on the basis of an average concentration relevant to the study area.
- The attributable fraction has then been calculated.
- Equation 4 has been used to calculate the increased number of cases associated with the incremental impact evaluated. The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered and the population (for the relevant age groups) present the area evaluated.

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

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

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m³ change in exposure concentration
B = baseline incidence of a given health effect per person (e.g. annual mortality rate)
ΔX_{mesh} = change (increment) in exposure concentration in µg/m³ 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 is calculated as:

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

Where:
β = slope coefficient relevant to the per cent change in response to a 1 µg/m³ change in exposure
ΔX = change (increment) in exposure concentration in µg/m³ relevant to the Project at the point of exposure
B = baseline incidence of a given health effect per person (eg annual mortality rate)

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

A3 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 (e.g. change in incidence from daily changes in nitrogen dioxide or particulate matter, or chronic incidence from long-term exposures to particulate matter).

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

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

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

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

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

For the calculations presented in this assessment - for long-term and short-term effects - annual average concentrations of nitrogen dioxide and particulate matter have thus been utilised.

Appendix B Risk calculations – $PM_{2.5}$ and PM_{10}

Quantification of Effects - $PM_{2.5}$ and PM_{10}
Tahmoor South Project

Air quality indicator:	**$PM_{2.5}$**	**$PM_{2.5}$**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
Endpoint:	**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Morbidity - Asthma ED Admissions**
Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Short-Term
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	1-14 years
β (change in effect per 1 μg/m³) (as per Table 5.4)	0.0058	0.0008	0.00041	0.0006	0.00148
Annual baseline incidence (per 100,000)	1026	9235	4168	519.3	1209
Baseline Incidence (per person per year)	0.01026	0.09235	0.04168	0.005193	0.01209

Sensitive Receptors	**Change in Annual Average PM10 Concentration (μg/m³)**	**Change in Annual Average PM2.5 Concentration (μg/m³)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Assessment of impacts are each receptor							
R1	7.7E+00	1.0E+00	6E-05	7E-05	2E-05	2E-05	2E-05
R2	4.7E+00	6.0E-01	4E-05	4E-05	1E-05	1E-05	1E-05
R3	6.5E+00	9.0E-01	5E-05	7E-05	2E-05	2E-05	2E-05
R4	5.2E+00	8.0E-01	5E-05	6E-05	1E-05	2E-05	1E-05
R5	2.7E+00	3.0E-01	2E-05	2E-05	5E-06	8E-06	5E-06
R6	4.2E+00	6.0E-01	4E-05	4E-05	1E-05	1E-05	1E-05
R7	3.3E+00	5.0E-01	3E-05	4E-05	9E-06	1E-05	9E-06
R8	3.7E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R9	2.1E+00	2.0E-01	1E-05	1E-05	3E-06	7E-06	4E-06
R10	7.3E+00	5.0E-01	3E-05	4E-05	9E-06	2E-05	9E-06
R11	3.8E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R12	3.9E+00	3.0E-01	2E-05	2E-05	5E-06	1E-05	5E-06
R13	2.2E+00	2.0E-01	1E-05	1E-05	3E-06	7E-06	4E-06
R14	2.4E+00	2.0E-01	1E-05	1E-05	3E-06	7E-06	4E-06
R15	3.2E+00	3.0E-01	2E-05	2E-05	5E-06	1E-05	5E-06
R16	2.9E+00	2.0E-01	1E-05	1E-05	3E-06	9E-06	4E-06
R17	3.0E-01	0.0E+00	0E+00	0E+00	0E+00	9E-07	0E+00
R18	2.0E-01	0.0E+00	0E+00	0E+00	0E+00	6E-07	0E+00
R19	5.0E-01	0.0E+00	0E+00	0E+00	0E+00	2E-06	0E+00
R20	1.0E-01	0.0E+00	0E+00	0E+00	0E+00	3E-07	0E+00
R21	1.0E-01	0.0E+00	0E+00	0E+00	0E+00	3E-07	0E+00
R22	7.0E-01	1.0E-01	6E-06	7E-06	2E-06	2E-06	2E-06
R23	5.0E-01	0.0E+00	0E+00	0E+00	0E+00	2E-06	0E+00
R24	9.0E-01	1.0E-01	6E-06	7E-06	2E-06	3E-06	2E-06
R25	6.3E+00	8.0E-01	5E-05	6E-05	1E-05	2E-05	1E-05
R26	1.0E-01	0.0E+00	0E+00	0E+00	0E+00	3E-07	0E+00
R27	1.1E+00	1.0E-01	6E-06	7E-06	2E-06	3E-06	2E-06
R28	3.9E+00	5.0E-01	3E-05	4E-05	9E-06	1E-05	9E-06
R29	8.4E+00	1.1E+00	7E-05	8E-05	2E-05	3E-05	2E-05
R30	6.1E+00	8.0E-01	5E-05	6E-05	1E-05	2E-05	1E-05
R31	3.7E+00	5.0E-01	3E-05	4E-05	9E-06	1E-05	9E-06
R32	3.2E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R33	4.3E+00	6.0E-01	4E-05	4E-05	1E-05	1E-05	1E-05
R34	4.7E+00	6.0E-01	4E-05	4E-05	1E-05	1E-05	1E-05
R35	4.0E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R36	4.1E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R37	4.3E+00	4.0E-01	2E-05	3E-05	7E-06	1E-05	7E-06
R38	2.9E+00	3.0E-01	2E-05	2E-05	5E-06	9E-06	5E-06
R39	2.8E+00	3.0E-01	2E-05	2E-05	5E-06	9E-06	5E-06
R40	2.5E+00	2.0E-01	1E-05	1E-05	3E-06	8E-06	4E-06

Assessment of Increased Incidence - $PM_{2.5}$ and PM10
Tahmoor South Project

	Primary Indicators			Secondary Indicators	
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**PM10 Mortality - All Causes, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 5.4)	0.0058	0.0008	0.00041	0.0006	0.00148
Worst case year					
Total Population in study area:	9460	9460	9460	9460	9460
% population in assessment age-group:	59%	13%	13%	100%	21%
Average change Δx (μg/m^3):	0.375	0.375	0.375	3.288	0.375
Baseline Incidence (per 100,000) (as per Table 3.2)	1026	9235	4168	519.3	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.04168	0.00519	0.01209
Relative Risk:	1.002177	1.000300	1.000154	1.001974	1.000555
Attributable fraction (AF):	2.2E-03	3.0E-04	1.5E-04	2.0E-03	5.5E-04
Increased number of cases in population:	0.13	0.035	0.0081	0.097	0.013
Risk:	2.2E-05	2.8E-05	6.4E-06	1.0E-05	6.7E-06

Appendix C Risk calculations – NO_2

Quantification of Effects - NO_2
Maxwell Project

	Constant emissions at licence limits		
Air quality indicator:	**NO2**	**NO2**	**NO2**
Endpoint:	**Mortality - All Causes (non-trauma)**	**Mortality - Respiratory**	**Asthma - ED Hospital admissions**
Effect Exposure Duration:	Short-term	Short-term	Short-term
Age Group:	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 NO2) (as per Table 5.7)	0.00188	0.00426	0.00115
Annual baseline incidence (per 100,000)	519.3	52.4	1209
Baseline Incidence (per person per year)	0.005193	0.000524	0.01209

Sensitive Receptors	Change in Annual Average NO2 Concentration (μg/m^3)	Risk	Risk	Risk
R1	0.08	8E-07	2E-07	1E-06
R2	0.07	7E-07	2E-07	1E-06
R3	0.05	5E-07	1E-07	7E-07
R4	0.07	7E-07	2E-07	1E-06
R5	0.07	7E-07	2E-07	1E-06
R6	0.08	8E-07	2E-07	1E-06
R7	0.03	3E-07	7E-08	4E-07
R8	0.04	4E-07	9E-08	6E-07
R9	0.04	4E-07	9E-08	6E-07
R10	0.02	2E-07	4E-08	3E-07
R11	0.07	7E-07	2E-07	1E-06
R12	0.02	2E-07	4E-08	3E-07
R13	0.05	5E-07	1E-07	7E-07
R14	0.06	6E-07	1E-07	8E-07
R15	0.06	6E-07	1E-07	8E-07
R16	0.03	3E-07	7E-08	4E-07
R17	0.03	3E-07	7E-08	4E-07
R18	0.02	2E-07	4E-08	3E-07
R19	0.02	2E-07	4E-08	3E-07
R20	0.02	2E-07	4E-08	3E-07
R21	0.01	1E-07	2E-08	1E-07
R22	0.02	2E-07	4E-08	3E-07
R23	0.04	4E-07	9E-08	6E-07
R24	0.02	2E-07	4E-08	3E-07
R25	0.07	7E-07	2E-07	1E-06
R26	0.03	3E-07	7E-08	4E-07
R27	0.03	3E-07	7E-08	4E-07
R28	0.05	5E-07	1E-07	7E-07
R29	0.12	1E-06	3E-07	2E-06
R30	0.09	9E-07	2E-07	1E-06
R31	0.06	6E-07	1E-07	8E-07
R32	0.05	5E-07	1E-07	7E-07
R33	0.06	6E-07	1E-07	8E-07
R34	0.04	4E-07	9E-08	6E-07
R35	0.06	6E-07	1E-07	8E-07
R36	0.06	6E-07	1E-07	8E-07
R37	0.04	4E-07	9E-08	6E-07
R38	0.04	4E-07	9E-08	6E-07
R39	0.04	4E-07	9E-08	6E-07
R40	0.04	4E-07	9E-08	6E-07