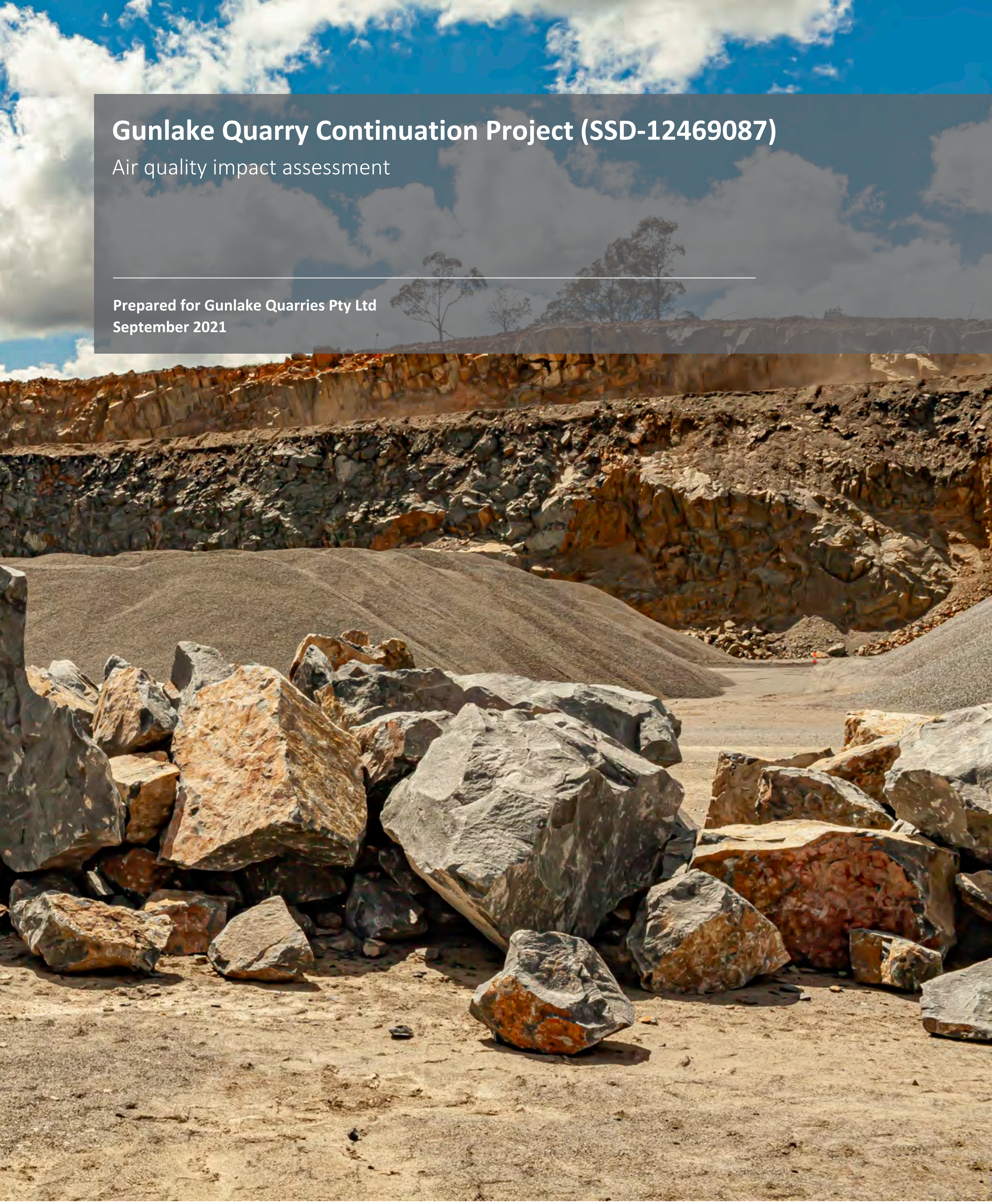
F.4 Air quality impact assessment

Gunlake Quarry Continuation Project (SSD-12469087)

Air quality impact assessment

Prepared for Gunlake Quarries Pty Ltd
September 2021



EMM
creating opportunities

EMM
creating opportunities

Servicing projects throughout Australia and internationally

SYDNEY
Ground Floor, 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE
Level 3, 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE
Level 1, 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

ADELAIDE
Level 4, 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE
Ground Floor, 188 Normanby Road
Southbank VIC 3006
T 03 9993 1905

PERTH
Suite 9.02, Level 9, 109 St Georges Terrace
Perth WA 6000
T 02 9339 3184

CANBERRA
Level 2, Suite 2.04, 15 London Circuit
Canberra City ACT 2601

www.emmconsulting.com.au

Gunlake Quarry Continuation Project (SSD-12469087)

Air quality impact assessment

Report Number

J190263 RP15

Client

Gunlake Quarries Pty Ltd

Date

14 September 2021

Version

v1 Final

Prepared by

Scott Fishwick
National Technical Leader - Air Quality
14 September 2021

Approved by

Francine Manansala
Associate - Air Quality
14 September 2021

Executive Summary

ES1 Introduction

Gunlake Quarries Pty Ltd (Gunlake) operates a hard rock quarry (the 'Quarry') located at 715 Brayton Road, Marulan NSW. The Quarry is approximately 7 kilometres (km) north-west of the centre of Marulan in the Goulburn Mulwaree local government area. The land surrounding the Quarry is rural land with a low population density. Gunlake commenced operations in 2009 under project approval 07-0074 granted in September 2008.

Since the Quarry received approval for the Extension Project in 2017 (SSD 7090, NSW Land and Environmental Court Approval 20017/108663), the tonnage of saleable product dispatched by the Quarry has steadily increased and, with an infrastructure boom across the State, Gunlake forecast that demand for products from the Quarry will continue to increase. In response to the increased demand for products from the Quarry, it is proposed to transport more saleable product along the Primary Transport Route. This will require an increase in truck movements than what is currently approved. The additional truck movements will all occur on the recently upgraded Primary Transport Route that has been designed to accommodate comfortably the additional truck movements. The Project is known as the Gunlake Quarry Continuation Project (the 'Continuation Project'). The ignimbrite hard-rock resource will continue to be extracted and processed using the methods currently employed at the Quarry.

The Continuation Project is classified as a State Significant Development (SSD) under Schedule 1, Clause 7 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP). This report accompanies a new SSD application and environmental impact statement (EIS) for the Continuation Project.

ES2 Gunlake Quarry Continuation Project

Gunlake seeks a new development approval for the Continuation Project that allows:

- ongoing Quarry operations;
- a maximum of 375 inbound and 375 outbound daily truck movements with up to 4.2 million tonnes per annum (Mtpa) of Quarry products transported from the site in any calendar year;
- 24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday;
- an extraction depth of 546 metres Australian Hight Datum (mAHD); and
- a 30-year Quarry life (from the date of Continuation Project approval).

ES3 Evaluation of the project

This air quality impact assessment (AQIA) considers the potential impacts of the Continuation Project based on emissions quantification and dispersion modelling. In summary, the AQIA found:

- the dispersion modelling predicted that impacts from Continuation Project operations will not result in exceedance of any applicable criteria at any neighbouring assessment location; and
- annual scope 1 and 2 GHG emissions generated will represent approximately 0.0136% of total greenhouse gas (GHG) emissions for NSW and 0.0035% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2019.

Table of Contents

Annexures

Tables

Figures

1 Introduction

1.1 Overview

Gunlake Quarries Pty Ltd (Gunlake) operates a hard rock quarry (the 'Quarry') located at 715 Brayton Road, Marulan NSW. The Quarry is approximately 7 kilometres (km) north-west of the centre of Marulan in the Goulburn Mulwaree local government area (Figure 1.1). The land surrounding the Quarry is rural land with a low population density. Gunlake commenced operations in 2009 under project approval 07-0074 granted in September 2008.

Since the Quarry received approval for the Extension Project in 2017 (SSD 7090, NSW Land and Environmental Court Approval 20017/108663), the tonnage of saleable product dispatched by the Quarry has steadily increased and, with an infrastructure boom across the State, Gunlake forecast that demand for products from the Quarry will continue to increase. In response to the increased demand for products from the Quarry, it is proposed to transport more saleable product along the Primary Transport Route. This will require an increase in truck movements than what is currently approved. The additional truck movements will all occur on the recently upgraded Primary Transport Route that has been designed to accommodate comfortably the additional truck movements. The Project is known as the Gunlake Quarry Continuation Project (the 'Continuation Project'). The ignimbrite hard-rock resource will continue to be extracted and processed using the methods currently employed at the Quarry.

The Continuation Project is classified as a State Significant Development (SSD) under Schedule 1, Clause 7 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). This report accompanies a new SSD application and environmental impact statement (EIS) for the Continuation Project.

1.2 Assessment requirements

This air quality impact assessment (AQIA) report has been conducted in general accordance with the guidelines specified by the NSW Environment Protection Authority (EPA) in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA 2017), hereafter "the Approved Methods for Modelling". Consistent with Section 2.1 of the Approved Methods for Modelling, this AQIA is classed as a Level 2 assessment and implements a refined dispersion modelling approach using site-specific/representative input.

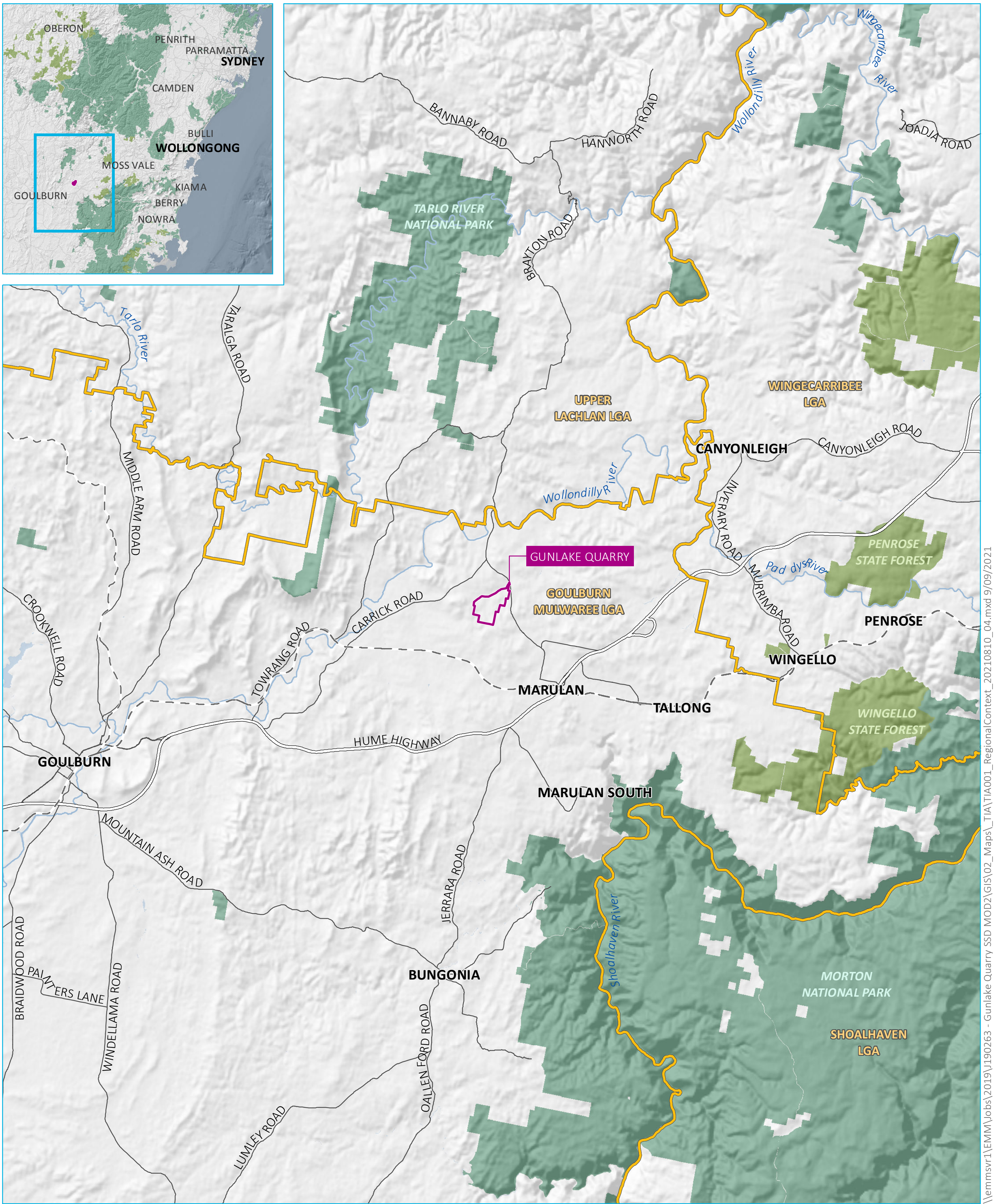
This report comprises of the following sections:

- a description of the project, local setting and surrounds of the Quarry;
- relevant pollutants for assessment and applicable impact assessment criteria;
- a description of existing environment conditions, specifically:
  - meteorology and climate; and
  - background air quality environment;
- a detailed air pollution emissions inventory for the Quarry;
- results of atmospheric dispersion modelling conducted for the Quarry, including an analysis of Quarry-only and cumulative impacts accounting for baseline air quality;
- overview of mitigation measures and monitoring requirements for the Quarry; and
- a greenhouse gas (GHG) assessment for the Quarry.

The AQIA was prepared in accordance with the requirements of the Planning Secretary's Environmental Assessment Requirements (SEARs) for the proposed development, issued on 6 May 2021. The SEARs identify matters which must be addressed in the EIS. The individual requirements relevant to this AQIA and where they are addressed in this report are provided in Table 1.1.

Table 1.1 SEARs relating to air quality impact assessment

Assessment requirement from SEARs	Section of report where addressed
A detailed assessment of potential construction and operational air quality impacts, in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*, with a focus on dust emissions including $PM_{2.5}$ and PM_{10}, and having regard to the *Voluntary Land Acquisition and Mitigation Policy*.	Section 6 and 7



Source: EMM (2021); DFSI (2017); GA (2011); ASGC (2006)

KEY

- Site boundary
- Local government area
- Rail line
- Highway
- Major road
- River
- Waterbody
- NPWS reserve
- State forest

Regional context

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure 1.1

EMM creating opportunities

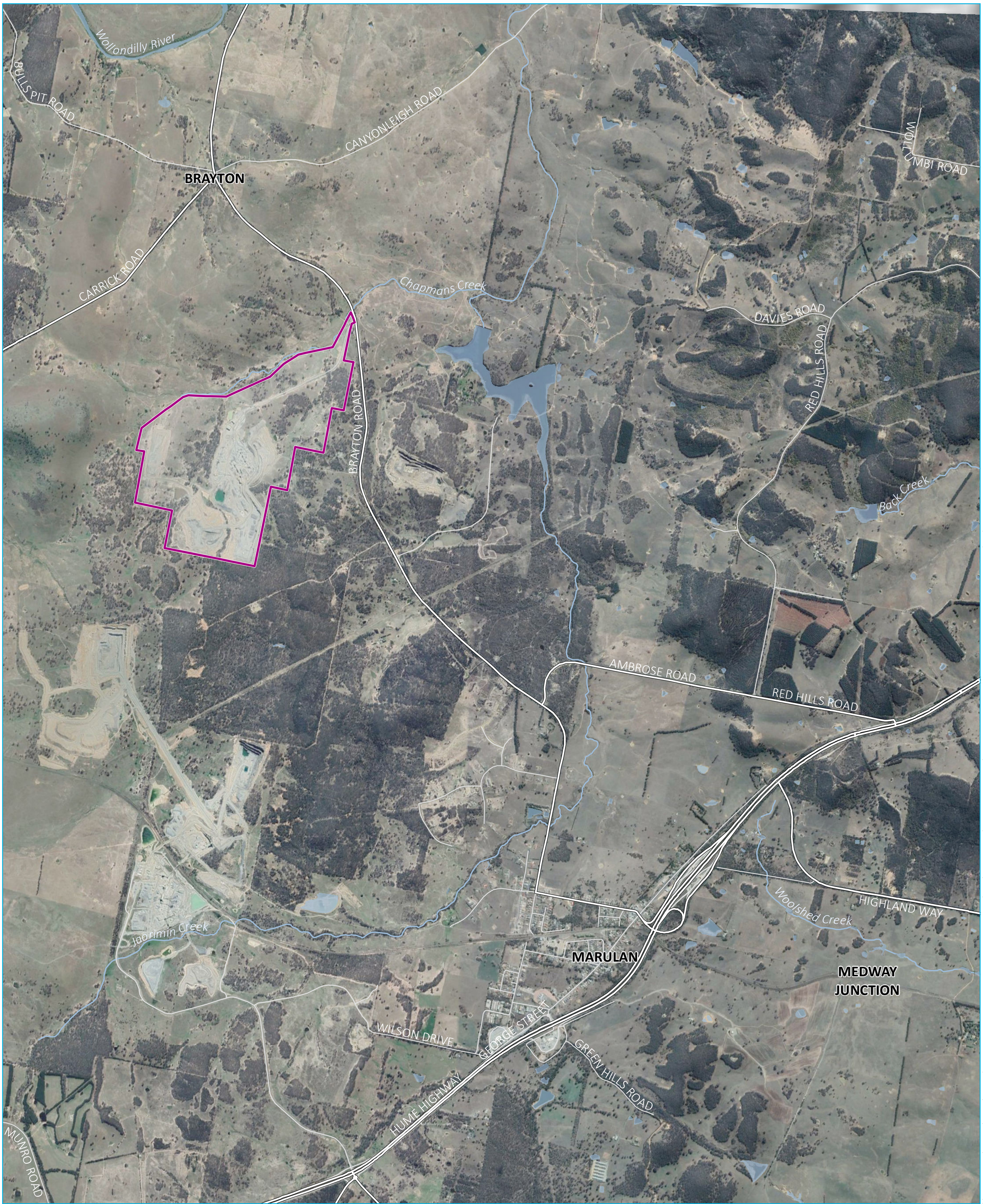
2 Project description and setting

2.1 The site

The Quarry is located wholly on Lot 13 DP 1123374 (the ‘Quarry site’). There are biodiversity management areas in Lot 13 DP1123374, Lot 12 DP1123374, Lot 271 DP750053 and Lot 1 DP841147. These lots are owned by Gunlake Quarries Pty Ltd.

The land surrounding the Quarry is rural with low population density, predominately used for agriculture, generally grazing. Built features immediately surrounding the Quarry include dams, access tracks and fences. There are a small number of residences around the Quarry (Figure 2.1). The nearest town is Marulan, about 7 km south-east of the site boundary.

There are four local operational quarries within approximately 15 km of the Quarry site: Lynwood Quarry; Peppertree Quarry; Marulan South Limestone Mine; and Johnniefelds Quarry.



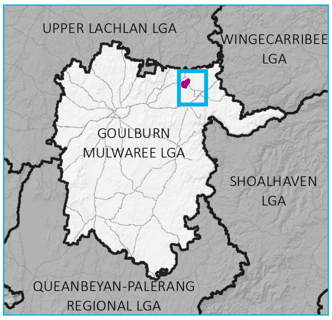
\\emmsvr1\EMM\Jobs\2019\J190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_Groundwater\GW012_LocalContext_20210827_02.mxd 14/09/2021

Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011); ASGC (2006)

0 1 2 km

GDA 1994 MGA Zone 55

N



KEY

Site boundary

Major road

Minor road

Named watercourse

Waterbody

Local context

Gunlake Quarry Continuation Project

Air quality impact assessment

Figure 2.1

EMM

creating opportunities

2.2 Continuation Project description

Gunlake seeks a new development approval for the Continuation Project that allows:

- ongoing Quarry operations;
- a maximum of 375 inbound and 375 outbound daily truck movements with up to 4.2 million tonnes per annum (Mtpa) of Quarry products transported from the site in any calendar year;
- 24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday;
- an extraction depth of 546 metres Australian Hight Datum (mAHD); and
- a 30-year Quarry life (from the date of Continuation Project approval).

A summary of the key elements of the approved Extension Project compared to the Continuation Project is provided in Table 2.1.

Table 2.1 Extension Project compared to the Continuation Project

Project element	Approved Extension Project	Proposed Continuation Project
Extraction method	Blasting and excavation.	Blasting and excavation.
Resource	Ignimbrite hard-rock.	Ignimbrite hard-rock.
Extraction	Quarry pit - pit depth of 572 mAHD.	Quarry pit - pit depth of 546 mAHD (ie 26 m deeper than the Extension Project). No change to pit disturbance area.
Operations	Onsite rock processing, including crushing and screening.	Onsite rock processing, including crushing and screening.
Product transport	Transport of up to 2.6 million tonnes per annum (Mtpa) of Quarry products. Truck movements limited to: • a maximum of 295 inbound movements and 295 outbound movements, including no more than 38 outbound truck movements on the Secondary Transport Route, per working day; and • an average of 220 inbound movements and 220 outbound movements, including no more than 25 outbound movements on the Secondary Transport Route, per working day (averaged over the working days in each quarter).	Transport of up to 4.2 Mtpa of quarry products. Total truck movements limited to: • a maximum of 375 inbound movements and 375 outbound movements, including no more than 38 outbound laden movements on the Secondary Transport Route, per working day; and • an average of no more than 25 outbound movements on the Secondary Transport Route, per working day (averaged over the working days in each quarter).
General infrastructure	Offices, amenity buildings, processing plant and other minor infrastructure.	Offices, amenity buildings, processing plant and other minor infrastructure.

Table 2.1 Extension Project compared to the Continuation Project

Project element	Approved Extension Project	Proposed Continuation Project
Management of wastes	Overburden[1] is emplaced in designated emplacement areas. Receipt of up to 30,000 tonnes of cured concrete per calendar year for beneficial reuse/recycling. No other classified waste materials to be received on site.	Overburden is emplaced in designated emplacement areas. Receipt of up to 50,000 tonnes of cured concrete per calendar year for beneficial reuse/recycling. No other classified waste materials to be received on site.
Hours of operation	24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday.	24-hours Quarry operations Monday to Saturday, except 6 pm Saturday to 2 am Monday.
Blasting	Up to twice weekly, 9 am to 5 pm Monday to Friday.	Up to twice weekly, 9 am to 5 pm Monday to Friday.
Quarry life	To 30 June 2042.	Extension of the Quarry life to 30 years from the date of approval.

Further information on the project is available in the Continuation Project EIS.

2.3 Assessment locations

Air quality impacts from the Quarry have been assessed at the nearest sensitive receptors (hereafter referred to as 'assessment locations'). Details of these selected assessment locations are provided in Table 2.2 and shown in Figure 2.2.

Table 2.2 Assessment locations

ID	Description
R1	Gunlake owned
R2	Acquisition upon request (noise basis) as per Schedule 3 Condition 1 of the Conditions of Consent of the NSW Land and Environment Court (LEC) Approval 2017/108663
R3	Gunlake owned
R4	Gunlake owned
R5	Private residence
R6	Private residence
R7	Private residence
R8	Private residence
R9	Private residence
R10	Private residence

1 'Overburden': any extracted unsalable material.

Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

0 1 2 km

GDA 1994 MGA Zone 55

N

KEY

Site boundary

Air quality assessment location

Other property*

Major road

Minor road

Vehicular track

Named watercourse

Waterbody

* R1, R3 and R4 are owned by Gunlake.

Assessment locations

Gunlake Quarry Continuation Project

Air quality impact assessment

Figure 2.2

EMM

creating opportunities

3 Pollutants and assessment criteria

3.1 Potential air pollutants

Operational emission sources associated with the Quarry include a mixture of the following:

- fugitive sources of particulate matter, such as in pit extractive operations (drill and blast, truck loading), conveying and processing activities, the movement of mobile plant and equipment, and wind erosion of exposed surfaces and material stockpiles; and
- combustion sources, such as exhaust emissions from Quarry mobile equipment fleet and road trucks.

A detailed description of emission sources associated with the Quarry is presented in Chapter 6.

The primary air pollutants emitted by the Quarry comprise of:

- particulate matter, specifically:
  - total suspended particulate matter (TSP);
  - particulate matter less than 10 micrometres (µm) in aerodynamic diameter (PM_{10}); and
  - particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$);
- oxides of nitrogen (NO_x)[2], including nitrogen dioxide (NO_2);
- sulphur dioxide (SO_2);
- carbon monoxide (CO); and
- volatile organic compounds (VOCs).

This assessment focuses on emissions of particulate matter pollutants (TSP, PM_{10}, $PM_{2.5}$ and associated dust deposition). The emissions and associated impacts of fuel combustion pollutants (NO_x, SO_2, CO and VOCs) are expected to be minor and have not been considered further.

The Quarry must demonstrate compliance with the impact assessment criteria for these pollutants, as defined in the Approved Methods for Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA 2017) ('the Approved Methods for Modelling'). The impact assessment criteria are designed to maintain ambient air quality that allows for the protection of human health and well-being. The applicable criteria are presented in Section 3.2.

3.2 Impact assessment criteria

The NSW EPA's impact assessment criteria for particulate matter, as documented in Section 7 of the Approved Methods for Modelling, are presented in Table 3.1. The assessment criteria for PM_{10} and $PM_{2.5}$ are consistent with the national air quality standards that are defined in the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) (Department of the Environment 2016).

[2] By convention, NO_x = Nitrous oxide (NO) + NO_2.

TSP, which relates to airborne particles less than around 50 µm in diameter, is used as a metric for assessing amenity impacts (reduction in visibility, dust deposition and soiling of buildings and surfaces) rather than health impacts (NSW EPA 2013). Particles less than 10 µm in diameter, accounted for in this assessment by PM_{10} and $PM_{2.5}$, are a subset of TSP and are fine enough to enter the human respiratory system and can therefore lead to adverse human health impacts. The NSW EPA impact assessment criteria for PM_{10} and $PM_{2.5}$ are therefore used to assess the potential impacts of airborne particulate matter on human health.

The Approved Methods for Modelling classifies TSP, PM_{10}, $PM_{2.5}$ and dust deposition as 'criteria pollutants'. The impact assessment criteria for criteria pollutants are applied at the nearest existing or likely future off-site sensitive receptors[3], and compared against the 100th percentile (ie the highest) dispersion modelling prediction for the relevant averaging. Both the incremental (Quarry-only) and cumulative (Quarry plus background) impacts need to be presented, with the latter requiring consideration of the existing ambient background concentrations.

For dust deposition, the NSW EPA (2017) specifies criteria for the project-only increment and cumulative dust deposition levels. Dust deposition impacts are derived from TSP emission rates and particle deposition calculations in the dispersion modelling process.

The air quality impact assessment criteria presented in Table 3.1 are consistent with Schedule 3 Condition 14, Table 6, of the LEC Consent, with the exception of annual average PM_{10} (30 µg/m^3 in the LEC Consent).

Table 3.1 Impact assessment criteria for particulate matter

PM metric	Averaging period	Impact assessment criterion
TSP	Annual	90 µg/m^3
PM_{10}	24 hour	50 µg/m^3
	Annual[1]	25 µg/m^3
$PM_{2.5}$	24 hour	25 µg/m^3
	Annual	8 µg/m^3
Dust deposition	Annual	2 g/m^2/month (project increment only)
		4 g/m^2/month (cumulative)

Notes: µg/m^3: micrograms per cubic meter; g/m^2/month: grams per square metre per month
1. Criterion of 30 µg/m^3 specified in Schedule 3 Condition 14, Table 6, of the Conditions of Consent of the NSW Land and Environment Court (LEC) Approval 2017/108663.

[3] NSW EPA (2017) defines a sensitive receptor as a location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area.

3.3 POEO (Clean Air) regulation

The statutory framework for managing air emissions in NSW is provided in the *Protection of the Environment Operations Act 1997*[4] (POEO Act). The primary regulations for air quality made under the POEO Act are:

- Protection of the Environment Operations (Clean Air) Regulation 2010[5].
- Protection of the Environment Operations (General) Regulation 2009[6].

The Quarry will comply with the POEO regulations as follows:

- as a scheduled activity under the POEO regulations, the Quarry is required to operate under Environment Protection Licence (EPL) 1087 issued by the NSW EPA and comply with requirements including emission limits, monitoring and pollution-reduction programmes (PRPs);
- the Quarry does not feature significant odour-generating emission sources and is therefore unlikely to generate odourous emissions; and
- no open burning is performed on-site.

3.4 Voluntary land acquisition and mitigation policy

In September 2018, the Department of Planning, Industry and Environment (DPIE) released the Voluntary Land Acquisition and Mitigation Policy (VLAMP) for State Significant Mining, Petroleum and Extractive Industry Developments. The VLAMP describes the voluntary mitigation and land acquisition policy to address dust and noise impacts, and outlines mitigation and acquisition criteria for particulate matter.

Under the VLAMP, if a development cannot comply with the relevant impact assessment criteria, or if the mitigation or acquisition criteria may be exceeded, the applicant should consider a negotiated agreement with the affected landowner or acquire the land. In doing so, the land is then no longer subject to the impact assessment, mitigation or acquisition criteria, although provisions do apply to the "use of the acquired land", primarily related to informing and protecting existing or prospective tenants.

In relation to dust, voluntary mitigation rights apply when a development contributes to exceedances of the criteria set out in Table 3.2. Voluntary acquisition rights apply when a development contributes to exceedances of the criteria set out in Table 3.3. The criteria for voluntary mitigation and acquisition are the same, except for the number of days the short-term impact assessment criteria for PM_{10} and $PM_{2.5}$ can be exceeded, which is zero for mitigation and five for acquisition.

Voluntary mitigation rights apply to any residence on privately-owned land or any workplace on privately-owned land where the consequences of the exceedance, in the opinion of the consent authority, are unreasonably deleterious to worker health or the carrying out of business.

Voluntary acquisition rights also apply to any residence or any workplace on privately-owned land, but also apply when an exceedance occurs across more than 25% of any privately-owned land where there is an existing dwelling or where a dwelling could be built under existing planning controls.

[4] http://www.legislation.nsw.gov.au/maintop/view/inforce/act+156+1997+cd+0+N

[5] http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+428+2010+cd+0+N

[6] http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+211+2009+cd+0+N

Table 3.2 VLAMP mitigation criteria

Pollutant	Averaging period	Mitigation criterion	Impact type
PM_{10}	24-hour	50 µg/m³**	Human health
	Annual	25 µg/m³*	Human health
$PM_{2.5}$	24-hour	25 µg/m³**	Human health
	Annual	8 µg/m³*	Human health
TSP	Annual	90 µg/m³*	Amenity
Deposited dust	Annual	2 g/m²/month**	Amenity
		4 g/m²/month*	

Note: * - cumulative impact (project + background); ** - incremental impact (project only) with zero allowable exceedances of the criteria over the life of the development

Table 3.3 VLAMP acquisition criteria

Pollutant	Averaging period	Mitigation criterion	Impact type
PM_{10}	24-hour	50 µg/m³**	Human health
	Annual	25 µg/m³*	Human health
$PM_{2.5}$	24-hour	25 µg/m³**	Human health
	Annual	8 µg/m³*	Human health
TSP	Annual	90 µg/m³*	Amenity
Deposited dust	Annual	2 g/m²/month**	Amenity
		4 g/m²/month*	

Note: * - cumulative impact (project + background); ** - incremental impact (project only) with five allowable exceedances of the criteria over the life of the development

4 Meteorology and climate

4.1 Monitoring data resources

Gunlake maintains a meteorological monitoring station as part of the Quarry air quality monitoring network (see Section 5.2 for further discussion on the monitoring network). The Quarry meteorological station (hereafter QMS) is located immediately to the north of the Quarry processing plant.

An analysis of the meteorological data recorded between 2014 and 2020 from the QMS was completed (Annexure A). The analysis demonstrated greater than 95% data completeness for all recorded parameters across all years and a similarity across years in the most important parameters for pollutant dispersion, such as wind speed and wind direction.

Data from the QMS were supplemented by the Bureau of Meteorology (BoM) Goulburn Airport automatic weather station, located 27 km to the west-south-west of the QMS. Specifically, cloud measurements not measured at the QMS were sourced from the BoM Goulburn Airport automatic weather station.

The most recent complete year of meteorological data at the time of reporting was 2020. However, due to regional-scale dust storms linked to the intensification of drought conditions throughout 2019, and extensive bushfire events across NSW between November 2019 and February 2020, the ambient air quality conditions (specifically elevated levels of PM_{10} and $PM_{2.5}$) recorded during 2019 and 2020 were not representative of a typical year. Consequently, the 2018 calendar year was selected as the modelling period for this assessment. Further discussion regarding ambient air quality is presented in Section 5.

4.2 Inter-annual analysis

Data from the QMS recorded between January 2014 and December 2020 inclusive, were collated and processed. The dataset featured a high level of data completeness for the entire analysed period, with each year featuring at least 95% hourly data completeness.

Analysis of wind speed and direction data recorded between 2014 and 2020 is presented in Annexure A and showed that 2018 was representative of conditions experienced at the Quarry. It is noted that 2016 and 2017 featured extended periods of lower recorded wind speed, likely attributable to sensor malfunction.

The recorded winds across all analysed years were predominately from the east-north-east or west-south-west. With the exception of 2016 and 2017, the annual average recorded wind speed ranged from 3.0 m/s to 3.3 m/s, while the frequency of calm conditions (ie wind speeds less than 0.5 m/s) occurred between 8.4% and 14.3% of the time.

The inter-annual profiles for air temperature and relative humidity presented in Annexure A for the period between 2014 and 2020 show that the 2018 and 2019 datasets feature higher temperatures and lower relative humidity than the other years in the analysis period. This is considered reflective of the increasing drought conditions experienced across NSW through 2018 and 2019.

4.3 Meteorological modelling and processing

Atmospheric dispersion modelling for this assessment has been completed using the AMS[7]/USEPA[8] regulatory model AERMOD (model version v21112, further discussion presented in Section 7.1). The meteorological inputs for AERMOD were generated using the AERMET meteorological processor (model version v21112), using local surface observations and upper air profiles generated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) The Air Pollution Model (TAPM) meteorological modelling module.

Further details of the TAPM meteorological modelling and AERMET data processing completed to prepare the inputs for AERMOD are documented in Annexure A.

4.4 AERMET meteorological dataset

4.4.1 Wind speed and direction

A wind rose showing the wind speed and direction from the QMS 2018 AERMET dataset is presented in Figure 4.1. The QMS 2018 AERMET dataset features a combination of station measurements from the 2018 calendar year and data gap substitutions (interpolation and substitution methods, as per Annexure A).

As discussed in Section 4.1, the recorded wind pattern for 2018 was dominated by west-south-west and east-north-east air flow. The annual average wind speed for the QMS 2018 AERMET was 3.2 m/s, with a frequency of calm conditions in the order of 11.7%.

Seasonal and diurnal wind roses for the QMS 2018 AERMET are provided in Figure 4.2 and Figure 4.3 respectively. The dominant air flow across all seasons is west-south-west and east-north-east, however the colder months feature a higher proportion of west-south-westerly winds. Wind speeds are greatest during the winter months. The frequency of calm wind conditions is highest during autumn.

Diurnal variation in recorded wind speed and wind direction varied on a diurnal basis in the QMS 2018 AERMET. The night-time hours feature a higher proportion of west-south-westerly winds than daytime hours, which experience a higher proportion of air flow from the east-north-east. The wind speeds during the day are highest, with average wind speeds of 3.9 m/s during the day compared with 2.5 m/s during the night. Calm conditions are also more prevalent during night hours.

7 AMS - American Meteorological Society

8 USEPA - United States Environmental Protection Agency

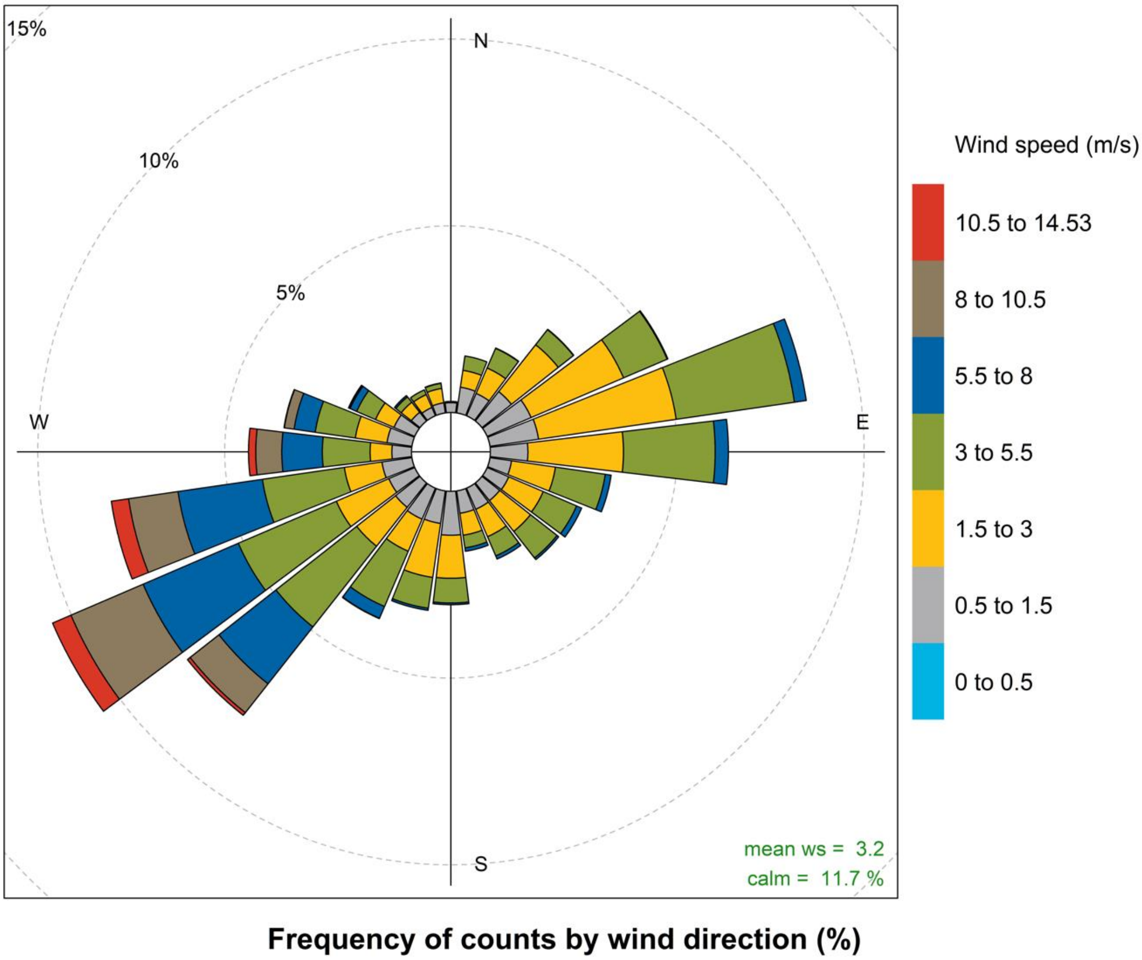


Figure 4.1 Wind speed and direction – QMS 2018 AERMET

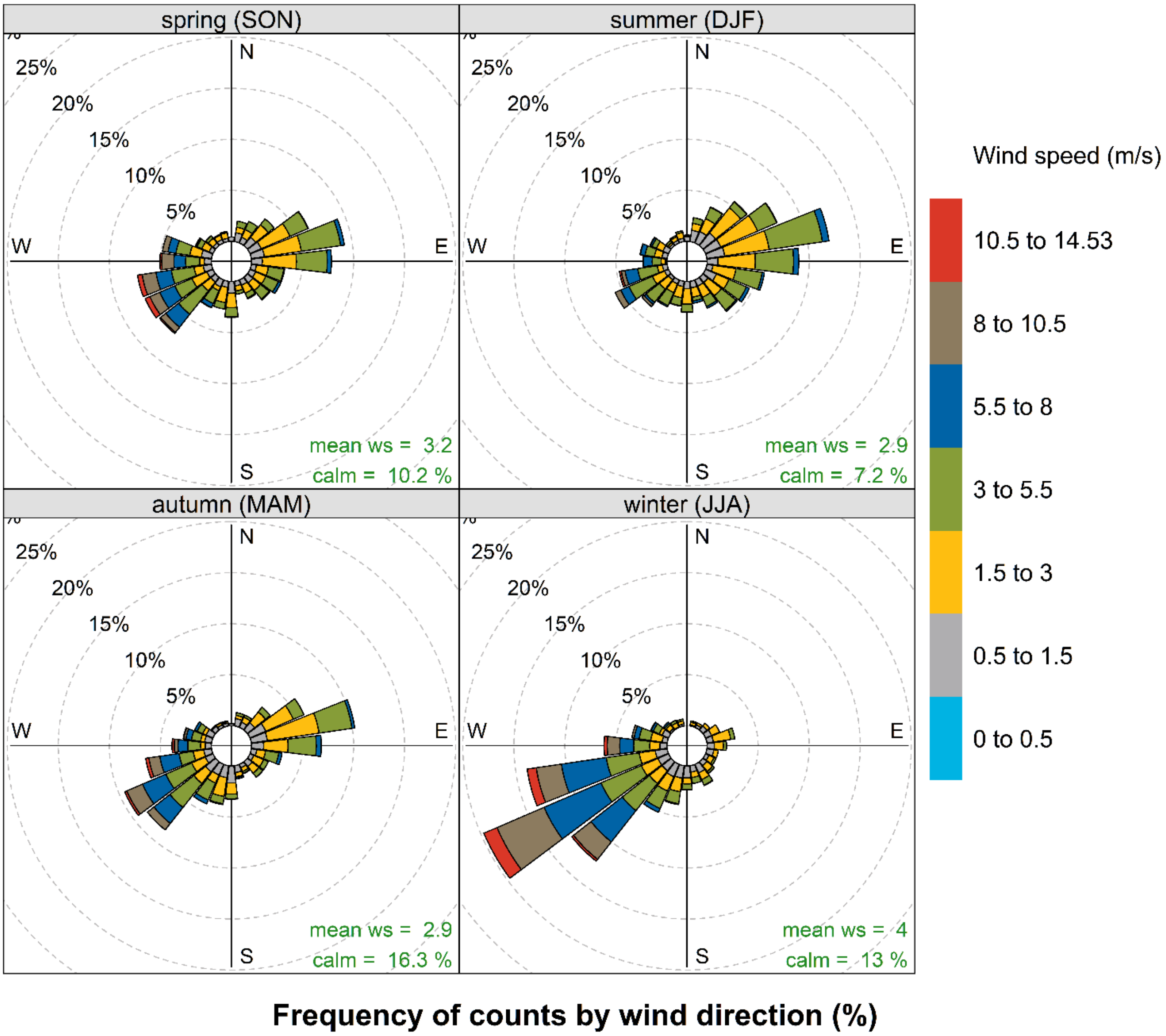


Figure 4.2 Seasonal wind speed and direction – QMS 2018 AERMET

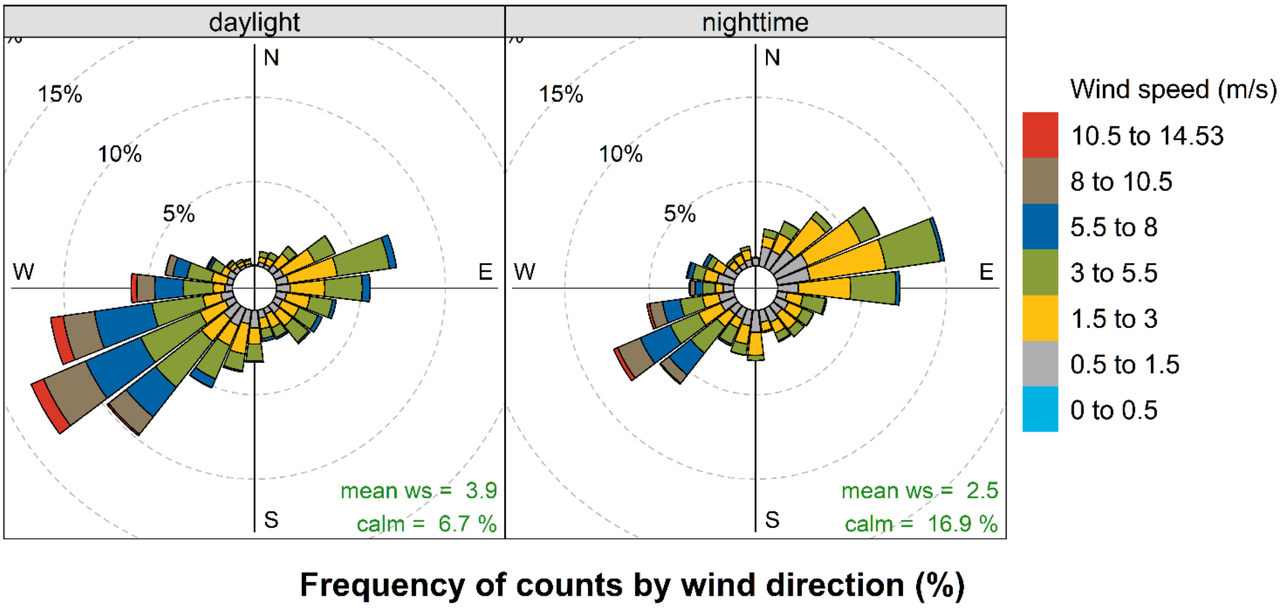


Figure 4.3 Diurnal wind speed and direction – QMS 2018 AERMET

4.4.2 Atmospheric stability and mixing depth

Atmospheric stability refers to the degree of turbulence or mixing that occurs within the atmosphere and is a controlling factor in the rate of atmospheric dispersion of pollutants.

The Monin-Obukhov length (L) provides a measure of the stability of the surface layer (ie the layer above the ground in which vertical variation of heat and momentum flux is negligible; typically, about 10% of the mixing height). Negative L values correspond to unstable atmospheric conditions, while positive L values correspond to stable atmospheric conditions. Very large positive or negative L values correspond to neutral atmospheric conditions.

Figure 4.4 illustrates the overall diurnal variation of atmospheric stability derived from the Monin-Obukhov length calculated by AERMET based on the 2018 calendar year dataset from the QMS. The diurnal profile shows that atmospheric instability increases during the daylight hours as the sun generated convective energy increases, whereas stable atmospheric conditions prevail during the night-time. This profile indicates that the potential for effective atmospheric dispersion of emissions would be greatest during day-time hours and lowest during evening through to early morning hours.

Mixing depth refers to the height of the atmosphere above ground level within which air pollution can be dispersed, otherwise known as the boundary layer. The mixing depth of the atmosphere is influenced by mechanical (associated with wind speed) and thermal (associated with solar radiation) turbulence. Similar to the Monin-Obukhov length analysis above, higher daytime wind speeds and the onset of incoming solar radiation increases the amount of mechanical and convective turbulence in the atmosphere. As turbulence increases, so too does the depth of the boundary layer, generally contributing to higher mixing depths and greater potential for the atmospheric dispersion of pollutants.

Hourly-varying atmospheric boundary layer depths were generated by AERMET, the meteorological processor for the AERMOD dispersion model. The variation in AERMET-calculated boundary layer depth by hour of the day is illustrated in Figure 4.5. Greater boundary layer depths occur during the daytime hours, peaking in the mid to late afternoon.

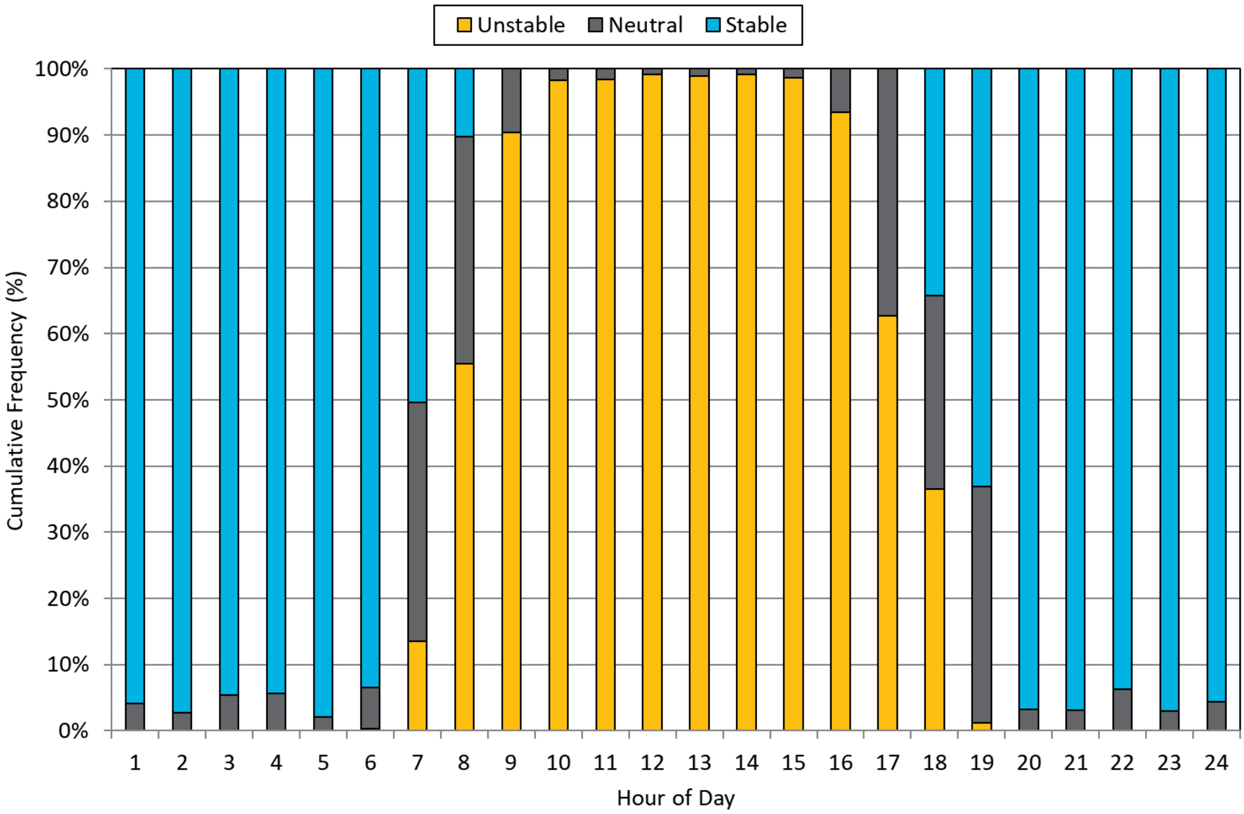


Figure 4.4 AERMET-calculated diurnal variation in atmospheric stability – QMS 2018 AERMET

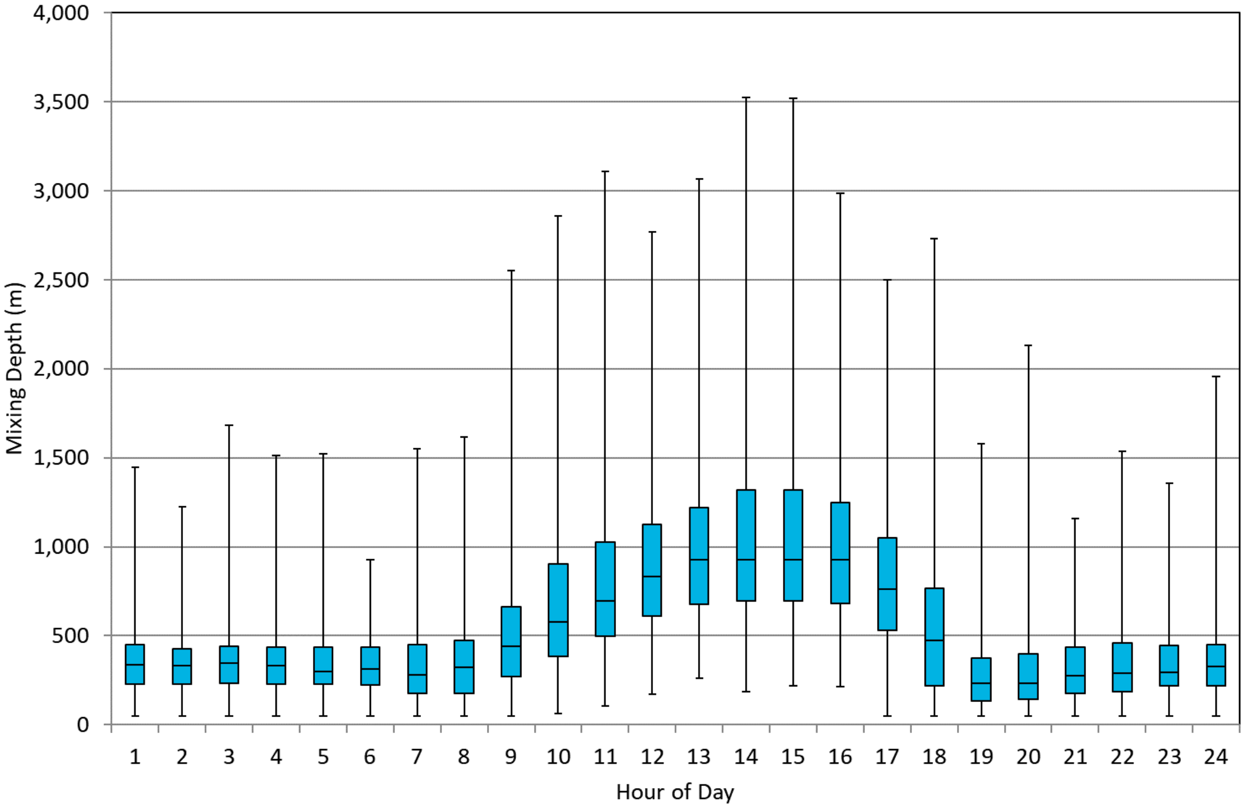


Figure 4.5 AERMET-calculated diurnal variation in atmospheric mixing depth – QMS 2018 AERMET

5 Background air quality

5.1 Existing sources of emissions

The National Pollutant Inventory (NPI 2021) and NSW EPA environment protection licence (EPA 2021) databases have been reviewed to identify significant existing sources of air pollutants within 5 km of the Quarry. The review identified the existing Holcim-owned Lynwood Quarry (approximately 1 km to the south of the Quarry approved southern extraction limit) and the Johnniefelds Quarry (approximately 1 km east of the Quarry processing plant). Further afield are the Boral Peppertree Quarry (approximately 10 km to the south-east of the Quarry processing plant) and Marulan South limestone mine (approximately 12 km to the south-east of the Quarry processing plant).

Other sources of air pollutant emissions that contribute to background air quality include:

- dust entrainment due to vehicle movements along unsealed and sealed town and rural roads with high silt loadings;
- dust emissions from agricultural activities;
- fuel combustion-related emissions from on-road and non-road engines;
- wind generated dust from exposed areas within the surrounding region; and
- seasonal emissions from household wood burning for heating during winter.

More remote sources which contribute episodically to suspended particulates in the region include dust storms and bushfires. With the exception of neighbouring quarry operations, it is considered that the above emission sources are accounted for in the monitoring data analysed in the following sections of this report.

5.2 Air quality monitoring data resources

Gunlake maintains an air quality monitoring network at the Quarry for annual environmental compliance reporting purposes. The air quality monitoring network, illustrated in Figure 5.1, comprises of the following monitoring equipment:

- two high volume air sampler (HVAS) units that record 24-hour average PM_{10} concentrations on a one-in-six day schedule; and
- three dust deposition gauges.

Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 55
N

KEY

- Site boundary
- Major road
- Vehicular track
- Named watercourse

Air quality monitoring

- Dust deposition
- Meteorological station
- HVAS

Monitoring locations

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure 5.1

EMM
creating opportunities

In addition to data from the Quarry's air quality monitoring network, data from the following sources have been referenced to quantify background particulate matter levels:

- daily-varying 24-hour average PM_{10} and $PM_{2.5}$ concentrations from the ACT Government Florey air quality monitoring station (approximately 102 km south-west of the Quarry);
- daily-varying 24-hour average PM_{10} and $PM_{2.5}$ concentrations from the NSW DPIE air quality monitoring stations at Goulburn (approximately 23 km south-west of the Quarry) and Bargo (approximately 69 km north-east of the Quarry); and
- paired PM_{10} and TSP measurements from the Boral Peppertree Quarry (approximately 10 km south-east of the Quarry).

The DPIE Goulburn air quality monitoring station, while closest to the Quarry site, was only installed in late 2019. Therefore, data from the DPIE Bargo and ACT Florey air quality monitoring stations were also referenced to analyse regional trends in ambient particulate matter concentrations.

5.3 Background particulate matter concentrations

Gunlake HVAS and regional 24-hour average PM_{10} datasets for the period between 2015 and 2020 have been collated and presented in Figure 5.2.

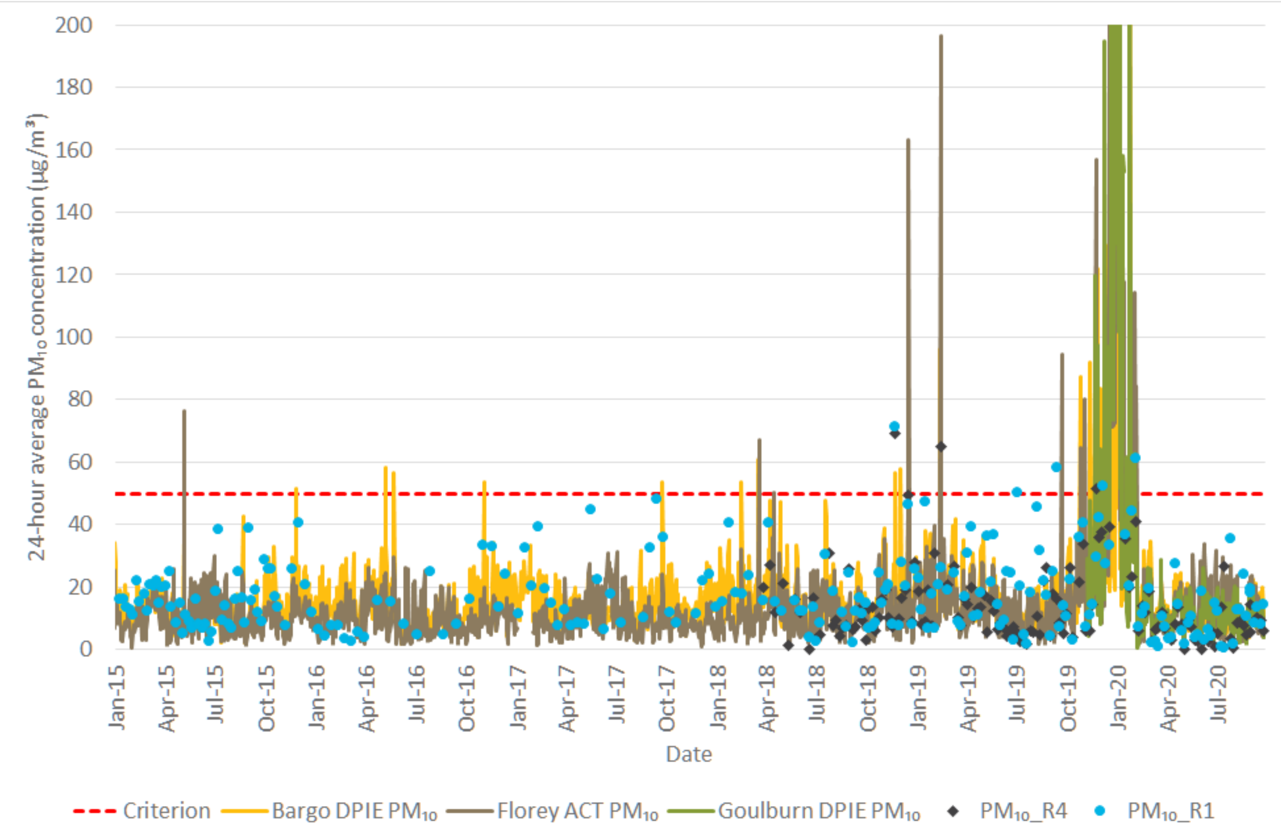


Figure 5.2 Regional 24-hour average PM_{10} concentrations – Gunlake and regional monitoring resources – 2015 to 2020

Note: Y axis cropped at 200 µg/m³ for improved data visualisation.

Several key points are identified from the regional PM_{10} dataset analysis:

- daily concentrations fluctuate at all monitoring locations throughout the presented period;
- exceedances of the NSW EPA impact assessment criterion of 50 µg/m³ occur across all monitoring locations during the majority of presented years; and
- the frequency of exceedance days increases between 2018 and 2020 and is reflective of intensifying drought conditions and state-wide bushfires.

To illustrate the relationship between regional PM_{10} concentrations with those at the Quarry, the regional PM_{10} concentrations from the DPIE Bargo, DPIE Goulburn and Florey ACT air quality monitoring stations coincident with the one-in-six day PM_{10} concentrations from the Gunlake HVAS units were extracted. Of the two Gunlake HVAS units, the R1 location provides the longest data period and was therefore used as the primary reference monitor dataset. Concurrent 24-hour average PM_{10} concentrations are illustrated in Figure 5.3. With the exception of some notable outliers (eg two elevated concentrations at Florey ACT relative to the other monitoring datasets), all presented datasets exhibit a general linear increasing trend relative to the R1 concentrations.

It is considered that Figure 5.3 illustrates that daily-varying concentrations across the region are comparable on a daily-varying basis, indicating that regional-scale particulate matter transportation is an influencing factor for ambient particulate matter concentrations at the Quarry.

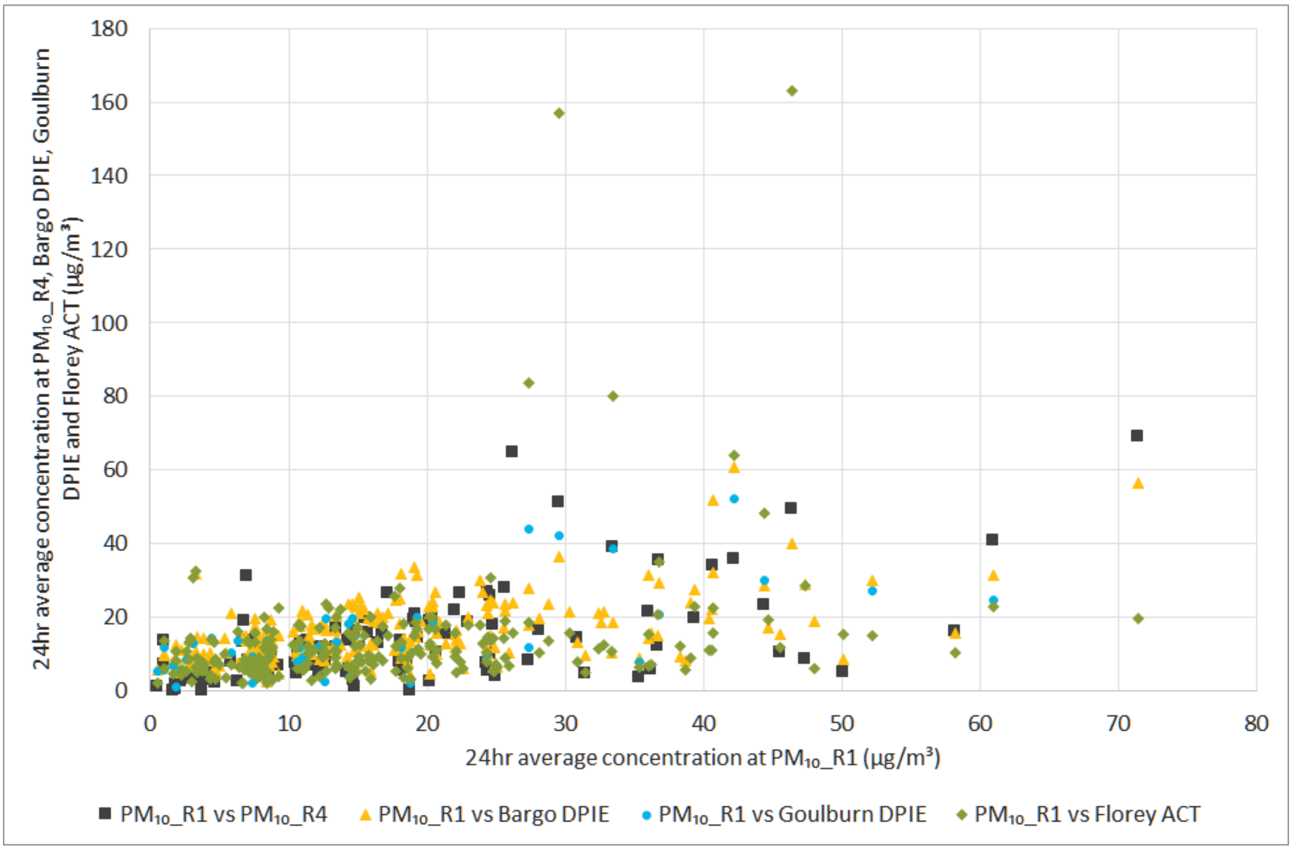


Figure 5.3 **Relationship between concurrent 24-hour average PM_{10} concentrations – Gunlake and regional monitoring resources – 2015 to 2020**

In order to generate a daily-varying PM_{10} background dataset for the cumulative impact assessment purposes, the Gunlake R1, Gunlake R4, Bargo DPIE and Florey ACT PM_{10} monitoring datasets were combined to calculate a regional average concentration for each day of the 2018 calendar year.

There was no $PM_{2.5}$ monitoring conducted at the Quarry. Therefore, to generate a daily-varying $PM_{2.5}$ background dataset for the cumulative impact assessment purposes, the Bargo DPIE and Florey ACT $PM_{2.5}$ monitoring datasets were combined to calculate a regional average concentration for each day of the 2018 calendar year.

The daily-average regional background datasets for 2018 are illustrated in Figure 5.4 and Figure 5.5 for PM_{10} and $PM_{2.5}$ respectively.

It is noted that in the adopted regional background datasets, there are three and two existing exceedances of the applicable criteria for 24-hour average PM_{10} and $PM_{2.5}$ respectively. For cumulative impact assessment purposes, these are therefore classed as existing exceedances.

The average concentration of the adopted regional PM_{10} and $PM_{2.5}$ background datasets is 14.5 µg/m^3 and 6.9 µg/m^3 respectively.

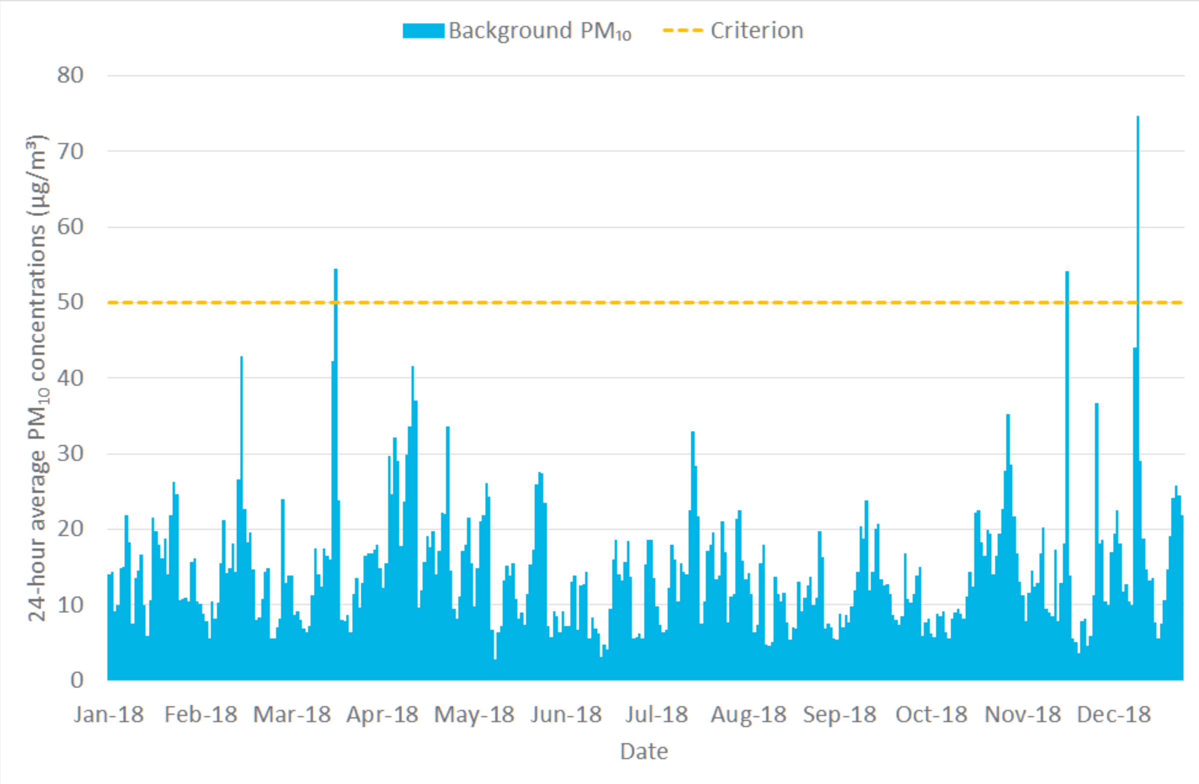


Figure 5.4 **Regional 24-hour average PM_{10} background dataset - 2018**

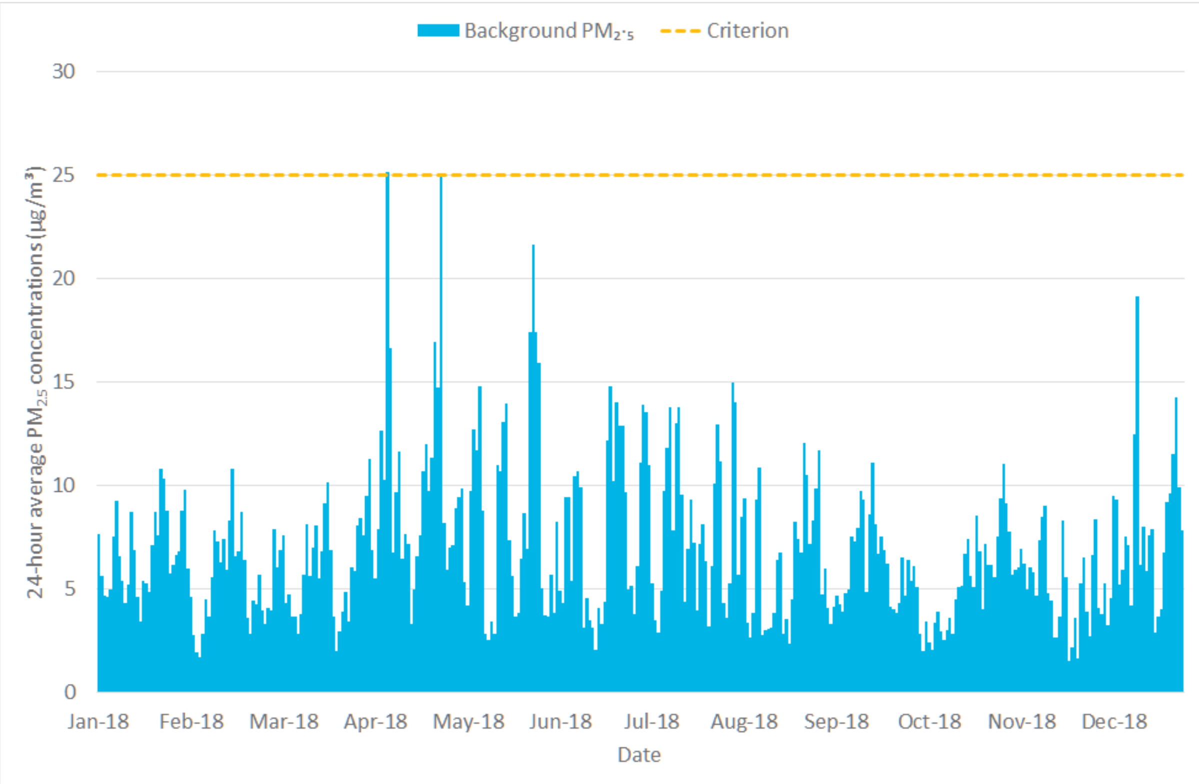


Figure 5.5 **Regional 24-hour average $PM_{2.5}$ background dataset – 2018**

The Boral Peppertree Quarry records concurrent TSP and PM_{10} concentration by HVAS on a one-in-six day cycle. During 2018, the average relationship between concurrent PM_{10} and TSP concentrations was 0.49. This ratio value has been applied to the average of the adopted PM_{10} background dataset (14.5 µg/m^3), returning an annual average TSP concentration of 29.6 µg/m^3.

Dust deposition levels are recorded at the Quarry at three locations. The annual average dust deposition levels recorded during 2018 at the Quarry was 2.8 g/m^2/month, relative to the NSW EPA impact assessment criterion of 4 g/m^2/month. This value has been adopted as the background dust deposition levels for cumulative impact assessment purposes.

To summarise, background values adopted for cumulative assessment, based on the analysed datasets are as follows:

- annual average TSP – 29.6 µg/m^3, derived from the annual average PM_{10} concentration using the relationship between PM_{10} and TSP measurements at the Peppertree Quarry site (Boral 2021);
- 24-hour PM_{10} – daily varying concentrations from regional average dataset for the 2018 calendar year. Concentrations range from 2.8 µg/m^3 to 74.7 µg/m^3;
- annual average PM_{10} – 14.5 µg/m^3, regional average dataset for the 2018 calendar year;
- 24-hour $PM_{2.5}$ – daily varying concentrations from regional average dataset for the 2018 calendar year. Concentrations range from 1.5 µg/m^{3}to 25.1 µg/m^3;
- annual average $PM_{2.5}$ – 6.9 µg/m^3, regional average dataset for the 2018 calendar year; and
- annual dust deposition – 2.8 g/m^2/month, from the average of the three Quarry dust deposition gauges during 2018.

5.4 Neighbouring quarry emissions

Finally, in addition to the ambient background dataset, the contribution to background from the neighbouring Lynwood Quarry and Johnniefelds Quarry operations were explicitly accounted for in the modelling consistent with the approach implemented in Extension Project AQIA (Ramboll 2016).

For the Lynwood Quarry, annual emissions for the Stage 6 operational scenario were taken from the 2015 air quality impact assessment completed for that project (Pacific Environment 2015).

The Johnniefelds Quarry is EPA licenced to quarry up to 500,000 tpa (extracted, processed or stored). No emissions quantification or dispersion modelling studies are available for the Johnniefelds Quarry site. On the basis that the Lynwood Quarry is approved for the extraction and processing of up to 5 Mtpa, 10% of calculated emissions from the Lynwood Quarry assessment (Pacific Environment 2015) have been assumed for the Johnniefelds Quarry.

A summary of adopted emissions from the two quarry sites is presented in Table 5.1.

Table 5.1 Adopted annual emissions – neighbouring quarry operations

Pollutant	Annual Emissions (kg/annum)	
	Lynwood Quarry	Johnniefelds Quarry
TSP	384,946	38,495
PM_{10}	137,384	13,738
$PM_{2.5}$	18,710	1,871

In order to assess cumulative impacts, model predictions from the Quarry (see Section 7.2) have been paired with the predictions from these two neighbouring quarries and the background air quality monitoring data (summarised in Section 5.3). Further details regarding the cumulative assessment approach are provided in Section 7.3.

6 Emissions inventory

6.1 Sources of emissions

Sources of atmospheric emissions associated with the Quarry include:

- removal, handling, hauling and dumping of topsoil and overburden[9];
- removal, handling, hauling and dumping of hard rock product, including drilling and blasting in the quarry pit;
- material processing (crushing, screening and conveying);
- wind erosion from stockpiles and exposed surfaces;
- transportation (hauling) of product and overburden along unpaved internal roads, the paved site access road and paved public roads; and
- diesel fuel combustion by Quarry plant and equipment.

6.2 Emission scenario calculations

On 30 June 2017, the Extension Project was approved by the New South Wales Land and Environment Court (NSW LEC) 2017/108663 (LEC Approval), allowing the Quarry to transport up to 2 million tonnes of quarry products from the site per year. This approval applies to all quarry operations. An AQIA (Ramboll 2016) was completed as part of the EIS for the Extension Project.

The emissions inventory for the Continuation Project has been based on the emissions inventory developed for the Extension Project, with refinements made where necessary, including:

- where dust control measures were not previously accounted for, better alignment with actual dust mitigation measures implemented at the processing plant (eg enclosure or dust extraction);
- correction of assumptions regarding number and location of fixed plant (ie crushers and screens); and
- correction of truck weights and diesel consumption rates.

The Continuation Project emissions inventory conservatively assumes Quarry operations to allow a product dispatch rate of 4.2 Mtpa. For dispersion modelling purposes (see Chapter 7), in order to illustrate the difference between peak and average day product dispatch rates, 24-hour average concentrations are related to emissions during normal quarry operations and peak days when there are the maximum daily outbound truck movements (375 trucks per day).

Fugitive dust sources associated with the Quarry were quantified through the application of NPI emission estimation techniques and USEPA AP-42 emission factor equations. Particulate matter emissions were quantified for the three size fractions identified in Chapter 3.1, with the TSP fraction also used to provide an indication of dust deposition rates. Emission rates for coarse particles (PM_{10}) and fine particles ($PM_{2.5}$) were estimated using ratios for the different particle size fractions available in the literature (principally the USEPA AP-42).

[9] 'Overburden': any extracted unsalable material.

Total annual emissions associated with Quarry operations are presented in Table 6.1. Particulate matter mitigation measures, discussed in detail in Section 6.3, are accounted for in Table 6.1 where appropriate. A detailed breakdown of emissions by source is presented in Annexure B.

Table 6.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – Continuation Project

	Calculated annual emissions (t/annum)		
	TSP	PM_{10}	$PM_{2.5}$
Continuation Project	505.33	152.29	22.89

The contribution of source type to total annual emissions by particle size are illustrated in Figure 6.1.

Across all particle sizes, the most significant sources of emissions are the movement of trucks along unpaved and paved surfaces, wind erosion of exposed surfaces and stockpiles and the processing plant. Further details regarding emission estimation factors and assumptions are provided in Annexure B.

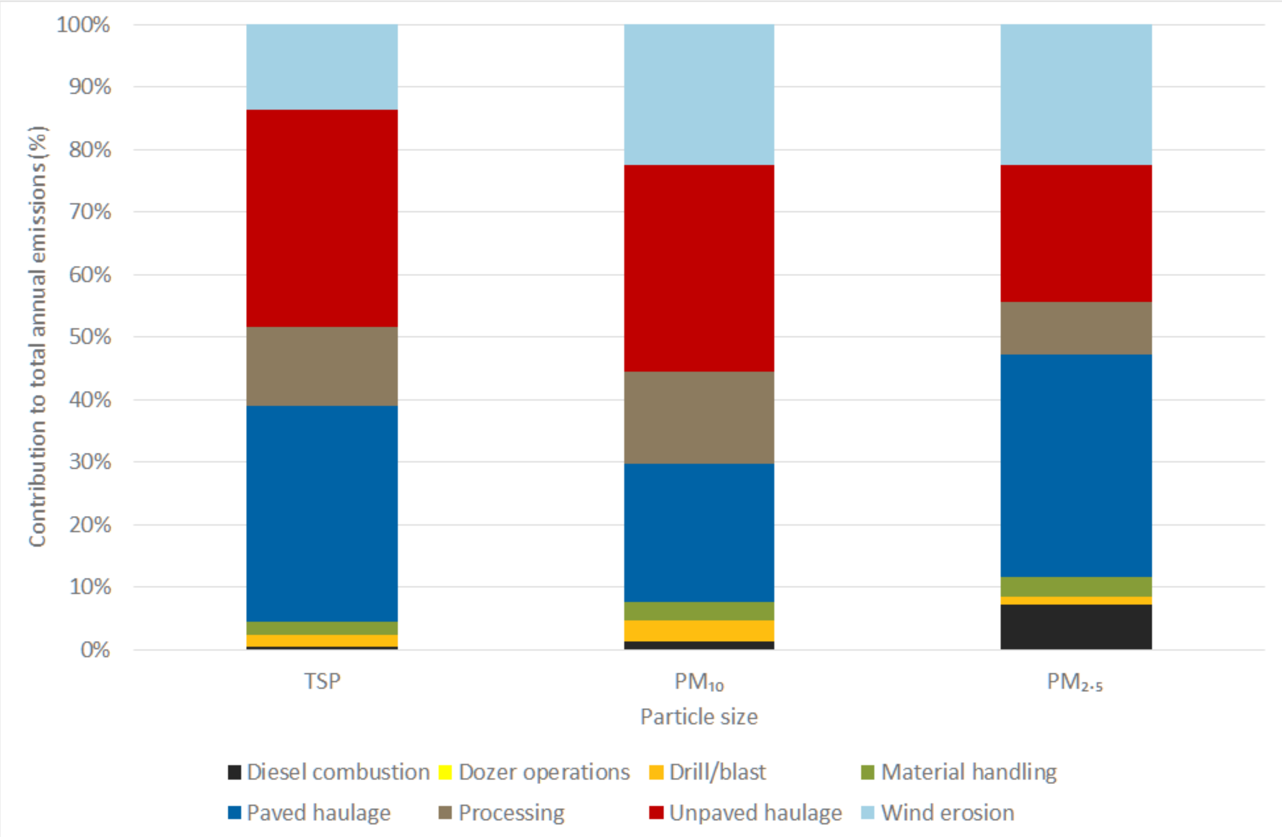


Figure 6.1 Contribution to annual emissions by emissions source type and particle size – Continuation Project

6.3 Particulate matter emissions mitigation measures

An overview of particulate matter emission control and mitigation measures implemented at the Quarry, as summarised in the Gunlake Quarry Air Quality Management Plan (Gunlake 2020), is presented in Table 6.2.

Table 6.2 Overview of mitigation measures at the Quarry

Quarry activity	Emission control or management practice
Stripping, transport, and emplacement/stockpiling of topsoil	Minimise clearing ahead of extraction activities Revegetation of completed surfaces
Removal, transport and placement of overburden	Water trucks used on haul roads Temporarily cease or relocate activities if excessive dust cannot be controlled
Drilling activities	Dust apron on drill rig
Face loading	Water truck used on hardstand areas including extraction benches
Hauling raw product on internal haul roads	Water truck Speed limit applied to roads
Conveyors and transfer points	Water sprays
Processing plant (crushing, screening)	Water sprays Enclosure of primary crusher Dust extraction to the processing plant
Product stockpiles	Located in nominated areas with topographic shielding Carry over moisture from processing plant water sprays
Product loading and dispatch	Use of minimal heights when loading Water cart used on hardstand areas Road registered trucks equipped with automatic tarps Use of bypass road avoids residential areas of Marulan
Internal haul roads	Water truck
General on-site activities	Water truck Weather station equipped with alarm to warn when wind speeds exceed 8 m/s

7 Air dispersion modelling

7.1 Dispersion model selection and configuration

Atmospheric dispersion of pollutants was modelled using the AERMOD dispersion model (version v21112). AERMOD is designed to handle a variety of pollutant source types, including surface and buoyant elevated sources, in a wide variety of settings such as rural and urban as well as flat and complex terrain.

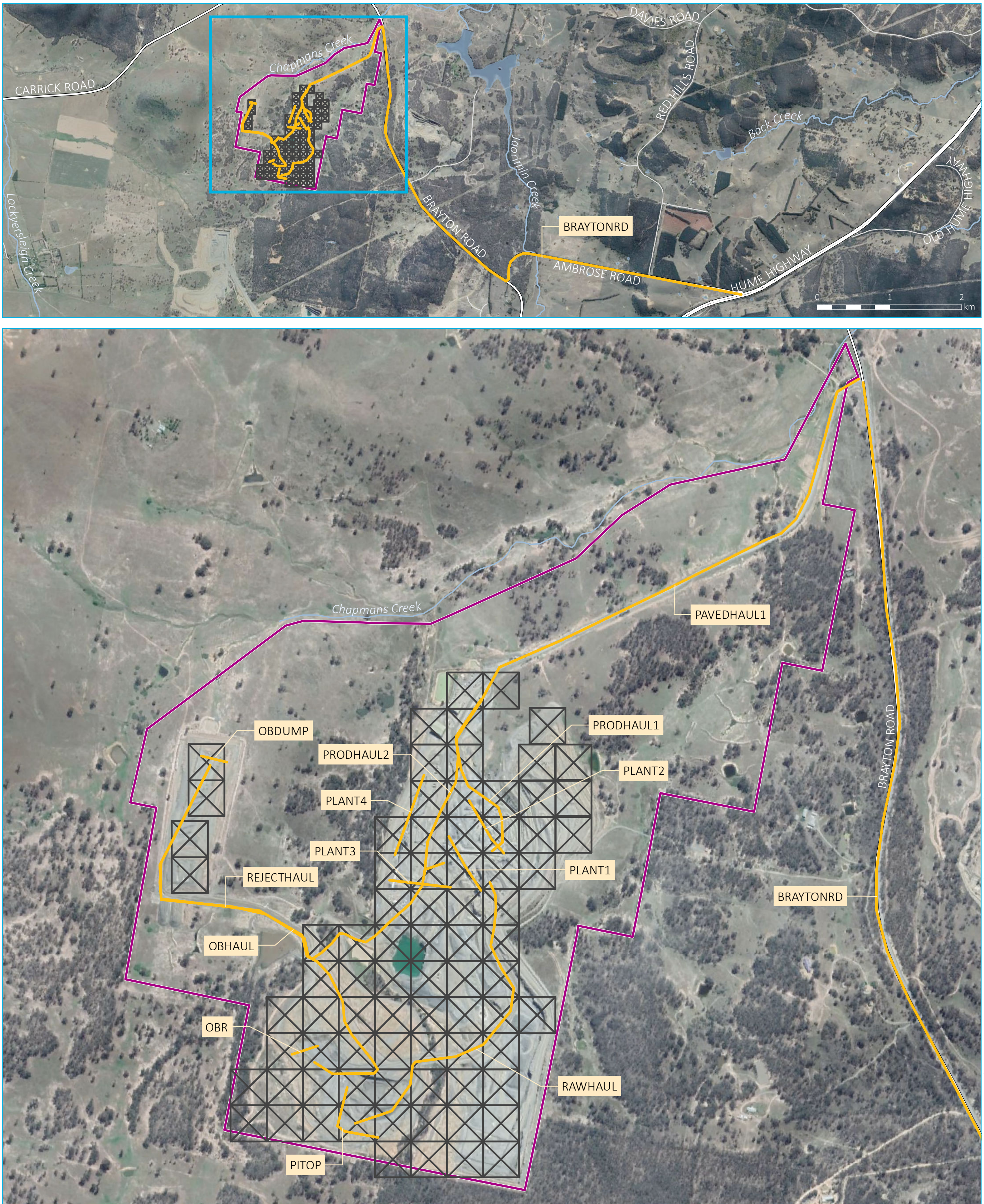
In addition to the 10 assessment locations (documented in Table 2.2), air pollutant concentrations were predicted over the following nested model grid domains:

- a 4 km by 4 km domain with 200 m resolution;
- a 7 km by 7 km domain with 500 m resolution; and
- a 13 km by 13 km domain with 1 km resolution.

The current modelling incorporates fine resolution terrain for the Quarry site based on a drone survey completed in February 2021.

Emission releases were represented by line-volume sources (material haulage routes, quarry and waste dump works areas and processing plant) or volume sources (wind erosion). The modelled source locations are shown in Figure 7.1.

Simulations were undertaken for the 12-month 2018 calendar year using the AERMET-generated file based largely on the Gunlake QMS dataset as input (see Chapter 4 for a description of input meteorology).



Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

\\emmsvr1\EMM\Jobs\2019\J190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA003_ModelSources_20210909_01.mxd 14/09/2021

0 250 500 m

GDA 1994 MGA Zone 55

N

KEY

- Site boundary
- Major road
- Minor road
- Named watercourse
- Waterbody
- Volume source (wind erosion)
- Line-volume source

OBR | Overbuden removal
OBHAUL | Overburden haul
OBDUMP | Overburden dump
PITOP | Quarry pit operations
RAWHAUL | Raw material haulage
PRODHAUL1&2 | Unpaved product haulage
PLANT1 | Processing Plant 1
PLANT2 | Processing Plant 2
PLANT3 | Processing Plant 3
PLANT4 | Processing Plant 4
PAVEDHAUL1 | Paved product haulage
BRAYTONRD | Brayton Road haulage
REJECTHAUL | Reject haulage

Model source locations

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure 7.1

EMM
creating opportunities

7.2 Incremental (Quarry-only) results

The predicted incremental (Quarry only) concentrations and deposition rates are presented in Table 7.1.

To illustrate the difference between peak and average day product dispatch rates, 24-hour average concentrations are related to emissions during peak day operations (375 trucks per day) while the annual average concentrations are related to emissions during normal daily outbound truck movements.

Table 7.1 Incremental (Quarry only) concentration and deposition results

Assessment location ID	Predicted incremental concentrations (µg/m³) or deposition rates (g/m²/month)					
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**2**
R1*	9.1	18.6	4.7	2.9	0.9	0.7
R2	7.0	24.5	3.1	2.6	0.5	0.6
R3*	4.2	18.0	2.1	2.4	0.4	0.3
R4*	1.6	8.5	1.0	1.1	0.1	0.1
R5	0.6	3.8	0.3	0.5	0.1	<0.1
R6	0.8	5.0	0.6	0.8	0.1	<0.1
R7	8.9	13.9	3.3	3.1	0.8	0.7
R8	4.0	9.5	1.9	2.0	0.4	0.3
R9	2.4	8.1	1.2	1.6	0.3	0.2
R10	2.7	7.6	1.6	1.5	0.3	0.2

Notes: Criteria for TSP, PM_{10} and $PM_{2.5}$ is applicable to cumulative (increment + background) and is provided for comparison purposes only.
* = Gunlake owned property

The predicted concentrations and deposition rates for all pollutants and averaging periods presented in Table 7.1 are below the applicable NSW EPA assessment criteria and the air quality criteria specified in Schedule 3 Condition 14, Table 6, of the LEC Consent. It is noted that, excluding dust deposition, the assessment criteria listed are applicable to cumulative concentrations.

Isopleth plots illustrating spatial variations in incremental TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates from the Quarry are provided in Annexure C. Isopleth plots of the maximum 24-hour average concentrations presented in Annexure C do not represent the dispersion pattern on any individual day, but rather illustrate the maximum daily concentration that was predicted to occur at each model calculation point given the range of meteorological conditions occurring over the 2018 modelling period.

7.3 Cumulative (Quarry plus neighbouring quarries plus background) results

Predicted cumulative TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates at surrounding assessment locations are presented in Table 7.2. For each day of the 2018 modelling period, cumulative concentrations were quantified through the combination of the following:

- the daily-varying predictions of impacts from Quarry emissions;

- the concurrent daily-varying predictions of impacts from neighbouring quarries; and
- the concurrent daily-varying concentrations from the regional background dataset.

Table 7.2 Cumulative (Quarry plus neighbouring quarries plus background) concentration and deposition results

Assessment location ID	Predicted cumulative concentrations (µg/m³) or deposition rates (g/m²/month)					
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition
	Annual	24-hour (4th highest)	Annual	24-hour (3rd highest)	Annual	Annual
Criterion	**90**	**50**	**25**	**25**	**8**	**4**
R1*	39.8	48.9	19.5	22.6	7.9	3.7
R2	38.3	47.1	18.0	22.4	7.6	3.6
R3*	35.5	46.1	17.1	22.5	7.4	3.3
R4*	31.5	45.5	15.6	22.1	7.1	2.9
R5	30.4	45.0	14.9	21.9	7.0	2.9
R6	30.6	45.0	15.2	21.9	7.0	2.9
R7	40.0	48.1	18.2	22.8	7.8	3.7
R8	35.0	46.1	16.9	22.5	7.5	3.3
R9	33.6	45.4	16.2	22.4	7.4	3.1
R10	33.4	45.4	16.3	22.1	7.3	3.1

Note: the fourth and third highest cumulative concentrations are presented for 24-hour average PM_{10} and $PM_{2.5}$ due to three and two existing exceedance events respectively.
* = Gunlake owned property

As stated in Section 5.3, there are three and two existing exceedance days in the 24-hour average PM_{10} and $PM_{2.5}$ datasets respectively. Section 5.1.3 of the Approved Methods for Modelling states that in the event of existing ambient air pollutant concentrations in exceedance of applicable impact assessment criteria, the assessment must:

> …demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity and that best management practices will be implemented to minimise emissions of air pollutants as far as is practical.

To analyse if emissions from the Quarry will lead to additional exceedances of the applicable criteria, the 4th highest 24-hour cumulative PM_{10} and 3rd highest 24-hour cumulative $PM_{2.5}$ concentrations at each assessment location are reported in Table 7.2. If the presented 4th or 3rd highest cumulative concentration is above the relevant criteria, this is classed as an additional exceedance event. It is stressed that data points have not been removed from the background datasets but simply, the next highest result not affected by background above the criterion is presented in the results tables.

The predicted cumulative concentrations for all pollutants and averaging periods comply with the applicable NSW EPA assessment criteria (and the air quality criteria specified in Schedule 3 Condition 14, Table 6, of the LEC Consent) at all assessment locations.

To illustrate the contribution of background concentrations, neighbouring quarries and Quarry emission sources to cumulative concentrations, the following figures have been generated:

- Figure 7.2 – cumulative 24-hour average PM_{10} concentrations at the most impacted assessment location (R7);
- Figure 7.3 – cumulative 24-hour average $PM_{2.5}$ concentrations at the most impacted assessment location (R7);
- Figure 7.4 – cumulative annual average PM_{10} concentrations at all assessment locations; and
- Figure 7.5 – cumulative annual average $PM_{2.5}$ concentrations at all assessment locations.

These figures illustrate that the predicted daily-varying cumulative concentrations are below applicable impact assessment criteria at all assessment locations. Further, the figures illustrate that ambient background concentrations are the major contributor to cumulative concentrations.

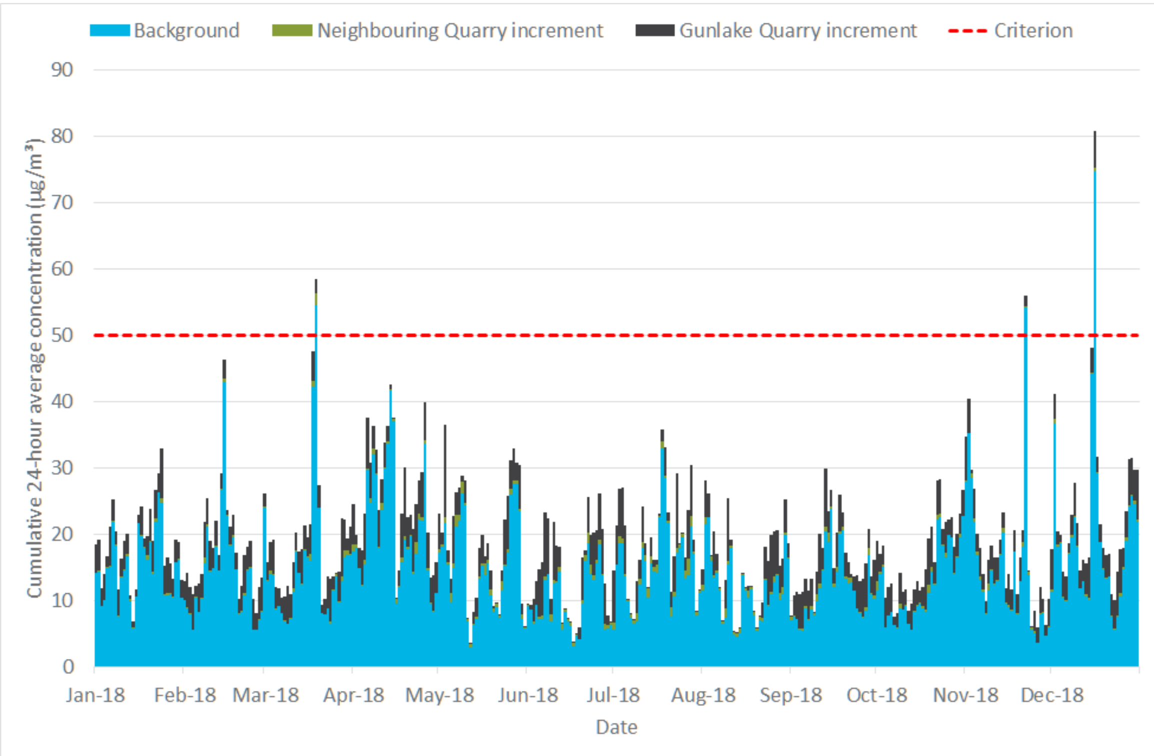


Figure 7.2 Daily-varying cumulative 24-hour average PM_{10} concentrations – assessment location R7

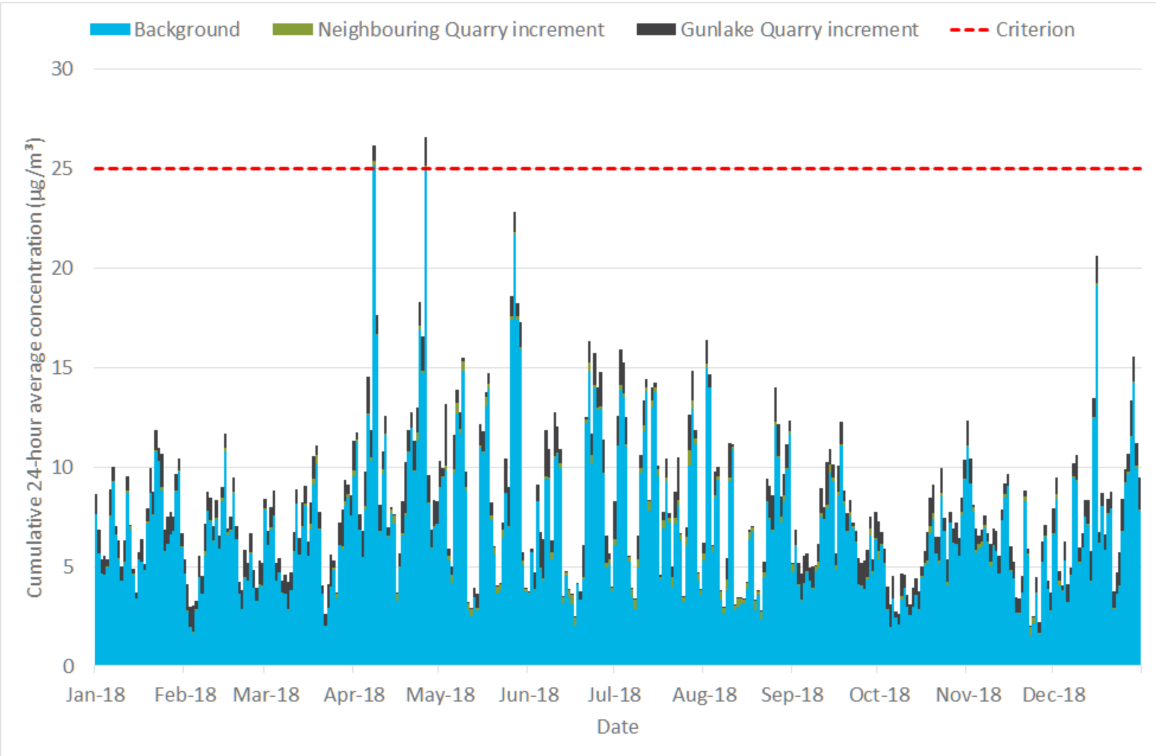


Figure 7.3 Daily-varying cumulative 24-hour average $PM_{2.5}$ concentrations – assessment location R7

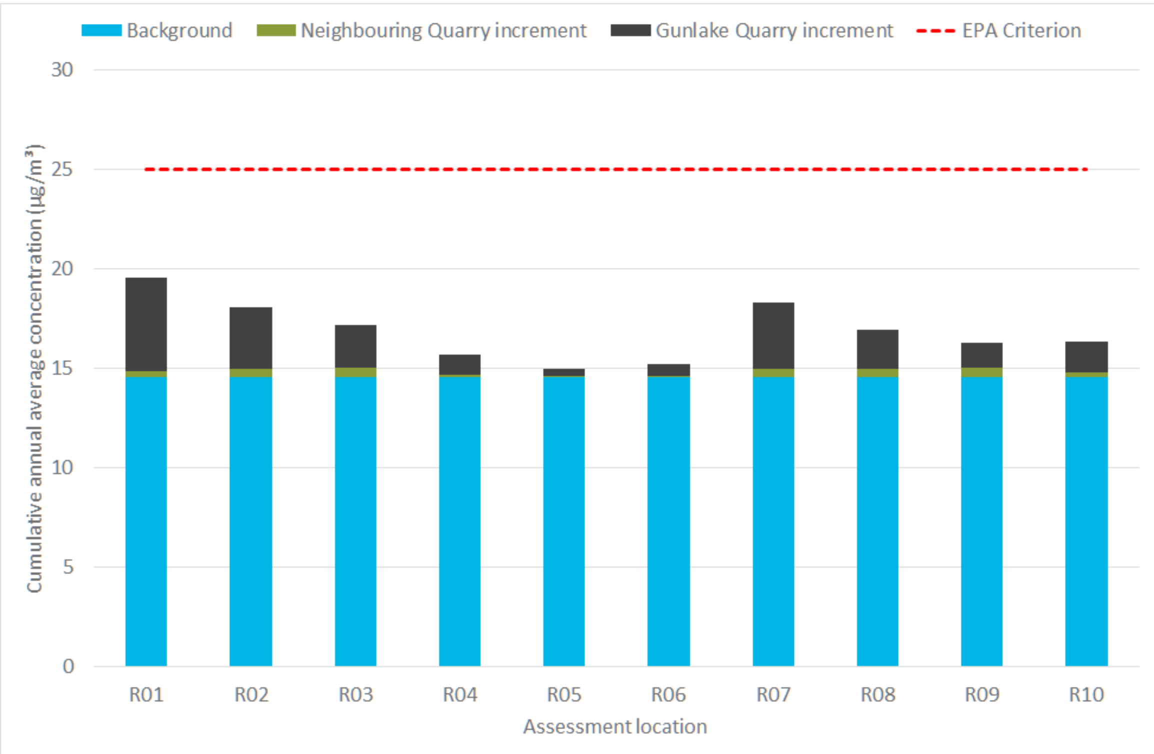


Figure 7.4 Cumulative annual average PM_{10} concentrations – all assessment locations

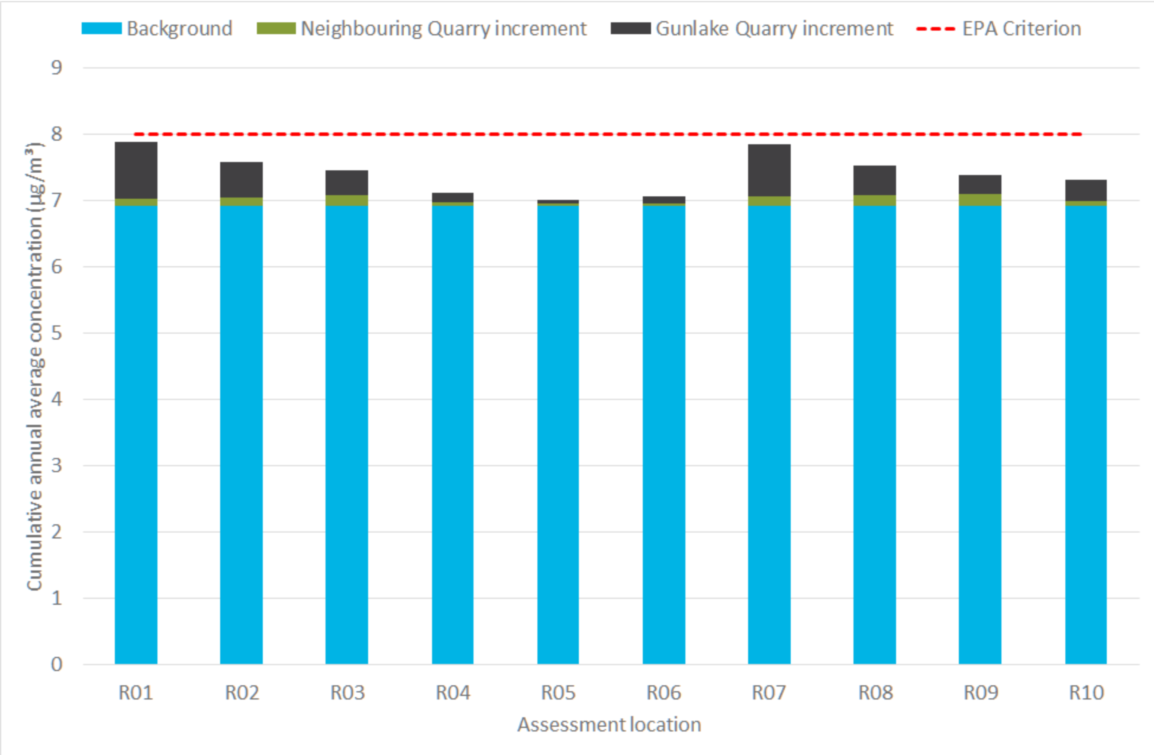


Figure 7.5 Cumulative annual average $PM_{2.5}$ concentrations – all assessment locations

7.4 Voluntary land acquisition criteria

The results presented in Section 7.2 and Section 7.3 show compliance with the relevant VLAMP criteria for both mitigation and acquisition presented in Section 3.4. As stated, VLAMP criteria also apply if the development contributes to an exceedance on more than 25% of privately-owned land upon which a dwelling could be built under existing planning controls.

The contour plots presented in Annexure C show that Quarry-only 24-hour PM_{10} and $PM_{2.5}$ concentrations will not exceed 50 µg/m³ or 25 µg/m³ across more than 25% of any privately-owned land.

To assess against voluntary land acquisition criteria for cumulative annual average PM_{10}, $PM_{2.5}$, TSP or dust deposition, the relevant fixed background value from Section 5 was added to the incremental contour plots presented in Annexure C. This analysis found that no exceedance of relevant VLAMP criteria across more than 25% of any privately-owned land is predicted to occur.

8 Air quality monitoring

As documented in Section 5.2, Gunlake maintain an air quality monitoring network at the Quarry for ongoing compliance reporting purposes. The existing network comprises of two HVAS units to record 24-hour average PM_{10} concentrations on a one-in-six day routine and three dust deposition gauges (monthly dust deposition gauges). Additionally, the Gunlake monitoring network features the Quarry meteorological monitoring station.

Gunlake will install an additional HVAS unit to record $PM_{2.5}$ concentrations at the Quarry, with the location to be finalised during a post approval revision to the existing Gunlake Quarry Air Quality Management Plan (Gunlake 2020).

Daily and annual average PM_{10} concentrations and monthly average dust deposition results will continue to be recorded and reported in annual environmental management reports.

9 Greenhouse gas assessment

9.1 Introduction

The estimation of greenhouse gas (GHG) emissions for the Quarry was based on the Department of Industry, Science, Energy and Resources National Greenhouse Accounts Factors (NGAF) workbook (DISER 2020). The methodologies in the NGAF workbook follow a simplified approach, equivalent to the 'Method 1' approach outlined in the National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (DoE 2014). The Technical Guidelines are used for the purpose of reporting under the Commonwealth National Greenhouse and Energy Reporting Act 2007.

For accounting and reporting purposes, GHG emissions are defined as 'direct' and 'indirect' emissions. Direct emissions (also referred to as scope 1 emissions) occur within the boundary of an organisation as a result of that organisation's activities. Indirect emissions are generated as a consequence of an organisation's activities but are physically produced by the activities of another organisation (DISER 2020). Indirect emissions are further defined as scope 2 and scope 3 emissions. Scope 2 emissions occur from the generation of the electricity purchased and consumed by an organisation. Scope 3 emissions occur from all other upstream and downstream activities, for example the upstream extraction and production of raw materials or the downstream use of products and services.

Scope 3 is an optional reporting category (Bhatia et al 2010) and should not be used to make comparisons between organisations, for example in benchmarking the GHG intensity of products or services. Typically, only major sources of scope 3 emissions are accounted for, and reported by, organisations. Clause 14(2) of the State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 requires that a consent authority give consideration to GHG emissions (including downstream Scope 3 emissions) from an extractive industry development.

9.2 Emission sources

The GHG emission sources included in this assessment, representing the most significant sources associated with the Quarry, are listed in Table 9.1.

Annual GHG emissions from the Quarry are estimated using the methodologies outlined in the NGAF workbook, using fuel energy contents and scope 1, 2 and 3 emission factors for diesel and electricity use in NSW.

Table 9.1 Scope 1, 2 and 3 emission sources

Scope 1	Scope 2	Scope 3
Direct emissions from diesel combustion by onsite mobile plant and equipment.	Indirect emissions associated with the consumption of purchased electricity.	Indirect emissions from the extraction, production and transport of diesel. Indirect emissions from the transport of product from site. Indirect emissions from electricity lost in delivery in the transmission and distribution network. Indirect emissions from fuel for employee travel.

9.3 Excluded emission sources

The following GHG emission sources are considered minor relative to diesel and electricity consumption and have been excluded from this GHG assessment:

- onsite liquid petroleum gas and petrol consumption (scope 1);
- fugitive leaks from high voltage switch gear and refrigeration (scope 1);
- use of paints, solvents, oils and grease (scope 1); and
- disposal of solid waste at landfill (scope 3).

9.4 Activity data

The following outlines the activity rate assumptions for the Continuation Project:

- The current annual onsite diesel consumption by the Quarry (eg mobile quarrying equipment, haul trucks, etc.) has been upscaled from current approved operations (2 Mtpa) to the Continuation Project activity rates (4.5 Mtpa). This equates to an annual onsite diesel consumption rate of 2,700 kilolitres (kL)/year.
- Gunlake has advised that approximately 900 kL is currently used by the six Gunlake-owned road trucks to dispatch product material to market. Gunlake have advised that the Gunlake-owned trucks complete up to five return trips per day (ie 30 return trips per day by Gunlake-owned trucks for product dispatch). The remaining truck movements required for product dispatch are completed by third-party owned trucks (see below for further discussion).
- The current monthly electricity consumption rate by the Quarry has been upscaled from current approved operations to the Continuation Project activity rates. This equates to an annual electricity consumption rate of 10.8 Megawatt-hours/year. This consumption rate has been upscaled to the Continuation Project activity rates.
- In addition to the Gunlake-owned product dispatch truck movements listed above, third party trucks are also used to dispatch product to market. For calculation purposes, it is assumed that there are 315 third-party truck movements per day for product dispatch purposes. The return distance for all product trips is 340 km (the return trip distance to Gunlake Silverwater or Banksmeadow concrete batching plants).
- Scope 3 GHG emissions from employee travel-related petrol consumption for trips to and from the Quarry were calculated based on Gunlake employee numbers (assumed to be up to 55 employees), travel distances (a weighted average return trip of 69.1 km) and potential employee days per year (249 working days per employee). Additional truck movements associated with the Continuation Project will be completed by third-party drivers, therefore there are no additional employee trips to and from the Quarry associated with the Continuation Project.
- Emission factors adopted in the Continuation Project GHG assessment were based on the latest GHG emission factors currently in force (DISER 2020).
- Fuel consumption rates for third-party product dispatch truck movements and employee travel calculations were taken from the Australian Bureau of Statistics *Survey of Motor Vehicles Use, Australia* (ABS 2019). Specifically, an articulated truck fuel consumption rate of 55.2 L/100 km and a passenger vehicles consumption rate of 10.8 L/100 km were adopted for product transportation and employee travel respectively.

The activity rates for the Continuation Project GHG assessment are presented in Table 9.2.

Table 9.2 Activity data inputs for GHG calculations - Continuation Project

Process	Continuation Project
Diesel used for onsite operations (kL)	2,700
Diesel used for product transportation (kL) – Gunlake-owned trucks	900
Diesel used for product transportation (kL) – third party trucks	17,913.1
Employee travel petrol consumption (kL)	102.6
Electricity (kWh)	10,800,000

9.5 GHG emission estimates

The estimated annual GHG emissions for each emission source for the Continuation Project are presented in Table 9.3. Details of the GHG emissions calculations are provided in Annexure D.

The significance of the Quarry's GHG emissions relative to NSW and national GHG emissions is made by comparing annual average GHG emissions calculations for the Continuation Project against the most recent available total GHG emissions inventories (calendar year 2019[10]) for NSW (136,579 kt CO_2-e) and Australia (529,298 kt CO_2-e).

Annual average GHG emissions (scope 1 and 2) generated by the Continuation Project represent approximately 0.0136% of total GHG emissions for NSW and 0.0035% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2019.

Table 9.3 Estimated annual GHG emissions – Continuation Project

Source	Scope 1 (t CO_2-e/year)	Scope 2 (t CO_2-e/year)	Scope 3 (t CO_2-e/year)	Total
Diesel combustion	9,784	-	2,989	12,774
Electricity consumption	-	8,748	972	9,720
Petrol consumption	-	-	13	13
Total	**9,784**	**8,748**	**3,974**	**22,506**

10 https://ageis.climatechange.gov.au/SGGI.aspx

10 Conclusions

An AQIA focusing on the quantification of emissions and resultant air quality impacts from the Gunlake Quarry Continuation Project has been conducted by EMM Consulting Pty Limited. Emissions of TSP, PM_{10} and $PM_{2.5}$ were quantified for all significant Quarry emission sources under increased daily truck dispatch numbers. Emissions were quantified predominately using publicly available emission estimation techniques.

Atmospheric dispersion modelling predictions of air pollution emissions were undertaken using the AERMOD dispersion model.

10.1 Evaluation of the project

In summary, the AQIA found:

- the dispersion modelling predicted that impacts from Continuation Project operations will not result in exceedance of any applicable criteria at any neighbouring assessment location; and
- annual scope 1 and 2 GHG emissions generated will represent approximately 0.0136% of total greenhouse gas (GHG) emissions for NSW and 0.0035% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2019.

References

ABS 2019, 9208.0 - Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2018.Australian Bureau of Statistics.

Bhatia, P, Cummis, C, Brown, A, Rich, D, Draucker, L & Lahd, H 2010, *Greenhouse Gas Protocol. Corporate Value Chain (Scope 3) Accounting and Reporting Standard. Supplement to the GHG Protocol Corporate Accounting and Reporting Standard,* World Resources Institute & World Business Council for Sustainable Development.

BoM 2020, Long-term climate statistics and observations from Goulburn Airport automatic weather station and Marulan (070063), Johnniefelds (070269) and Brayton (070143) rainfall monitoring locations.

Countess Environmental 2006, *WRAP Fugitive Dust Handbook.*

Department of Environment 2014, *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines*

Department of Environment 2016, *National Environment Protection (Ambient Air Quality) Measure*

Department of Industry, Science, Energy and Resources 2020, *National Greenhouse Accounts Factors*, October 2020

Department of Industry, Science, Energy and Resources 2021, Australian Greenhouse Emissions Information System, State and National GHG Inventory. https://ageis.climatechange.gov.au/SGGI.aspx

Department of Planning and Environment 2018, *Voluntary Land Acquisition and Mitigation Policy for State Significant Mining, Petroleum and Extractive Industry Developments*

Department of Planning, Industry and Environment 2021, Climate and Atmospheric Research Branch, air quality monitoring data from Goulburn and Bargo air quality monitoring stations

Gunlake 2020, *Gunlake Quarry Air Quality Management Plan*, March 2020

NPI 2021, NPI Search by Map – facility search, http://www.npi.gov.au/npidata/action/load/map-search

NSW EPA 2013, *Air Emissions in My Community web tool Substance information*. NSW EPA

NSW EPA 2017, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*

NSW EPA 2021, EPL search, https://www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences

Pacific Environment 2015, *Lynwood Quarry Extraction Area Modification Project – Air Quality Impact Assessment*. 12 November 2015

Ramboll Environ 2016, *Gunlake Quarry Air Quality Impact and Greenhouse Gas Assessment.* Report prepared for Gunlake Quarries Pty Ltd.

US-EPA 1998, AP-42 Chapter 11.9 - *Western Surface Coal Mining*

US-EPA 2004, AP-42 Chapter 11.19.2 – *Crushed Stone Processing and Pulverized Mineral Processing*

US-EPA 2006a, AP-42 Chapter 13.2.2 – *Unpaved roads*

US-EPA 2006b, AP-42 Chapter 13.2.4 – *Aggregate Handling and Storage Piles*

US-EPA 2011, AP-42 Chapter 13.2.1 – *Paved Roads*

US-EPA 2013, AERSURFACE User's Guide

Abbreviations

AERMOD	AMS/US-EPA regulatory model
AHD	Australian height datum
Approved Methods for Modelling	*Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*
AQIA	air quality impact assessment
AQMS	air quality monitoring station
BoM	Bureau of Meteorology
CO_2-e	carbon dioxide equivalent
CO	carbon monoxide
Continuation Project	Gunlake Quarry Continuation Project
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DISER	Department of Industry, Science, Energy and Resources
DPIE	Department of Planning, Industry and Environment
EIS	environmental impact statement
EMM	EMM Consulting Pty Ltd
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPL	Environment protection licence
GHG	Greenhouse gas
Gunlake	Gunlake Quarries Pty Ltd
HVAS	High volume air sampler
kL	kilolitre
kW	kilowatt
Mtpa	Million tonnes per annum
NGAF	National Greenhouse Accounts Factors
NO_x	Oxides of nitrogen
NPI	National Pollution Inventory
PM_{10}	Particulate matter less than 10 microns in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerodynamic diameter
The Quarry	Gunlake Quarry

SEARs	Planning Secretary's Environmental Assessment Requirements
SO_2	Sulphur dioxide
SSD	State Significant Development
SSD SEPP	State Environmental Planning Policy (State and Regional Development)
TAPM	The Air Pollution Model
TSP	Total Suspended Particulate Matter
US-EPA	United States Environmental Protection Agency
VLAMP	Voluntary Land Acquisition and Mitigation Policy
VOC	Volatile organic compounds

Annexure A

Meteorological modelling and processing

A.1 Meteorological monitoring datasets

As discussed in Section 4.1, meteorological datasets were collated from the following monitoring stations:

- Gunlake Quarry onsite meteorological monitoring station (QMS); and
- BoM Goulburn Airport automatic weather station, located 27 km to the west-south-west of the QMS.

The Gunlake QMS is the primary resource for meteorological data in this assessment. Data from this station was collected for the period between January 2014 and December 2020. Data availability and analysis of inter-annual trends is presented in the following sections.

A.1.1 Data availability

A summary of data availability from the Gunlake QMS for the period between 2014 and 2020 is provided in Figure A.1.

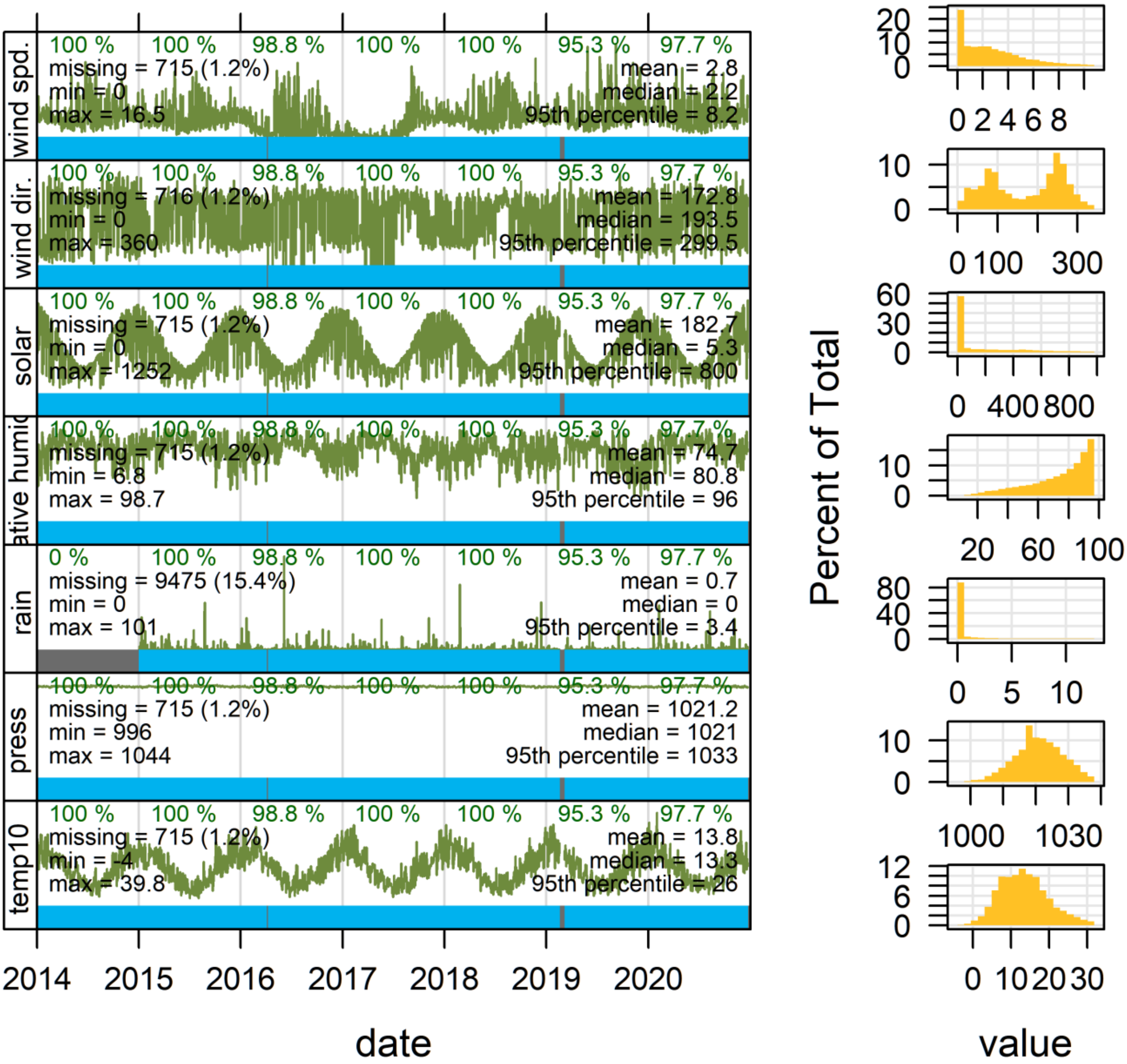


Figure A.1 **Data completeness analysis plot – Gunlake QMS – 2014 to 2020**

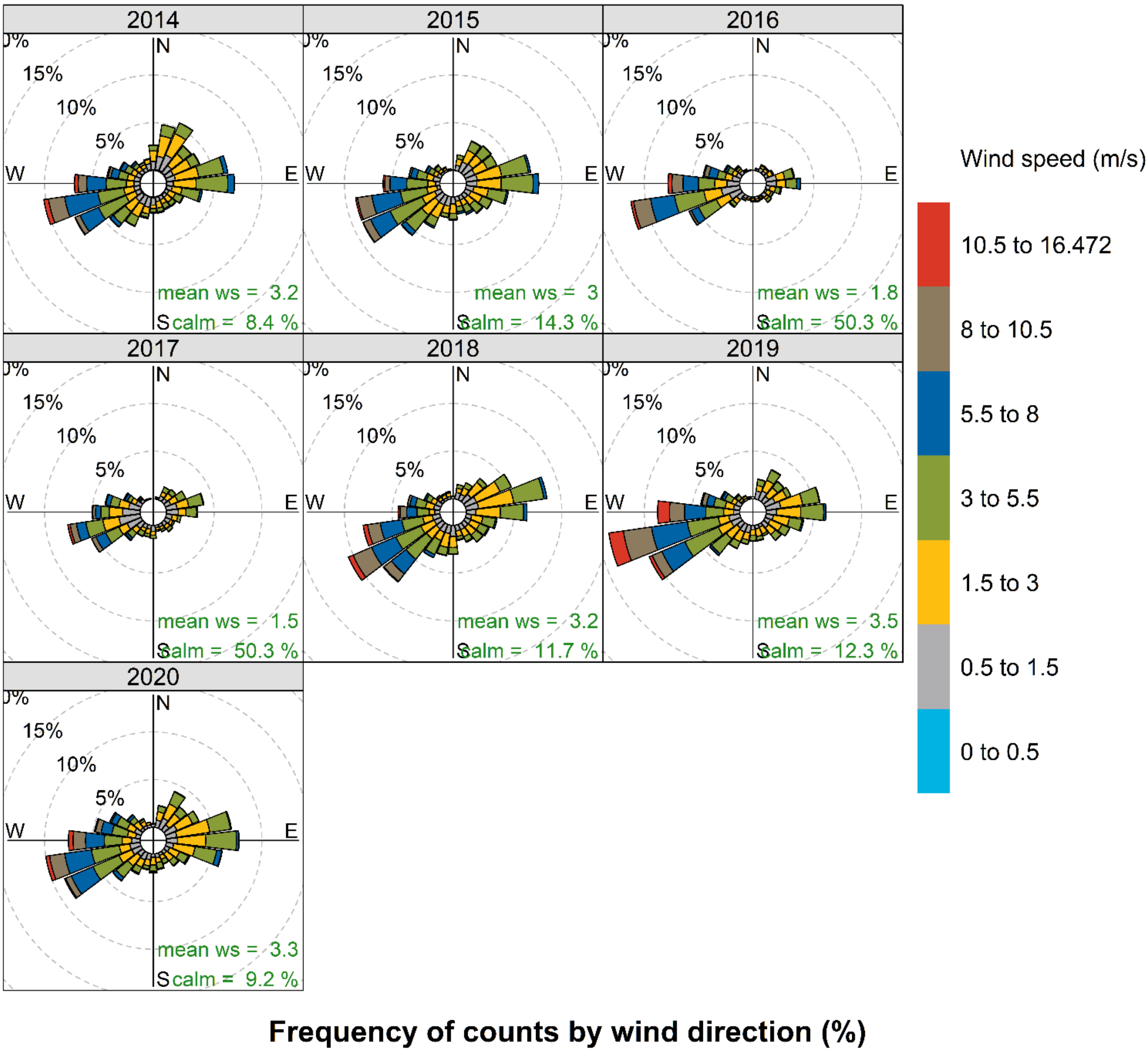


Figure A.2 **Inter-annual wind roses – Gunlake QMS – 2014 to 2020**

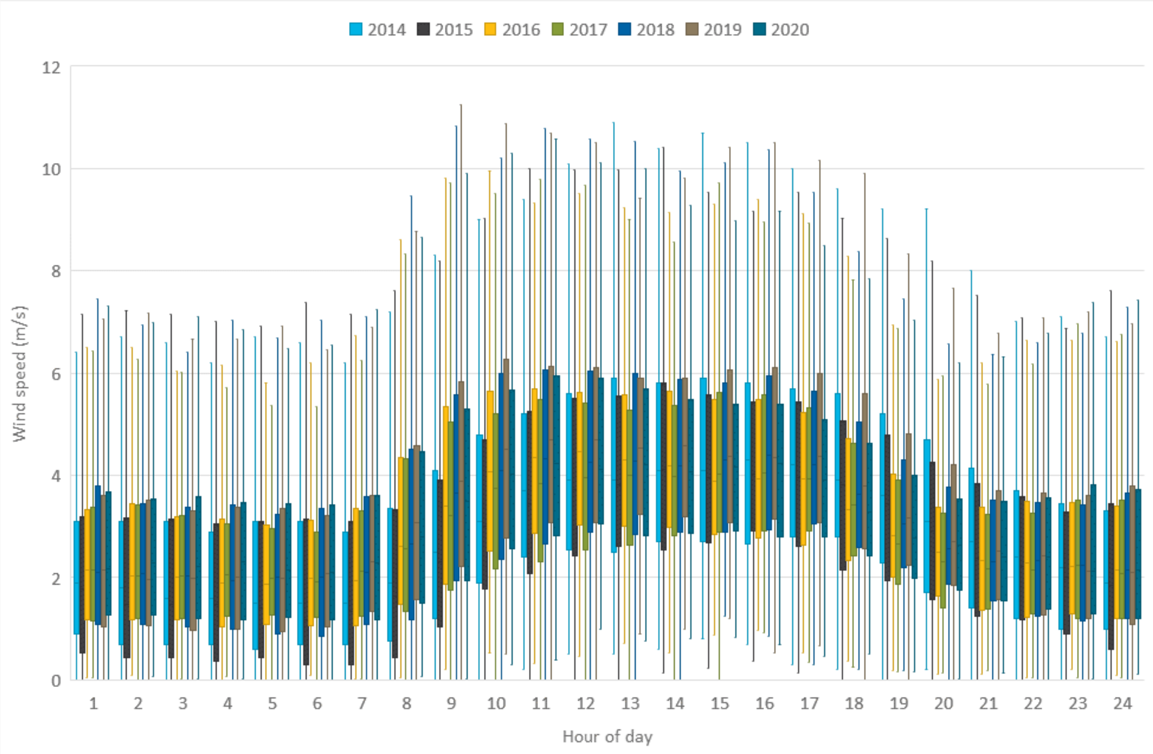


Figure A.3 Inter-annual variability in diurnal wind speed – Gunlake QMS – 2014 to 2020

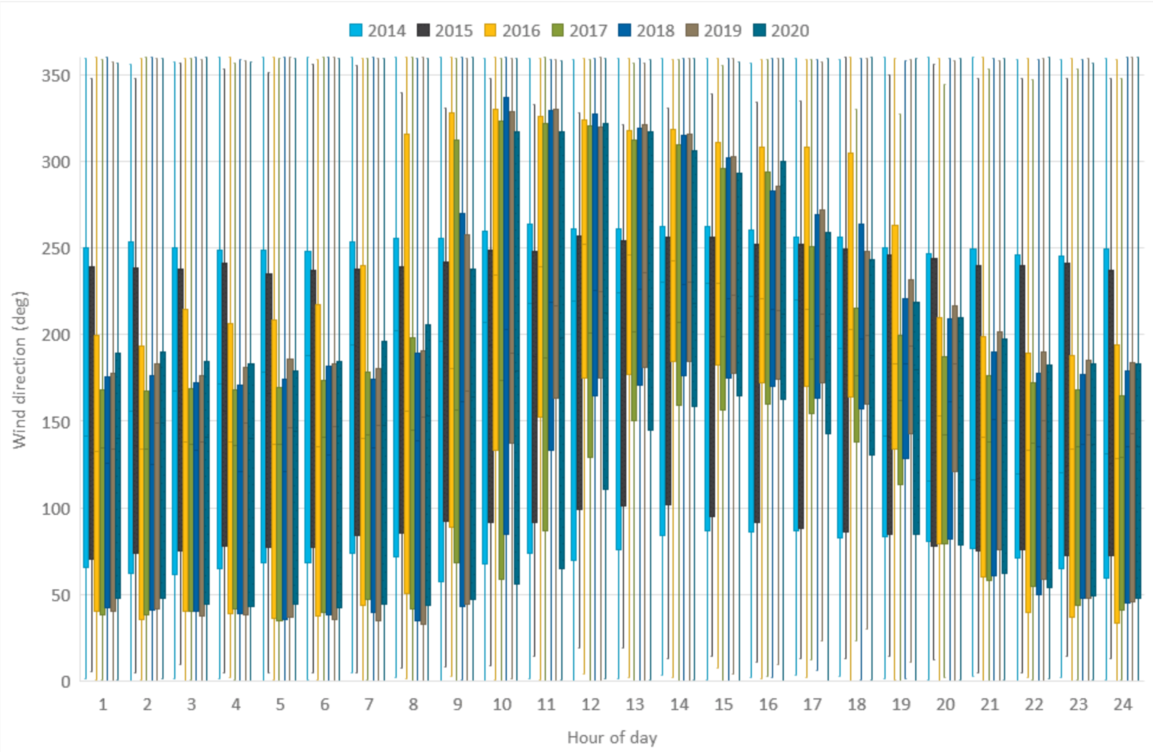


Figure A.4 Inter-annual variability in diurnal wind direction – Gunlake QMS – 2014 to 2020

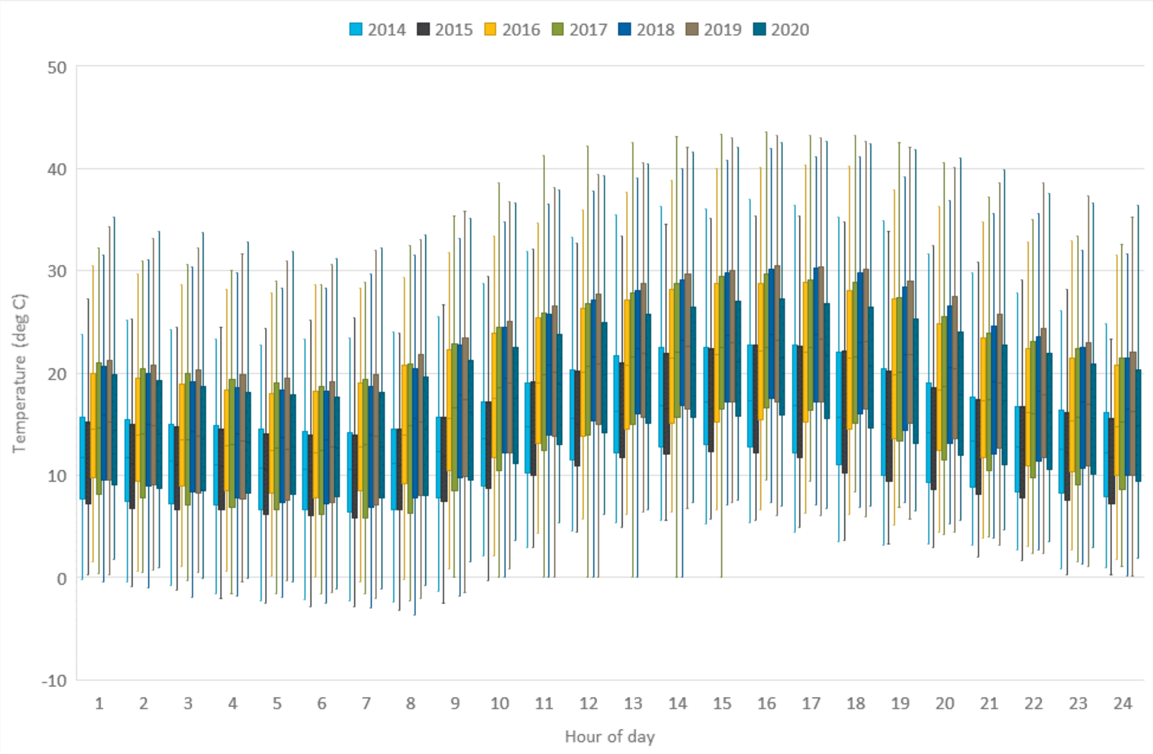


Figure A.5 Inter-annual variability in diurnal air temperature – Gunlake QMS – 2014 to 2020

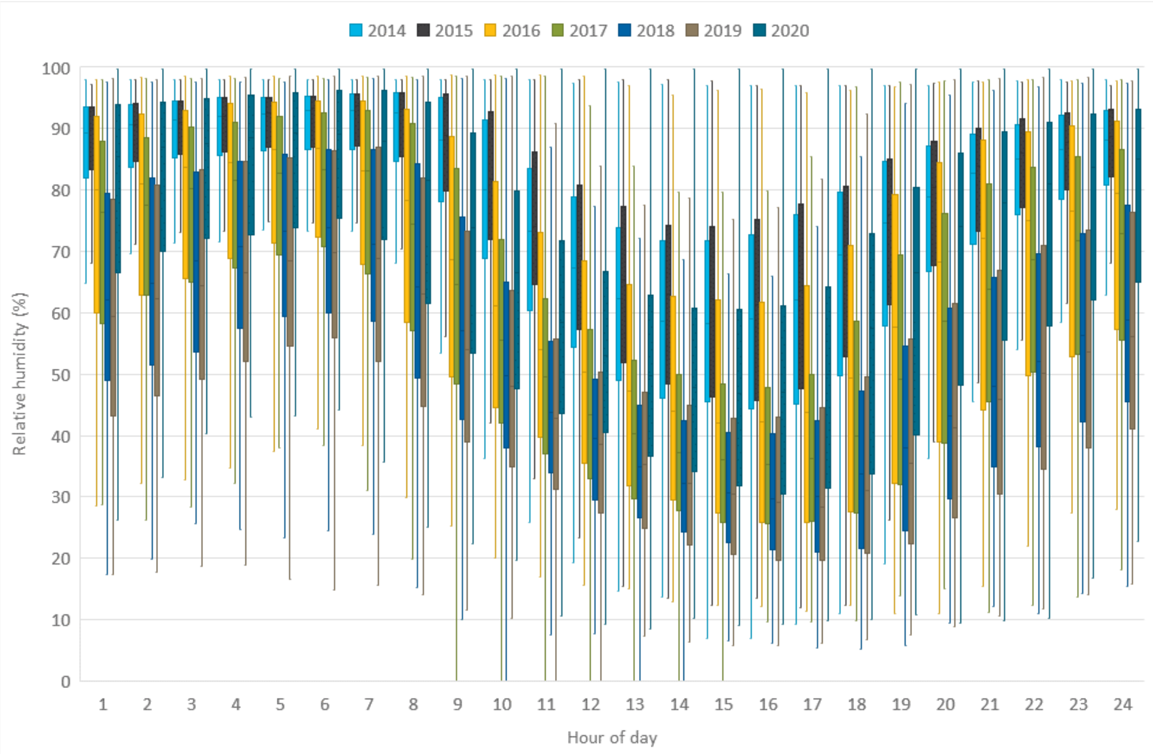


Figure A.6 Inter-annual variability in diurnal relative humidity – Gunlake QMS – 2014 to 2020

A.2 TAPM modelling

To supplement the meteorological monitoring datasets adopted for this assessment, the Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model The Air Pollution Model (TAPM) was used to generate required parameters that are not routinely measured, specifically mixing height and vertical wind/temperature profile.

TAPM was configured and run in accordance with Section 4.5 of the Approved Methods for Modelling as follows:

- TAPM version 4.0.5;
- inclusion of high resolution (90 m) regional topography (improvement over default 250 m resolution data);
- Grid domains with cell resolutions of 30 km, 10 km, 3 km, 1 km and 0.3 km. Each grid domain features 25 x 25 horizontal grid points and 25 vertical levels;
- TAPM default databases for land use, synoptic analyses and sea surface temperature; and
- TAPM defaults for advanced meteorological inputs.

A.3 AERMET meteorological processing

The meteorological inputs for AERMOD were generated using the AERMET meteorological processor (v21112). The following sections provide an overview of meteorological processing completed for this assessment.

A.3.1 Surface characteristics

Prior to processing meteorological data, the surface characteristics of the area surrounding the adopted monitoring station require parameterisation. The following surface parameters are required by AERMET:

- surface roughness length;
- albedo; and
- Bowen ratio.

As detailed by USEPA (2013), the surface roughness length is related to the height of obstacles to the wind flow (eg vegetation, built environment) and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

The land cover of the 10 km by 10 km area surrounding the QMS station was mapped (see Figure A.7). Using the AERSURFACE tool and following the associated guidance of USEPA (2013), surface roughness was determined for 12 (30 degree) sectors grouped by similar land use types within a 1 km radius around the on-site meteorological station, while the Bowen ratio and albedo were determined for the total 10 km by 10 km area. Monthly-varying values for surface roughness, Bowen ratio and albedo were allocated to each sector based on the values prescribed by USEPA (2013), as specified in Table A.1 and Table A.2. The following profiles were applied to individual months:

- Midsummer – January, February, December;

- Autumn – March, April, May;
- Late autumn/winter without snow – June, July, August; and
- Transitional spring – September, October, November.

The surface moisture characteristics for the 2018 modelling period was determined by comparing the period rainfall total to the previous 30-year rainfall records from the following BoM long term rainfall stations:

- Marulan (070063);
- Johnniefelds (070269); and
- Brayton (070143).

Annual rainfall for 2018 modelling period was 572 mm, which places the 12-month period between the 30th and 70th percentile rainfall totals for the previous 30 years, and therefore an 'average' surface moisture classification was allocated. It is noted that the rainfall records are not incorporated into dispersion model predictions (ie no wet deposition is modelled).

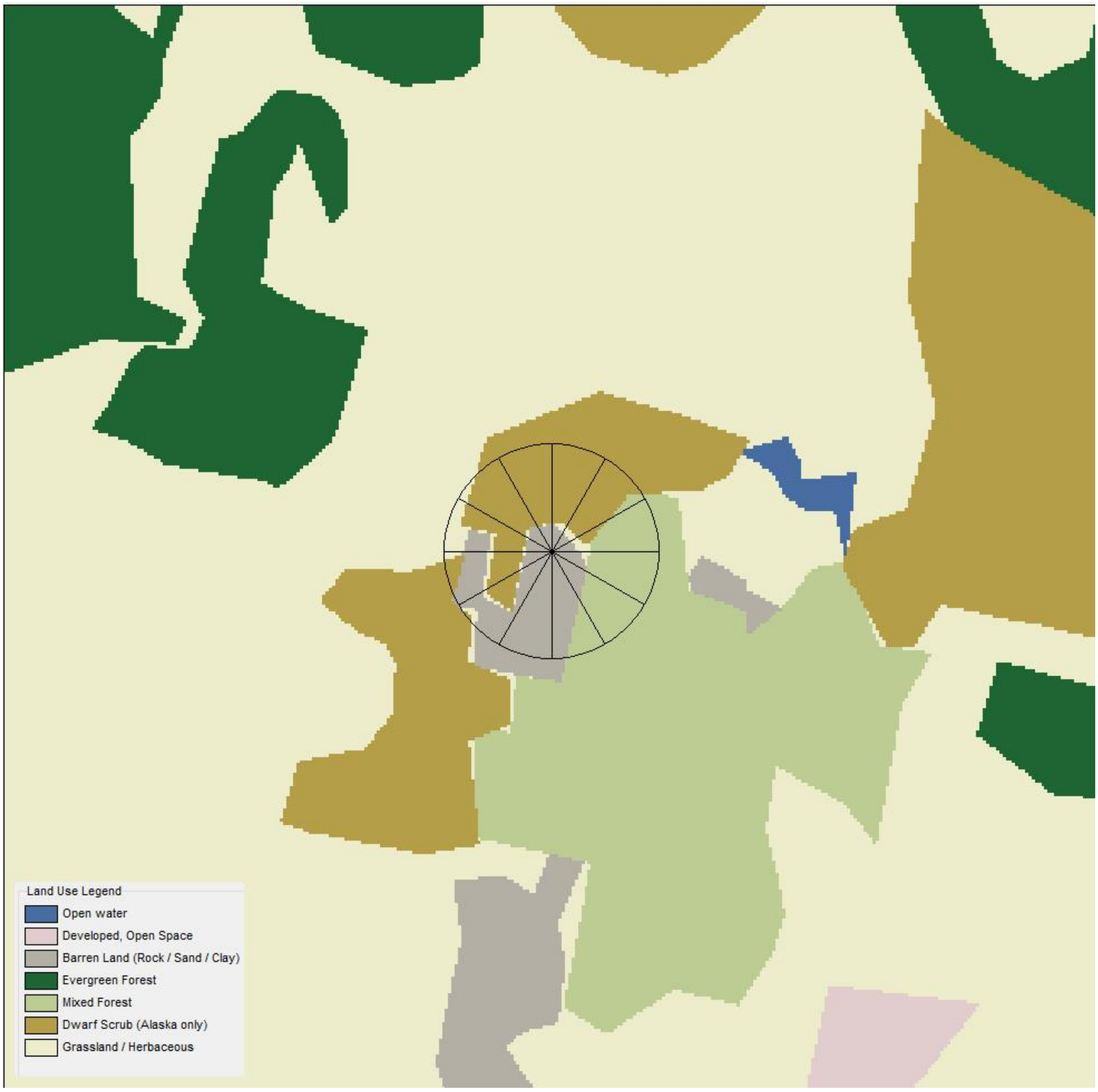


Figure A.7 Land use map for AERSURFACE processing – Gunlake QMS

Note: Marked in figure are the 1 km radius for surface roughness (12 sectors defined) and 10 km x 10 km for albedo/Bowen ratio (total image shown)

Table A.1 Monthly surface roughness length values by sector

Month	Surface roughness length (m) by sector (degrees)											
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-0
Jan	0.089	0.089	0.089	0.089	0.081	0.081	0.081	0.081	0.087	0.087	0.089	0.089
Feb	0.097	0.097	0.097	0.097	0.083	0.083	0.083	0.083	0.092	0.092	0.097	0.097
Mar	0.326	0.326	0.326	0.326	0.211	0.211	0.211	0.211	0.277	0.277	0.326	0.326
Apr	0.499	0.499	0.499	0.499	0.351	0.351	0.351	0.351	0.432	0.432	0.499	0.499
May	0.335	0.335	0.335	0.335	0.270	0.270	0.270	0.270	0.304	0.304	0.335	0.335
Jun	0.109	0.109	0.109	0.109	0.100	0.100	0.100	0.100	0.104	0.104	0.109	0.109
Jul	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Aug	0.062	0.062	0.062	0.062	0.053	0.053	0.053	0.053	0.059	0.059	0.062	0.062
Sep	0.071	0.071	0.071	0.071	0.058	0.058	0.058	0.058	0.067	0.067	0.071	0.071
Oct	0.074	0.074	0.074	0.074	0.048	0.048	0.048	0.048	0.065	0.065	0.074	0.074
Nov	0.085	0.085	0.085	0.085	0.075	0.075	0.075	0.075	0.082	0.082	0.085	0.085
Dec	0.082	0.082	0.082	0.082	0.081	0.081	0.081	0.081	0.082	0.082	0.082	0.082

Table A.2 Monthly Bowen ratio and albedo values (all sectors)

Month	Monthly value (all sectors)	
	Bowen ratio	Albedo
January	0.17	0.62
February	0.17	0.62
March	0.17	0.62
April	0.17	0.96
May	0.18	0.96
June	0.18	0.96
July	0.18	0.96
August	0.18	0.96
September	0.17	0.50
October	0.17	0.50
November	0.17	0.62
December	0.17	0.62

A.3.2 Meteorological inputs

Monitoring data from the QMS and BoM Goulburn Airport (70330) automatic weather station were combined with TAPM meteorological modelling outputs for input to AERMET. Data gaps were filled through a combination of interpolation and substitution.

The following parameters were input as on-site data to AERMET:

- wind speed and direction – QMS;
- sigma-theta (standard deviation of wind direction) - QMS;
- temperature (heights of 2 m and 10 m) - QMS;
- relative humidity - QMS;
- station level pressure – QMS;
- cloud cover - BoM Goulburn Airport;
- solar radiation – QMS; and
- mixing depth – TAPM at QMS.

The period of meteorological data input to AERMET was 1 January 2018 to 31 December 2018.

A.3.3 Upper air profile

Due to the absence of necessary local upper air meteorological measurements, the hourly profile file generated by TAPM at the QMS location was adopted. Using the temperature difference between levels, the TAPM-generated vertical temperature profile for each hour was adjusted relative to the hourly surface (10m) temperature observations from the QMS.

Annexure B

Emissions inventory background

B.1 Introduction

Air emission sources associated with the Quarry were quantified through the application of accepted published emission estimation factors, collated from a combination of US-EPA AP-42 Air Pollutant Emission Factors and NPI emission estimation manuals.

Particulate matter emissions were quantified for various particle size fractions. The dispersion of TSP emissions was simulated to predict dust deposition rates. Coarse and fine particulate matter (PM_{10} and $PM_{2.5}$) were estimated using ratios for the different particle size fractions available within the literature (principally the US-EPA AP-42), as documented in subsequent sections.

B.2 Emissions inventory assumptions

Material parameters adopted within the emissions inventory are presented in Table B.1.

Table B.1 Assumed material parameters

Material	Parameter	Value	Source
Silt Content of Unpaved Roads internal haul roads	%	8.3	Silt content for Quarrying - Haul Road to/from pit AP42 13.2.2
Silt Content of Unpaved Roads Product transportation	%	7.1	Silt content for Sand and Gravel Processing - Material Storage Area AP42 13.2.2
Silt loading for paved roads	g/m^2	0.6	Silt loading (g/m^2) for road <500 trucks/day
Silt Content of Overburden	%	7	US-EPA AP42 (1998) mean value for “overburden”
Silt Content of raw material	%	6	Gunlake provided
Silt Content of product	%	3	Gunlake provided
Moisture Content of Overburden	%	15	Gunlake provided
Moisture Content of raw material	%	8	Gunlake provided
Moisture Content of product	%	12	Gunlake provided

B.3 Material haulage assumptions

Assumptions adopted for material haulage about the Quarry are presented in Table B.2.

Table B.2 Haulage calculations – Continuation Project

Haulage source	Distance (km)	Truck capacity (t)	Truck Weight empty (t)	Truck weight full (t)	Truck weight average (t)	Throughput (tpa)	Loads per year	VKT per year (km)
Overburden - pit to dump	1.45	50	35.4	85.4	60.4	55,000	1,100	3,190
Raw material - pit to processing	1.0	50	35.4	85.4	60.4	4,500,000	90,000	180,000
Rejects - processing to dump	1.4	50	35.4	85.4	60.4	300,000	6,000	16,800
Product Haul 1 (Plant 2)	0.5	36	20	56	38	1,117,729	31,048	31,048
Product Haul 2 (Plant 1, 3 and 4)	0.5	36	20	56	38	2,972,771	82,577	82,577
Product transport – weighbridge to exit	1.5	36	20	56	38	4,090,500	113,625	340,875
Product transport - Brayton Rd	7.7	36	20	56	38	4,090,500	113,625	1,749,825

Note: VKT = vehicle kilometres travelled

B.4 Onsite diesel combustion emissions

Emissions generated by onsite plant and equipment diesel combustion was quantified through the following assumptions:

- annual diesel consumption rate of 2,700,000 L per year;
- the corresponding USEPA (USEPA 2016) Tier 2 emission standards for PM of 0.2 g/kWh was selected;
- the g/kWh emission standard was converted to g per litre of diesel by applying a scaling factor of 3, as per the notes for Table 35 in *NPI Emission Estimation Technique Manual for Combustion Engines* (NPI 2008); and
- the PM emission standard is assumed to correspond to PM_{10}, with $PM_{2.5}$ emissions derived from the relationship between PM_{10} and $PM_{2.5}$ emission factors presented in Table 35 in NPI, 2008 (91.7%).

Annual diesel combustion emissions from product truck dispatching material from the Quarry were quantified through the following assumptions:

- annual vehicle kilometres travelled of 2,204,325 km per year was quantified for movements along the internal product transport route and Brayton Road to the Hume Highway (final four rows in Table B.2);
- emissions from diesel combustion by road trucks were quantified through the calculated annual VKT and the EPA PM Emission Factor for road trucks (EPA 2012), based on the specifications of 2011 ADR80/03.

B.5 Emissions inventory table

A summary of the emissions inventory is presented in Table B.3.

Table B.3 Continuation Project emissions inventory

Source name	Emission estimate TSP (kg/year)	Emission estimate PM_{10} (kg/year)	Emission estimate $PM_{2.5}$ (kg/year)	Activity rate	Units	TSP emission factor	PM_{10} emission factor	$PM_{2.5}$ emission factor	Unit	Parameter 1	Unit	Parameter 2	Unit	Parameter 3	Unit	Parameter 4	Unit	Reduction factor	Emission control	Emission factor source
Overburden removal - bulldozer	333.75	59.68	6.27	420	Hrs/year	0.7946	0.1421	0.0149	kg/hr	7.00	Silt content	15.0	Moisture content (%)							USEPA AP-42 11.9.2 - Dozer on other material
OB loading to trucks - excavator	6.47	3.06	0.46	55,000	t/y	0.0001	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	15.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
OB haulage - unsealed	1,922.81	546.78	54.68	3,190	VKT/year	4.3054	1.2243	0.1224	kg/VKT	8.3	Road silt content (%)	2.9	Return haul distance (km)	89	Loads/year	60	Average weight (t)	0.86	Watering + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
OB trucks unloading	6.47	3.06	0.46	55,000	t/y	0.0001	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	15.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
OB dump management - bulldozer	333.75	59.68	6.27	420	Hrs/year	0.7946	0.1421	0.0149	kg/hr	7.00	Silt content	15.0	Moisture content (%)							USEPA AP-42 11.9.2 - Dozer on other material
Truck loading in pit - raw material	1,275.44	603.25	91.35	4,500,000	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Raw material haulage - unsealed	108,497.13	30,852.67	3,085.27	180,000	VKT/year	4.3054	1.2243	0.1224	kg/VKT	8.3	Road silt content (%)	2.0	Return haul distance (km)	5,000	Loads/year	60.4	Average weight (t)	0.86	Watering + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Truck unloading to hopper	637.72	301.62	45.67	4,500,000	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Watering	USEPA AP-42 13.2.4 - Materials handling equation
Raw material rehandle	7.97	3.77	0.57	56,250	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Watering	USEPA AP-42 13.2.4 - Materials handling equation
Plant 1 - Screen 1	1,265.63	435.38	29.42	675,000	t/y	0.0125	0.0043	0.0003	kg/t									0.85	Water sprays + enclosure	USEPA AP-42 11.19.2 - screening
Plant 1 - Primary crusher	410.06	182.25	33.75	1,012,500	t/y	0.0027	0.0012	0.0002	kg/t									0.85	Water sprays + enclosure	USEPA AP-42 11.19.2 - tertiary crushing
Plant 1 - Screen 2	4,781.25	1,644.75	111.13	765,000	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 1 - Secondary crusher	1,139.06	506.25	93.75	843,750	t/y	0.0027	0.0012	0.0002	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - tertiary crushing
Plant 1 - Screen 3	8,546.48	2,939.99	198.65	1,367,438	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 2 - Screen 1	3,842.58	1,321.85	89.31	614,813	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 2 - Secondary crusher	830.00	368.89	68.31	614,813	t/y	0.0027	0.0012	0.0002	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - tertiary crushing
Plant 2 - Screen 2	768.52	264.37	17.86	122,963	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 2 - Tertiary crusher	1,493.99	664.00	122.96	1,106,663	t/y	0.0027	0.0012	0.0002	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - tertiary crushing
Plant 2 - Screen 3	4,807.27	1,653.70	111.74	769,163	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 2 - Quartenary crusher	455.63	202.50	37.50	337,500	t/y	0.0027	0.0012	0.0002	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - tertiary crushing
Plant 2 - Screen 4	2,348.44	807.86	54.59	375,750	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 3 - Screen 1	2,109.38	725.63	49.03	1,125,000	t/y	0.0125	0.0043	0.0003	kg/t									0.85	Water sprays + enclosure	USEPA AP-42 11.19.2 - screening
Plant 3 - Primary crusher	683.44	303.75	56.25	1,687,500	t/y	0.0027	0.0012	0.0002	kg/t									0.85	Water sprays + enclosure	USEPA AP-42 11.19.2 - tertiary crushing
Plant 3 - Screen 2	8,789.06	3,023.44	204.29	1,406,250	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 3 - Secondary crusher	1,898.44	843.75	156.25	1,406,250	t/y	0.0027	0.0012	0.0002	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - tertiary crushing
Plant 3 - Screen 3	14,238.28	4,897.97	330.94	2,278,125	t/y	0.0125	0.0043	0.0003	kg/t									0.5	Water sprays	USEPA AP-42 11.19.2 - screening
Plant 4 - Screen 1	1,078.77	371.10	25.07	1,015,313	t/y	0.0125	0.0043	0.0003	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - screening
Plant 4 - Secondary crusher	237.53	105.57	19.55	1,035,000	t/y	0.0027	0.0012	0.0002	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - tertiary crushing
Plant 4 - Screen 2	218.14	75.04	5.07	205,313	t/y	0.0125	0.0043	0.0003	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - screening
Plant 4 - Tertiary crusher	423.43	188.19	34.85	1,845,000	t/y	0.0027	0.0012	0.0002	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - tertiary crushing
Plant 4 - Quartenary crusher	115.67	51.41	9.52	504,000	t/y	0.0027	0.0012	0.0002	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - tertiary crushing
Plant 4 - Screen 3	1,960.31	674.35	45.56	1,845,000	t/y	0.0125	0.0043	0.0003	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - screening
Plant 4 - Screen 4	705.23	242.60	16.39	663,750	t/y	0.0125	0.0043	0.0003	kg/t									0.915	Water sprays + dust extractor/fabric filter	USEPA AP-42 11.19.2 - screening
Plant 1 - conveyor transfer point enclosed (1 point)	39.65	18.76	2.84	932,738	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.85	Water sprays + enclosure	USEPA AP-42 13.2.4 - Materials handling equation
Plant 1 - conveyor transfer points (11 points)	1,454.01	687.71	104.14	10,260,113	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 1 - stockpile loading	64.89	30.69	4.65	457,875	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 2 - conveyor transfer points (16 points)	1,276.79	603.88	91.45	9,009,514	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 2 - stockpile loading	174.26	82.42	12.48	1,229,625	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 3 - conveyor transfer point enclosed (1 point)	67.20	31.78	4.81	1,580,625	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.85	Water sprays + enclosure	USEPA AP-42 13.2.4 - Materials handling equation
Plant 3 - conveyor transfer points (8 points)	1,791.99	847.56	128.35	12,645,000	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 3 - stockpile loading	108.01	51.09	7.74	762,188	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 4 - conveyor transfer points enclosed (8 points)	345.63	163.47	24.75	8,129,571	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.85	Water sprays + enclosure	USEPA AP-42 13.2.4 - Materials handling equation
Plant 4 - conveyor transfer points (12 points)	1,728.13	817.36	123.77	12,194,357	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Plant 4 - stockpile loading	290.56	137.43	20.81	2,050,313	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)					0.5	Water sprays	USEPA AP-42 13.2.4 - Materials handling equation
Loading to product trucks - Plant 1	66.87	31.63	4.79	416,208	t/y	0.0002	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	12.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Loading to product trucks - Plant 2	179.58	84.94	12.86	1,117,729	t/y	0.0002	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	12.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Loading to product trucks – Plant 3	111.31	52.65	7.97	692,828	t/y	0.0002	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	12.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Loading to product trucks – Plant 4	299.44	141.62	21.45	1,863,734	t/y	0.0002	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	12.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Loading rejects to trucks	85.03	40.22	6.09	300,000	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Unloading rejects at dump	85.03	40.22	6.09	300,000	t/y	0.0003	0.0001	0.0000	kg/t	3.26	Average wind speed (m/s)	8.0	Moisture content (%)							USEPA AP-42 13.2.4 - Materials handling equation
Unpaved - product transportation – Plant 1 to weighbridge	13,468.51	3,829.96	383.00	27,526	VKT/year	3.4951	0.9939	0.0994	kg/VKT	8.3	Road silt content (%)	0.5	One way haul distance (km)	27,526	Loads/year	38	Average weight (t)	0.86	Water cart + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Unpaved - product transportation - Plant 2 to weighbridge	15,192.03	4,320.07	432.01	31,048	VKT/year	3.4951	0.9939	0.0994	kg/VKT	8.3	Road silt content (%)	0.5	One way haul distance (km)	31,048	Loads/year	38	Average weight (t)	0.86	Water cart + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Unpaved - product transportation – Plant 3 to weighbridge	13,468.51	3,829.96	383.00	27,526	VKT/year	3.4951	0.9939	0.0994	kg/VKT	8.3	Road silt content (%)	0.5	One way haul distance (km)	27,526	Loads/year	38	Average weight (t)	0.86	Water cart + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Unpaved - product transportation – Plant 4 to weighbridge	13,468.51	3,829.96	383.00	27,526	VKT/year	3.4951	0.9939	0.0994	kg/VKT	8.3	Road silt content (%)	0.5	One way haul distance (km)	27,526	Loads/year	38	Average weight (t)	0.86	Water cart + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Unpaved - rejects transportation to dump	10,126.40	2,879.58	287.96	16,800	VKT/year	4.3054	1.2243	0.1224	kg/VKT	8.3	Road silt content (%)	1.4	One way haul distance (km)	6,000	Loads/year	60	Average weight (t)	0.86	Water cart + speed reductions	USEPA AP-42 13.2.2 - Unpaved roads
Paved - product transportation – weighbridge to site entry	28,532.84	5,476.89	1,325.05	340,875	VKT/year	0.0837	0.0161	0.0039	kg/VKT	0.6	Road silt loading (g/m^2)	1.5	One way haul distance (km)	113,625	Loads/year	38	Average weight (t)			USEPA AP-42 13.2.1 - Paved roads
Brayton Road - product transportation	146,468.59	28,114.71	6,801.95	1,749,825	VKT/year	0.0837	0.0161	0.0039	kg/VKT	0.6	Road silt loading (g/m^2)	7.7	One way haul distance (km)	113,625	Loads/year	38	Average weight (t)			USEPA AP-42 13.2.1 - Paved roads
Drill	9,204.00	4,786.08	276.12	15,600	holes per year	0.5900	0.3068	0.0177	kg/hole	150	holes per blast									USEPA AP-42 11.19.2 - tertiary crushing
Blast	423.74	220.35	12.71	104	blasts per year	4.0745	2.1187	0.1222	kg/blast	700	area per blast									USEPA AP-42 11.19.2 - screening
Wind Erosion - exposed surfaces and stockpiles	68,850.00	34,425.00	5,163.75	81.00	Area (ha)	850	425	64	kg/ha/year											USEPA AP-42 11.9.2 - Wind erosion of exposed areas
Diesel combustion – onsite	1,620.00	1,620.00	1,485.00	2,700,000	L/year	0.0006	0.0006	0.0006	kg/l											
Diesel combustion – product dispatch to Hume Hwy	168.17	168.17	163.12	2,204,325	VKT/year	1.2000	1.2000	1.1000	kg/kL											

Table B.4 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – Continuation Project

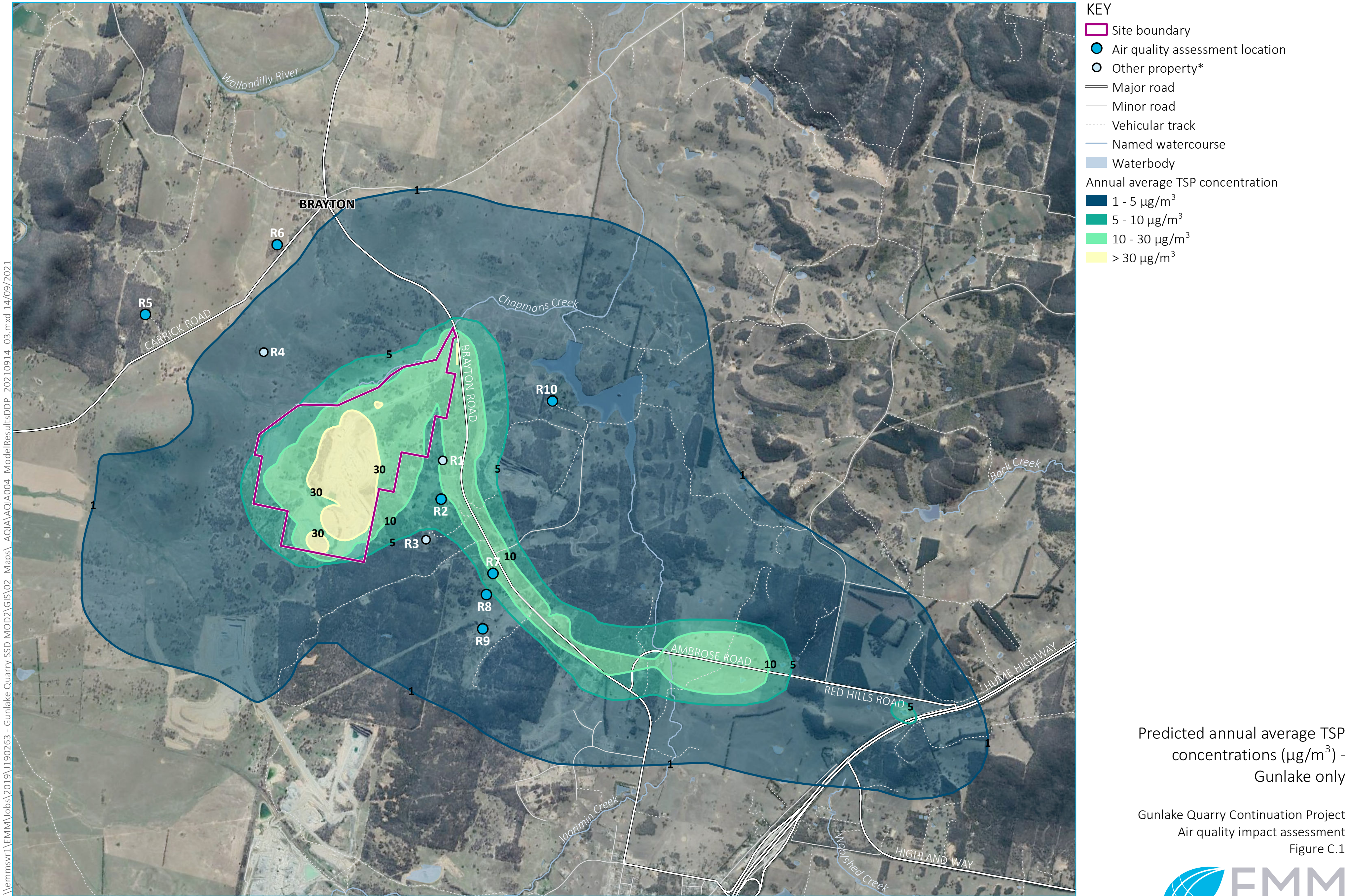
Emissions source	Calculated annual emissions (t/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Topsoil/overburden removal - bulldozer	0.33	0.06	0.01
Topsoil/overburden loading to trucks - excavator	0.01	<0.01	<0.01
Topsoil/overburden haulage - unsealed	1.92	0.55	0.05
Topsoil/overburden trucks unloading at waste dump	0.01	<0.01	<0.01
Waste dump management - bulldozer	0.33	0.06	0.01
Truck loading in pit - raw material	1.28	0.60	0.09
Raw material haulage - unsealed	108.50	30.85	3.09
Truck unloading to hopper	0.64	0.30	0.05
Raw material rehandle	0.01	<0.01	<0.01
Plant 1 - Screen 1	1.27	0.44	0.03
Plant 1 - Primary crusher	0.41	0.18	0.03
Plant 1 - Screen 2	4.78	1.64	0.11
Plant 1 - Secondary crusher	1.14	0.51	0.09
Plant 1 - Screen 3	8.55	2.94	0.20
Plant 2 - Screen 1	3.84	1.32	0.09
Plant 2 - Secondary crusher	0.83	0.37	0.07
Plant 2 - Screen 2	0.77	0.26	0.02
Plant 2 - Tertiary crusher	1.49	0.66	0.12
Plant 2 - Screen 3	4.81	1.65	0.11
Plant 2 - Quaternary crusher	0.46	0.20	0.04
Plant 2 - Screen 4	2.35	0.81	0.05
Plant 3 - Screen 1	2.11	0.73	0.05
Plant 3 - Primary crusher	0.68	0.30	0.06
Plant 3 - Screen 2	8.79	3.02	0.20
Plant 3 - Secondary crusher	1.90	0.84	0.16
Plant 3 - Screen 3	14.24	4.90	0.33
Plant 4 - Screen 1	1.08	0.37	0.03
Plant 4 - Secondary crusher	0.24	0.11	0.02
Plant 4 - Screen 2	0.22	0.08	0.01
Plant 4 - Tertiary crusher	0.42	0.19	0.03
Plant 4 - Quaternary crusher	0.12	0.05	0.01
Plant 4 - Screen 3	1.96	0.67	0.05
Plant 4 - Screen 4	0.71	0.24	0.02

Table B.4 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – Continuation Project

Emissions source	Calculated annual emissions (t/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Plant 1 - conveyor transfer point enclosed (1 point)	0.04	0.02	0.00
Plant 1 - conveyor transfer points (11 points)	1.45	0.69	0.10
Plant 1 - stockpile loading	0.06	0.03	0.00
Plant 2 - conveyor transfer points (16 points)	1.28	0.60	0.09
Plant 2 - stockpile loading	0.17	0.08	0.01
Plant 3 - conveyor transfer point enclosed (1 point)	0.07	0.03	0.00
Plant 3 - conveyor transfer points (8 points)	1.79	0.85	0.13
Plant 3 - stockpile loading	0.11	0.05	0.01
Plant 4 - conveyor transfer points enclosed (8 points)	0.35	0.16	0.02
Plant 4 - conveyor transfer points (12 points)	1.73	0.82	0.12
Plant 4 - stockpile loading	0.29	0.14	0.02
Loading to product trucks - Plant 1	0.07	0.03	0.00
Loading to product trucks - Plant 2	0.18	0.08	0.01
Loading to product trucks – Plant 3	0.11	0.05	0.01
Loading to product trucks – Plant 4	0.30	0.14	0.02
Loading reject material to trucks	0.09	0.04	0.01
Unloading rejects at waste dump	0.09	0.04	0.01
Unpaved - product transportation – Plant 1 to weighbridge	13.47	3.83	0.38
Unpaved - product transportation - Plant 2 to weighbridge	15.19	4.32	0.43
Unpaved - product transportation – Plant 3 to weighbridge	13.47	3.83	0.38
Unpaved - product transportation – Plant 4 to weighbridge	13.47	3.83	0.38
Unpaved – processing plant rejects transportation to waste dump	10.13	2.88	0.29
Paved - product transportation – weighbridge to site entry	28.53	5.48	1.33
Brayton Road - product transportation	146.47	28.11	6.80
Drill	9.20	4.79	0.28
Blast	0.42	0.22	0.01
Wind Erosion - exposed surfaces and stockpiles	68.85	34.43	5.16
Diesel combustion – onsite	1.62	1.62	1.49
Diesel combustion – product dispatch to Hume Hwy	0.17	0.17	0.16
Total	**505.33**	**152.29**	**22.89**

Annexure C

Isopleth plots



\\emmsvr1\EMM\Jobs\2019\190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021

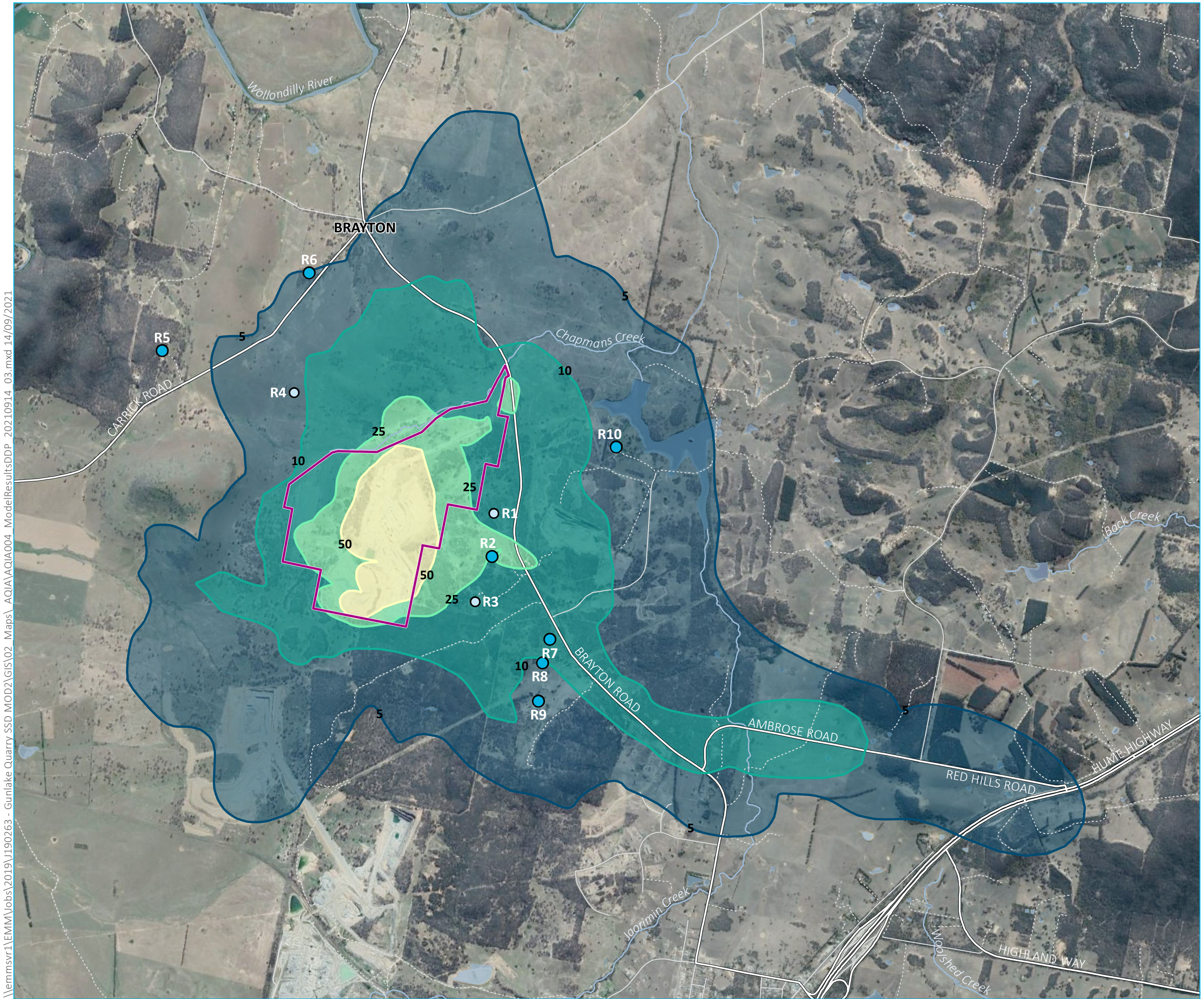
Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

Predicted annual average TSP concentrations ($\mu g/m^3$) - Gunlake only

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.1

EMM
creating opportunities



KEY

- Site boundary
- Air quality assessment location
- Other property*
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody

24-hour average PM_{10} concentration

- 5 - 10 µg/m^3
- 10 - 25 µg/m^3
- 25 - 50 µg/m^3
- > 50 µg/m^3

Maximum predicted 24-hour average PM_{10} concentrations (µg/m^3) - Gunlake only

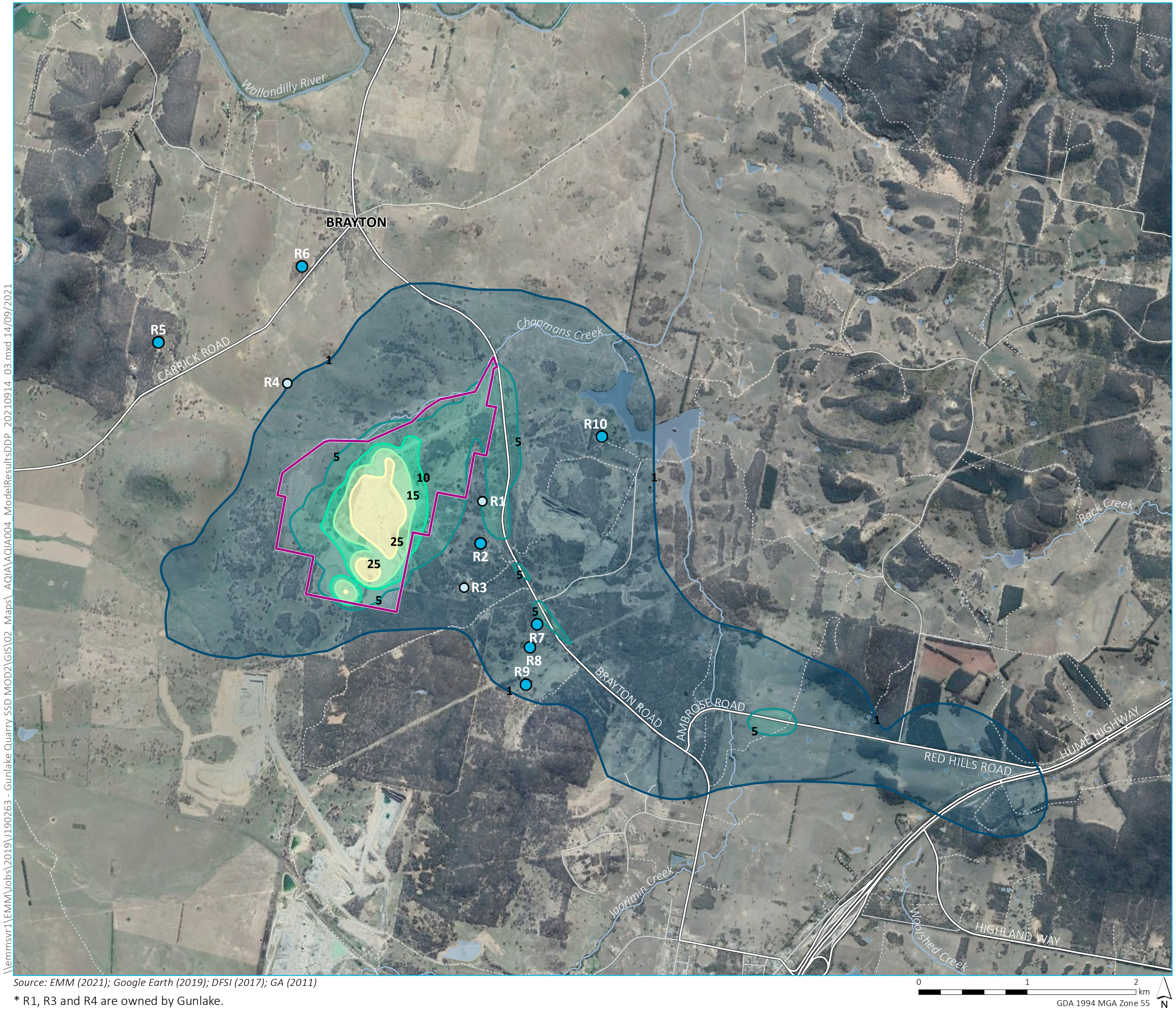
Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.2

EMM
creating opportunities

Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

\\emmsvr1\EMM\Jobs\2019\J190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021



KEY

- Site boundary
- Air quality assessment location
- Other property*
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody

Annual average PM_{10} concentration

- 1 - 5 µg/m^3
- 5 - 10 µg/m^3
- 10 - 15 µg/m^3
- 15 - 25 µg/m^3
- > 25 µg/m^3

\\emmsvr1\EMM\Jobs\2019\190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021

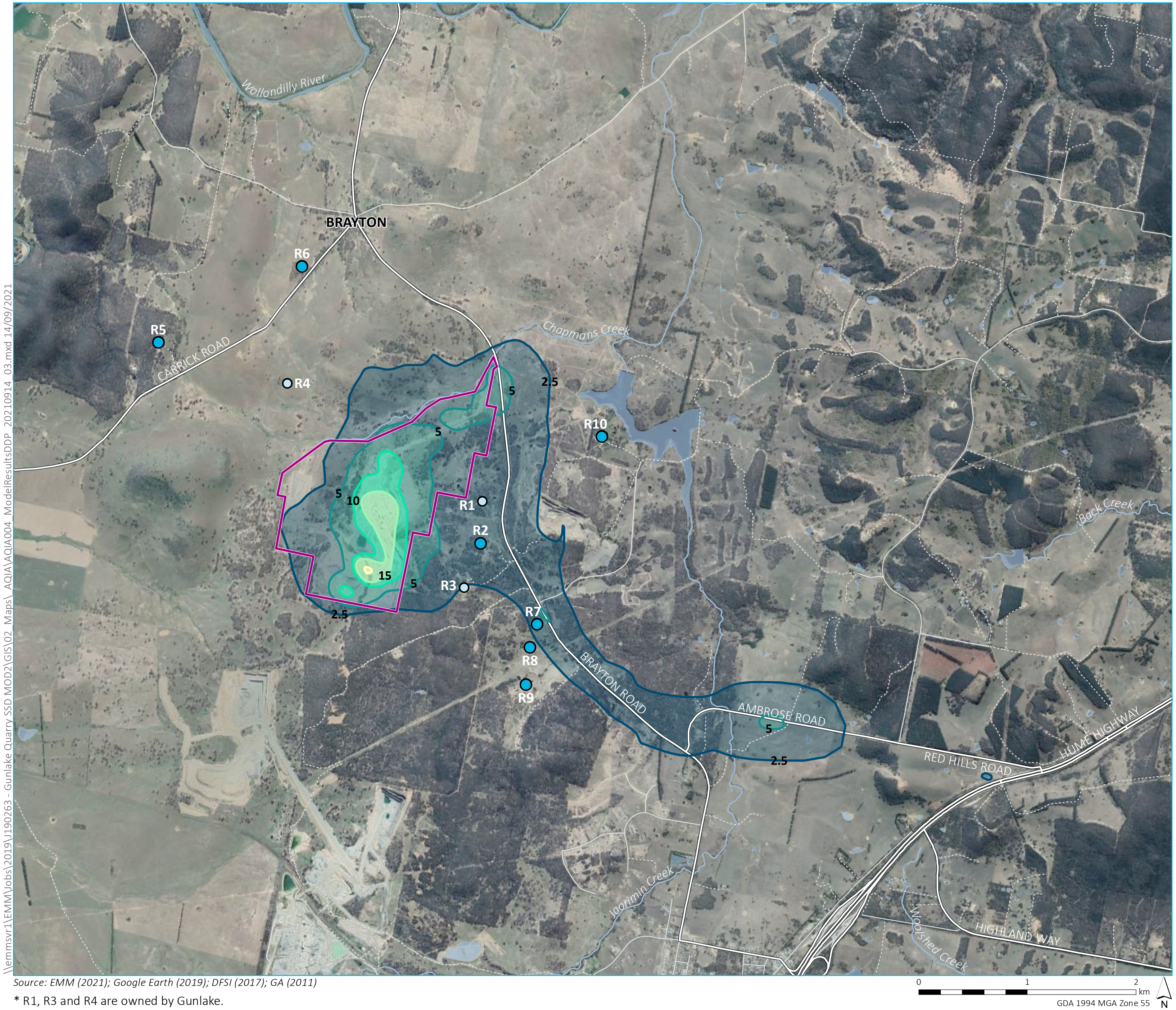
Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

Predicted annual average PM_{10} concentrations (µg/m^3) - Gunlake only

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.3

EMM
creating opportunities



KEY

- Site boundary
- Air quality assessment location
- Other property*
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody

24-hour average $PM_{2.5}$ concentration

- 2.5 - 5 $\mu g/m^3$
- 5 - 10 $\mu g/m^3$
- 10 - 15 $\mu g/m^3$
- 15 - 25 $\mu g/m^3$
- > 25 $\mu g/m^3$

Maximum predicted 24-hour average $PM_{2.5}$ concentrations ($\mu g/m^3$) - Gunlake only

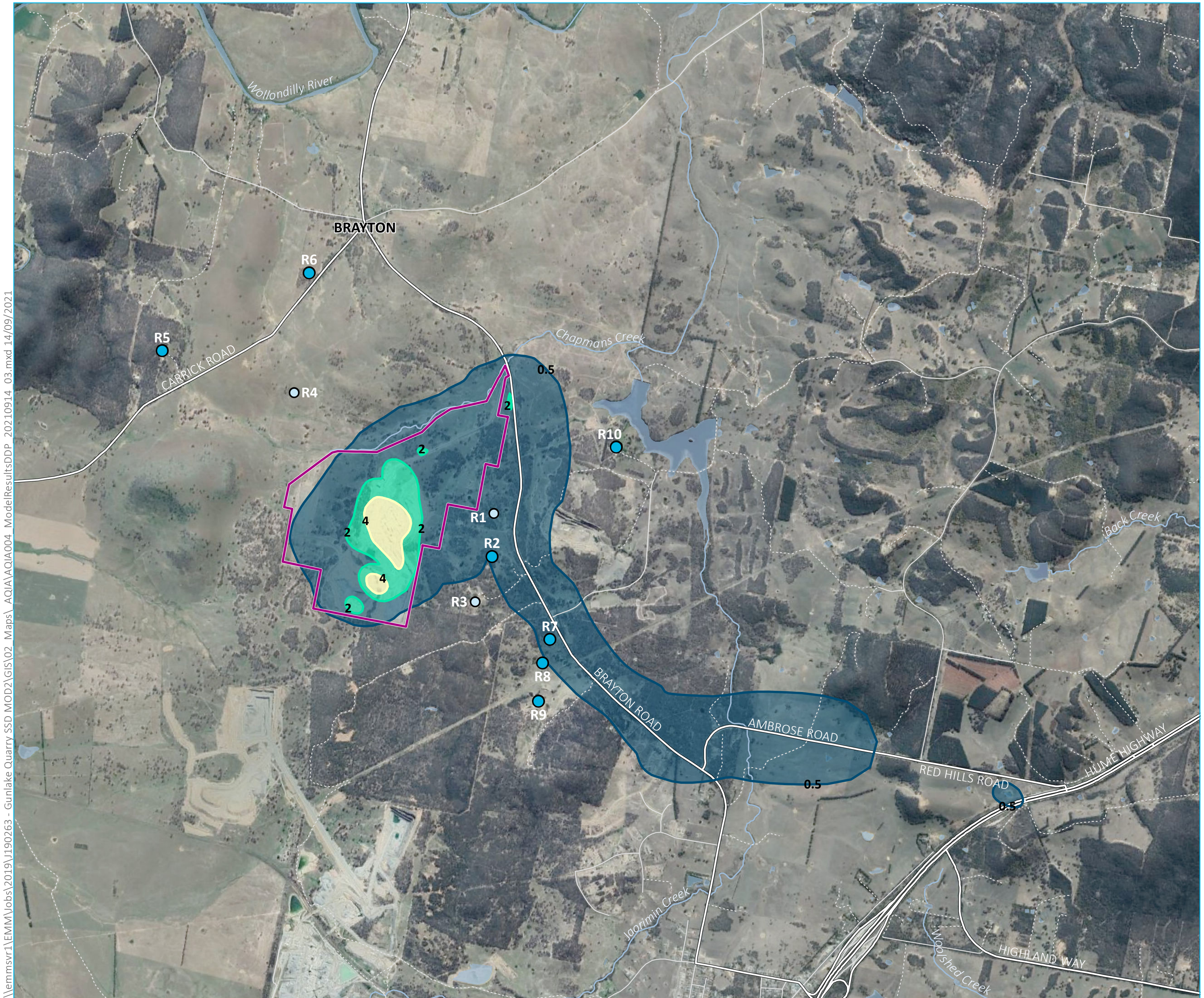
Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.4

EMM
creating opportunities

Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

\\emmsvr1\EMM\Jobs\2019\J190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021



KEY
- Site boundary
- Air quality assessment location
- Other property*
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody

Annual average $PM_{2.5}$ concentration
- 0.5 - 2 $\mu g/m^3$
- 2 - 4 $\mu g/m^3$
- > 4 $\mu g/m^3$

\\emmsvr1\EMM\Jobs\2019\190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021

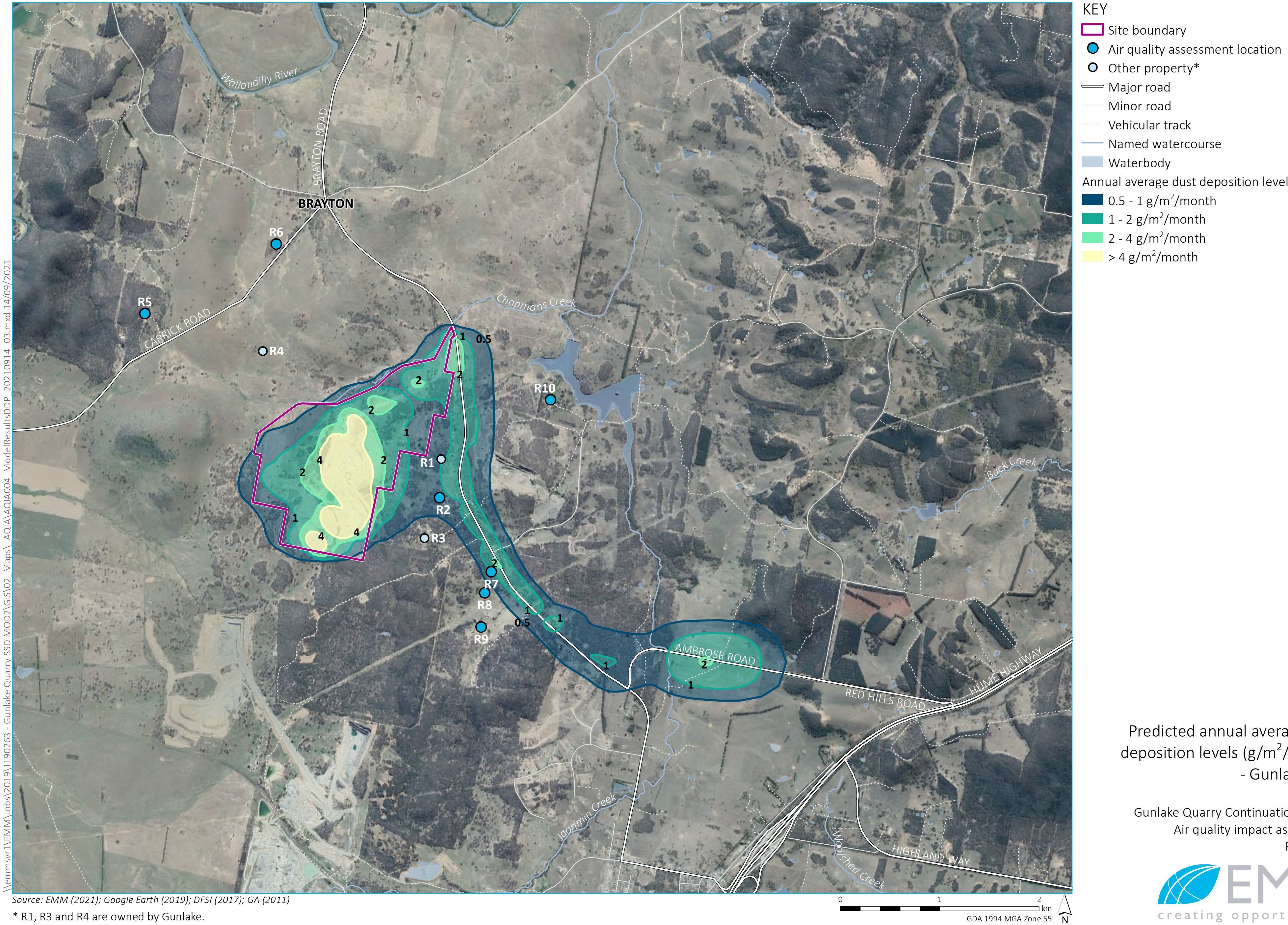
Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

Predicted annual average $PM_{2.5}$ concentrations ($\mu g/m^3$) - Gunlake only

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.5

EMM creating opportunities



Source: EMM (2021); Google Earth (2019); DFSI (2017); GA (2011)

* R1, R3 and R4 are owned by Gunlake.

Predicted annual average dust deposition levels ($g/m^2/month$) - Gunlake only

Gunlake Quarry Continuation Project
Air quality impact assessment
Figure C.6

EMM creating opportunities

\\emmsvr1\EMM\Jobs\2019\190263 - Gunlake Quarry SSD MOD2\GIS\02_Maps_AQIA\AQIA004_ModelResultsDDP_20210914_03.mxd 14/09/2021

Annexure D

GHG emission calculations

D.1 Fuel consumption

D.1.1 Diesel (onsite quarrying and offsite product transport)

GHG emissions from diesel consumption were estimated using the following equation:

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$$

Where:

E_{ij}	=	Emissions of GHG from diesel combustion	(t CO_2-e)
Q_i	=	Quantity of fuel	(kL)
EC_i	=	Energy content of fuel	(GJ/kL)[11]
EF_{ijoxec}	=	Emission factor (scope 1 or 3) for diesel consumption	(kg CO_2-e/GJ)[12]

GHG emission factors and energy content for diesel were sourced from the NGAF (DISER 2020). These are presented in Table D.1.

The estimated annual GHG emissions from onsite diesel consumption are presented in Table D.2. The estimated GHG emissions from offsite product transport diesel consumption are presented in Table D.3 (Gunlake-owned trucks) and Table D.4 (third-party owned trucks).

Table D.1 Diesel GHG emission factors – onsite quarrying activities, offsite product transport

Fuel type	Energy content (GJ/kL)	Scope 1 Emission Factors (kg CO_2-e/GJ)			Scope 3 Emission Factor (kg CO_2-e/GJ)
		CO_2	CH_4	N_2O	CO_2
Diesel	38.6	69.9	0.01	0.5	3.6

Table D.2 Estimated CO_2-e (tonnes) for onsite diesel consumption per year

Scenario	Diesel use (L/annum)	Emissions (t CO_2-e)	
		Scope 1	Scope 3
Continuation Project	2,700,000	7,338	375

11 GJ = gigajoules

12 kg CO_2-e/GJ = kilograms of carbon dioxide equivalents per gigajoule

Table D.3 Estimated CO_2-e (tonnes) for Gunlake-owned product transport diesel consumption per year

Scenario	Diesel use (L/annum)	Emissions (t CO_2-e)	
		Scope 1	Scope 3
Continuation Project	900,000	2,446	125

Table D.4 Estimated CO_2-e (tonnes) for third party product transport diesel consumption per year

Scenario	Diesel use (L/annum)	Emissions (t CO_2-e)	
		Scope 1	Scope 3
Continuation Project	17,913,118	-	2,489

D.1.2 Employee travel

GHG emissions from employee travel were estimated using the following equation:

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$$

Where:

E_{ij}	=	Emissions of GHG from gasoline combustion	(t CO_2-e)
Q_i	=	Quantity of fuel	(kL)
EC_i	=	Energy content of fuel	(GJ/kL)
EF_{ijoxec}	=	Emission factor (scope 3) for gasoline consumption	(kg CO_2-e/GJ)

GHG emission factors and energy content for gasoline were sourced from the NGAF (DISER 2020). These are presented in Table D.5.

The estimated annual GHG emissions from employee travel are presented in Table D.6.

Table D.5 Gasoline GHG emission factors

Fuel type	Energy content (GJ/kL)	Scope 3 Emission Factor (kg CO_2-e/GJ)
		CO_2
Gasoline	34.2	3.6

Table D.6 Estimated CO_2-e (tonnes) for employee travel

Scenario	Gasoline use (L/annum)	Emissions (t CO_2-e)
		Scope 3
Continuation Project	102,190	13

D.2 Electricity use

GHG emissions associated with electricity consumption were estimated using the following equation:

$$E_{CO_2-e} = \frac{Q \times EF}{1000}$$

Where:

$E_{CO2\text{-}e}$	=	Emissions of GHG from electricity consumption	(t CO_2-e)
Q_i	=	Quantity of electricity	(kWh)[13]
EF	=	Emission factor (scope 2 or 3) for electricity consumption	(kg CO_2-e/kWh)[14]

GHG emission factors for electricity use were sourced from the NGAF (DISER 2020) and are presented in Table D.7. The scope 3 emissions were taken from the NSW 'latest estimate' section of the NGAF.

The estimated annual GHG emissions from electricity are presented in Table D.8.

Table D.7 Electricity GHG emission factors

Use	Emission Factors (kg CO_2-e/kWh)	
	Scope 2	Scope 3
Electricity	0.81	0.09

Table D.8 Estimated CO_2-e (tonnes) for electricity consumption

Scenario	Electricity use (kWh)	Emissions (t CO_2-e)	
		Scope 2	Scope 3
Continuation Project	10,800,000	8,748	972

13 kWh = kilowatt hours

14 kg CO_2-e/kWh = kilograms of carbon dioxide equivalents per kilowatt hour

www.emmconsulting.com.au

www.emmconsulting.com.au