APPENDIX V

DUNGOWAN DAM AND PIPELINE EIS

Air Quality and Greenhouse Gas Assessment

NSW GOVERNMENT | EMM creating opportunities

Dungowan Dam and pipeline project

Air Quality and Greenhouse Gas Assessment

Prepared for Water Infrastructure NSW

September 2022

Dungowan Dam and pipeline project

Air Quality and Greenhouse Gas Assessment

Water Infrastructure NSW

J200042 DUN-EMM-EN-RPT-0022

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Version	Date	Prepared by	Approved by	Comments
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Executive Summary

ES1 Introduction

The Air Quality and Greenhouse Gas Assessment for the Dungowan Dam and pipeline project focuses on project construction. Impacts during operation of the project are expected to be negligible and the operational assessment was limited to GHG estimates. The objectives of this assessment are to:

- describe the existing air quality and meteorological environment;
- identify potential emissions to air during construction of the project;
- assess potential impacts arising from emissions to air during construction of the project;
- calculate greenhouse gas (GHG) emissions associated with the project and benchmark in the context of NSW and Australian GHG accounts;
- provide appropriate mitigation measures to reduce the impacts from the project; and
- provide recommendations for air quality monitoring during construction.

The air quality assessment has been prepared in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW EPA 2016). The GHG assessment has been prepared in general accordance with the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (*DoE 2014) and *GHG Protocol Corporate Accounting and Reporting Standard* (Bhatia et al 2010).

ES2 Existing environment and project description

The project includes a new dam at Dungowan approximately 3.5 km downstream of the existing Dungowan Dam, decommissioning of the existing Dungowan Dam, and a new section of pipeline about 32 km long between the proposed new Dungowan Dam outlet and the tie in point to existing pipeline infrastructure in Dungowan.

The new Dungowan Dam infrastructure is located approximately 50 km south-east of Tamworth and approximately 5 km south-east of Ogunbil, within the Peel Valley catchment area. The main construction works are located within a valley and surrounded by predominantly agricultural land uses.

Meteorological modelling is typically driven by local observations, however, there are no local meteorological monitoring stations in the vicinity of the project. The closest automatic weather station with available data is located at Tamworth, approximately 50 km north-west of the project. Dispersion modelling for this assessment uses the CALPUFF modelling system, which is commonly used in NSW for applications where non-steady state conditions may occur (ie complex terrain). CALPUFF is suitable for this assessment as the project area is located within valley terrain and, in the absence of local observations, the CALMET derived meteorological field takes into account the local terrain slope flows and blocking effects that are expected in the local area.

Cumulative impacts are assessed by taking into account the existing baseline or background air quality, which is described based on monitoring data collected at the closest air quality monitoring station location at Tamworth.

ES3 Emissions and assessment

The assessment focuses on key emissions sources and pollutants applicable to the construction of the project, including fugitive dust from material extraction, handling, processing and movement, and wind erosion of exposed surfaces. An emissions inventory was developed for a single construction year, selected to assess the worst-case air quality impacts (ie during main embankment construction when material handling/movement is at a maximum). The emission scenario also accounts for road realignment works, which is slated to occur concurrently with the main dam construction.

The highest predicted impacts occur at the receptors within the inundation zone (R1- R13), all of which are now vacant, therefore no further discussion or assessment of these receptors is required.

Other than these receptors, the highest predicted increment occurs at the accommodation camp (C1). When background concentrations are added to the modelled increment, there are no additional exceedances of the 24-hour average impact assessment criteria for PM_{10}[1] and $PM_{2.5}$[2] at any receptor outside of the inundation zone, including the accommodation camp. Similarly, there are no exceedances of the annual average impact assessment criteria for PM_{10}, Total Suspended Particulate matter (TSP) and dust deposition.

The annual average background $PM_{2.5}$ concentration (8.3 µg/m^3) is already above the impact assessment criterion, therefore it is difficult to assess compliance based on cumulative predictions. The annual average $PM_{2.5}$ concentration at the accommodation camp is 1.8% of the impact assessment criterion, which is slightly above screening criteria used to assess significance. For all other receptors (not within the inundation zone), the annual average $PM_{2.5}$ concentration is 0.3% of the impact assessment criterion and can be considered insignificant.

Vegetation waste disposal may require controlled burning under suitable conditions. A screening level modelling assessment found that open burning has the potential to add additional days over the impact assessment criteria for 24-hour average PM_{10} and $PM_{2.5}$. Therefore, in addition to selecting a location that is as far as possible from the accommodation camp and occupied residences, during controlled burning of vegetation, periods of poor dispersion should be avoided, such as stable atmospheric conditions.

ES4 Assessment of pipeline and powerline construction

Based on the low-risk nature of these activities, the air quality impact from the construction phase of the pipeline and new overhead powerline have been assessed using a qualitative assessment approach. A low to medium risk rating was identified for dust soiling impacts, human health impacts and ecological impacts from uncontrolled emissions. With the successful implementation of recommended dust mitigation measures, the risk of dust soiling or human health and ecological impacts would be further reduced.

ES5 Decommissioning of existing dam

A screening assessment for the decommissioning of the existing dam found that the risk of dust impacts would be negligible, and no further assessment was therefore required.

[1] particulate matter less than 10 micrometres (µm) in aerodynamic diameter

[2] particulate matter less than 2.5 µm in aerodynamic diameter

ES6 Greenhouse gas assessment

Greenhouse gas (GHG) emissions during construction include direct (scope 1) emissions associated with the combustion of fuel (diesel) by onsite plant and equipment and emissions released from explosive use for rock extraction. Although not a direct source of GHG emissions, vegetation stripping and tree removal during construction would result in the loss of a carbon sink and is categorised as a Scope 1 emission source for the construction phase. Scope 2 emissions during construction would be limited to consumption of electricity by site offices and the accommodation camp. Scope 3 emissions would occur from offsite production of construction materials such as aggregate and steel and emissions from the combustion of fuel when transporting materials and staff.

GHG emissions during the operation phase of the project also includes direct (scope 1) emissions associated with the combustion of fuel and indirect (scope 2) emissions associated with electricity use for operation of the dam. There would also be GHG emissions from the decomposition of carbon in submerged soil and vegetation within the inundation zone and very minor Scope 3 emissions from waste generated during operation.

Annual average GHG emissions (scope 1) generated during construction represent approximately 0.005% of total GHG emissions for NSW and 0.001% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018[3]. The comparison does not include vegetation removal, which represents loss of a carbon sink and is not expressed on a per annum basis.

Annual average GHG emissions (scope 1 and scope 2) generated during operation, including emissions from storage of water in the inundation zone, represent approximately 0.002% of total GHG emissions for NSW and 0.0004% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018.

ES7 Mitigation

An Air Quality Management Plan will be prepared and implemented as part of the Construction Environment Management Plan for the project and would outline measures that would be implemented to mitigate the project's air quality impacts.

[3] calendar year 2018 emissions taken from http://ageis.climatechange.gov.au/

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1 Introduction

1.1 The project

The Peel Valley, part of the Namoi River catchment, provides water for irrigation as well as being the primary water supply for the city of Tamworth. Prompted by the millennium drought, investigations into the future water supply and demand for bulk water were undertaken for the regional city of Tamworth and Peel Valley water users. The Dungowan Dam and pipeline project (the project) is a critical project to improving long-term water security for the region. The project includes a new dam at Dungowan (new Dungowan Dam) approximately 3.5 km downstream of the existing Dungowan Dam and a new section of pipeline about 32km long between the proposed Dam outlet and the tie in point to an existing pipeline from Dungowan Showground to the Calala Water Treatment Plant (WTP).

In September 2022, the Minister for Planning and Homes declared the project to be Critical State Significant Infrastructure (CSSI) as it is a development that is essential for the State for economic and social reasons. This requires Schedule 5 of the *State Environmental Planning Policy (Planning Systems) 2021* to be updated to reflect the CSSI status of the project. As CSSI, the project is subject to Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), which requires the preparation of an environmental impact statement (EIS) and the approval of the NSW Minister for Planning and Homes.

The EIS has been prepared for the planning approval application for the project. This Air Quality and Greenhouse Gas Assessment (AQGHGA) has been prepared to support the EIS.

In addition to requiring approval from the NSW Minister for Planning and Homes, the project has been deemed a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Commonwealth Minister for the Environment. The Minister for the Environment has accredited the NSW planning process for the assessment of the project. Therefore, a single EIS has been prepared to address the requirements set out by the NSW Department of Planning and Environment (DPE) and the Commonwealth Department of Agriculture, Water and Environment.

1.2 Project location

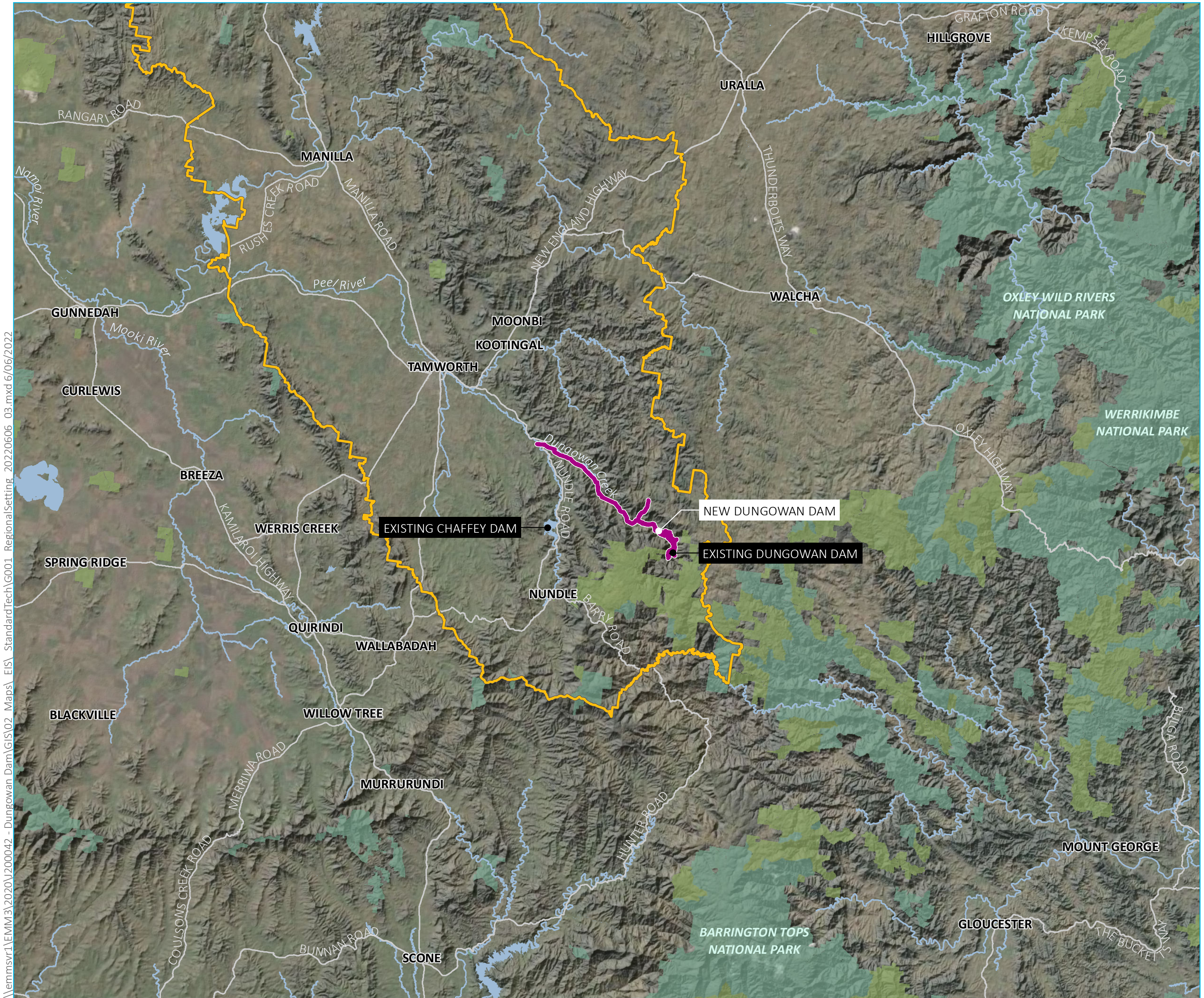
The project is located in the Tamworth Regional local government area (LGA), the New England Tablelands bioregion and part of the New England and North West region of NSW, west of the Great Dividing Range (DPE 2017). The New England and North West region is home to approximately 186,900 people and has a total area of around 99,100 km^2 (ABS 2018).

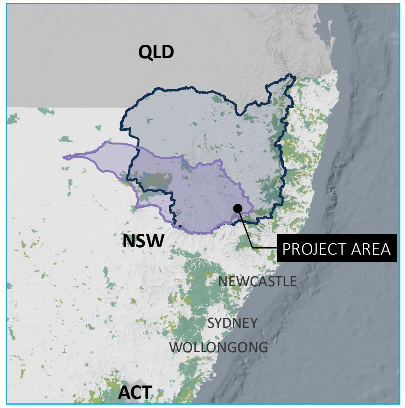
The city of Tamworth is the nearest (and largest) town to the project with over 40,000 residents. Other nearby regional towns include Quirindi (70 km west), Manilla (90 km north-west), Gloucester (90 km south-east), Armidale (100 km north) and Gunnedah (110 km west of the project).

The existing Dungowan Dam is in the Namoi River catchment approximately 50 km south-east of Tamworth in NSW. The Namoi catchment covers 4,700 km^2 and borders the Gwydir and Castlereagh catchments and is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north.

The existing Dungowan Dam is on Dungowan Creek, which is a tributary of the Peel River. Dungowan Creek is confined by the existing Dungowan Dam, while the Peel River system is regulated by Chaffey Dam, located in the upper catchment near the town of Woolomin, approximately 45 km from Tamworth.

The project's regional setting is shown in Figure 1.1.





KEY
- Project footprint
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest
- Tamworth Regional local government area

INSET KEY
- Namoi River catchment
- New England North West region

Source: EMM (2022); WaterNSW (2021); DFSI (2017); GA (2013)

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Regional setting

Dungowan Dam and pipeline project
Figure 1.1

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1.2.1 Project impact areas

In outlining the project, a project footprint has been defined to facilitate the assessment of direct impacts from the project:

- Project footprint: all areas where direct impacts may be experienced during construction and/or operation.

The project footprint has an area of 315 ha and is comprised of the construction and operational footprints, of which there is some overlap:

- Construction footprint: areas where vegetation clearing and/or ground disturbance is required for construction of the dam, pipeline and ancillary facilities, including the area needed to decommission and rehabilitate the existing dam.

- Operational footprint: areas where there would be permanent operational elements or easements, including infrastructure needed to operate the new Dungowan Dam and pipeline. The operation footprint includes the inundation area, being the area defined by the proposed full supply level (FSL) for the project.

The project construction and operational footprints are shown in Figure 1.2.

Additional areas outside the project footprint have also been considered where relevant to the assessment of project impacts and include:

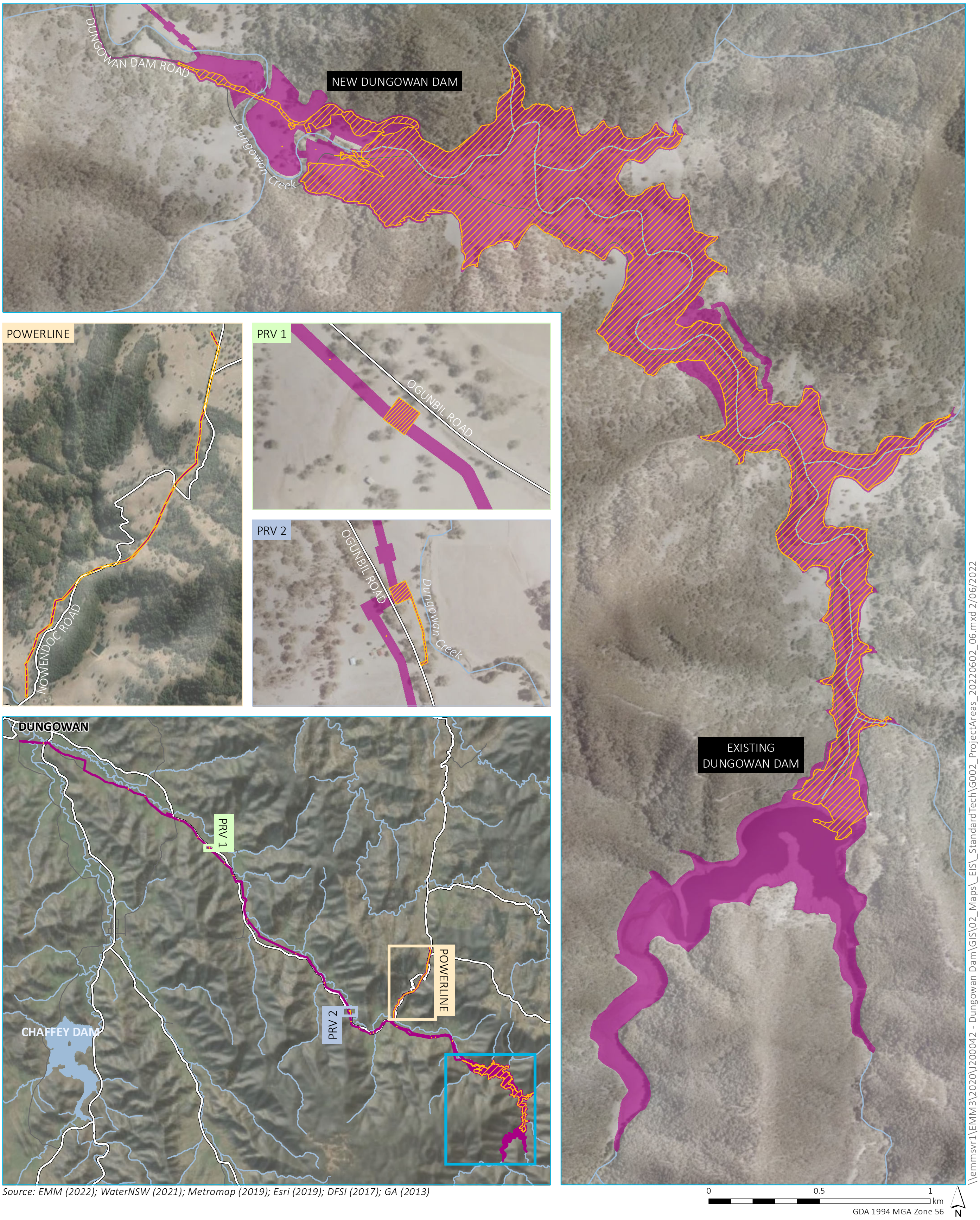
- Upstream flood extent: An area above the FSL to the level of a probable maximum flood (PMF) event that would be inundated for relatively short periods during operation associated with extreme rainfall events.

- Project area: A 10 km buffer around the project footprint defined to allow for assessment of potential indirect impacts.

- Downstream impact area: the area where hydrological changes may occur due to the project. This area is discussed in detail in the Surface Water Assessment (EMM 2022) as well as other technical reports subject to changed flow regimes as a result of the new Dungowan Dam operation. The downstream impact area includes Dungowan Creek and also the Peel River downstream of Chaffey Dam.

1.2.2 AQGHGA study scope

The air quality assessment focuses on project construction. Air quality impacts during operation of the project are expected to be negligible, limited to infrequent vehicle movements. Also, potential odour impacts following the filling and operation of the reservoir would be controlled through operational management measures to maintain the quality of the water in the reservoir. For these reasons, operation impacts have not been assessed further. Key components of the construction footprint, relevant to the air quality assessment, are shown in Figure 1.2. The greenhouse gas assessment considered both construction and operation of the project.



Source: EMM (2022); WaterNSW (2021); Metromap (2019); Esri (2019); DFSI (2017); GA (2013)

KEY

Construction footprint

Operational footprint

Existing environment

Major road

Minor road

Named watercourse

Named waterbody

Project footprint

Dungowan Dam and pipeline project
Figure 1.2

EMM creating opportunities

1.3 Purpose of this report

This AQGHGA supports the EIS for the project. Potential air quality impacts are assessed during project construction, which are anticipated to take approximately six years. The objectives of this assessment are to:

- describe the existing air quality and meteorological environment;
- identify potential emissions to air during construction of the project;
- assess potential impacts arising from emissions to air during construction of the project;
- calculate GHG emissions associated with the project and benchmark in the context of NSW and Australian GHG accounts;
- provide appropriate mitigation measures to reduce the impacts from the project;
- provide recommendations for air quality mitigation and monitoring measures.

The air quality assessment is prepared in accordance with *the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (hereafter the Approved Methods for Modelling, NSW EPA 2016). The greenhouse gas assessment is prepared in general accordance with the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines (*DoE 2014) and *GHG Protocol Corporate Accounting and Reporting Standard* (Bhatia et al 2010).

1.3.1 Assessment guidelines and requirements

This AQGHGA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for the Dungowan Dam and pipeline project as well as relevant government assessment requirements, guidelines and policies, and in consultation with the responsible government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report. To inform preparation of the SEARs, DPE invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs.

Table 1.1 Relevant matters raised in SEARs

Requirement	Chapter/Section addressed
Air	
47. A quantitative assessment of the potential air quality, dust and odour impacts of the project in accordance with the relevant guidelines. This is to include the identification of existing and potential future sensitive receivers and consideration of approved and/or proposed developments in the vicinity.	A quantitative assessment of air quality impacts is presented in this report, prepared in accordance with the *Approved Methods for Modelling* (NSW EPA 2016). Sensitive receptors are identified in Chapter 3 and the approach for cumulative impact assessment is described in Chapter 6.
48. Details and justification of proposed air quality mitigation and monitoring measures.	Chapter 12
Greenhouse Gas	
73. Assessment of the greenhouse gas emissions from the construction and operation of the project for the life of infrastructure, including:	Chapter 11

Table 1.1 Relevant matters raised in SEARs

Requirement		Chapter/Section addressed
a)	documentation and justification of an appropriate methodology for estimating greenhouse gas emissions for the project as a water storage, or water reservoirs project where permanent land use change occurs.	Section 11.3.2
b)	assessment of carbon dioxide, nitrous oxide and methane gas emissions, including gases emitted by decomposing plants and organic material within the dam inundation areas.	Section 11.3.2
c)	quantitative assessment of Scope 1, 2 and 3 greenhouse gas emissions.	Chapter 11
d)	an assessment of reasonable and feasible measures to minimise greenhouse gas emissions and ensure energy efficiency.	Section 11.5
e)	project emissions as a proportion of NSW and Australia's greenhouse gas emissions budgets.	Section 11.3.7 and 11.4.5
f)	details of all proposed mitigation, management and monitoring measures.	Chapter 12

2 Description of the project

This chapter provides a summary of the Dungowan Dam and pipeline project. It outlines the permanent infrastructure required to operate the project, as well as the key construction elements and activities required to construct the project. A comprehensive and detailed description of the project is provided as Appendix B1 of the EIS, which has been relied upon for the basis of this technical assessment.

2.1 Project overview

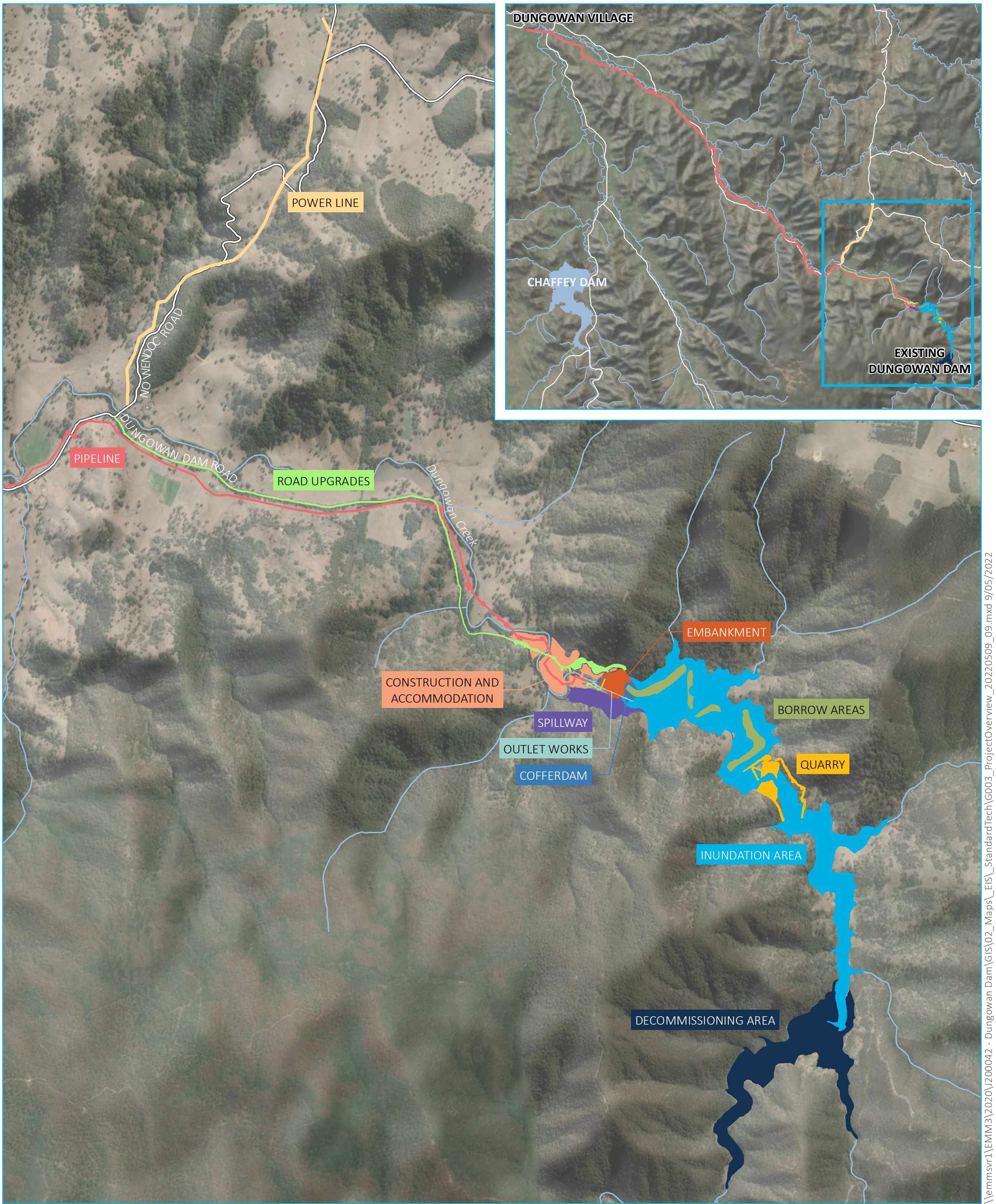
Water Infrastructure NSW proposes to build a new dam at Dungowan (new Dungowan Dam) about 3.5 km downstream of the existing Dungowan Dam and an enlarged delivery pipeline from the new Dungowan Dam outlet to the tie in point to the existing pipeline from Dungowan Showground to the Calala WTP. The existing pipeline from Dungowan Showground to the Calala WTP is not part of the Dungowan Dam and pipeline project. A summary of project elements is provided in Table 2.1. An overview of the project is provided in Figure 2.1.

Table 2.1 Overview of the project

Project element	Summary of the project
New Dungowan Dam infrastructure	Earth and rockfill embankment dam with height of ~58 m and a dam crest length of ~270 m.
	Storage capacity of 22.5 GL at full supply level (FSL) of RL 660.2 m AHD.
	The new Dungowan Dam on Dungowan Creek has a catchment size of 175 km^2 and is part of the Peel Valley and Namoi River catchment.
	Inundation extent (to FSL) of 130 ha (1.3 km^2)
	Spillway to the south of the dam wall including an approach channel, uncontrolled concrete ogee crest, chute and stilling basin. Free standing multiple-level intake tower connected with a bridge to the embankment, diversion tunnel with outlet conduit, valve house and associated pipework and valves.
	A permanent access road over the Dam crest to the valve house for operation and maintenance.
	Water diversion works including a diversion tunnel and temporary pipeline and upstream and downstream cofferdams to facilitate construction of the dam wall embankment.
Pipeline infrastructure	31.6 km of buried high density polyethylene (HDPE) pipe between 710 mm to 900 mm nominal diameter.
	Maximum 71 ML/day from the proposed dam to the junction with the pipeline from Chaffey Dam to the Calala Water Treatment Plant, to replace the existing 22 ML/day pipeline. The pipeline would connect to the valve house on the left abutment of the embankment. Valve infrastructure would include control valves installed in two above ground buildings along the pipeline.
	10 m wide easement for the 31.6 km length of the pipeline. This pipeline extends from the new Dungowan Dam to a connection point of the previously approved pipeline between Dungowan Showground and Calala WTP.
Ancillary infrastructure and works	Road works to improve existing roads to provide construction access, temporary establishment and use of a construction compound, an accommodation camp, two upstream quarries and four borrow areas within the inundation area.
	A new 4.2 km long 11 kV overhead powerline (including a new easement and access track) connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.
Decommissioning of existing Dungowan Dam	Dewatering of existing dam, removal of existing Dungowan Dam infrastructure and full height breach of the existing Dungowan Dam wall. Rehabilitation of inundation area of the existing Dungowan Dam.

Table 2.1 Overview of the project

Project element	Summary of the project
Disturbance	Areas of disturbance have been identified based on the direct impacts of the project. There is some overlap in the areas disturbed during construction and operation, with a resulting total disturbance area proposed for the project of 315 ha (project footprint). Disturbance would occur in a staged manner, with construction requiring disturbance of approximately 315 ha (construction footprint). Following construction and once rehabilitation is completed, there would be a permanent disturbance of approximately 158 ha comprising the inundation area and permanent infrastructure (operational footprint).
Construction	Construction duration of approximately 6 years.
	Construction workforce of approximately 125 workers at construction peak.
Operation	WaterNSW would be responsible for management, operation and general maintenance of the new dam. Tamworth Regional Council would be responsible for the management, operation and general maintenance of the pipeline. Public use and access to the dam would not be permitted and there would be no public facilities available during operation.
	One to two new full time workers plus part time work for existing WaterNSW operations team. Due to the new Dungowan Dam being prioritised over Chaffey Dam for Tamworth's future water supply, the water reserved for town water in Chaffey Dam would increase from 14.3 GL to 30 GL to ensure that water is set aside to meet Tamworth's town water supply water demand in years when rainfall is low.
Design life	100 years for zoned earthen embankment, structural concrete elements of the dam and the pipeline. 50 years for other project elements.
Assessment period (operational)	The assessment end point is when the water system performance reaches a level when an additional water supply option or change to the Water Sharing Plan is required. This has been estimated to be when the mean average annual water demand from Tamworth increases to 11 GL/year.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

KEY

- Inundation area
- Borrow areas
- Construction and accommodation camp
- Outlet works
- Cofferdams
- Embankment
- Quarries
- Spillway
- Road upgrade
- Decommissioning area
- Power line footprint
- Pipeline construction footprint

Existing environment

- Major road
- Minor road
- Named watercourse
- Named waterbody

Project overview

Dungowan Dam and pipeline project
Figure 2.1

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3 Local setting and assessment locations

3.1 Local setting, land use and topography

The dam infrastructure is located approximately 50 km south-east of Tamworth and approximately 5 km south-east of Ogunbil, within the Peel Valley catchment area. The main construction works are located within a valley and surrounded by predominantly agricultural land uses. The elevation in the valley drops from approximately 1200 m AHD on surrounding hills to approximately 600 m AHD at the valley floor. A three-dimensional representation of the local topography, and cross-sectional view of the local valley, is presented in Figure 3.1.

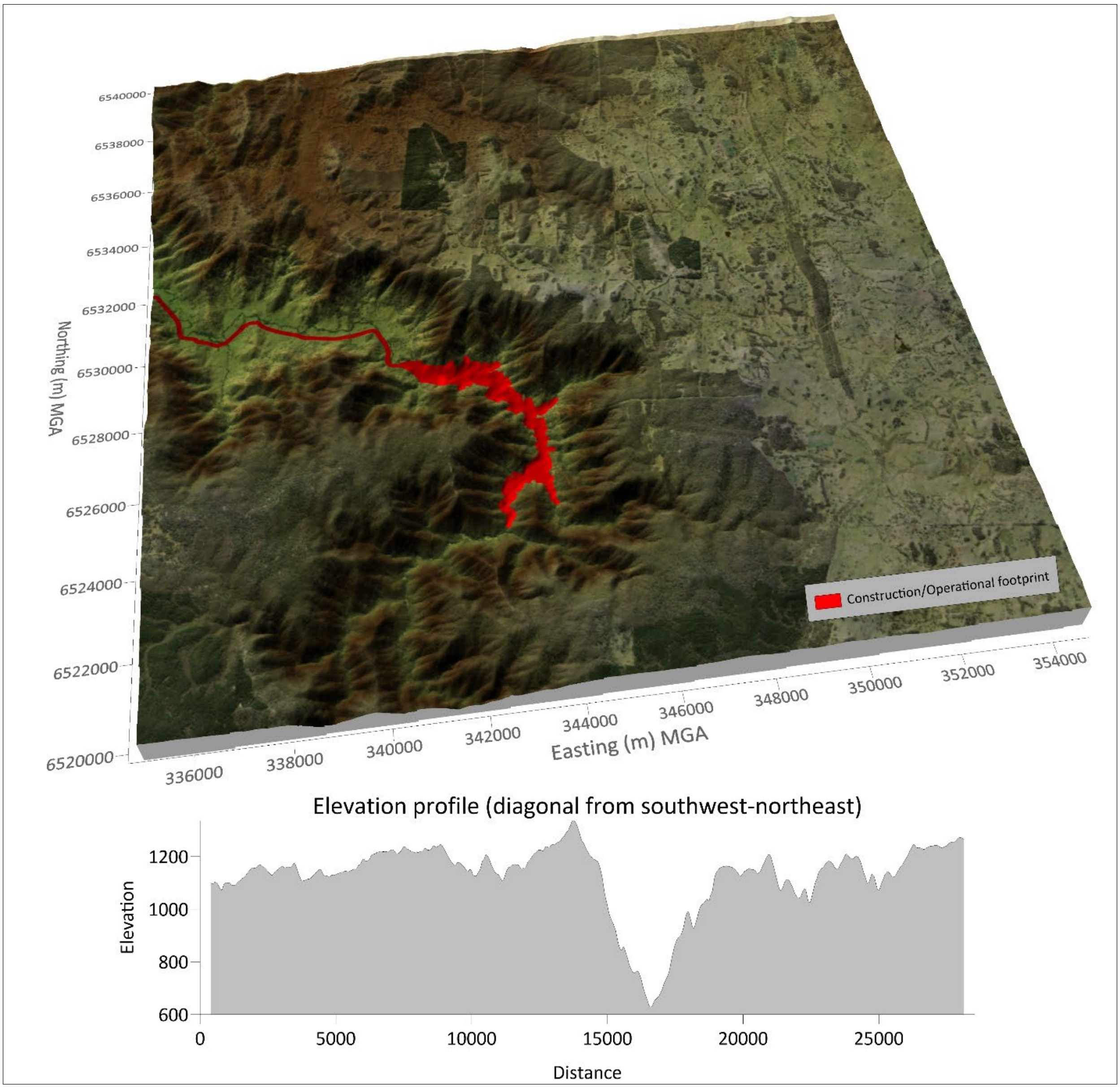


Figure 3.1 3-dimensional topography of the project site and surrounding area

Source: NASA Shuttle Radar Topography Mission data

3.2 Assessment locations

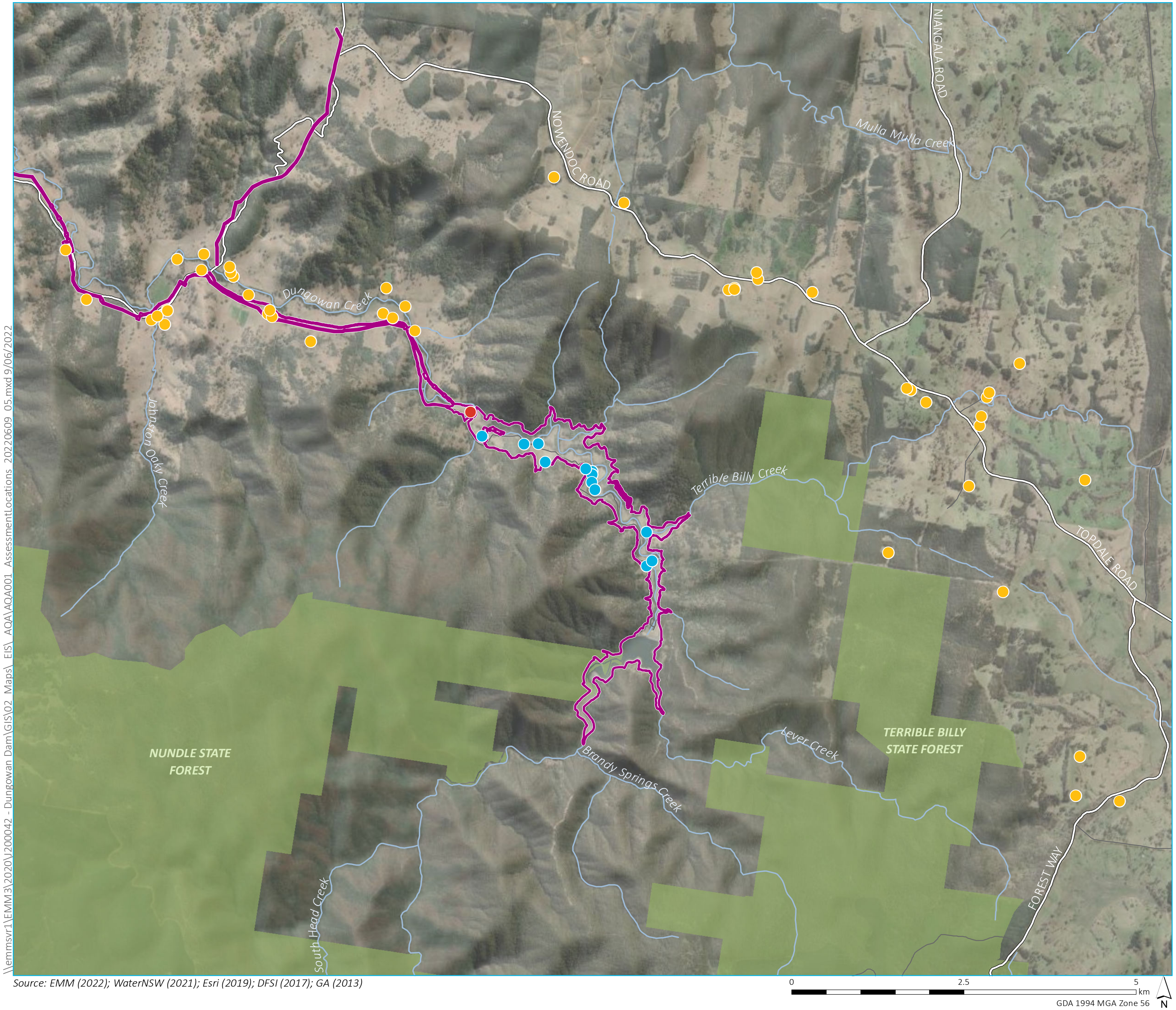
The construction of the project occurs in the vicinity of several rural residential properties.

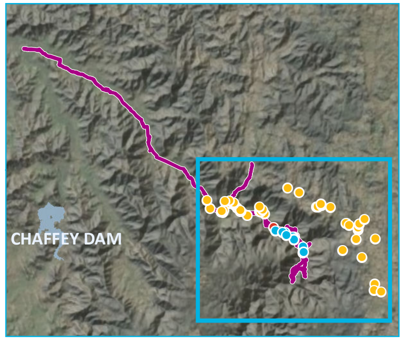
To assess potential air quality impacts from dam infrastructure construction, residences within an approximate 10 km radius of the project have been selected as discrete model prediction locations. Details are provided in Table 3.1 and their locations are shown in Figure 3.2.

The closest properties to the dam infrastructure construction activities are located within the inundation footprint and are now vacant. These properties are labelled 1 – 13 in Table 3.1 and are not considered sensitive receptors for the purpose of this AQGHGA. The proposed location for the accommodation camp is approximately 500 m from the dam wall embankment. Assessment locations considered for the pipeline construction are discussed and assessed in Chapter 10.

Table 3.1 Assessment locations for modelling

ID	Type	Easting	Northing	ID	Type	Easting	Northing	ID	Type	Easting	Northing
C1	Accommodation camp	341175	6529024	20	Unknown	338314	6530441	40	Shed	345094	6530792
1	Vacant	343026	6528153	21	Unknown	338040	6530711	41	House	345436	6530944
2	Vacant	343031	6528107	22	Unknown	337814	6530983	42	Shed	345420	6531043
3	Vacant	342934	6528186	23	Unknown	338375	6530398	43	Shed	346227	6530752
4	Vacant	343021	6527992	24	Unknown	338341	6530496	44	House	347660	6529329
5	Vacant	343065	6527883	25	Unknown	337355	6531078	45	Shed	347597	6529353
6	Vacant	343818	6527265	26	Unknown	337778	6531042	46	Shed	347878	6529156
7	Vacant	343821	6526773	27	Unknown	337761	6531122	47	House	348653	6528812
8	Vacant	343896	6526844	28	Unknown	337389	6531312	48	House	348684	6528949
9	Vacant	341259	6529015	29	House	336817	6530285	49	Shed	348765	6529227
10	Vacant	341430	6528662	30	Unknown	336853	6530497	50	Shed	348796	6529297
11	Vacant	342245	6528551	31	House	336857	6530484	51	House	349239	6529716
12	Vacant	342041	6528545	32	House	336622	6530350	52	Dwelling	347332	6526965
13	Vacant	342347	6528282	33	House	336713	6530406	53	Shed	348500	6527937
14	Unknown	340450	6530189	34	House	336999	6531234	54	House	348997	6526401
15	Unknown	339991	6530446	35	House	335680	6530646	55	House	350186	6528024
16	Unknown	340132	6530376	36	House	342472	6532429	56	House	350117	6524005
17	Unknown	340312	6530545	37	Shed	343488	6532053	57	House	350055	6523436
18	Unknown	340034	6530815	38	Shed	345007	6530788	58	Shed	350687	6523352
19	Unknown	338942	6530035	39	House	345094	6530815	59	House	335382	6531371





KEY
Project footprint
Assessment location
Vacant
Accommodation camp
Occupied
Existing environment
Major road
Minor road
Named watercourse
State forest
Named waterbody

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

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Assessment locations for modelling

Dungowan Dam and pipeline project
Air quality assessment
Figure 3.2

EMM creating opportunities

4 Pollutants and assessment criteria

4.1 Potential air pollutants

The key emissions sources and pollutants applicable to the construction of the project include:

- fugitive dust from material extraction, handling and processing, movement of plant and equipment and wind erosion of exposed surfaces, comprising:
  - 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 ($PM_{2.5}$).
- diesel exhaust emissions from construction equipment, comprising:
  - $PM_{2.5}$;
  - oxides of nitrogen (NO_x)[4], including nitrogen dioxide (NO_2);
  - sulphur dioxide (SO_2);
  - carbon monoxide (CO); and
  - volatile organic compounds (VOCs).

Gaseous air pollutant emissions generated by construction equipment diesel combustion do not generally result in significant off-site concentrations relative to ambient air quality goals. Accordingly, with the exception of PM, diesel combustion emissions have not been quantitatively assessed.

The emission factors developed for fugitive dust emission inventories do not separate PM emissions from mechanical processes (ie crustal material) and diesel exhaust (combustion). Accordingly, the emissions of PM_{10} and $PM_{2.5}$ presented in Chapter 7 are assumed to include the contribution from diesel combustion in construction equipment.

Greenhouse gas emissions from diesel combustion are considered in Chapter 11.

4.2 Assessment criteria

The NSW EPA's impact assessment criteria for particulate matter, as documented in Section 7 of the *Approved Methods for Modelling* (NSW EPA 2016), are presented in Table 4.1. The assessment criteria are applied at the nearest existing or likely future sensitive receptor[5].

4 By convention, NOx = Nitrous oxide (NO) + NO_2.

5 NSW EPA (2016) 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.

Table 4.1 Impact assessment criteria – 'criteria' pollutants

Pollutant	Averaging period	Impact assessment criteria
TSP	Annual	90 µg/m^3
PM_{10}	24-hour	50 µg/m^3
	Annual	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

TSP, which relates to airborne particles less than around 50 µm in diameter, is used as a metric for assessing amenity impacts (eg reduction in visibility, dust deposition and soiling of buildings and surfaces) rather than health impacts (NSW EPA 2013). Dust deposition impacts are derived from TSP emission rates and particle deposition calculations in the dispersion model.

PM_{10} and $PM_{2.5}$ are a subset of TSP and are fine enough to enter the human respiratory system and can 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 following must be reported for the pollutants in Table 4.1:

- the incremental impact (ie the predicted impact due to the project alone); and
- the total impact (ie the incremental impact plus the existing background concentration). Guidance on the selection of background concentrations is provided in the *Approved Methods for Modelling* (NSW EPA 2016).

In the case of the short-term criteria (24-hour PM_{10} and 24-hour $PM_{2.5}$), the total prediction must be reported as the 100^{th} percentile (ie the highest) value. At some locations, the background concentrations can exceed the impact assessment criteria. This is most commonly the case for PM_{10} and $PM_{2.5}$, which are affected by events such as bushfires and dust storms. In such circumstances, there is a requirement to demonstrate that no additional exceedances of the impact assessment criteria would occur as a result of the proposed activity and that best management practices would be implemented to minimise emissions of air pollutants as far as is practical.

4.3 Odour

There are no significant sources of odour identified for the construction phase of the project that would generate off-site nuisance odour impacts. All waste generated during construction would be managed appropriately and removed for off-site disposal. Vegetation that is removed would be appropriately managed prior to becoming an odour source in accordance with the Waste Management Report appended to the EIS.

Potential odour may be generated following the filling and operation of the reservoir, due to cyanobacteria and algae, actinomycete bacteria, fungi and other aquatic microbiota (Hobson et al 2010). However, operational management measures to maintain the quality of the water in the reservoir should be sufficient to control potential odour from the reservoir surface. Regular monitoring of water quality within the reservoir would ensure water quality does not deteriorate to the point that odour would become an issue. Operational water quality management measures are outlined in the Surface Water Assessment (EMM 2022).

5 Meteorology and climate

Meteorological mechanisms govern the generation, dispersion, transformation and eventual removal of pollutants from the atmosphere. To characterise and simulate the dispersion meteorology of a region, information is needed on the prevailing wind regime, ambient temperature, rainfall, relative humidity, mixing depth and atmospheric stability.

5.1 Overview of meteorological modelling

Meteorological modelling is typically driven by local observations, however, there are no local meteorological monitoring stations in the vicinity of the project. The closest automatic weather station (AWS) with available data is located at Tamworth, approximately 50 km north-west of the project.

The atmospheric dispersion modelling for this assessment uses the CALMET/CALPUFF model suite. In the absence of local observations for input into the model, CALMET has been run using a large domain (60 km x 60 km) to enable the observation data from Tamworth to be included as a surface station in the modelling. It is noted that due to the distance from these observations to the project site, the prevailing meteorology for the local area would not be biased to those observations and the final wind field predicted by CALMET would be more influenced by local terrain features, such as slope flows and terrain blocking effects.

Similarly, in the absence of upper air measurements, CALMET has been run using prognostic upper air data (as a three-dimensional '3D.dat' file), which is used to derive an initial wind field (known as the Step 1 wind field in the CALMET model). The model then incorporates mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the "hybrid" approach (TRC 2011) and is adopted for this assessment. The Air Pollution Model (TAPM) was used to generate the upper air data ('3D.dat') for each hour of the model run period, for input into CALMET. TAPM and CALMET model settings are described in Annexure A, selected in accordance with recommendations in the *Approved Methods for Modelling* (NSW EPA 2016) and in TRC (2011).

5.2 Surface observations

As described previously, the closest surface observation sites are located at Tamworth, as follows:

- Tamworth Airport, operated by the Bureau of Meteorology (BoM);
- Tamworth (Hyman Park) air quality monitoring station (AQMS), operated by DPE; and
- Southeast Tamworth, operated by WaterNSW/Department of Primary Industries (DPI).

Surface observations are typically included in the modelling to improve the accuracy of the predicted meteorology field. In this case, due to the distance from the observations to the project site, there would be little influence from observations at Tamworth on the final wind field used for modelling. Observations are therefore primarily included in the modelling to allow the model to run.

Annual wind roses for the year 2018 from each of the Tamworth sites is presented in Figure 5.1. The dominant prevailing wind directions at Tamworth Airport and Tamworth DPE are from the southeast, whereas the Southeast Tamworth DPI site displays dominant prevailing winds from the east to southeast. Annual mean wind speeds are higher at Tamworth Airport (3.7 m/s) (frequently observed at airport sites due to a high proportion of surrounding cleared land) and similar at Tamworth DPE and Tamworth DPI (1.9 m/s). The percentage occurrence of calm winds (less than or equal to 0.5 m/s) is lowest at Southeast Tamworth DPI (1.3%), highest at Tamworth DPE (5.8%) and in between at Tamworth Airport (2.8%).

There is little value in including all Tamworth sites as observations in the modelling, as the radius of influence for each observation (the distance at which the observation influences the model) would overlap. Tamworth Airport is therefore used as the primary observation site, as it measures more of the parameters required for modelling (ie cloud data, atmospheric pressure) and the data availability is excellent (greater than 99% in all years). Gaps in the Tamworth Airport dataset were filled with data from the other two observations sites. Surface observations are included as observations into both TAPM and CALMET modelling.

5.3 Selection of a representative dataset for modelling

In selecting a representative year for modelling, the following criteria were considered:

- data availability – the higher the data capture rate the more complete the modelling period;
- representativeness of the selected year when compared to longer term conditions – this is particularly important for wind conditions, which have the greatest influence on dispersion for fugitive dust sources; and
- representativeness of the existing ambient background when compared to longer term conditions – the modelling year should also avoid years with significantly lower or higher ambient background concentrations if these years are not representative of longer term averages.

Ten years of hourly data from the Tamworth Airport were reviewed and annual wind roses for the period 2010 to 2019 are presented in Figure B.1 in Annexure B . The analysis shows consistency in wind direction, average wind speed and percentage occurrence of calm winds (less than or equal to 0.5 m/s). The high degree of consistency in winds across all years indicates that each calendar year would be suitable for modelling.

The inter-annual variation in temperature at Tamworth Airport is also presented in Figure B.2 in Annexure B. The box and whisker plots show monthly median temperature (marked by line) and the monthly quantile ranges (bars for $5^{th}/95^{th}$ and $25^{th}/75^{th}$ quantile ranges). The plots demonstrate that temperatures measured across each year are consistent and therefore representative when compared with this recent period of measurements.

The calendar year 2018 was selected for modelling based on the following:

- data capture rate of greater than 99% for all parameters;
- annual wind roses show consistency in wind direction, average wind speed and percentage occurrence of calm winds (<= 0.5 m/s); and
- the calendar year 2019 was specifically excluded because the extensive bushfire events in November and December have resulted in elevated levels of PM10 and PM2.5, which are not representative of a typical year. In 2019, exceptional events led to poor air quality on 127 days, compared with 50 days in 2018 and 18 days in 2017[6].

[6] https://www.environment.nsw.gov.au/topics/air/air-quality-statement

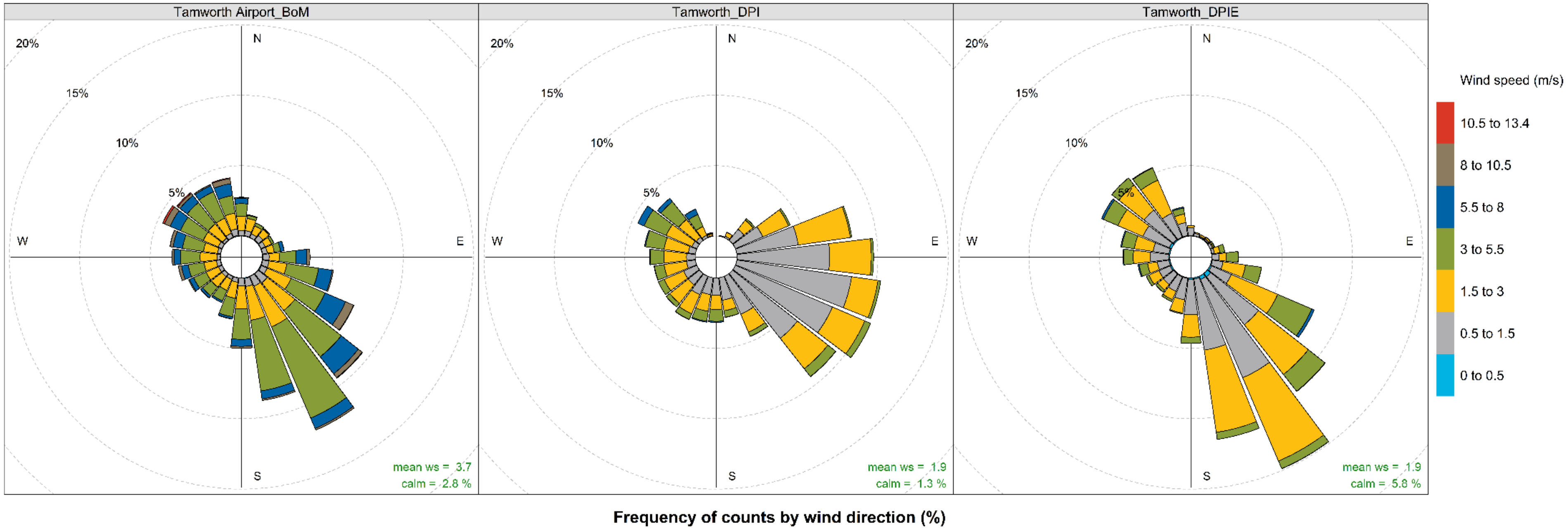


Figure 5.1 Regional wind roses for observation sites

5.4 CALMET predicted winds

CALMET predicted winds were extracted at three points within the valley (Figure 5.2) and presented as a wind rose in Figure 5.3.

The wind roses provide an indication of the variation in wind flow within a valley, which is primarily influenced by local terrain features (slope flows and terrain blocking effects). At Ogunbil, dominant winds are from the east and aligned with east-west orientation of the valley. A similar pattern is predicted by CALMET in the vicinity of the quarry sites. The wind rose extracted for a point near the accommodation camp displays a slightly different pattern, with a northwest to southeast flow evident. Here the model takes into account the slight shift in orientation of terrain features with the winds predicted to be blocked and channelled by a north-south aligned ridgeline.

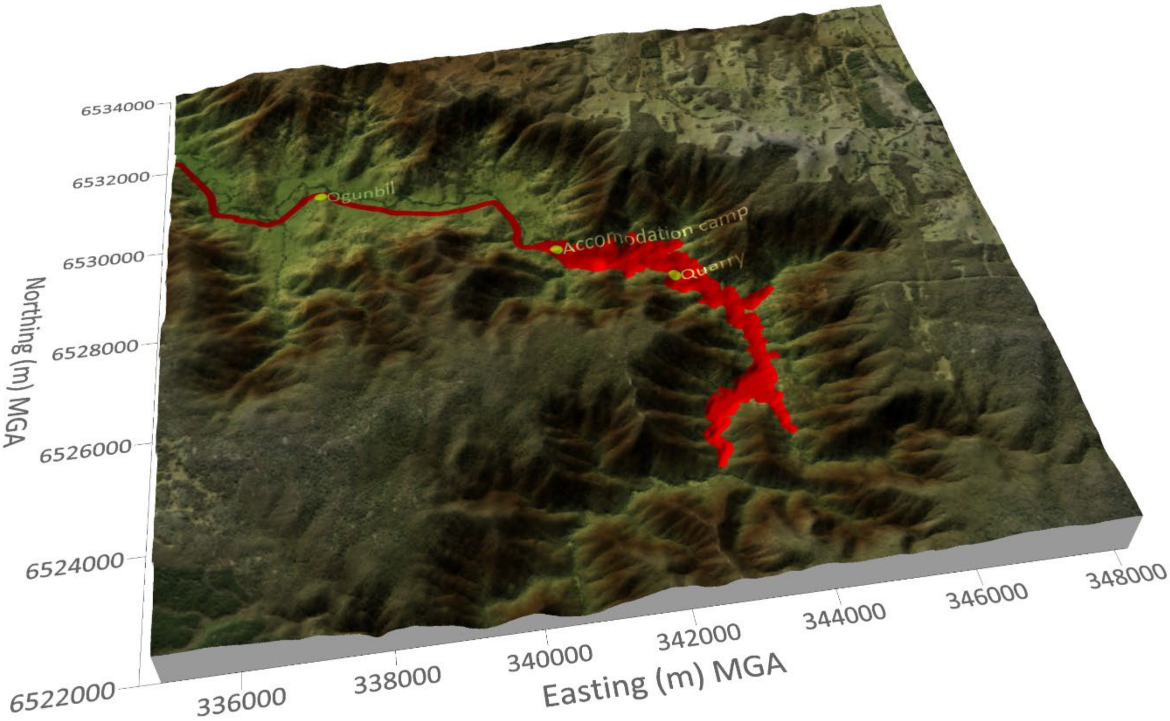


Figure 5.2 CALMET extract points and 3-dimensional topography

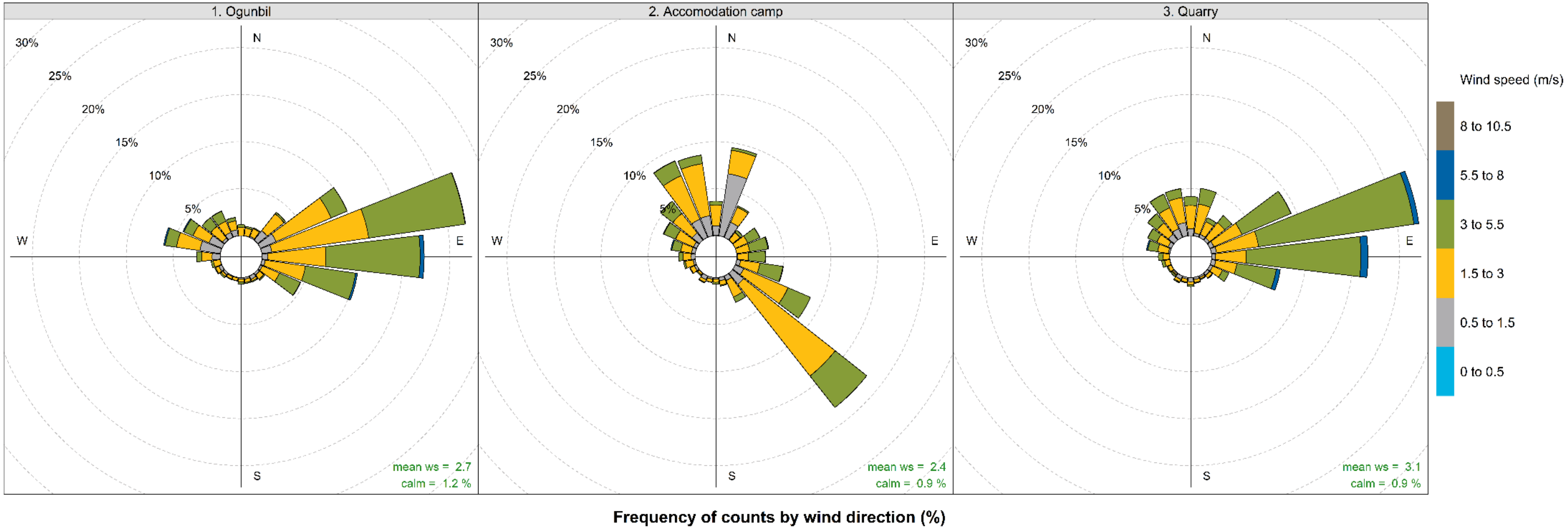


Figure 5.3 Wind roses for CALMET extracts

5.5 Rainfall

Precipitation is important to air pollution, as it impacts on dust generation potential and represents a removal mechanism for atmospheric pollutants. Fugitive emissions may be harder to control during low rainfall years while drier periods may also result in more frequent dust storms and bushfire activity, resulting in higher regional background dust levels. Rainfall also acts as a removal mechanism for dust, lowering pollutant concentrations by removing them more efficiently than during dry periods.

Monthly rainfall data were obtained from the BoM rainfall station at Ogunbil (Amaroo) (located 2.5 km northwest of the dam infrastructure). The local area is characterised by moderate rainfall with a mean annual rainfall in the order of 750 mm. Monthly variation in rainfall is illustrated in Figure 5.4. Monthly mean rainfall is highest between November and February, peaking in December while, on average, June records the highest number of days with rain. Generally, dust mitigation (ie watering) would need to be increased during warmer months when evaporation rates are higher or during prolonged dry periods.

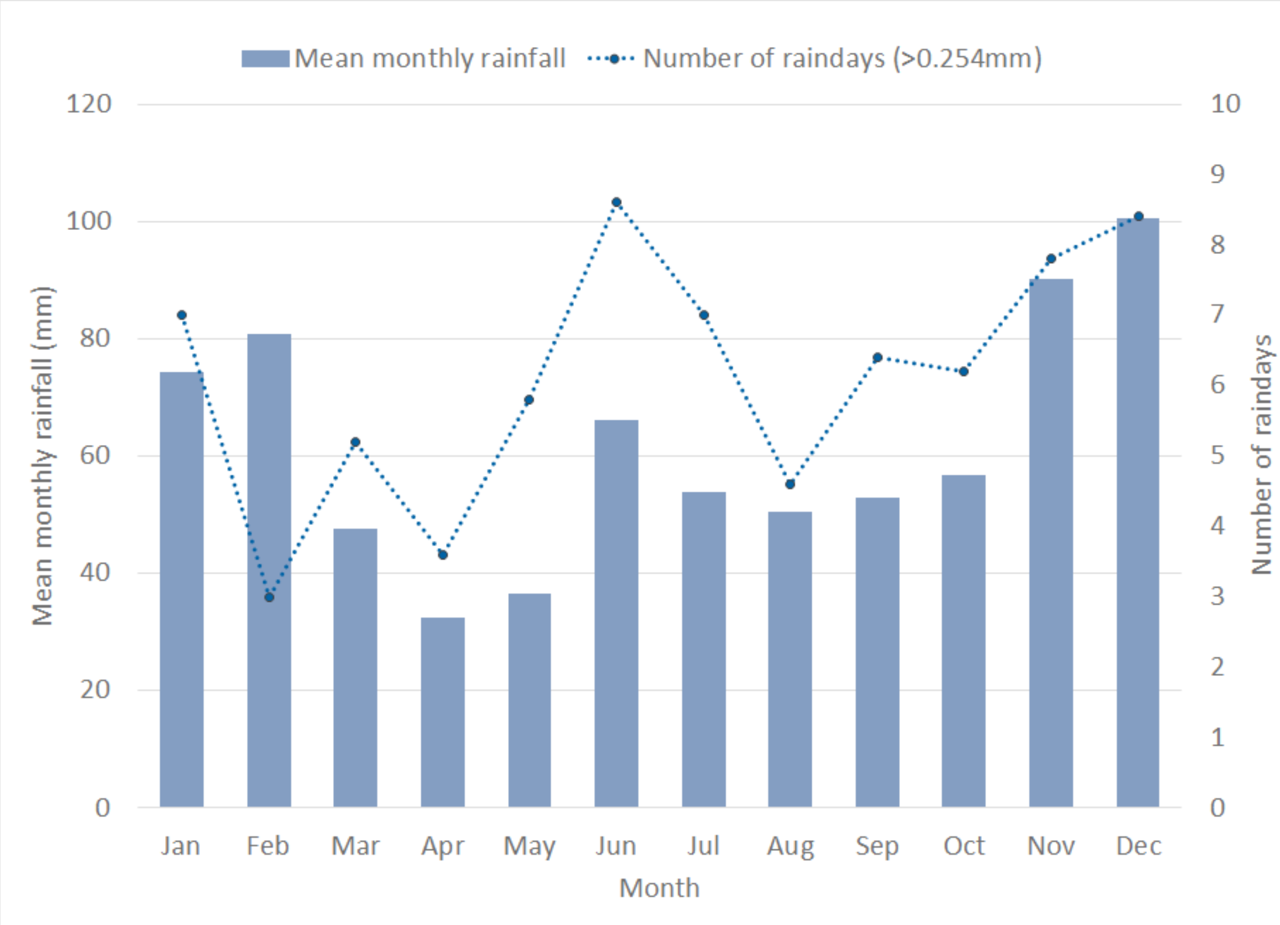


Figure 5.4 Monthly mean rainfall from the BoM Ogunbil rainfall station

5.6 Atmospheric stability and boundary layer heights

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 5.5 illustrates the diurnal variation of atmospheric stability, derived from the Monin-Obukhov length calculated by CALMET. 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.

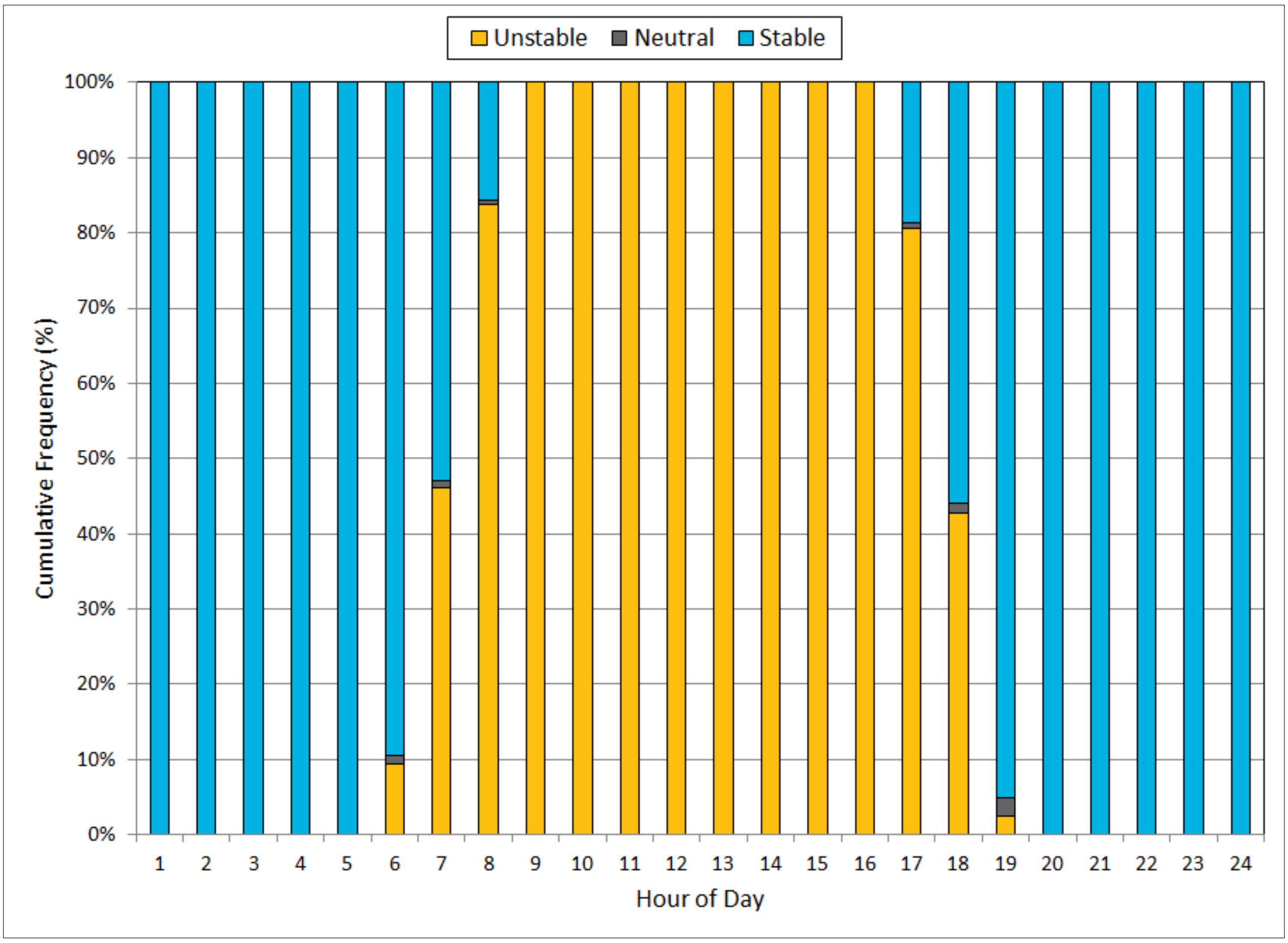


Figure 5.5 Diurnal variations in CALMET-generated atmospheric stability

Mixing height refers to the height of the atmosphere above ground level within which the dispersion of air pollution occurs. The mixing height 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 heights and greater potential for the atmospheric dispersion of pollutants.

Figure 5.6 presents the hourly-varying atmospheric boundary layer depths generated by CALMET. This diurnal profile for stability and mixing height indicates that the dispersion of emissions would be greatest during daytime hours, corresponding to construction hours for the project.

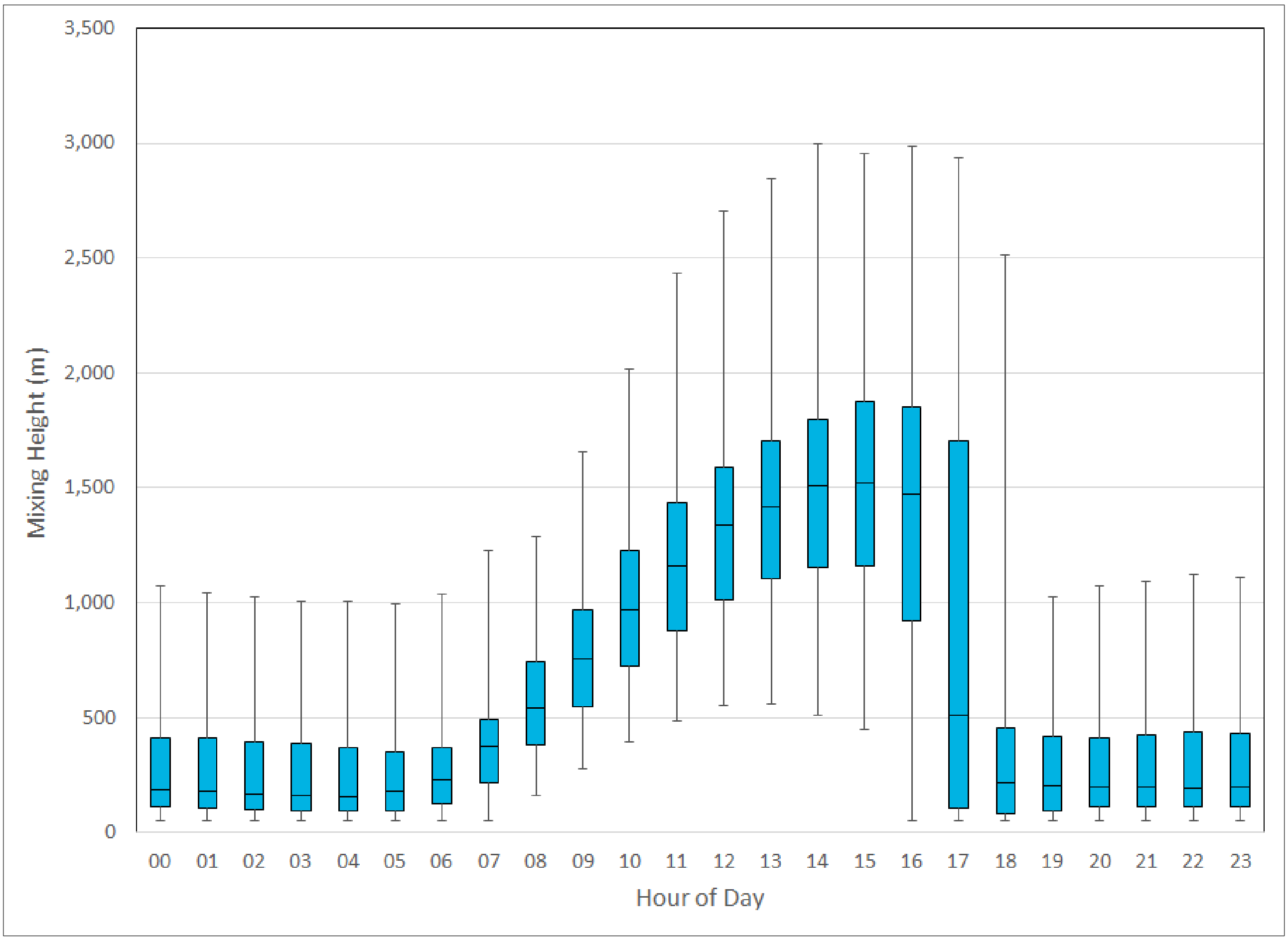


Figure 5.6 Diurnal variation in CALMET-generated mixing heights

6 Existing ambient air quality

To demonstrate compliance with impact assessment criteria, consideration of cumulative impact is required to assess how the project would interact with existing and future sources of emissions. There are no anticipated future developments for the local area that would generate new sources of emissions, therefore cumulative impacts are assessed by taking into account the existing baseline or background air quality.

The local air quality environment is expected to be primarily influenced by:

- local traffic travelling along unsealed roads;
- fugitive dust during dry conditions, from agricultural activity and wind erosion from exposed ground;
- seasonal emissions from household wood heaters;
- episodic emissions from bushfires;
- seasonal pollen from grass and trees; and
- long-range transport of fine particles into the region.

Baseline or background air quality is primarily based on monitoring data collected at the closest DPE air quality monitoring station (AQMS) location at Tamworth, approximately 50 km northwest of the dam infrastructure.

6.1 PM_{10} and $PM_{2.5}$ concentrations

6.1.1 Summary statistics

A summary of the key statistics for Tamworth is provided in Table 6.1 (PM_{10} from 2010 - 2019) and Table 6.2 ($PM_{2.5}$ from 2016-2019). Background air quality for the region can be described as good, with compliance with annual air quality standards achieved in most years. Exceedances of the air quality standards for 24-hour average PM_{10} and $PM_{2.5}$ are typically caused by smoke from bushfires/hazard reduction burns or regional dust storms. The extensive bushfire events in November and December 2019 resulted in elevated levels of PM_{10} and $PM_{2.5}$, which are not representative of a typical year. In 2019, exceptional events led to exceedances of the of the air quality standards for 24-hour average PM_{10} and $PM_{2.5}$ on 52 and 33 days respectively.

Background PM_{10} and $PM_{2.5}$ concentrations for 2018 are also higher than other years, primarily due to intensifying drought conditions contributing to local and regional dust storms across NSW, however, to provide a conservatively high background, the calendar year 2018 is selected for modelling.

Table 6.1 Summary statistics for PM_{10} -Tamworth 2010-2019

Year	Maximum 24-hour average (µg/m^3)	Number of days above goal (50 µg/m^3)	Annual average (µg/m^3)
2010	29.1	0	12.0
2011	50.9	1	13.1
2012	55.1	1	15.9
2013	47.5	0	16.6
2014	66.6	1	15.8
2015	52.7	1	14.1

Table 6.1 Summary statistics for PM_{10} -Tamworth 2010-2019

Year	Maximum 24-hour average (µg/m^3)	Number of days above goal (50 µg/m^3)	Annual average (µg/m^3)
2016	51.7	1	15.3
2017	54.1	2	15.3
2018	145.4	9	20.1
2019	240.2	52	33.7

Table 6.2 Summary statistics for $PM_{2.5}$ -Tamworth 2016-2019

Year	Maximum 24-hour average (µg/m^3)	Number of days above goal (25 µg/m^3)	Annual average (µg/m^3)
2016	17.6	0	7.6
2017	21.6	0	7.8
2018	24.2	0	8.3
2019	164.2	33	14.4

Timeseries plots of the 24-hour average PM_{10} and $PM_{2.5}$ are presented in Annexure B.

6.1.2 2018 dataset for modelling

As described above, the calendar year 2018 was selected for modelling. To provide a continuous dataset for modelling, gaps in the data were filled as follows:

- for hours where one of PM_{10} or $PM_{2.5}$ concentrations is missing, gaps were filled using a simple linear regression, derived by plotting the relationship between all contemporaneous measurements of PM_{10} and $PM_{2.5}$; and
- for remaining hours where both the PM_{10} and $PM_{2.5}$ concentrations were missing, gaps were filled using the 70th percentile of the complete data record.

Timeseries plots of the daily 24-hour PM_{10} and $PM_{2.5}$ concentrations for 2018 are presented in Figure B.5 and Figure B.6 in Annexure B, showing the original and filled datasets. There are nine existing exceedances of the daily PM_{10} criterion and no existing exceedances of the daily $PM_{2.5}$ criterion in the 2018 background dataset. The highest PM_{10} concentration not already above the criterion is 47.4 µg/m^3 (the 10th highest) and is presented for cumulative assessment purposes to determine if additional exceedances would occur as a result of project construction-phase emissions. The *NSW Air Quality Statement for 2018* (OEH 2019) reported that all of the PM_{10} exceedances at Tamworth were due to specific events (ie bushfires, hazard reduction burns and dust storms).

The annual average PM_{10} and $PM_{2.5}$ concentrations for the 2018 Tamworth DPE AQMS dataset are 20.1 µg/m^3 and 8.3 µg/m^3.

6.2 TSP concentrations

TSP concentrations are not measured at the Tamworth DPE AQMS. In the absence of local measurements, annual average TSP concentrations can be derived from the PM_{10} data, based on ratios of PM_{10}/TSP, which typically ranges from 0.4 to 0.5 in rural area (ie PM_{10} is typically 40% to 50% of TSP).

To derive an annual average TSP concentration consistent with the 2018 background period, the ratio of 0.4 has been applied to the annual average PM_{10} concentration for the 2018 Tamworth DPE AQMS dataset (see Section 6.1.2), returning a TSP background concentration of 50.1 µg/m³.

6.3 Dust deposition

There is no local monitoring data available for dust deposition, therefore modelling results are assessed against the incremental impact assessment criteria only.

6.4 Summary of adopted background for cumulative assessment

The following background values are adopted for cumulative assessment:

- 24-hour PM_{10} concentration – daily varying for 2018. The highest concentration that is not already above the impact assessment criteria is 47.4 µg/m³;
- annual average PM_{10} concentration – 20.1 µg/m³;
- 24-hour $PM_{2.5}$ concentration – daily varying with a maximum of 24.2 µg/m³;
- annual average $PM_{2.5}$ concentration – 8.3 µg/m³; and
- annual average TSP concentration – 50.1 µg/m³ assuming PM_{10} is 40% of TSP.

It is noted the adopted background for annual average $PM_{2.5}$ is already above impact assessment criterion of 8.0 µg/m³. An assessment of air quality risk from the project would therefore be made based on the incremental change that occurs as a result of the project, in the context of an existing high background. It is noted that the adopted background from Tamworth, which has a higher population density than the project area, provides a conservatively high background for the assessment.

7 Emissions inventory

7.1 Emissions scenario

Air quality emissions during operation of the dam would be minor and limited to infrequent light vehicle movements within the operational footprint. The air quality assessment therefore focuses on the construction phase.

In accordance with the *Approved Methods for Modelling* (NSW EPA 2016), an emissions inventory has been developed for a single construction year, selected to assess the worst-case air quality impacts (ie when material handling/movement is at a maximum). The construction schedule occurs over a period of approximately six years. The main embankment construction would occur during years two to four of the construction schedule, with the most significant dust generating activities occurring during construction of the main embankment dam and spillway (plus associated quarrying). The emissions scenario therefore focuses on this period of construction and includes the following activities and assumptions:

- excavation of spillway, including:
  - stripping of soil and overburden and temporary stockpiling; and
  - excavation and hauling to main dam embankment for emplacement.
- rock quarrying, including:
  - extraction and processing of material (crushing and screening/sizing); and
  - hauling of material to main dam embankment and concrete batch plant.
- borrow area, including:
  - excavation and hauling to main dam embankment for emplacement.
- construction of main dam embankment including:
  - placement and shaping of material from spillway, quarry, borrow area and external commercial source;
- operation of concrete batch plant, including:
  - import of material from quarry and external source;
  - handling of material, including cement; and
  - hauling to spillway and main dam embankment.
- realignment of the existing Dungowan Dam road.

The construction of the access roads, construction compound and accommodation camp are scheduled to occur during the first year of construction and are therefore not considered as concurrent emissions sources for the emissions scenario. Similarly, decommissioning of the existing dam and construction of the pipeline and powerline are not considered as a concurrent emissions source for the quantitative emissions scenario. Notwithstanding, dust management and monitoring for the entire construction period is outlined in Chapter 12. Construction of the pipeline, powerline and decommissioning of the dam are assessed separately in Chapter 10.

A detailed description of the assumptions adopted in the development of the emissions inventory are provided in Annexure C.

7.2 Emission reduction factors

The following dust mitigation measures have been incorporated into the emission inventory based on emission reduction factors reported by the National Pollution Inventory (NPI 2011):

- emission from hauling are controlled by 75%, based on level 2 watering (application rate >2 litres per m^2 per hour);
- emissions from rock screening/sizing and crushing are controlled by 50%, based on water sprays; and
- emission from drilling are controlled 70%, based on water sprays.

7.3 Emission estimates

Fugitive dust emissions were quantified using US EPA AP-42 emission factor equations (US EPA 1995). A description of the AP-42 emission factor equations adopted and assumptions and inputs used for the development of the emissions inventory are provided in Annexure C. Fugitive dust emission factors are also provided in the NPI emission estimation technique manuals published by the Australian Government (eg NPI 2011). However, the NPI emission factors are largely based on the AP-42 documentation and the use of the AP-42 emission factors for fugitive dust emission inventories is therefore accepted by the NSW EPA for use in NSW.

Particulate matter emissions were quantified for the three size fractions identified in Chapter 4, with the TSP fraction also used to model dust deposition. 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 US EPA AP-42).

7.3.1 Summary of emissions

A summary of the contribution to annual dust emissions by project component and source type is provided in Figure 7.1 and Figure 7.2. The most significant source of TSP and PM_{10} emissions are with hauling (wheel generated dust), handling of material and wind erosion. The significance of diesel combustion emissions increases with decreasing particle size (diesel combustion is the largest source of $PM_{2.5}$). The estimated annual emissions by project component and source is presented in Table 7.1. Particulate matter control measures, as documented in Section 7.2, are accounted for in these emission totals.

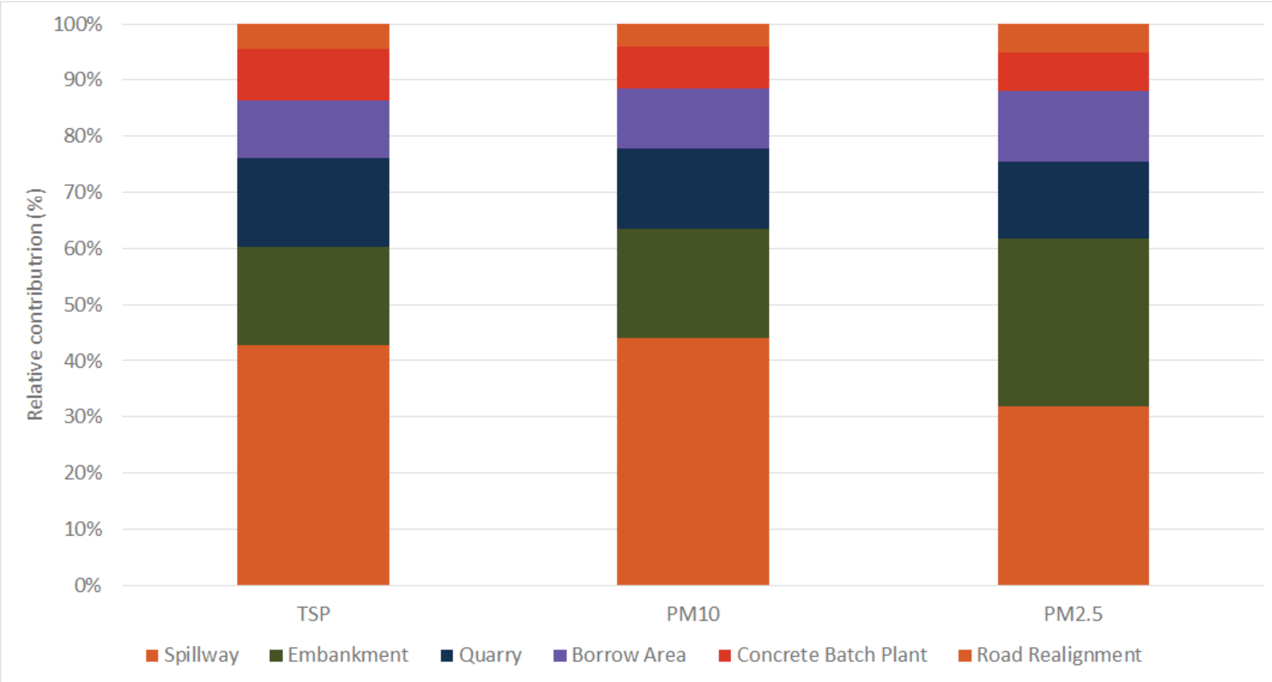


Figure 7.1 Contribution to annual emissions by project component and particle size

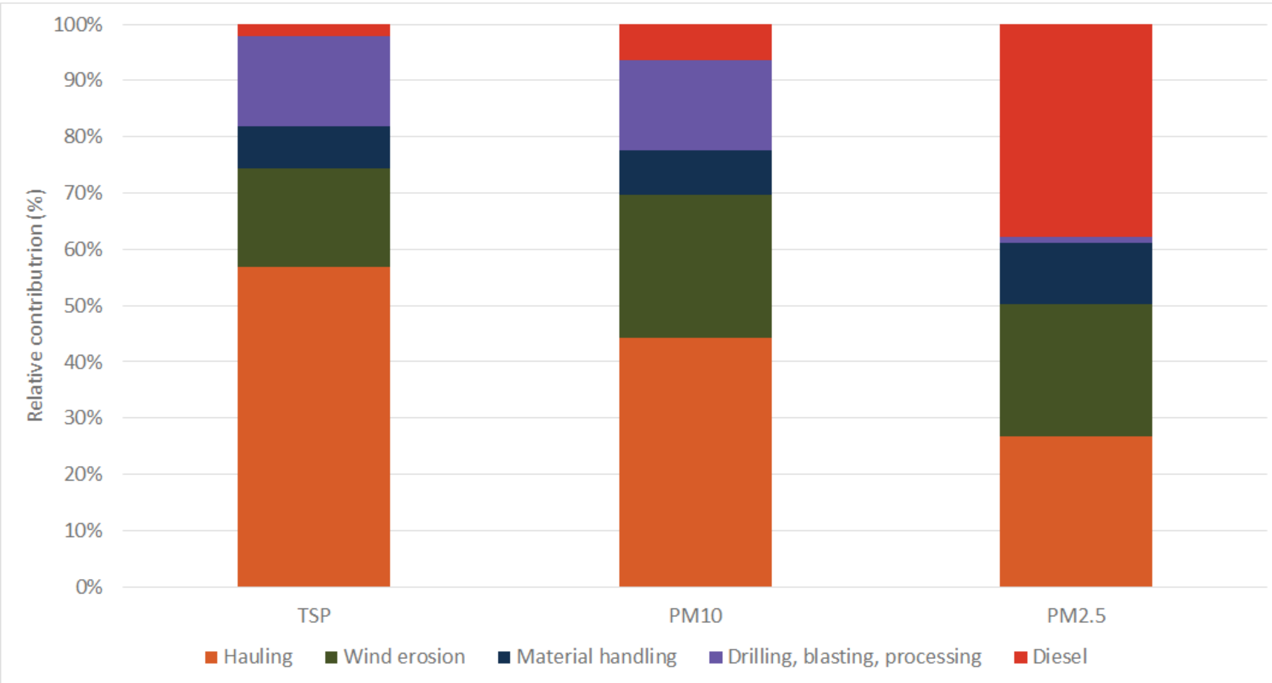


Figure 7.2 Contribution to annual emissions by emissions source type and particle size

Table 7.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions

Emission source	Calculated annual emissions (kg/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Spillway			
Stripping soil/OB	4.7	2.2	0.3
Loading trucks with soil/OB	4.7	2.2	0.3
Hauling soil/OB across spillway area	289.4	74.4	7.4
Emplacement of soil/OB to temporary stockpile	6.4	3.0	0.5
Drilling	442.5	230.1	13.3
Blasting	173.9	90.4	5.2
Ripping	1,272	601	91.1
Screening/sizing	16,646	5,726	33.3
Rehandle to trucks	1,272	601	91.1
Hauling rockfill from spillway to embankment placement	18,530	4,761	476.1
Exposed ground - spillway	6,800	3,400	510.0
Main Dam Embankment			
Stripping soil/OB	3.8	1.8	0.3
Loading trucks with soil/OB	3.8	1.8	0.3
Hauling soil/OB across embankment area	247.1	63.5	6.3
Emplacement of soil/OB to temporary stockpile	3.8	1.8	0.3
Trucks unloading rockfill from spillway	1,272	601	91.1
Trucks unloading rockfill from quarry	131.8	62.3	9.4
Truck unloading fill from borrow areas	62.1	29.4	4.4
Import fill from external commercial source	10,026	2,576	258
Unloading fill from external commercial source	95.5	45.2	258
Excavator shaping/spreading	1,466	693	105
Exposed ground - embankment	5,525	2,763	414
Rock Quarrying			
Pre-strip (n/a - completed in 2022)	0	0	0
Drilling	442.5	230.1	13.3
Blasting	173.9	90.4	5.2
Excavator ripping	131.8	62.3	9.4
Crushing	517.5	49.7	9.2
Screening/sizing	517.5	178.0	1.0

Table 7.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions

Emission source	Calculated annual emissions (kg/annum) by source		
	TSP	PM_{10}	$PM_{2.5}$
Excavator loading trucks	131.8	62.3	9.4
Hauling from quarry to embankment placement	12,914	3,318	332
Exposed ground - quarry	1,955	978	147
Borrow area			
Pre-strip	1.5	0.7	0.1
Excavator ripping	1.5	0.7	0.1
Excavator loading trucks	11.7	5.5	0.8
Hauling from borrow to embankment placement	6,517	1,675	167
Exposed ground	4,250	2,125	319
Concrete batch plant			
Hauling from quarry to CBP	6,918	1,778	177.8
Import aggregate from external commercial source	494.2	127.0	12.7
Trucks unloading sand/aggregate	65.6	31.0	4.7
Rehandle	65.6	31.0	4.7
Transfer to hopper	65.6	31.0	4.7
Cement unloading	25.0	8.5	1.0
Hauling from CBP to spillway	2,219	570	57.0
Stockpiles	17.0	8.5	1.3
Miscellaneous			
Grader (road maintenance)	9,099	3,179	282
Onsite diesel consumption	2,575	2,575	2,497
Road realignment			
Scraper	2,597	357	32
Rehandle	10.5	5.0	0.8
Unloading gravel	37.3	17.6	2.7
Exposed ground wind erosion	2,125	1,063	159
Total	**118,157**	**40,888**	**6,626**

8 Dispersion modelling

8.1 Dispersion model selection and configuration

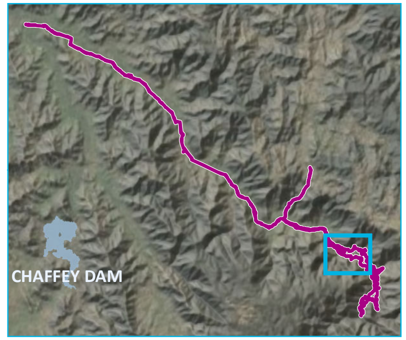
Dispersion modelling for this assessment uses the CALPUFF modelling system, which is commonly used in NSW for applications where non-steady state conditions may occur (ie complex terrain or coastal locations). CALPUFF is suitable for this assessment as the project area is located within valley terrain and, in the absence of local observations, the CALMET derived meteorological field would take into account the local terrain slope flows and blocking effects expected in the local area.

The activities and emission sources listed in Table 7.1 are represented by a series of line-volume, volume and area sources, positioned across the construction footprint, as follows:

- haulage is modelled as line-volume sources, positioned along the main haulage routes;
- wind erosion is modelled as area source covering the total footprint for each project component; and
- material excavation, handling and processing is modelled as a series of volumes sources, positioned across the footprint for each project component.

The modelled source locations are shown in Figure 8.1.

The predicted project increment and cumulative ground level concentrations (GLCs) are tabulated for each assessment location. Gridded GLCs were also predicted over a 18 km by 13 km domain with a 500 m spacing and used to generate contour plots, showing the extent of predicted ground level concentrations across the local area (Figure 8.2 to Figure 8.7).



KEY

- Project footprint
- Minor road
- Named watercourse
- Named waterbody
- Material handling sources
- Wheel generated dust sources
- Concrete batch plant
- Wind erosion areas

Source locations for modelling

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.1

EMM
creating opportunities

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_AQA\AQA008_SourceLocations_20220511_05.mxd 11/05/2022

8.2 Annual average PM_{10}, $PM_{2.5}$, TSP and dust deposition

The predicted project increment and cumulative annual average PM_{10}, $PM_{2.5}$, TSP concentrations and dust deposition levels are presented in Table 8.1. Cumulative results are calculated by adding the modelled increment to the adopted background concentrations described in Section 6.4.

The highest predicted increment occurs at the assessment locations within the inundation zone (R1- R13), all of which are now vacant. Other than these assessment locations, the highest predicted increment occurs at the accommodation camp (C1). When background concentrations are added to the modelled increment, there are no exceedances of the annual average impact assessment criteria for $PM_{10,}$ TSP and dust deposition.

The annual average background $PM_{2.5}$ concentration (8.3 µg/m^3) is already above the impact assessment criterion, therefore it is difficult to assess compliance based on cumulative predictions. Other jurisdictions had adopted screening criteria, used to screen out insignificant impacts for new projects. For example, in Western Australia, the WA Department of Water and Environmental Regulation (DWER) use screening concentrations (SC) to screen out emission sources as insignificant (DWER 2019). The SC are expressed as a percentage of their air quality guidelines values (AGVs) and for annual averages, the SC are <1% of the AGV. These screening concentrations are consistent with those referenced in the UK for permitting, where the Environment Agency allows for screening out insignificant impacts if the contribution from a source is less than 1% of the annual standard (Environment Agency 2011).

The annual average $PM_{2.5}$ concentration at the accommodation camp is 1.8% of the impact assessment criterion, which is slightly above the screening criteria. For all other assessment locations (not within the inundation zone), the annual average $PM_{2.5}$ concentration is 0.3% of the impact assessment criterion and can be considered insignificant.

Table 8.1 Predicted annual average ground level concentrations and deposition

ID	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)		TSP (µg/m^3)		Dust deposition (g/m^2/month)
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment
	Impact assessment criteria						
	25 µg/m^3		8 µg/m^3		90 µg/m^3		2 g/m^2/month
C_1	1.0	22.1	0.1	8.4	2.6	52.7	0.1
R_1	1.8	22.9	0.3	8.6	5.0	55.1	0.2
R_2	1.8	22.9	0.3	8.6	4.9	55.0	0.2
R_3	8.0	29.1	1.4	9.7	23.6	73.7	0.9
R_4	1.7	22.8	0.3	8.6	4.4	54.5	0.2
R_5	1.9	23.0	0.3	8.6	4.9	55.0	0.2
R_6	0.5	21.6	0.1	8.4	1.3	51.4	0.1
R_7	0.8	21.9	0.1	8.4	1.7	51.8	0.1
R_8	0.5	21.6	0.1	8.4	1.0	51.1	<0.1
R_9	0.7	21.8	0.1	8.4	1.6	51.7	0.1
R_10	3.2	24.3	0.5	8.8	7.3	57.4	0.5

Table 8.1 Predicted annual average ground level concentrations and deposition

ID	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		TSP (µg/m³)		Dust deposition (g/m²/month)
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment
	Impact assessment criteria						
	25 µg/m³		8 µg/m³		90 µg/m³		2 g/m²/month
R_11	2.6	23.7	0.5	8.8	6.0	56.1	0.6
R_12	3.4	24.5	0.6	8.9	8.0	58.1	0.9
R_13	3.5	24.6	0.6	8.9	7.7	57.8	0.4
R_14	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_15	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_16	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_17	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_18	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_19	0.1	21.2	<0.1	8.3	0.3	50.4	<0.1
R_20	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_21	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_22	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_23	0.1	21.2	<0.1	8.3	0.2	50.3	<0.1
R_24	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_25	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_26	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_27	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_28	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_29	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_30	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_31	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_32	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_33	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_34	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1
R_35	0.1	21.2	<0.1	8.3	0.1	50.2	<0.1
R_36	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_37	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1

Table 8.1 Predicted annual average ground level concentrations and deposition

ID	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		TSP (µg/m³)		Dust deposition (g/m²/month)
	Increment	Cumulative	Increment	Cumulative	Increment	Cumulative	Increment
	Impact assessment criteria						
	25 µg/m³		8 µg/m³		90 µg/m³		2 g/m²/month
R_38	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_39	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_40	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_41	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_42	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_43	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_44	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_45	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_46	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_47	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_48	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_49	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_50	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_51	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_52	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_53	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_54	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_55	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_56	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_57	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_58	<0.1	21.1	<0.1	8.3	<0.1	50.1	<0.1
R_59	<0.1	21.1	<0.1	8.3	0.1	50.2	<0.1

8.3 24-hour average PM_{10} and $PM_{2.5}$

The predicted project increment and cumulative 24-hour average PM_{10} and $PM_{2.5}$ concentrations are presented in Table 8.2. Cumulative results are calculated by adding the modelled increment to the daily varying background concentrations described in Section 6.4.

The highest predicted increment occurs at the assessment locations within the inundation zone (R1- R13). When background concentrations are added to the modelled increment, there are exceedances of the 24-hour average impact assessment criteria for PM_{10} and $PM_{2.5}$ at eight of the 13 receptors located within the inundation zone. As all of these assessment locations are now vacant, no further discussion or assessment is required.

Other than these assessment locations, the highest predicted increment occurs at the accommodation camp (C1). When background concentrations are added to the modelled increment, there are no additional exceedances of the 24-hour average impact assessment criteria for PM_{10} and $PM_{2.5}$ at any assessment locations outside of the inundation zone, including the accommodation camp.

Table 8.2 Predicted 24-hour average ground level concentrations

ID	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Increment	Cumulative	Increment	Cumulative
	Impact assessment criteria			
	50 µg/m³		25 µg/m³	
C_1	8.0	47.9	1.6	24.3
R_1	11.9	**51.4**	2.1	**26.1**
R_2	11.5	**51.6**	2.1	**26.1**
R_3	24.2	**59.3**	4.2	**26.7**
R_4	10.2	**51.1**	2.5	**25.8**
R_5	11.2	**50.5**	2.5	**25.5**
R_6	6.1	49.2	1.4	24.8
R_7	4.0	49.3	0.7	24.4
R_8	3.2	48.8	0.5	24.5
R_9	5.4	47.6	1.4	24.2
R_10	27.7	48.5	5.8	24.3
R_11	15.6	**50.1**	3.4	**25.9**
R_12	23.4	**50.5**	5.4	**25.5**
R_13	21.7	**54.1**	4.9	**26.6**
R_14	1.1	47.4	0.2	24.2
R_15	1.1	47.4	0.2	24.2
R_16	1.1	47.4	0.2	24.2
R_17	0.8	47.4	0.1	24.2
R_18	0.7	47.4	0.1	24.2
R_19	1.4	47.4	0.3	24.2
R_20	1.1	47.4	0.2	24.2
R_21	1.0	47.4	0.2	24.2

Table 8.2 Predicted 24-hour average ground level concentrations

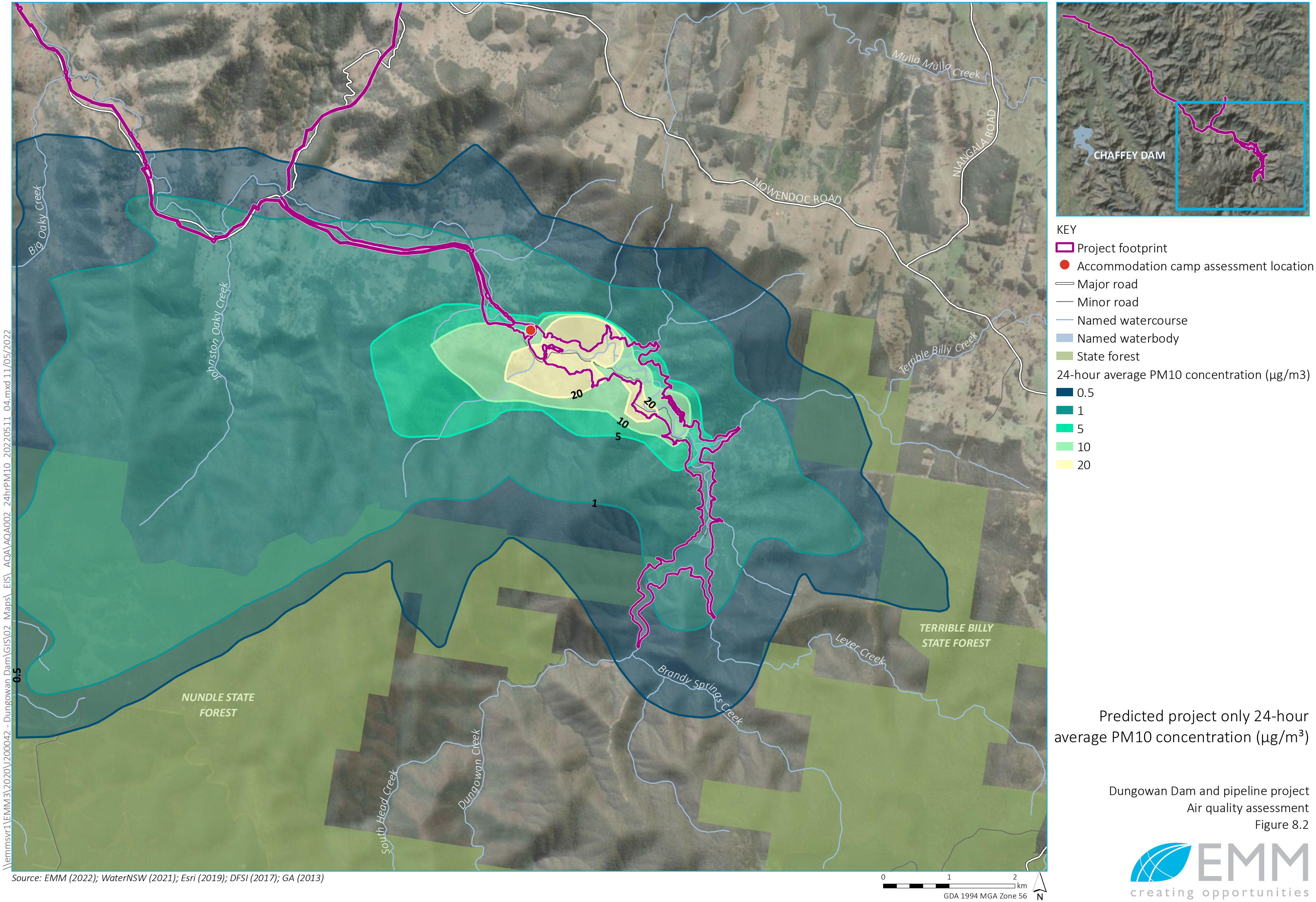
ID	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Increment	Cumulative	Increment	Cumulative
	Impact assessment criteria			
	50 µg/m³		25 µg/m³	
R_22	0.8	47.4	0.1	24.2
R_23	1.1	47.4	0.2	24.2
R_24	1.1	47.4	0.2	24.2
R_25	0.8	47.4	0.1	24.2
R_26	0.8	47.4	0.1	24.2
R_27	0.7	47.4	0.1	24.2
R_28	0.7	47.4	0.1	24.2
R_29	1.7	47.4	0.4	24.2
R_30	1.6	47.4	0.3	24.2
R_31	1.6	47.4	0.4	24.2
R_32	1.6	47.4	0.4	24.2
R_33	1.6	47.4	0.4	24.2
R_34	0.7	47.4	0.1	24.2
R_35	1.2	47.4	0.3	24.2
R_36	0.2	47.4	<0.1	24.2
R_37	0.2	47.4	<0.1	24.2
R_38	0.3	47.4	0.1	24.2
R_39	0.3	47.4	<0.1	24.2
R_40	0.3	47.4	0.1	24.2
R_41	0.2	47.4	<0.1	24.2
R_42	0.2	47.4	<0.1	24.2
R_43	0.2	47.4	<0.1	24.2
R_44	0.2	47.4	<0.1	24.2
R_45	0.2	47.4	<0.1	24.2
R_46	0.2	47.4	<0.1	24.2
R_47	0.2	47.4	<0.1	24.2
R_48	0.2	47.4	<0.1	24.2
R_49	0.2	47.4	<0.1	24.2

Table 8.2 Predicted 24-hour average ground level concentrations

ID	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Increment	Cumulative	Increment	Cumulative
	Impact assessment criteria			
	50 µg/m³		25 µg/m³	
R_50	0.2	47.4	<0.1	24.2
R_51	0.2	47.4	<0.1	24.2
R_52	0.3	47.4	0.1	24.2
R_53	0.2	47.4	<0.1	24.2
R_54	0.1	47.4	<0.1	24.2
R_55	0.1	47.4	<0.1	24.2
R_56	0.3	47.5	0.1	24.2
R_57	0.3	47.5	0.1	24.2
R_58	0.2	47.5	0.1	24.2
R_59	0.8	47.4	0.2	24.2

8.4 Contour plots

Contour plots for the predicted project only PM_{10}, $PM_{2.5}$, TSP and dust deposition are presented in Figure 8.2 to Figure 8.7, showing the extent of predicted ground level concentrations across the local area. The maximum ground level concentrations are predicted to occur within the inundation zone. The air quality risk on assessment locations outside the inundation zone is considered low.



Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

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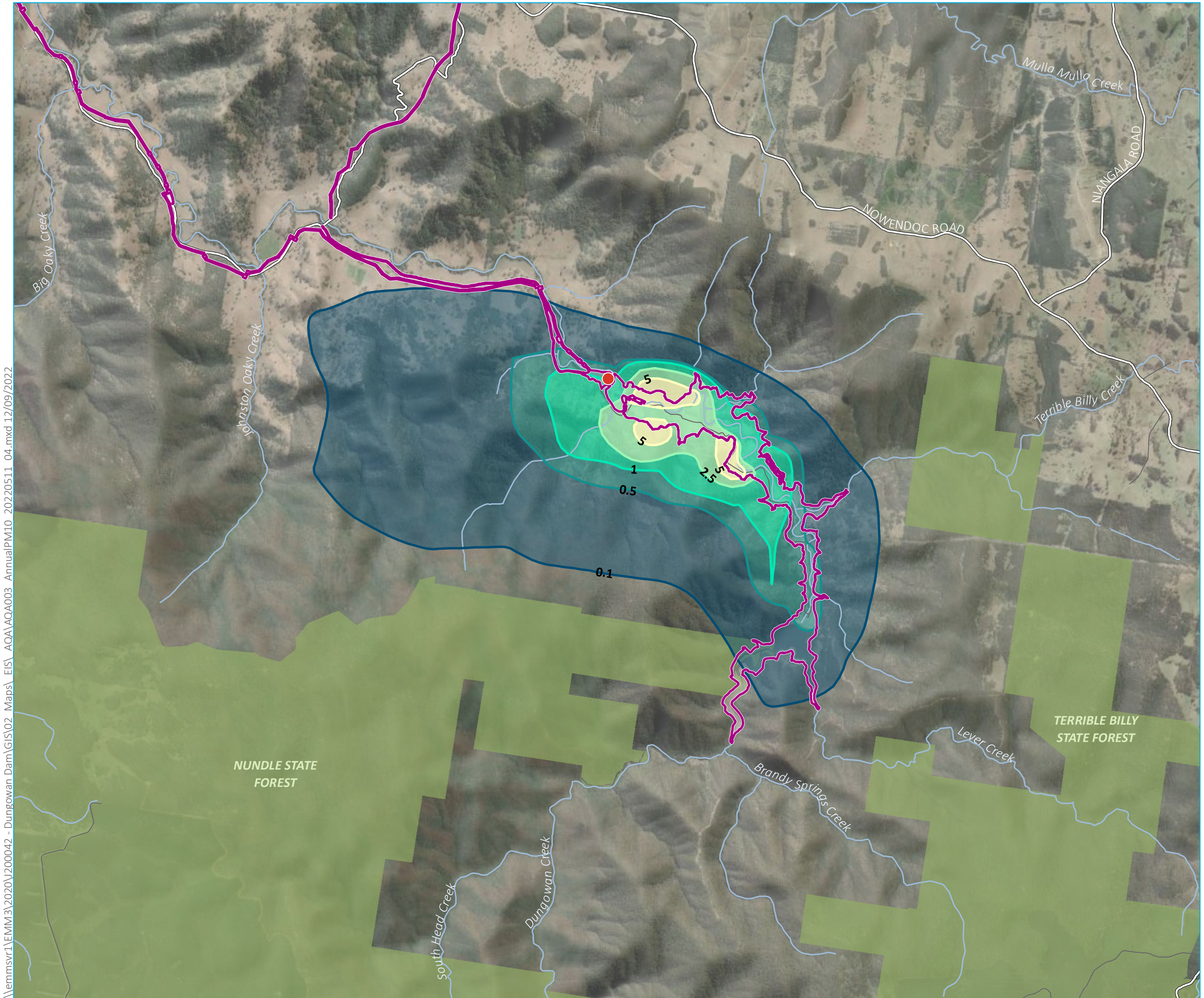
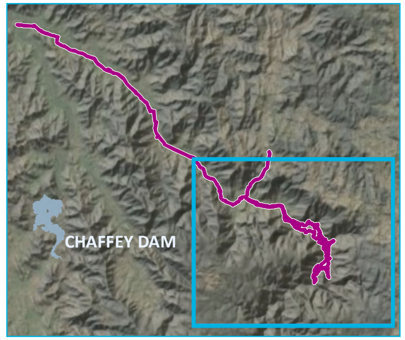
Predicted project only 24-hour average PM10 concentration (µg/m³)

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.2

EMM creating opportunities





KEY
- Project footprint
- Accommodation camp assessment location
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Annual average PM10 concentration (µg/m³)
- 0.1
- 0.5
- 1
- 2.5
- 5

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

0 1 2 km
GDA 1994 MGA Zone 56
N

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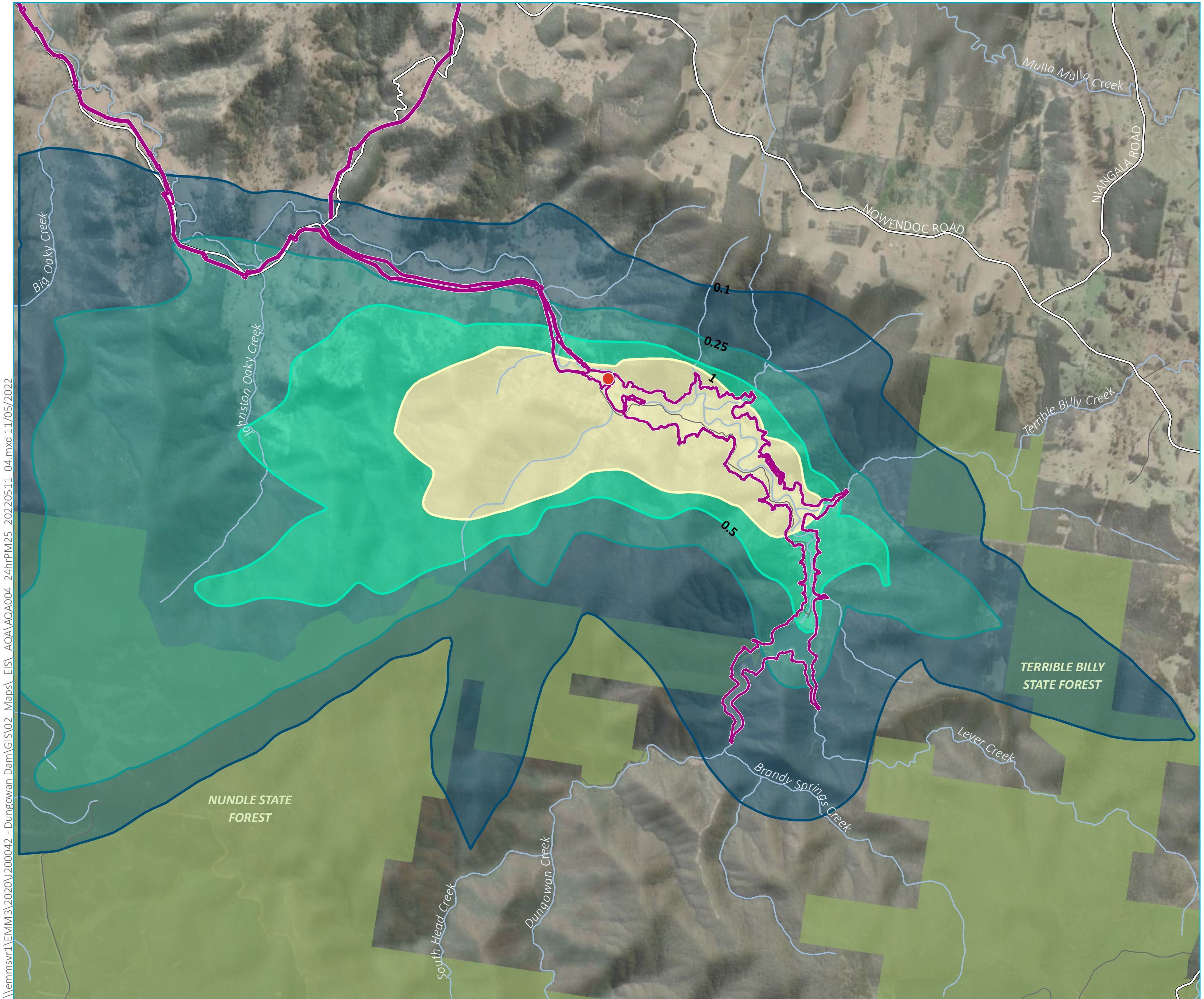
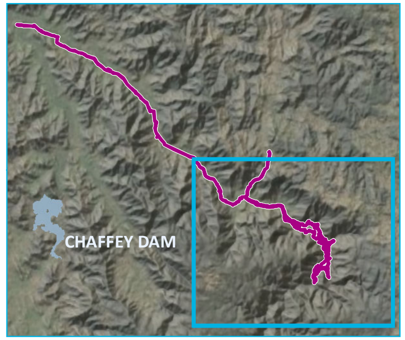
Predicted project only annual average PM10 concentration (µg/m³)

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.3

EMM
creating opportunities





KEY
- Project footprint
- Accommodation camp assessment location
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

24-hour average PM2.5 concentration (µg/m³)
- 0.1
- 0.25
- 0.5
- 1

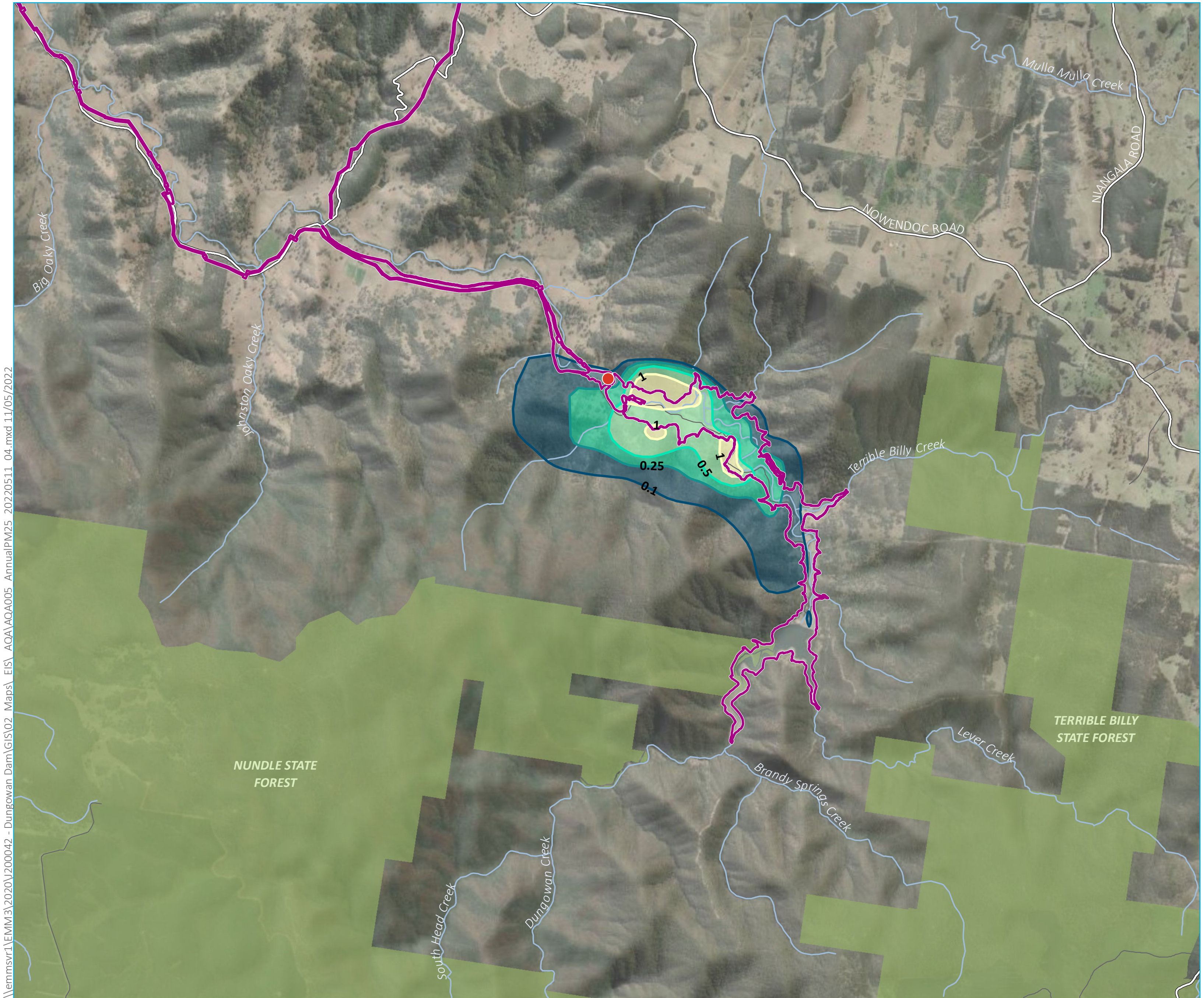
Predicted project only 24-hour average PM2.5 concentration (µg/m³)

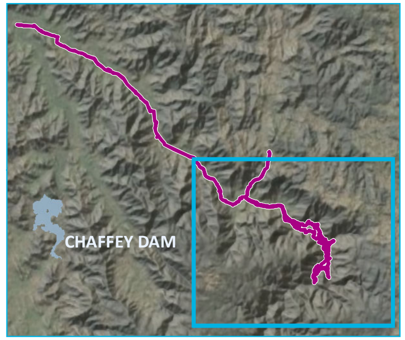
Dungowan Dam and pipeline project
Air quality assessment
Figure 8.4

EMM creating opportunities

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_AQA\AQA004_24hrPM25_20220511_04.mxd 11/05/2022





KEY
- Project footprint
- Accommodation camp assessment location
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Predicted project only annual average PM2.5 concentration (µg/m³)
- 0.1
- 0.25
- 0.5
- 1

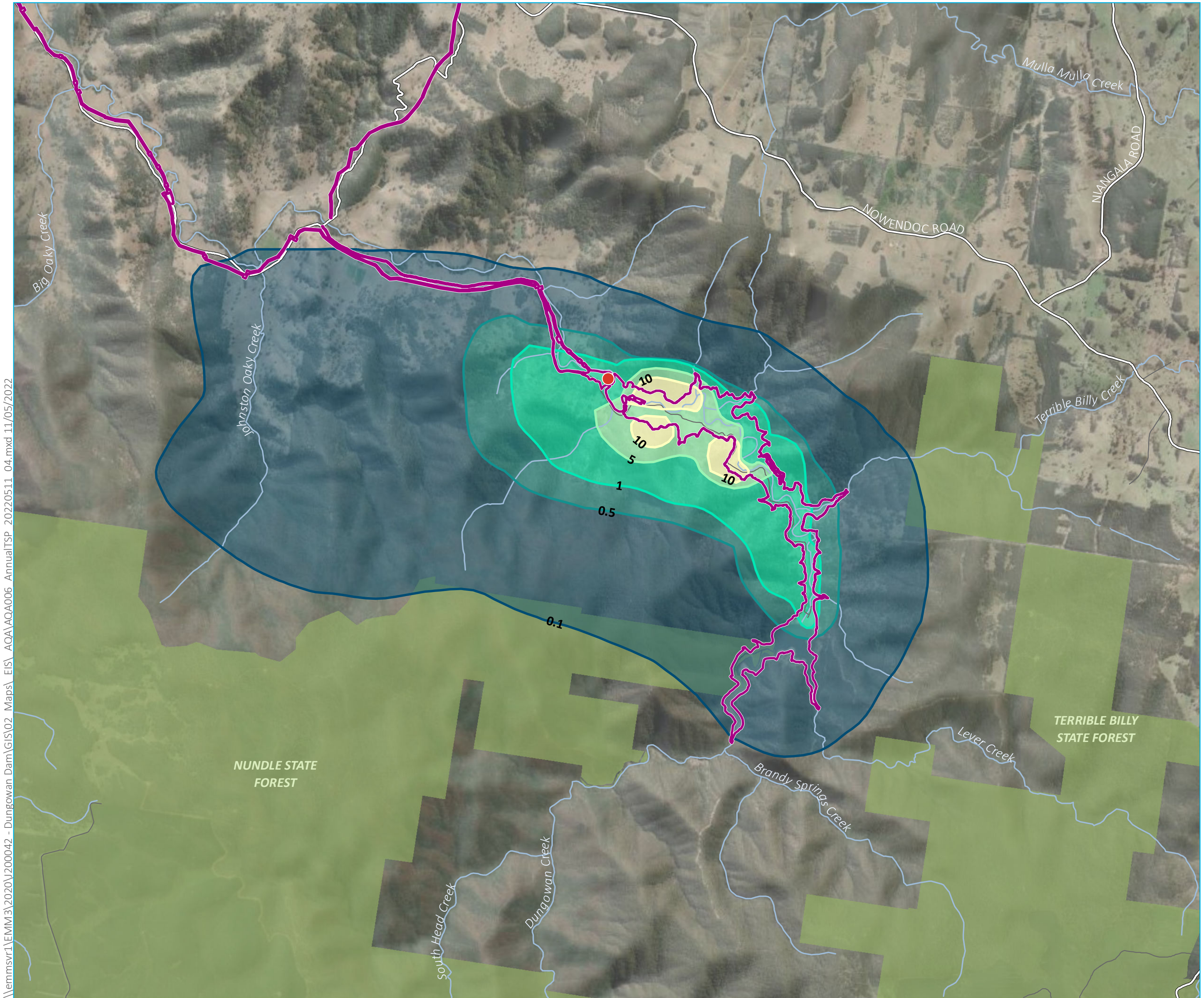
Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

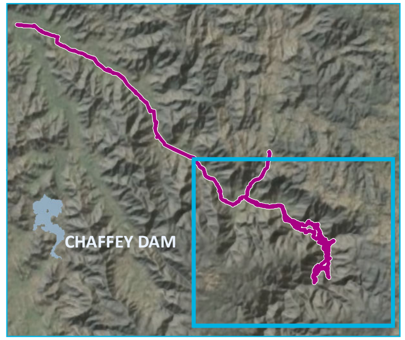
\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_AQA\AQA005_AnnualPM25_20220511_04.mxd 11/05/2022

Predicted project only annual average PM2.5 concentration (µg/m³)

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.5

EMM creating opportunities





KEY
- Project footprint
- Accommodation camp assessment location
- Major road
- Minor road
- Named watercourse
- Named waterbody
- State forest

Predicted project only annual average TSP concentration (µg/m³)
- 0.1
- 0.5
- 1
- 5
- 10

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

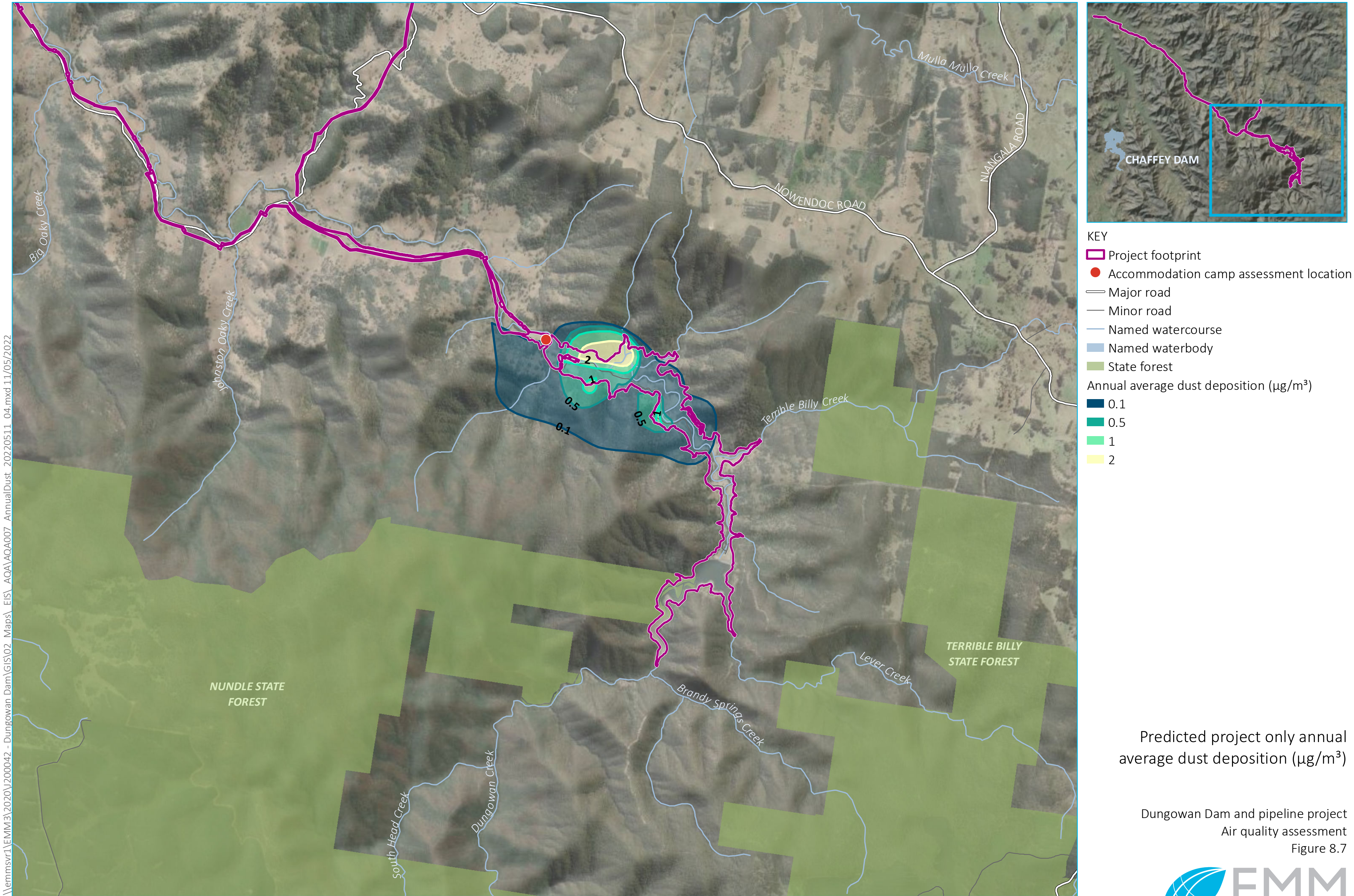
0 1 2 km
GDA 1994 MGA Zone 56
N

\\emmsvr1\EMM3\2020\J200042 - Dungowan Dam\GIS\02_Maps_EIS_AQA\AQA006_AnnualTSP_20220511_04.mxd 11/05/2022

Predicted project only annual average TSP concentration (µg/m³)

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.6

EMM
creating opportunities



\\emmsvr1\EMM3\2020\200042 - Dungowan Dam\GIS\02_Maps_EIS_AQA\AQA007_AnnualDust_20220511_04.mxd 11/05/2022

Source: EMM (2022); WaterNSW (2021); Esri (2019); DFSI (2017); GA (2013)

Predicted project only annual average dust deposition (µg/m³)

Dungowan Dam and pipeline project
Air quality assessment
Figure 8.7

EMM creating opportunities

9 Assessment of vegetation removal and disposal

Vegetation would be cleared to ground level to allow construction of project infrastructure, including the construction compounds/laydown areas, utilities, quarry, new augmented delivery pipeline from the new Dungowan Dam and access roads. All trees within the inundation area and up to 2 m above FSL would be cut to stump height and the stumps left in situ. It is estimated that the following volumes of vegetation waste would be generated by the project:

- 5,500 t woody material from tree removal;
- up to 1,400 t non-woody material; and
- 1,100 t weed infested material requiring treatment (EMM 2022)

The management of vegetation waste would follow the waste hierarchy outlined in the NSW *Waste Avoidance and Resource Recovery Strategy 2014-2021*. It is expected that the majority, and likely all, of the vegetation waste would be re-used or recycled through the construction and rehabilitation of the project. The options for management of vegetation waste that would be implemented and maximum quantities that could be disposed of are outlined in Table 9.1.

The residue from removal of trees such as barks, stems, undergrowth and soil may require disposal (onsite or offsite). A conservative approach towards estimation of residual waste has been applied considering the terrain and sporadic tree density. A wastage of 25% has been assumed, corresponding to up to 1,400 tonnes of non-woody vegetation waste that may be generated by the project on this basis. It is expected that there is sufficient capacity in the proposed rehabilitation areas to recycle all of this waste on site, so disposal of waste is not expected.

Nonetheless, where vegetation waste disposal is required, the residual waste would be pushed into a stockpile within 50 m to 100 m of the clearing area, depending on topography, and controlled burning of the stockpiles would then be undertaken under suitable conditions.

Table 9.1 Vegetation waste management options and indicative volumes

Priority	Waste hierarchy	Indicative maximum volumes required (tonnes)	Waste management activities
1	Avoid and reduce waste	-	Rerouting of infrastructure to avoid maximum possible ground disturbance.
2	Reuse waste	280	Cleared vegetation used onsite or through rehabilitation to provide wildlife habitat.
3	Recycle waste	13,200	Processing as compost or mulch for onsite or offsite use.
4	Recover energy	0	Using removed wood as fuel for power generation or heat.
5	Treat waste	1,100	Destruction of problematic weeds via biological control or herbicides.
6	Dispose waste	1,400	Disposal of residual vegetation at authorised landfills or burning.

9.1 Estimating emissions from open burning

To determine the impacts of open burning on local air quality, a screening level air quality assessment is presented. Emissions were quantified using the US EPA AP-42 emission factors for open burning (US EPA 1992), with emission factors taken from Table 2.5-5, for the category of Forest Residues. Emission factors are expressed as weight of pollutant (kg) per tonne of material burnt.

To derive a conceptual scenario for modelling, it is assumed that each individual burn would dispose of 100 tonnes. Therefore, the total amount of material would be burnt intermittently over 14 burns (for example once a week over a period of approximately three months).

The estimated emissions are presented in Table 9.2. Pollutant emission rates are converted to g/s for modelling based on an assumption that each weekly burn would occur over a single 24-hour period. This is a conservative assumption, as it assumes the total emissions from burning 100 tonnes are released within a 24-hour period. The assessment focuses on emissions of oxides of nitrogen (NO_x), carbon monoxide (CO) and particulate matter. It is assumed that all particulate matter would be within the $PM_{2.5}$ size fraction. The greenhouse gas implications for the various disposal options are addressed in Chapter 11.

Table 9.2 Emission estimates for open burning

Basis	$PM_{2.5}$	Carbon monoxide	Oxides of nitrogen
Kg per burn (100 tonnes)	800	7,000	200
g/s	9.3	11.6	0.3

9.2 Modelling of open burning sources

Indicative locations where vegetation disposal via burning could occur are provided in the Waste Management Assessment (EMM 2022). One of these nominal locations is selected for modelling, in the vicinity of the embankment area, to provide a worst-case assessment of potential impacts on the accommodation camp and the closest occupied residences.

To account for thermal buoyancy, the screening modelling assessment uses a ‘stack’ source, emitted at near ground level (2 m) and with a large diameter (50 m) to account for a horizontal plume spread more likely for a diffuse source such as open burning. A release temperature of 500 K is assumed (to account for thermal buoyancy) with momentum flux turned off so that there is no forced exit velocity (which would normally be applied for a conventional ‘stack’ source).

The increment modelling predictions for open burning are presented in Table 9.3. The modelling assessment focuses on short-term impacts, based on the assumed short-term and intermittent nature of burning activities.

The predicted 1-hour NOx concentration at the accommodation camp is 4.3 $\mu g/m^3$ (1.7% of the impact assessment criteria). Aside from the accommodation camp, the highest predicted 1-hour NOx concentration at an occupied assessment location is 2.0 $\mu g/m^3$ (0.8% of the impact assessment criteria). This is below the DWER screening concentrations (SC) for 1-hour averages (10% of the impact assessment criteria) and therefore not considered significant as a project increment. It is noted that the comparison uses NO_x concentrations to compare against the impact assessment criteria for NO_2. If the atmospheric conversion of NO_x to NO_2 is accounted for, the modelling predictions would be lower.

The predicted 1-hour CO concentration at the accommodation camp is 165 µg/m^3 (0.6% of the impact assessment criteria). Aside from the accommodation camp, the highest predicted 1-hour CO concentration at an occupied assessment location is 79.5 µg/m^3 (0.3% of the impact assessment criteria). This is below the DWER screening concentrations (SC) for 1-hour averages (10% of the impact assessment criteria) and therefore not considered significant as a project increment.

The predicted 24-hour $PM_{2.5}$ concentration at the accommodation camp is 33.2 µg/m^3 (133% of the impact assessment criteria). Aside from the accommodation camp, the highest predicted 24-hour $PM_{2.5}$ concentration at an occupied assessment location is 14.8 µg/m^3 (59% of the impact assessment criteria). Open burning has the potential, therefore, to add additional days over the impact assessment criteria for 24-hour average PM_{10} and $PM_{2.5}$ (when considered with the cumulative modelling results presented in Table 8.2 for dust impacts from other construction activities). Therefore, careful consideration of the location and periods selected for burning is a key management measure for the project (refer Section 9.3).

Table 9.3 Predicted ground level concentrations from open burning

ID	$PM_{2.5}$ (µg/m^3)	NOx (µg/m^3)	CO (µg/m^3)
	24-hour average	1-hour average	1-hour average
	Impact assessment criteria		
	25 µg/m^3	246 µg/m^3	30,000 µg/m^3
C_1	33.2	4.3	166
R_1	36.0	5.6	221
R_2	35.6	5.6	219
R_3	39.0	6.0	234
R_4	39.5	6.0	236
R_5	37.3	6.2	247
R_6	19.0	3.0	117
R_7	25.1	3.9	155
R_8	18.8	3.7	148
R_9	36.4	4.3	169
R_10	87.0	9.9	395
R_11	202.3	39.9	1545
R_12	309.3	32.5	1265
R_13	170.3	17.3	671
R_14	14.8	2.0	78
R_15	13.8	1.8	69
R_16	14.6	1.9	72
R_17	9.4	2.0	79
R_18	8.6	1.8	74
R_19	14.5	1.3	49

Table 9.3 Predicted ground level concentrations from open burning

ID	$PM_{2.5}$ (µg/m³)	NOx (µg/m³)	CO (µg/m³)
	24-hour average	1-hour average	1-hour average
	Impact assessment criteria		
	25 µg/m³	246 µg/m³	30,000 µg/m³
R_20	9.0	1.0	41
R_21	6.7	1.0	39
R_22	6.4	0.9	35
R_23	9.5	1.0	41
R_24	8.6	1.1	41
R_25	5.9	0.9	35
R_26	6.0	0.9	36
R_27	6.4	0.9	36
R_28	5.7	0.9	35
R_29	9.5	0.9	35
R_30	7.6	0.9	35
R_31	7.8	0.9	35
R_32	9.6	0.8	32
R_33	8.3	0.9	34
R_34	5.9	0.9	35
R_35	8.2	0.6	25
R_36	3.6	0.7	28
R_37	2.9	0.6	23
R_38	2.9	0.6	25
R_39	2.7	0.6	23
R_40	2.7	0.5	22
R_41	2.6	0.4	17
R_42	2.5	0.4	18
R_43	4.1	0.6	23
R_44	1.8	0.4	15
R_45	1.8	0.4	14
R_46	1.9	0.4	17
R_47	1.6	0.4	16
R_48	1.4	0.4	16

Table 9.3 Predicted ground level concentrations from open burning

ID	$PM_{2.5}$ (µg/m³)	NOx (µg/m³)	CO (µg/m³)
	24-hour average	1-hour average	1-hour average
	Impact assessment criteria		
	25 µg/m³	246 µg/m³	30,000 µg/m³
R_49	1.4	0.4	14
R_50	1.5	0.4	14
R_51	1.6	0.3	13
R_52	2.2	0.4	15
R_53	1.8	0.4	17
R_54	1.1	0.2	9
R_55	1.2	0.3	11
R_56	0.9	0.2	8
R_57	1.7	0.3	10
R_58	1.1	0.2	7
R_59	5.4	0.5	20

9.3 Proposed management measures for open burning

To manage and reduce the local air quality impacts during open burning, periods of poor dispersion should be avoided, such as stable atmospheric conditions. The maximum 1-hour average $PM_{2.5}$ concentrations at the accommodation camp are presented in Figure 9.1 by hour of the day and in Figure 9.2 by month of the year. The analysis shows that concentrations are higher during the early mornings, evenings and overnight and from April to August.

Therefore, in addition to selecting a location that is as far as possible from the accommodation camp and occupied residences, open burning could be planned for daytime hours only with avoidance of smouldering overnight where possible. Burning during warmer months may also provide a benefit for local air quality impacts, however scheduling would also have to consider bushfire risk and fire bans, which may override short-term risks to local air quality. These measures would be included in the Air Quality Management Plan (see Chapter 12).

As described previously, the management of vegetation waste would follow the waste hierarchy and it is expected that the majority, and likely all, of the vegetation waste would be re-used or recycled and open burning would not be required.

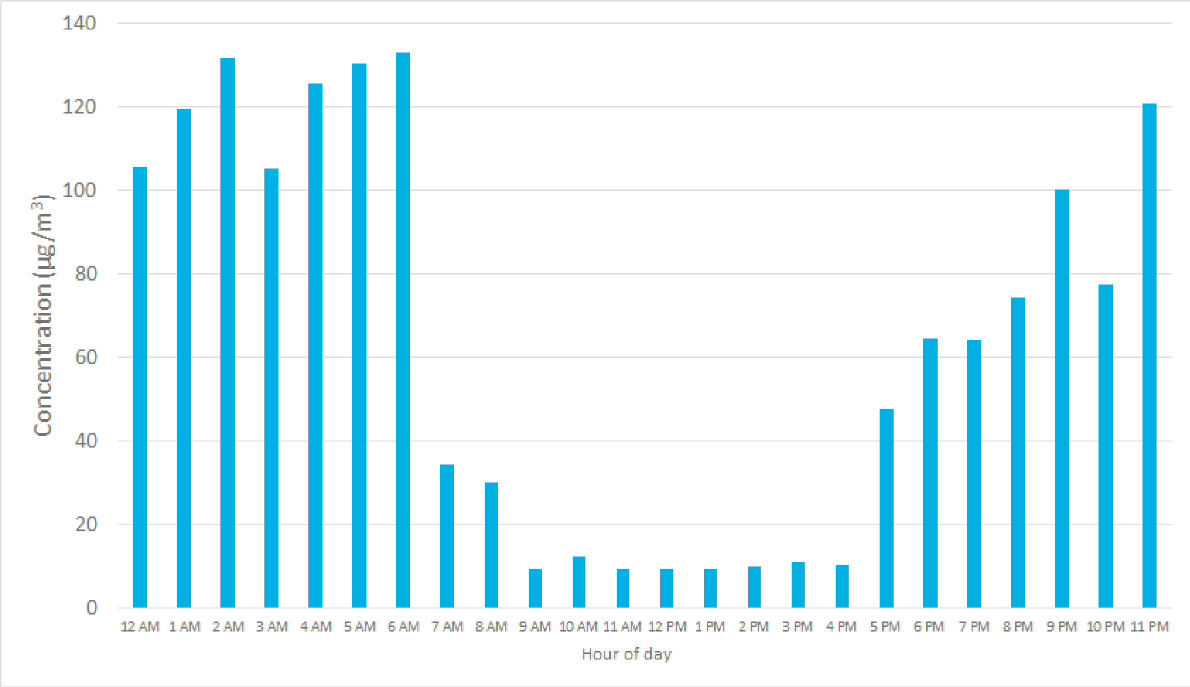


Figure 9.1 **Maximum 1-hour $PM_{2.5}$ concentration by hour of the day**

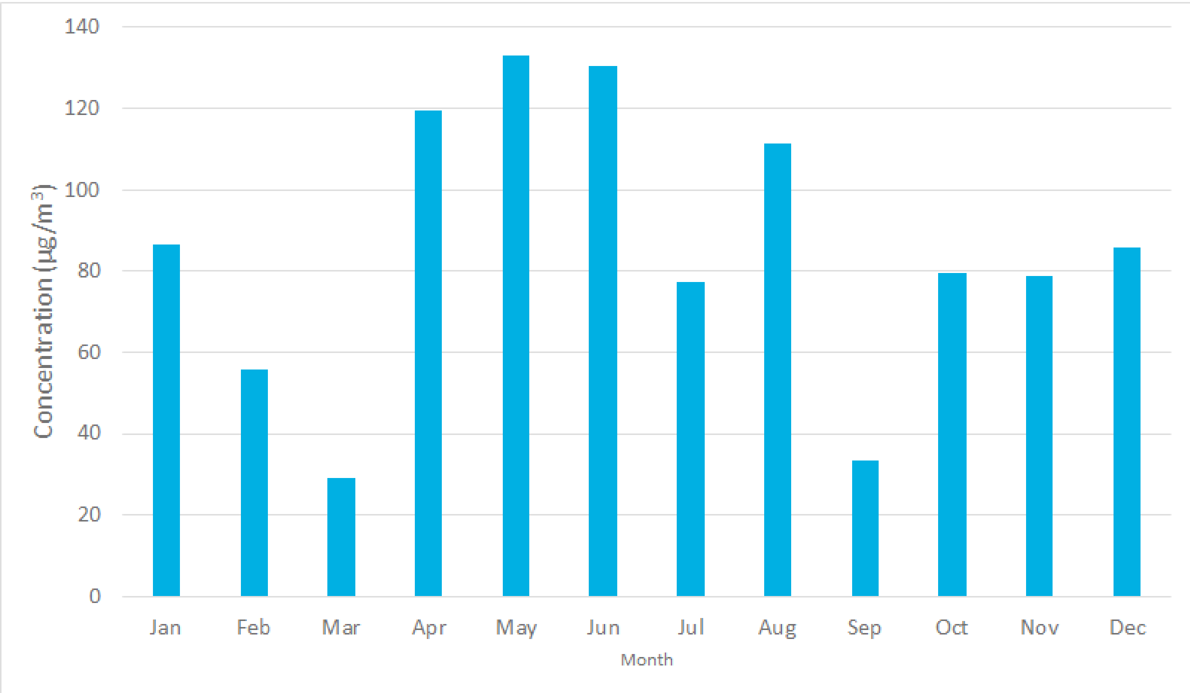


Figure 9.2 **Maximum 1-hour $PM_{2.5}$ concentration by month of the year**

10 Qualitative assessment of other construction phases

10.1 Methodology

The pipeline and powerline construction and the decommissioning of the existing dam activities are not concurrent emissions sources for the modelled emissions scenario. Based on the low-risk nature of these activities, the air quality impact of these activities are assessed using a qualitative assessment approach. It is noted that other aspects of construction that were not included in the modelled emissions scenario (access roads, accommodation camp, construction compound), are not assessed in this qualitative assessment as the receptors that are potentially impacted by these activities are the same as those assessed by the worst-case modelled emissions scenario.

While no specific methodology for such an assessment is available in Australia, the UK-based Institute of Air Quality Management (IAQM) has prepared the *Guidance on the Assessment of Dust from Demolition and Construction* (hereafter GADDC, IAQM 2014). The GADDC has been applied for construction projects in NSW and accepted by the NSW EPA as a progressive approach to assessing the particulate matter impact risk associated with short term construction and demolition projects. This is considered an appropriate methodology due to the short term and transient nature of construction works required for the pipeline, powerline and dam decommissioning.

The key steps to the GADDC approach in assessing air quality risks from construction and demolition projects are as follows:

- STEP 1 – screen requirement for a more detailed assessment based on proximity of surrounding receptors;
- STEP 2 – assess the risk of dust impacts from demolition, earthworks, construction and truck movements and the sensitivity of surrounding receptors;
- STEP 3 – determine the site-specific mitigation for each of the four potential activities in STEP 2;
- STEP 4 – examine the residual effects and determine significance; and
- STEP 5 – prepare dust assessment report.

10.2 Assessment of pipeline and powerline construction

10.2.1 Step 1 – Screen the need for a detailed assessment

Screening criteria for a detailed assessment is presented in Box 1 of Section 6 of the GADDC. The IAQM specify that if a human receptor is located within 350 m of the boundary of a site, or within 50 m of a route used by construction vehicles up to 500 m from the site entrance, then a detailed construction dust assessment should be undertaken.

A new section of pipeline about 32 km long, would be constructed between the new Dungowan Dam outlet and the tie in point to the newly constructed replacement pipeline from Dungowan Showground to the Calala WTP.

In addition, a new 4.2 km long 11 kV overhead powerline (including a new easement and access track) would be constructed connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.

The preferred pipeline alignment was reviewed for sensitive receptor locations located within 350 m of the pipeline construction corridor. The route passes through sparsely populated rural areas, commencing at the southern end of Dungowan village and passing through the village of Ogunbil. A total of 86 individual residences are estimated to be within 350 m of the construction footprint for the pipeline. In addition, the new powerline alignment would bring construction works within 350 m of one additional residence.

Consequently, the proposed construction activities trigger the GADDC criteria to undertake a more detailed assessment of dust impacts from proposed construction activities.

10.2.2 Step 2 - Assess the risk of dust impacts

The GADDC identifies that the risk category for dust impacts from construction activities should be allocated based on the following factors:

- the scale and nature of works (STEP 2A); and
- the sensitivity of the area to dust impacts (STEP 2B).

These factors are then combined to determine the risk of impacts from the works (STEP 2C). The risk rating process is addressed in the following sections.

i STEP 2A – Scale and nature of works

Section 7.2 of the GADDC requires that in allocating dust impact risk, the scale and nature of the following components are to be determined:

- demolition;
- earthworks;
- construction; and
- truck track out.

The GADDC prescribes a range of criteria that classify the magnitude of each activity as either large, medium or small. The proposed activities relevant to each component have been reviewed to allocate a dust emission magnitude in accordance with the GADDC guidance. The allocated dust emission magnitude ratings are presented in the following sections.

a Demolition phase

There are no significant demolition activities associated with the construction of the pipeline or powerline. Consequently, a 'negligible' dust emission magnitude rating has been allocated.

b Earthworks phase

The key features of the earthworks phase of the project include:

- open trenching and backfilling of material along the entire alignment of the proposed pipeline which would proceed in sections generally ranging from 50 metres to 200 metres per day;
- excavators used to dig the trench, with topsoil separated and then spoil stockpiled adjacent to the trench for backfilling after the pipeline is installed;
- the excavated trench would typically be up to 2.2 m deep and up to 4 m in width;

- approximately 2,000 m^3 of material would be excavated per day for the pipeline, the majority of which would be reused during the construction either through backfilling or in the construction of other infrastructure components; and

- excavation of footings for the new overhead powerline alignment.

Per GADDC, the site can be segregated into 'zones' for the dust risk assessment. At most, 2,800 m^2 of site earthworks would occur for the pipeline within a zone extending 350 m from a receptor (700 m length × 4 m width). This is expected to be more than earthworks required for the new powerline alignment, therefore applying the GADDC classification criteria, a dust emission magnitude rating of 'medium' is allocated, as a worse-case, to the earthworks phase (for both the pipeline and powerline).

c Construction phase

There are limited built permanent structures associated with the proposed pipeline, with a total footprint of approximately 0.8 hectares. There would be built structures associated with the above-ground pressure reduction valves, however these would be of low volume and constructed with materials with low potential for dust generation (concrete, metal). The pipeline segments would be laid in the excavated trench and backfilled. Similarly, there are limited built structures associated with the new powerline alignment.

Based on the GADDC classification criteria, a dust emission magnitude rating of 'small' is allocated to the construction phase (for both the pipeline and powerline).

d Truck track-out

The majority of truck movements associated with construction would be associated with the delivery of pipeline segments and raw materials for both the pipeline and overhead powerline. The majority of excavated material would be stockpiled, for example at the active area of earthworks for backfilling. Consequently, there is limited potential for truck track-out associated with the proposed pipeline or powerline alignment. As a worse case, it is estimated that there would be approximately 20 heavy vehicle movements per day for earthmoving, refuelling and pipe and raw material deliveries, along the pipeline and/or powerline alignment route. Based on the above and the GADDC classification criteria, a dust emission magnitude rating of 'medium' is allocated to the truck track-out of dust to public roads from the project.

e Summary of dust emission potential

The dust emission magnitude ratings for the project are summarised in Table 10.1.

Table 10.1 Summary of dust emission magnitude

Activity	Project details	Potential dust emission magnitude
Demolition	No demolition required.	Nil
Earthworks	Less than 20,000 tonnes of material would be excavated for a nominal work zone, which would classify the earthworks component as 'small'. However, a nominal works area of 2800 m^2 for each zone would increase the dust emission magnitude to medium.	Medium
Construction	Limited built permanent structures. Above-ground pressure reduction valves would be low volume and constructed with materials with low potential for dust generation.	Small

Table 10.1 Summary of dust emission magnitude

Activity	Project details	Potential dust emission magnitude
Track-out	Approximately 20 heavy vehicle movements per day for earthmoving, refuelling and pipe deliveries from ancillary facilities to along the pipeline route	Medium

ii Step 2B – Sensitivity of area

Section 7.3 of the GADDC details the approach to categorise the sensitivity of the surrounding environment reviewing the following factors:

- the specific sensitivities of receptors in the area;
- the proximity and number of those receptors; and
- local ambient concentrations of PM_{10} and likelihood of impact to human health.

a Specific sensitivities of receptors in the area – human and ecological

Section 7.3 of the GADDC provides classification definitions of receptor sensitivities to dust soiling, human health and ecological effects. The classification definitions in the GADDC were used to classify the sensitivity of receptors in the vicinity of the proposed pipeline alignment.

For human health and dust soiling impacts, human receptors in the area were allocated a 'high' sensitivity rating (Table 10.2), on the basis that:

- receptors are largely residential, where residences can reasonably expect enjoyment of a high level of amenity; or
- the appearance, aesthetics or value of their property would be diminished by soiling.

For ecological receptors affected by construction activities, the majority of the pipeline and powerline route passes through land that has been cleared for agricultural or residential purposes. However, the biodiversity assessment completed as part of this EIS identified a number of areas of native vegetation within and adjacent to the pipeline and powerline route, including hollow bearing trees and vegetation associated with threatened ecological communities. Ecological receptors were given a 'medium' sensitivity as they fit the GADDC criteria for locations where there is an important plant species but where dust sensitivity is uncertain, and locations with a national designation where features may be affected by dust deposition.

A summary of the receptor sensitivity to dust impacts is provided in Table 10.2.

Table 10.2 Summary of human and ecological receptor sensitivity to dust impacts

Activity	Human receptor sensitivity	Ecological receptor sensitivity
Demolition	NA	NA
Earthworks	High	Medium
Construction	High	Medium
Track-out	High	Medium

b Proximity and number of human receptors in the area

As stated previously, there are approximately 86 individual residential lots within 350 m of the pipeline construction footprint and one additional residence within 350 m of the powerline. The average number of people per dwelling for the Tamworth region in the 2016 Census[7] was 2.4, therefore an estimated 200 people are assumed to live within 350 m of the pipeline.

c Sensitivity rating of the local area to dust soiling effects

The receptor sensitivity to dust soiling effects (high) was combined with the number of human receptors in proximity to the construction area and the criteria listed in Table 10.3 (as documented in Table 2 the GADDC).

Table 10.3 Sensitivity rating criteria for dust soiling effects on people and property

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

Notes: Table source: Table 2 of GADDC

Dust impacts from soiling are unlikely beyond 350 m from the active trenching area. The number of receptors within 20 m of the pipeline route, for a nominal 350 m impact zone is likely to be between 1-10. There may be slightly more receptors within 50 m of the pipeline route, for the same nominal 350 m impact zone. Therefore, a sensitivity to dust soiling effects to people and property of 'medium' was allocated for the local area surrounding the pipeline construction footprint (Table 10.4). This is also adopted as a conservative rating for the new powerline alignment, which only effect one resident within 350m of the route.

7 https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SED10081

Table 10.4 Summary of sensitivity to dust soiling impacts

Activity	Sensitivity of local area to dust soiling impacts
Demolition	NA
Earthworks	Medium
Construction	Medium
Track-out	Medium

d Local ambient concentrations of PM_{10} and sensitivity of area to human health impacts

As presented in Chapter 6, baseline air quality for the project area has been characterised using data from the NSW DPE Tamworth AQMS. The period average PM_{10} concentration recorded between 2010 and 2018 was 15.3 µg/m³, which is applied for characterising baseline air quality along the pipeline alignment.

Combining the receptor sensitivity to human health effects (high) with the criteria listed in Table 10.5 (as documented in Table 3 the GADDC), a sensitivity to human health impacts of 'low' is allocated for the area along the pipeline alignment (summarised in Table 10.6).

Table 10.5 Sensitivity criteria for human health impacts

Receptor sensitivity	Annual mean PM_{10} concentration	Number of receptors	Distance from the source (m)				
			<20	<50	<100	<200	<350
High	>25 µg/m³	>100	High	High	High	Medium	Low
		10-100	High	High	Medium	Low	Low
		1-10	High	Medium	Low	Low	Low
	22 - 25 µg/m³	>100	High	High	Medium	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	High	Medium	Low	Low	Low
	19 - 22 µg/m³	>100	High	Medium	Low	Low	Low
		10-100	High	Medium	Low	Low	Low
		1-10	Medium	Low	Low	Low	Low
	<19 µg/m³	>100	Medium	Low	Low	Low	Low
		10-100	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
Medium	>25 µg/m³	>10	High	Medium	Low	Low	Low
		1-10	Medium	Low	Low	Low	Low
	22 - 25 µg/m³	>10	Medium	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
	19 - 22 µg/m³	>10	Low	Low	Low	Low	Low

Table 10.5 Sensitivity criteria for human health impacts

Receptor sensitivity	Annual mean PM_{10} concentration	Number of receptors	Distance from the source (m)				
			<20	<50	<100	<200	<350
		1-10	Low	Low	Low	Low	Low
	<19 µg/m³	>10	Low	Low	Low	Low	Low
		1-10	Low	Low	Low	Low	Low
Low	-	>1	Low	Low	Low	Low	Low

Notes: Table source: Table 3 of GADDC. It is noted that the PM_{10} concentrations have been adjusted from the GADDC to meet the NSW EPA criteria for annual average PM_{10}.

Table 10.6 Summary of sensitivity to human health impacts

Activity	Sensitivity of local area to human health impacts
Demolition	NA
Earthworks	Low
Construction	Low
Track-out	Low

e Ecological impacts

The sensitivity of the local area to ecological impacts is defined based on the sensitivity of ecological receptors and their distance from the construction activity. A sensitivity rating of medium was applied to the ecological receptors along the pipeline route.

Combining a sensitivity rating of medium with a distance of less than 20m to the works, under the GADDC criteria the sensitivity of the area to ecological impacts was determined to be 'medium' (Table 10.7).

Table 10.7 Summary of sensitivity to ecological impacts

Activity	Sensitivity of area to ecological impacts
Demolition	NA
Earthworks	Medium
Construction	Medium
Track-out	Medium

iii STEP 2C – Define the risk of impacts

To determine the risk of impacts with no mitigation applied, Section 7.4 of the GADDC requires that the dust magnitude rating (refer Table 10.1) is combined with the sensitivity rating of receptors in the surrounding area (refer to Table 10.4 and Table 10.6 and Table 10.7).

The risk ratings for each type of activity were allocated and are presented in Table 10.8. The risk rating allocated a low to medium risk for dust soiling, human health and ecological impacts from earthworks, construction and truck track-out related activities. A negligible risk rating was allocated to demolition activities.

Table 10.8 Summary of risk assessment

Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
		Dust soiling	Human health	Ecological	Dust soiling	Human health	Ecological
Demolition	Negligible	NA	NA	NA	Negligible	Negligible	Negligible
Earthworks	Medium	Medium	Low	Medium	Medium	Low	Medium
Construction	Small	Medium	Low	Medium	Low	Negligible	Low
Track-out	Medium	Medium	Low	Medium	Medium	Low	Medium

10.2.3 Step 3 - Safeguards and mitigation measures

The dust impact risk allocation in Table 10.8 relates to unmitigated construction dust emissions. Step 3 involves determining mitigation measures for each of the four potential activities in Step 2 to further reduce the residual risk for impacts to the surrounding area. This was based on the risk of dust impacts identified in Step 2C.

Recommended construction dust mitigation measures are listed in Chapter 12. These mitigation measures would proposed to be adopted and further addressed within an Air Quality Management Plan (AQMP), which will be prepared and implemented as part of the Construction Environment Management Plan (CEMP) for the project.

10.2.4 Step 4 - Significance of risks

Once the appropriate dust mitigation measures have been identified in Step 3, the next step in the GADDC is to determine whether there are residual significant effects arising from the construction phase of a proposed development. For almost all construction activities the aim should be to prevent significant effects on receptors through effective mitigation resulting in residual effect being 'not significant' (IAQM 2014).

As identified in Table 10.8, there is a low to medium risk rating for dust soiling impacts, human health impacts and ecological impacts at surrounding sensitive receptors from uncontrolled emissions from earthworks, construction and truck track-out emissions during pipeline and powerline construction. With the successful implementation of the recommended dust mitigation measures listed in Chapter 12, the risk of dust soiling or human health and ecological impacts is expected to not be significant.

10.3 Decommissioning of existing dam

Step 1 is to screen the requirement for a more detailed assessment, with no further assessment required if there are no receptors within a certain distance from the works. The distance-based screening criteria are as follows:

- a 'human receptor' is located within:
  - 350 m of the boundary of a site; or
  - 50 m of a route used by construction vehicles, up to 500 m from the site entrance.
- an 'ecological receptor' is located within:

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

The outcome of the screening assessment is as follows:

- the closest residential properties are located more than 3.5 km from the existing dam, therefore the decommissioning does not trigger the requirement for a detailed assessment for human receptors;
- the closest sensitive ecological community is located more than 350 m from the existing dam, therefore the decommissioning does not trigger the requirement for a detailed assessment for ecological receptors.

Where the need for a more detailed assessment is screened out, the GADDC concludes that the level of risk is “negligible” and consequent effects would be negligible. No further assessment of dam decommissioning is therefore required.

11 Greenhouse gas assessment

11.1 Introduction

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 and 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 2021).

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 downstream extraction and production of raw materials or the upstream use of products and services. Quantitative assessment of Scope 1, 2 and 3 emissions of the project are required by the SEARs. Notwithstanding, 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 GHG intensity of products or services.

Greenhouse gas emissions are presented as carbon dioxide equivalents (CO_2-e) and include emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide N_2O) calculated based on the Global Warming Potentials (GWPs) adopted by the Parties to the UN Framework Convention on Climate Change and its Kyoto Protocol (reported in DISER 2021).

11.2 Emission sources and scope of the assessment

GHG emissions during construction include Scope 1 emissions associated with the combustion of fuel (diesel) by onsite plant and equipment and emissions released from explosive use for rock extraction. Although not a direct source of GHG emissions, vegetation stripping and tree removal during construction would result in the loss of a carbon sink and is categorised as a Scope 1 emission source for the construction phase. The disposal or use of cleared vegetation also results in GHG emissions, the significance of which is dependent on the disposal/re-use method.

Scope 2 emissions during construction would be limited to consumption of electricity by site offices and the accommodation camp. Scope 3 emissions would occur from offsite production of construction materials such as aggregate and steel and emissions from the combustion of fuel when transporting materials and staff.

GHG emissions during the operation phase of the project also includes direct (Scope 1) emissions associated with the combustion of fuel and indirect (Scope 2) emissions associated with electricity use for operation of the dam. There would also be GHG emissions from the decomposition of carbon in submerged soil and vegetation within the inundation zone and very minor Scope 3 emissions from waste generated during operation.

The GHG emissions sources considered in this assessment is summarised in Table 11.1.

Table 11.1 Summary of GHG emission sources included in assessment

Phase	Source	Type
Construction	Onsite fuel combustion	Scope 1
	Direct emissions from explosive use	Scope 1
	Employee travel to site (via bus)	Scope 1
	Electricity consumption during construction	Scope 2
	Loss of carbon sink from vegetation stripping within construction footprint and inundation zone	Scope 1
	Onsite burning of removed vegetation	Scope 1
	Onsite decomposition of removed vegetation	Scope 1
	Upstream raw materials - extraction and transport of aggregates	Scope 3
	Upstream raw materials - production and transport of steel	Scope 3
	Upstream raw materials - production and transport of cement	Scope 3
	Decomposition of waste in landfill	Scope 3
Operation	Fuel combustion in employee vehicles	Scope 1
	Electricity consumption during operation of the dam	Scope 2
	Decomposition of above and below ground organic material within inundation zone	Scope 1
	Decomposition of waste in landfill	Scope 3

11.3 Construction phase GHG emissions

11.3.1 Scope 1 GHG emissions from fuel and explosive use

The total diesel consumption for the construction period is estimated at 9.737 million litres (ML). Approximately 80% of the total diesel consumption would occur from year 2 to year 4 (with the remaining occurring in year 1 (approximately 11%), year 5 (11%) and year 6 (4%). Diesel generators would provide power for the concrete batch plant and lighting.

An estimate of explosive usage is made based on an assumed intensity factor of 0.0002 tonnes explosive per tonne of extracted material[8]. Assuming 90% of the total embankment volume is rockfill, this equates to approximately 4 Mt of blasted rock and approximately 800 tonnes of explosive. It is assumed that all of the explosive use occurs between year 1 and year 4 of construction (approximately corresponding to quarry operation and excavation of the spillway), split evenly across the four years.

Scope 1 GHG emissions during construction are estimated using the methodologies outlined in the National Greenhouse Accounts Factors (NGAF) workbook (DISER 2021) and using fuel energy contents and emission factors for diesel and explosives, as follows:

- diesel consumption on-site (scope 1) – diesel oil factors from Table 3 of the NGAF workbook (2021); and

[8] Derived from explosive use in the mining and extractive sector.

- explosives use (scope 1) - emission factor for ammonium nitrate/fuel oil (ANFO), Note, this is taken from the 2008 NGAF workbook as it has been removed from subsequent workbooks.

The estimated annual GHG emissions for each emission source are presented in Table 11.2.

Table 11.2 Estimated annual scope 1 GHG emissions during construction

Project year	Scope 1 (t CO_2-e/year)	
	Diesel	Explosives
Year 1	1,721	34
Year 2	4,830	34
Year 3	7,186	34
Year 4	8,712	34
Year 5	2,804	0
Year 6	1,083	0
Annual average	**4,389**	**23**
Total	**26,336**	**137**

11.3.2 Scope 1 emissions from vegetation removal

Emissions from vegetation clearing are considered in two ways. Firstly, the net impact of vegetation clearing is less carbon dioxide (CO_2) being removed from the atmosphere (through loss of a carbon sink) and, for the purpose of this assessment, emissions are expressed as an equivalent amount of CO_2 remaining in the atmosphere. Secondly, the disposal or use of cleared vegetation also results in GHG emissions, the significance of which is dependent on the disposal/re-use method. GHG emissions from the combustion of fuel in equipment used for vegetation removal is also included in the estimates provided in Section 11.3.

i Loss of a carbon sink

The construction footprint (embankment, spillway, quarry, borrow area, construction compound, powerlines and pipeline corridor) would be cleared of trees and grassland. In addition, the entire inundation footprint would be cleared of trees prior to flooding.

As described in Section 9.1, the following volumes of vegetation waste generated by the project are:

- 5,500 t woody material from tree removal;
- up to 1,400 t non-woody material; and
- 1,100 t weed infested material requiring treatment.

Emissions from vegetation clearing are estimated based on a methodology developed by Australian state road authorities and NZ Transport Agency, under the banner of the Transport Authorities Greenhouse Group (TAGG 2013). The TAGG (2013) workbook methodology for vegetation clearing results in a conservatively high estimate in that it assumes that all carbon pools are removed, all carbon removed is converted to CO_2 and released, and sequestration from revegetation is not included.

Emission factors are provided in the TAGG workbook for defined vegetation classes (A to I) corresponding to potential maximum biomass classes (expressed as tonnes dry matter per hectare). Based on the estimated tonnes of vegetation removed for the project (~8,000 tonnes), a maximum biomass class of 2 appears most appropriate for the site, corresponding to a value of 50 tonnes dry matter per hectare.

A summary of the input data and emission estimates for vegetation clearing is provided in Table 11.3. Unlike the emission estimates presented in Table 11.2, the emission estimates are not expressed on a per annum basis. Instead, they represent the total emissions that would have otherwise been sequestered for the period that the vegetation would have remained under a business as usual scenario. It is assumed that most of the lost carbon sink would be replaced through the biodiversity offset plan for removed vegetation, however this is not considered in the GHG assessment.

Table 11.3 Summary of vegetation type, class and areas to be cleared and estimated emissions from vegetation clearing

Type	Disturbance footprint (ha)	Maxbio class[9] (t dry matter/ha)	Assigned vegetation class	Emission factor (t CO_2-e/ha)	GHG emissions (t CO_2-e)
Open eucalypt forest	Construction footprint – 86.4 ha (including powerlines and pipeline)	Class 1 (50-100)	C (open forest)	209	18,058
	Inundation area - 86 ha (excluding areas already disturbed)	Class 1 (50-100)	C (open forest)	209	17, 974
Grassland	Construction footprint – 37.9 ha (including powerlines and pipeline)	NA	I (grassland)	110	4,169

ii Vegetation reuse and disposal

Most of the removed vegetation would be re-used (as wildlife habitat, walkway delineation, silt control) or recycled (as mulch, compost or woodchips). When left to decompose naturally, the rate at which GHGs are emitted is very slow and considered negligible for this assessment.

As discussed in Section 9, a small amount of non-woody vegetation may be burned. As reported in the National Greenhouse Accounts Factors (NGAF) workbook (Department of Industry, Science, Energy and Resources [DISER] 2021), under the IPCC[10] Guidelines for National GHG Inventories (IPCC 2016), the emission factor for CO_2 released from combustion of biogenic carbon fuels is reported as zero, with emissions and removal of CO_2, based on changes to carbon stocks, estimated and reported under land-use change categories. For example, it is assumed that carbon emitted from burning would be replaced by re-growth as part of the biodiversity offset plan for removed vegetation.

Emissions of CO_2-e from open burning are therefore estimated for methane only, using the US EPA AP-42 emission factors for open burning (US EPA 1992). Using a methane emission factor of 2.8 kg/tonne, a GWP of 28 and up to 1,400 tonnes of vegetation to be burnt, annual emissions of 109.8 t CO_2-e are estimated.

9 Maximum potential biomass class

10 Intergovernmental Panel on Climate Change

11.3.3 Scope 2 emissions from electricity use

There is existing power supply to properties within the project area, therefore it is expected that a temporary connection to the grid would be established for the construction compound and accommodation camp. The quantity of electricity used is estimated based on an average per capita electricity consumption rate of 8,550 kWh per annum (derived from the electricity consumption for NSW in 2019 divided by the population[11]) and multiplied by the expected construction workforce (140). The NGAF workbook emission factors for purchased electricity are used to estimate annual emissions of 970 t CO_2-e.

11.3.4 Scope 3 emissions from waste generated during construction

Bulk construction and demolition (C&D) waste is largely inert and would likely be recovered/recycled for re-use, therefore GHG emissions are expected to be minimal. Waste generated by employees within the construction compound and accommodation camp is estimated based on an Australian average per capita waste consumption rate of 560 kg[12] per annum and a construction workforce of 125 people, resulting in a total construction waste production of 70 tonnes per annum.

The NGAF workbook emission factor for landfilling municipal solid waste (1.6 t CO_2-e / tonne) is used to estimate total emissions of 112 t CO_2-e.

11.3.5 Scope 3 emissions from the upstream supply of raw material

GHG emissions associated with the upstream supply of raw materials (aggregate and steel) are estimated using the emission factors provided for construction materials in the TAGG (2013) workbook, as follows:

- 0.005 t CO_2-e/tonne for aggregate;
- 0.82 t CO_2-e/tonne for Portland cement; and
- 1.05 t CO_2-e/tonne for structural steel.

Approximately 250,000 tonnes of aggregate would be required from external sources (to supplement what is extracted from the quarry areas). An estimate of the project's steel requirement (rebars) in tonnes is calculated as 0.5% of the total concrete volume. The project's concrete requirement (approximately 140,000 m^3) is estimated from the reported concrete aggregate requirement of 58,000 m^3 plus an equivalent sand and cement requirement (using a ratio of 1:2:4 for cement, sand and aggregate).

The GHG emissions associated with the transport of raw materials to site are estimated using the diesel oil emission factors from Table 3 of the NGAF workbook and fuel consumption estimated as follows:

- For aggregates deliveries a return trip of 100 km is assumed (local quarry) with each trip delivering 30 tonnes. Fuel consumption is calculated using the diesel fuel consumption rate of 0.552 litres per km for articulated trucks (ABS 2020).
- For cement deliveries a return trip of 114 km is assumed (Tamworth) with each trip delivering 20 tonnes. Fuel consumption is calculated using the diesel fuel consumption rate of 0.552 litres per km for articulated trucks (ABS 2020).

[11] https://www.aer.gov.au/wholesale-markets/wholesale-statistics/annual-electricity-consumption-nem

[12] https://www.environment.gov.au/system/files/resources/7381c1de-31d0-429b-912c-91a6dbc83af7/files/national-waste-report-2018.pdf

- For steel deliveries a return trip of 114 km is assumed (Tamworth) with each trip delivering 30 tonnes. Fuel consumption is calculated using the diesel fuel consumption rate of 0.552 litres per km for articulated trucks (ABS 2020).

A summary of the Scope 3 emissions from raw materials is presented in Table 11.4.

Table 11.4 Summary of Scope 3 emissions from raw materials (t CO_2-e)

Raw material	Production / extraction	Transport
Cement	27,347	285.6
Aggregates	988.5	1002
Steel	5,831	31.7

11.3.6 Scope 3 emissions from employee travel to site

Employee travel to site is estimated based on a return trip distance of 114 km (Tamworth) and an assumed 2 bus trips per day for 350 days of the year. Fuel consumption is calculated using the diesel fuel consumption rate of 0.284 litres per km for buses (ABS 2020). The diesel oil emission factors from Table 3 of the NGAF workbook are used to estimate annual emissions of 64.8 t CO_2-e.

11.3.7 Significance of emissions

A summary of the GHG emissions for construction are presented in Table 11.5. The significance of direct GHG emissions during construction is compared to annual average GHG emissions for the most recent available GHG accounts for NSW (131,685 kt CO_2-e) and Australia (537,446 kt CO_2-e) [13]. Annual average GHG emissions (scope 1) generated during construction represent approximately 0.005% of total GHG emissions for NSW and 0.001% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018 (AEGIS 2018). The comparison does not include vegetation removal, which represents loss of a carbon sink and is not expressed on a per annum basis.

Table 11.5 Summary of Scope 1, 2 and 3 emissions for construction (t CO_2-e)

Source	Scope 1	Scope 2	Scope 3	Basis
Onsite fuel consumption	4,389		225	Per annum
Explosives	22.8			Per annum
Vegetation stripping and removal of trees	17,444			Lifeline (loss of carbon sink)
Burning of vegetation	109.8			Total for construction period
Electricity use		970	144	Per annum
Employee travel to site (bus)				Per annum
Raw materials - extraction and transport of aggregates			1,990.4	Total for construction period
Raw materials - production and transport of steel			5,863	Total for construction period

[13] Calendar year 2018 emissions taken from http://ageis.climatechange.gov.au/

Table 11.5 Summary of Scope 1, 2 and 3 emissions for construction (t CO_2-e)

Source	Scope 1	Scope 2	Scope 3	Basis
Raw materials - production and transport of cement			27,633	Total for construction period
Waste			112	Per annum
Total	**24,194**	**970**	**36,013**	

11.4 Operation phase GHG emissions

11.4.1 Scope 1 GHG emissions from fuel use

As estimate of diesel consumption for the operation phase is based on two 4WD vehicles travelling from Tamworth on a daily basis plus a backup diesel generator operating, on average, for 1 hour per month. This equates to an annual diesel consumption of approximately 20 kL. The estimated annual GHG emissions for diesel consumption during operations is 54.4 t CO_2-e/year.

11.4.2 Scope 2 GHG emissions from electricity

The annual electricity use for the operation of the new dam is estimated from the electricity consumption for the existing dam. The average monthly consumption for the existing dam, the period from July 2017 to June 2020 is 30,702 kWh, which equates to an annual electricity consumption of 368,427 kWh.

Scope 2 GHG emissions during operations are estimated using the methodologies outlined in the NGAF workbook (2021) and using emission factors for electricity consumption in NSW. The estimated annual GHG emissions from electricity consumption is 298 t CO_2-e/year.

11.4.3 Scope 1 emissions from filling and operation of reservoir

Filling and operation of the reservoir may result in an increase in anaerobic decomposition, converting the organic matter in soil and vegetation to CO_2, methane (CH_4), and nitrous oxide (N_2O).

There is no applicable methodology for estimating emission from flooded reservoirs provided in the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines* (DoE 2014). The closest equivalent methodologies in the guidelines were '*flooding for irrigation in agriculture*' or 'a*nerobic decomposition of vegetation in landfills*'. However, neither option provided the correct mechanism to estimate emission for the project and therefore a literature review was used to identify suitable emission factors.

A comprehensive review of GHG emissions factors was reported in a global review of emissions from reservoirs (*Greenhouse Gas Emissions from Reservoir Water Surfaces*, Deemer et al (2016)). The review collated 267 flux measurements of GHG emissions from reservoirs, including 14 sites in Australia. The review focuses on two of the main emission pathways: diffusive flux (across air-water surface) and ebullition (gas bubbling from sediments). Degassing at spillways (or turbines for hydro storage) can also be a source of GHG emissions, due to sudden changes in pressure and temperature enhancing the rate of emissions, however there are limited measurements from this pathway and emissions from this pathway would only occur when the spillway operates.

Table 1 of Deemer et al (2016) provides emission flux for CO_2, CH_4 and N_2O expressed in mg/m^2/day. These can be combined with the total inundation area to provide an estimate of annual GHG emissions associated with flooding of the inundation zone. The mass emission flux for CO_2, CH_4 and N_2O are converted to CO_2-e using the global warming potential (GWP) of each gas. The emission factors and emission estimates are provided in Table 11.6.

Table 11.6 Estimated emissions from storage of water in the inundation zone

Inundation area (ha)	Emission flux (mg/m²/day)			GHG emissions (t CO_2-e/year)			
	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O	Total
130	120	330	0.3	1,595	157	38	1,789

11.4.4 Scope 3 emissions from waste generated during operation

Waste generated by employees during operations is estimated based on an Australian average per capita waste consumption rate of 560 kg[14] per annum and an assumed operational workforce of 2 full time workers, resulting in a total waste production of 1.1 tonnes per annum. The NGAF workbook emission factor for landfilling municipal solid waste (1.6 t CO_2-e / tonne) is used to estimate annual emissions of 1.8 t CO_2-e.

11.4.5 Significance of emissions

A summary of the estimated GHG emissions for operations is provided in Table 11.7. Annual average GHG emissions (scope 1 and scope 2) generated during operation, including emissions from storage of water in the inundation zone, represent approximately 0.002% of total GHG emissions for NSW and 0.0004% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018.

Table 11.7 Summary of Scope 1, 2 and 3 emissions for operations (t CO_2-e)

Source	Scope 1	Scope 2	Scope 3	Basis
Fuel consumption	54.4		2.8	Per annum
Electricity use		298.4	44.2	Per annum
Waste			1.8	Per annum
Decomposition of vegetation from operation of reservoir	1,789			Per annum
Total	**1,843**	**298.4**	**46.0**	

11.5 GHG emission management

A summary of the measures and practices designed to manage or mitigate project GHG emissions is presented in Table 11.8.

Table 11.8 Summary of GHG mitigation measures

Source	Mitigation proposed
Fuel combustion	Regular maintenance of plant and equipment to optimise fuel consumption
	Efficient scheduling and planning (eg minimising rehandling and haulage of materials) to minimise fuel consumption
	Consideration of fuel efficiency in the plant equipment selection phase

[14] https://www.environment.gov.au/system/files/resources/7381c1de-31d0-429b-912c-91a6dbc83af7/files/national-waste-report-2018.pdf

Table 11.8 Summary of GHG mitigation measures

Source	Mitigation proposed
	All staff would be trained to reduce idling and turn off equipment when not in use
	Use of 10% blended ethanol for all petrol-powered light vehicles, for construction and operation
Electricity	Selection of energy efficient equipment for accommodation camp and construction compound
	Education and signage to encourage energy efficiency at accommodation camp
	Use of motion detectors for lighting in common areas of the accommodation camp
	Commitment to the use of green power for purchased electricity
Raw materials	Procurement of low carbon alternatives where viable (ie use of lower carbon cement alternatives)
	Sourcing materials from local sources where possible
Refrigerants	Use of zero or low GWP refrigerants where possible within accommodation camp
Vegetation stripping	Implementation of a biodiversity offset plan for removed vegetation
Decomposition of vegetation	Ensure removal of all trees within the reservoir area, thereby reducing the available carbon for anerobic decomposition
	Encouraging reuse of the removed vegetation and trees for onsite rehabilitation and avoiding disposal to landfill or burning as firewood

12 Mitigation and monitoring

12.1 Mitigation

Measures that would be implemented to mitigate the project's air quality impacts are outlined in Table 12.1.

Table 12.1 Air quality mitigation measures

Impact	Ref#	Mitigation Measure	Responsible	Timing
Air quality	AR_01	An Air Quality Management Plan (AQMP) would be prepared and implemented as part of the CEMP. The AQMP would include, but not be limited to: • potential sources of air pollution; • air quality management objectives consistent with any relevant published EPA and/or EES/DPE guidelines; • mitigation and suppression measures to be implemented; • methods to manage work during strong winds or other adverse weather conditions; • a progressive rehabilitation strategy for exposed surfaces; and • monitoring of air quality within the project area.	Contractor	Pre-construction Construction Post Construction
Air quality	AR_02	Where reasonable and feasible, appropriate control methods would be implemented to minimise dust emissions from the project site.	Contractor	Pre-construction Construction Post Construction
Air quality	AR_03	Storage of materials that have the potential to result in dust generation would be minimised within project sites at all times.	Contractor	Pre-construction Construction
Air quality	AR_04	Suitable dust suppression and/or collection techniques would be used during cutting, grinding or sawing activities likely to generate dust in close proximity to sensitive receivers.	Contractor	Pre-construction Construction

As described in AR_01 an AQMP would be prepared for both the pipeline and dam infrastructure construction phase which would outline measures to manage dust. Table 12.2 provides a list of further detailed measures that are recommended for consideration as part of the AQMP.

Table 12.2 Recommended AQMP mitigation measures – construction

Impact	Mitigation measure	Responsibility	Timing
Reporting and record keeping	• Develop appropriate communications to notify the potentially impacted residences of the project (duration, types of works, etc), relevant contact details for environmental complaints reporting. • A complaints register should be maintained throughout the construction phase which should include any complaints related to dust. Where a dust complaint is received, the details of the response actions to the complaint should be detailed in the register. • Record any exceptional incidents that cause dust and/or air emissions, either on or off site, and the action taken to resolve the situation in the register. • Carry out regular site inspections, record inspection results, and make the logbook available for review as requested.	Contractor	Establish communications and register prior to the commencement of construction. Ongoing reporting and record keeping throughout the duration of construction activities.

Table 12.2 Recommended AQMP mitigation measures – construction

Impact	Mitigation measure	Responsibility	Timing
Dust generation - general	• Erect screens or barriers to site fences around potentially dusty activities and material stockpiles where practicable. • Provide an adequate water supply on the construction site for effective dust/particulate matter suppression/mitigation. Store water for dry periods and ensure that the contractor has adequate permitted access to water. • Avoid site runoff of water or mud. • Temporary cessation of non-essential dust generating activities during high winds (ie winds greater than 8m/s or when excessive dust is seen leaving the site).	Contractor	Throughout the duration of construction activities.
Materials handling	• Prevention of truck overloading to reduce spillage during loading/unloading and hauling. • Haul vehicle turning circles to be adequate diameter and gravel sheeted to reduce pulverising the soil. • Minimise drop heights from loading or handling equipment.	Contractor	Throughout the duration of construction activities.
Soil stripping	• Progressive soil stripping with areas required for extraction / construction of foundations etc, where practical.	Contractor	Throughout the duration of construction activities.
Exposed areas	• Only the minimum area necessary would be disturbed at any one time. • Exposed areas would be stabilised as soon as practicable. • Long-term soil stockpiles would be revegetated.	Contractor	Throughout the duration of construction activities.
Dust generation from vehicles moving on unpaved roads	• Watering of main haulage routes as required. • Routes to be clearly marked and speed limits enforced. • Gravel surfacing considered for long-term routes. • Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport.	Contractor	Throughout the duration of construction activities.
Vehicle fuel combustion emissions	• Ensure proper maintenance and tuning of all equipment engines. • Ensure vehicles switch off engines when stationary.	Contractor	Throughout the duration of construction activities.
Open burning	• Selecting a location that is as far as possible from the accommodation camp and occupied residences • Schedule burning during daytime hours only with avoidance of smouldering overnight where possible. • Avoid burning during warmer months, subject consideration of bushfire risk and fire bans.	Contractor	Throughout the duration of construction activities.

12.2 Monitoring

Daily visual inspections of activities would be undertaken and recorded to monitor the effectiveness of dust controls and allow for reactive and corrective measures to be implemented. The inspections would focus on:

- inspect and report on excessive dust being generated at source (wheel generated dust, excavators, wind erosion);
- inspect and report on water cart activity and effectiveness; and
- inspect and report on dust leaving the site and moving towards sensitive receptors.

Due to the low risk of air quality impacts during construction, no additional air quality monitoring is recommended.

13 Conclusion

The AQGHGA focused on key emissions sources and pollutants applicable to the construction of the project, including fugitive dust from material extraction, handling, processing and movement, and wind erosion of exposed surfaces. An emissions inventory was developed for a single construction year, selected to assess the worst-case air quality impacts (ie during main embankment construction when material handling/movement is at a maximum).

The highest predicted impacts occur at the receptors within the inundation zone (R1- R13), all of which are now vacant, therefore no further discussion or assessment of these receptors is required. Other than these receptors, the highest predicted increment occurs at the accommodation camp (C1). When background concentrations are added to the modelled increment, there are no additional exceedances of the 24-hour average impact assessment criteria for PM_{10} and $PM_{2.5}$ at any receptor outside of the inundation zone, including the accommodation camp.

Similarly, there are no exceedances of the annual average impact assessment criteria for $PM_{10,}$ TSP and dust deposition. The annual average background $PM_{2.5}$ concentration (8.3 µg/m^3) is already above the impact assessment criterion, therefore it is difficult to assess compliance based on cumulative predictions. The annual average $PM_{2.5}$ concentration at the accommodation camp is 1.8% of the impact assessment criterion, which is slightly above screening criteria used to assess significance. For all other receptors (not within the inundation zone), the annual average $PM_{2.5}$ concentration is 0.3% of the impact assessment criterion and can be considered insignificant.

Vegetation waste disposal may require controlled burning under suitable conditions. A screening level modelling assessment found that open burning has the potential to add additional days over the impact assessment criteria for 24-hour average PM_{10} and $PM_{2.5}$. Therefore, in addition to selecting a location that is as far as possible from the accommodation camp and occupied residences, periods of poor dispersion should be avoided, such as stable atmospheric conditions. To achieve this, open burning should be planned for daytime hours only with avoidance of smouldering overnight where possible.

To assess the air quality impact from the construction phase of the pipeline and powerline, a qualitative impact assessment has been undertaken. A low to medium risk rating was identified for dust soiling impacts, human health impacts and ecological impacts from uncontrolled emissions. With the successful implementation of recommended dust mitigation measures, the risk of dust soiling or human health and ecological impacts would be further reduced.

Annual average GHG emissions (scope 1) generated during construction represent approximately 0.005% of total GHG emissions for NSW and 0.001% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018. The comparison does not include vegetation removal, which represents loss of a carbon sink and is not expressed on a per annum basis. Annual average GHG emissions (scope 1 and scope 2) generated during operation, including emissions from storage of water in the inundation zone, represent approximately 0.002% of total GHG emissions for NSW and 0.0004% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2018.

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List of acronyms and abbreviations

4WD	4 wheel drive
AHD	Australian height datum
ANFO	Ammonium nitrate/fuel oil
AQMS	Air Quality Monitoring Station
AQGHGA	Air Quality and Greenhouse Gas Assessment
AWS	Automatic weather station
BoM	Bureau of Meteorology
CBP	Concrete batching plant
CEMP	Construction environmental management plan
CO_2-e	Carbon dioxide equivalent
CO	Carbon monoxide
CH_4	Methane
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSSI	Critical State significant infrastructure
DoEE	Department of the Environment and Energy
DPI	Department of Primary Industries
DWER	Department of Water and Environmental Regulation
EIS	Environmental impact statement
EPA	Environment Protection Authority
GADDC Construction	Guidance on the Assessment of Dust from Demolition and
GHG	Greenhouse gas
IAQM	Institute of Air Quality Management
kL	Kkilolitres
kW	Kilowatt
kW	Kilowatt hour
NGAF	National Greenhouse Accounts Factors
N_2O	Nitrous oxide
NO_x	Oxides of nitrogen
NPI	National Pollution Inventory
ML	Million litres / Megalitre
MSCL	mild steel cement lined
O_3	Ozone
PM_{10}	Particulate matter less than 10 microns in aerodynamic diameter

$PM_{2.5}$	Particulate matter less than 2.5 microns in aerodynamic diameter
SEARs	Secretary's Environmental Assessment Requirements
SO_2	Sulphur dioxide
SSI	State significant infrastructure
TAPM	The Air Pollution Model
TSP	total suspended particulate matter
US-EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WA	Western Australia
WTP	Water Treatment Plant

Annexure A
Model configuration

EMM
creating opportunities

A.1 TAPM modelling

To supplement the meteorological monitoring datasets adopted for this assessment, the Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model TAPM was used to generate required parameters that are not routinely measured, specifically cloud content and height data.

TAPM was configured and run as follows:

- TAPM version 4.0.5;
- grid domains with cell resolutions of 30 km, 10 km, 3 km, 1 km and 300 m. 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;
- TAPM defaults for advanced meteorological inputs; and
- two 'spin-up' days allowed at the beginning and end of the run.

A surface observations file was included in TAPM with meteorological data from the BoM Tamworth Airport AWS.

A.1.1 CALMET

CALMET was used to produce 3-dimensional meteorological fields for use in the CALPUFF model. In the absence of upper air measurements, CALMET can be run using prognostic upper air data (as a three-dimensional '3D.dat' file), which is used to derive an initial wind field (known as the Step 1 wind field in the CALMET model). The model then incorporates mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the 'hybrid' approach (TRC 2011) and is adopted for this assessment. TAPM was used to generate gridded upper air data for each hour of the model run period, for input into CALMET.

A CALMET grid of 60 km by 60 km was run with a grid spacing of 500 m. Surface meteorological data from the BoM Tamworth Airport AWS were included as a surface station in the modelling. The distance at which the observation influences the model (radius of influence) is determined by the CALMET setting 'RMAX'. The relative importance of the observation in the model (relative weighting of the Step 1 wind field and the observation) is determined by the CALMET setting 'R1'.

An RMAX of 20 km and R1 of 10 km was assigned in the model, primarily to allow the model to run (ie the radius of influence was selected to overlap with the edge of the modelling grid). It is noted that due to the distance from these observations to the project site, the prevailing meteorology for the local area would not be biased to those observations and the final wind field predicted by CALMET would be more influenced local terrain features (slope flows and terrain blocking effects).

The detailed CALMET model options used are presented in Table A.1. These were selected in accordance with recommendations in in TRC (2011).

Table A.1 CALMET model options used

Flag	Descriptor	Default	Value used
IEXTRP	Extrapolate surface wind observations to upper layers	Similarity theory	Similarity theory
BIAS (NZ)	Relative weighting given to vertically extrapolated surface observations versus upper air data	No default	NZ * 0 - layers in lower levels of the model would have stronger weighting towards surface, higher levels would have stronger weighting to upper air data
TERRAD	Radius of influence of terrain	No default (typically 5–15 km)	5
RMAX1 and RMAX2	Maximum radius of influence over land observations in layer 1 and aloft	No default	20,10
R1 and R2	Distance from observations in layer 1 and aloft at which observations and Step 1 wind field are weighted equally	No default	10,5

Annexure B

Analysis of existing environment

EMM
creating opportunities

B.1 Meteorology

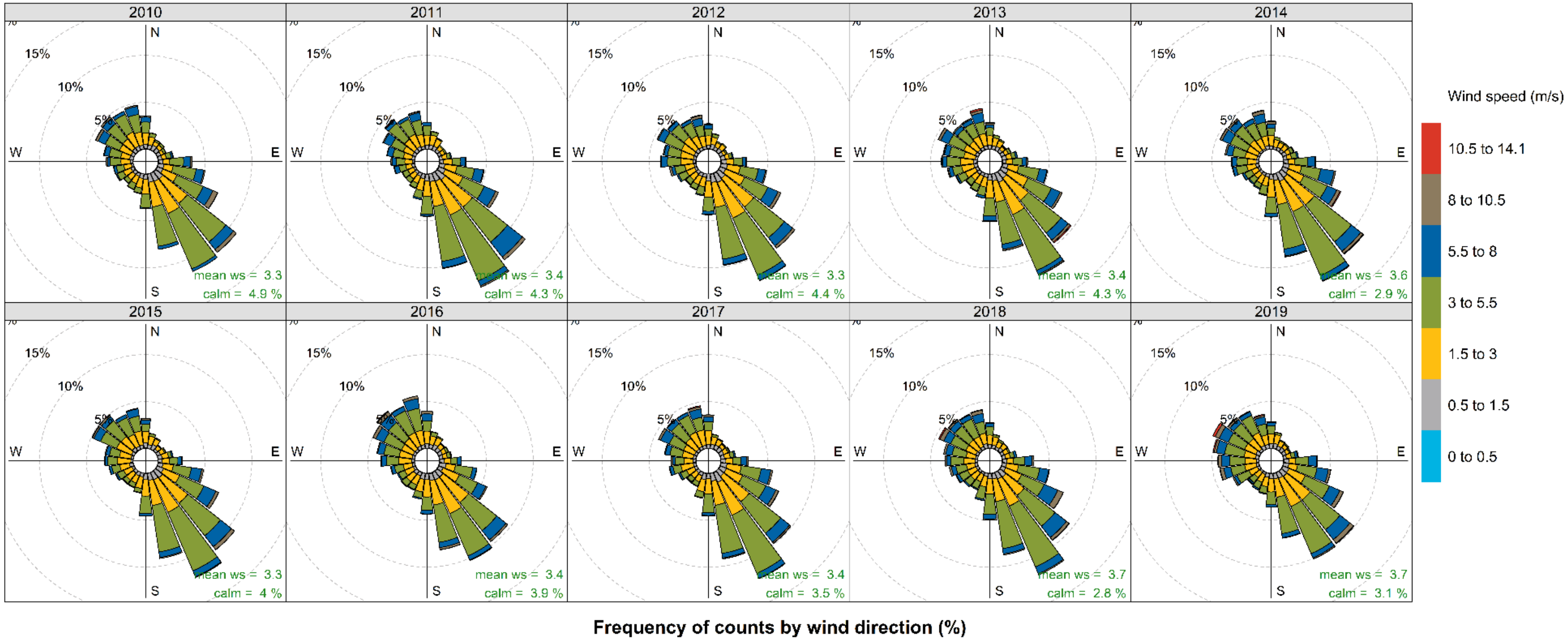

Figure B.1 Annual wind roses for Tamworth Airport 2010-2019

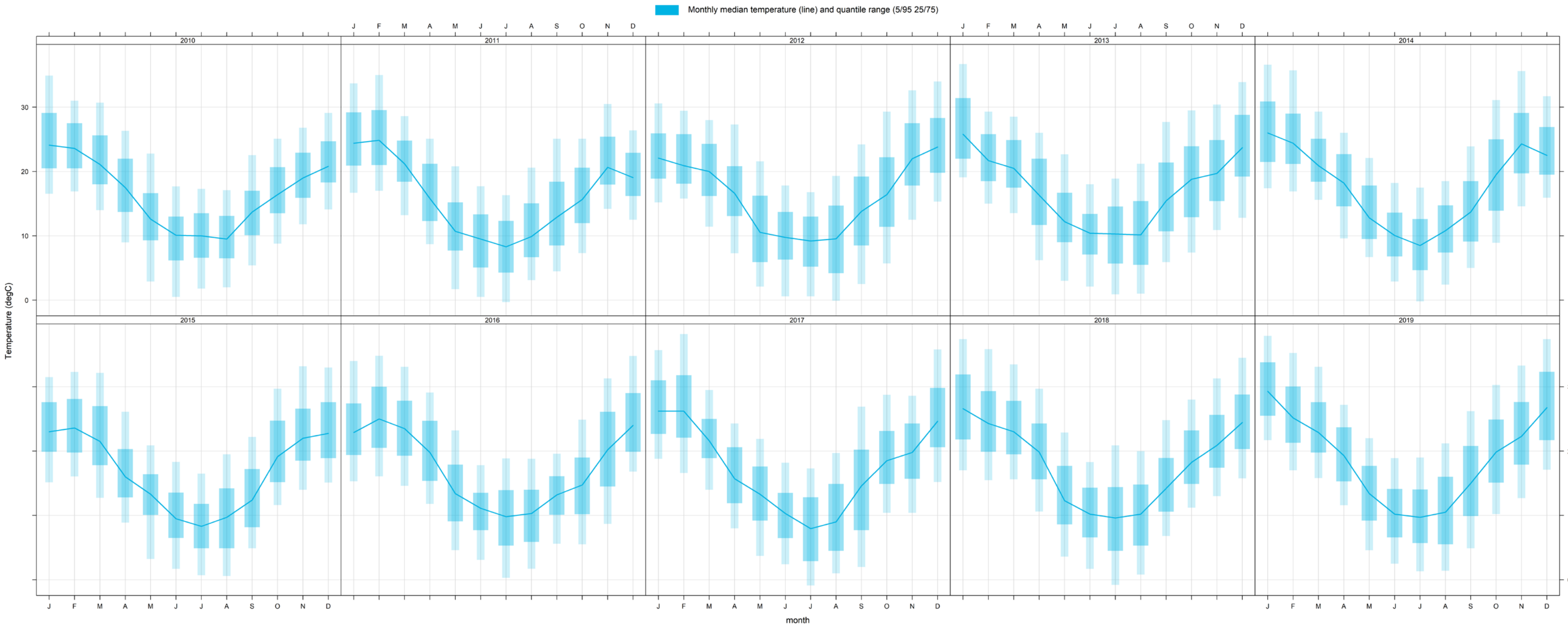

Figure B.2 Interannual variation in temperature for Tamworth Airport

B.2 Timeseries analysis for background air quality

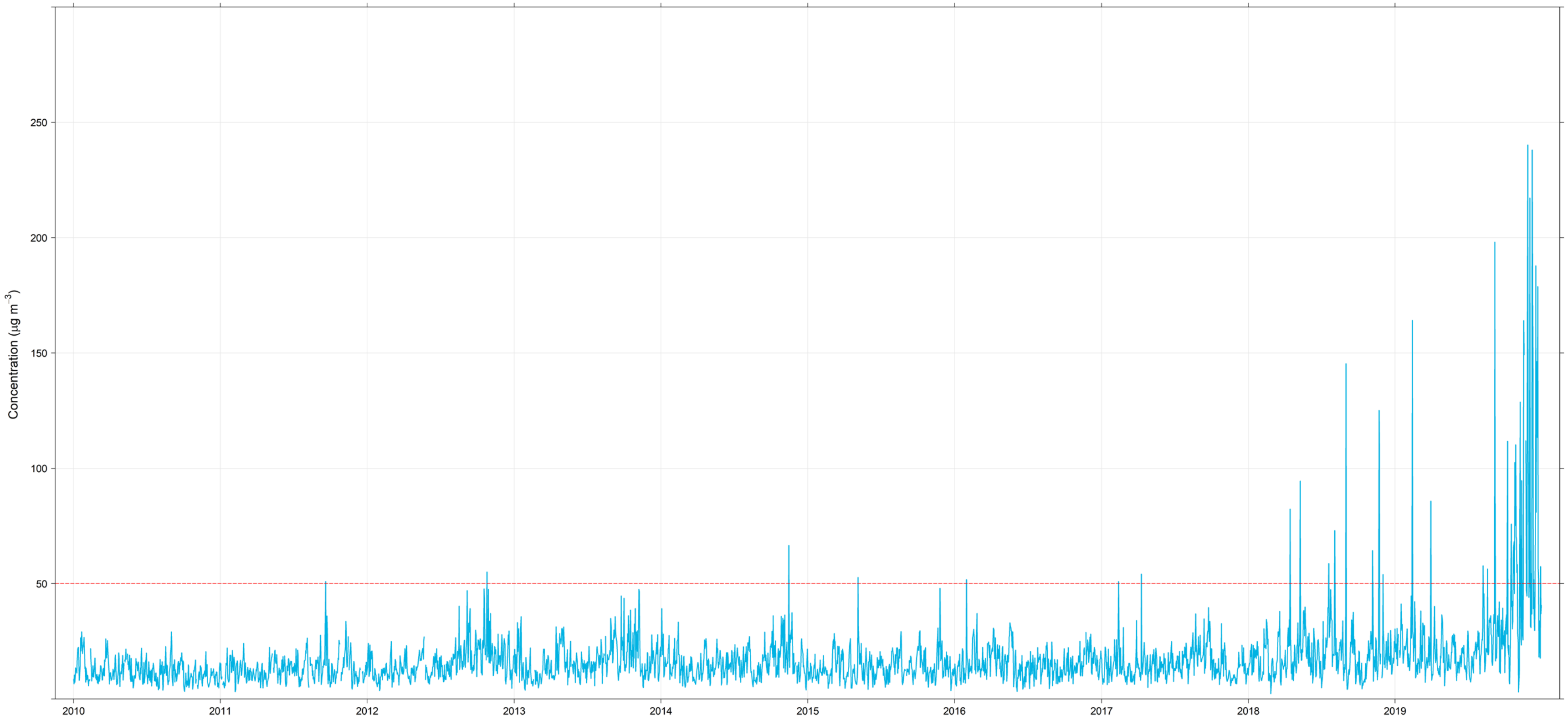

Figure B.3 Timeseries of 24-hour PM_{10} concentrations – Tamworth 2010-2019

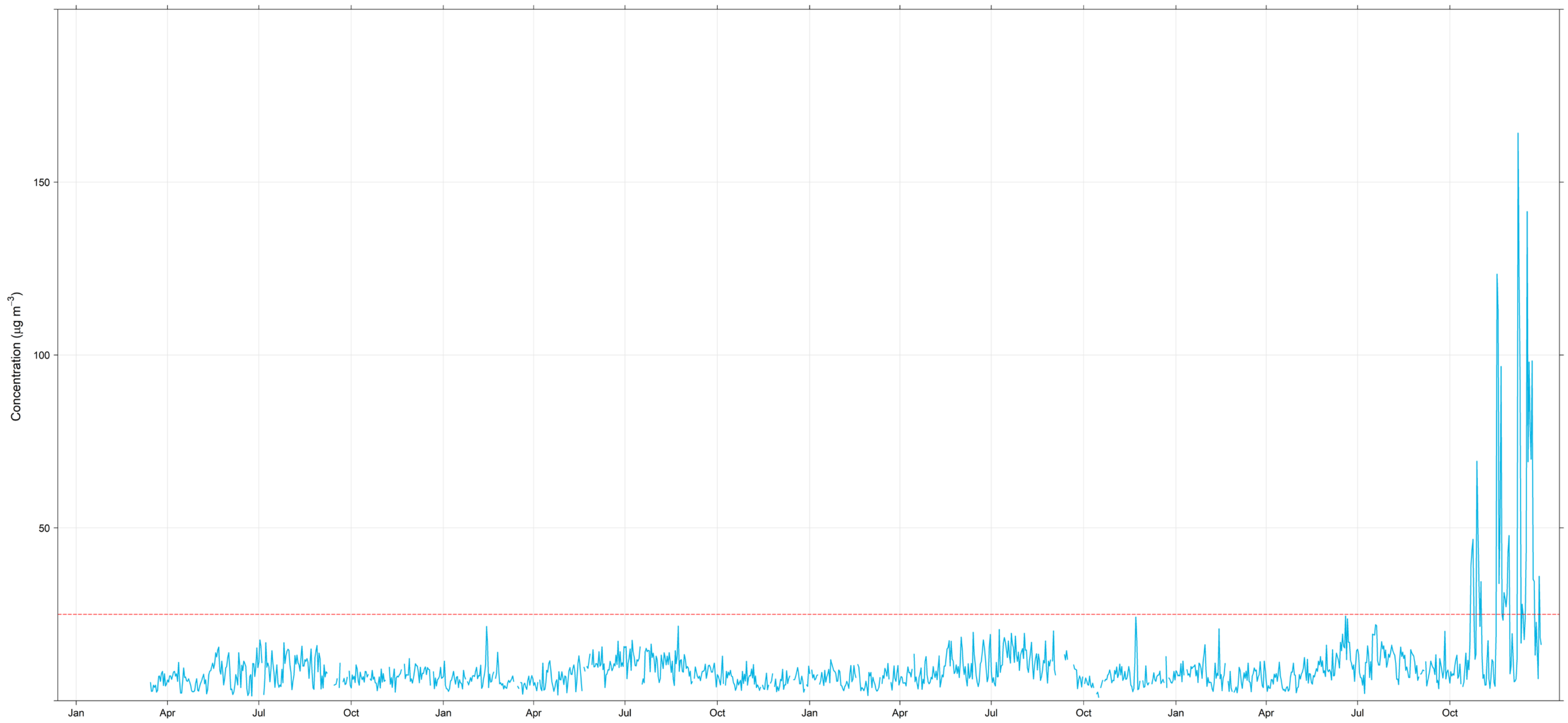

Figure B.4 Timeseries of 24-hour $PM_{2.5}$ concentrations – Tamworth 2016-2019

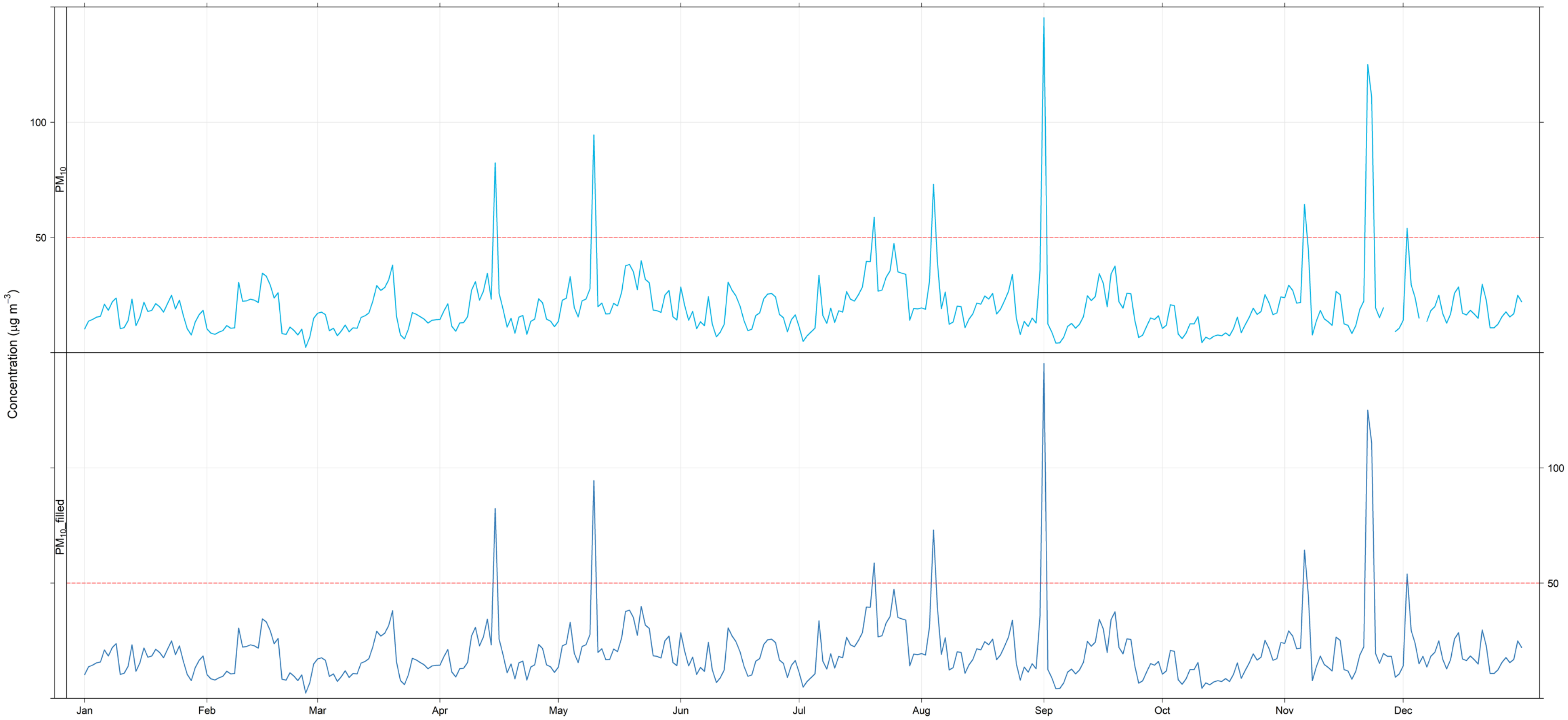

Figure B.5 Timeseries of 24-hour PM_{10} concentrations – Tamworth 2018 (original and filled dataset)

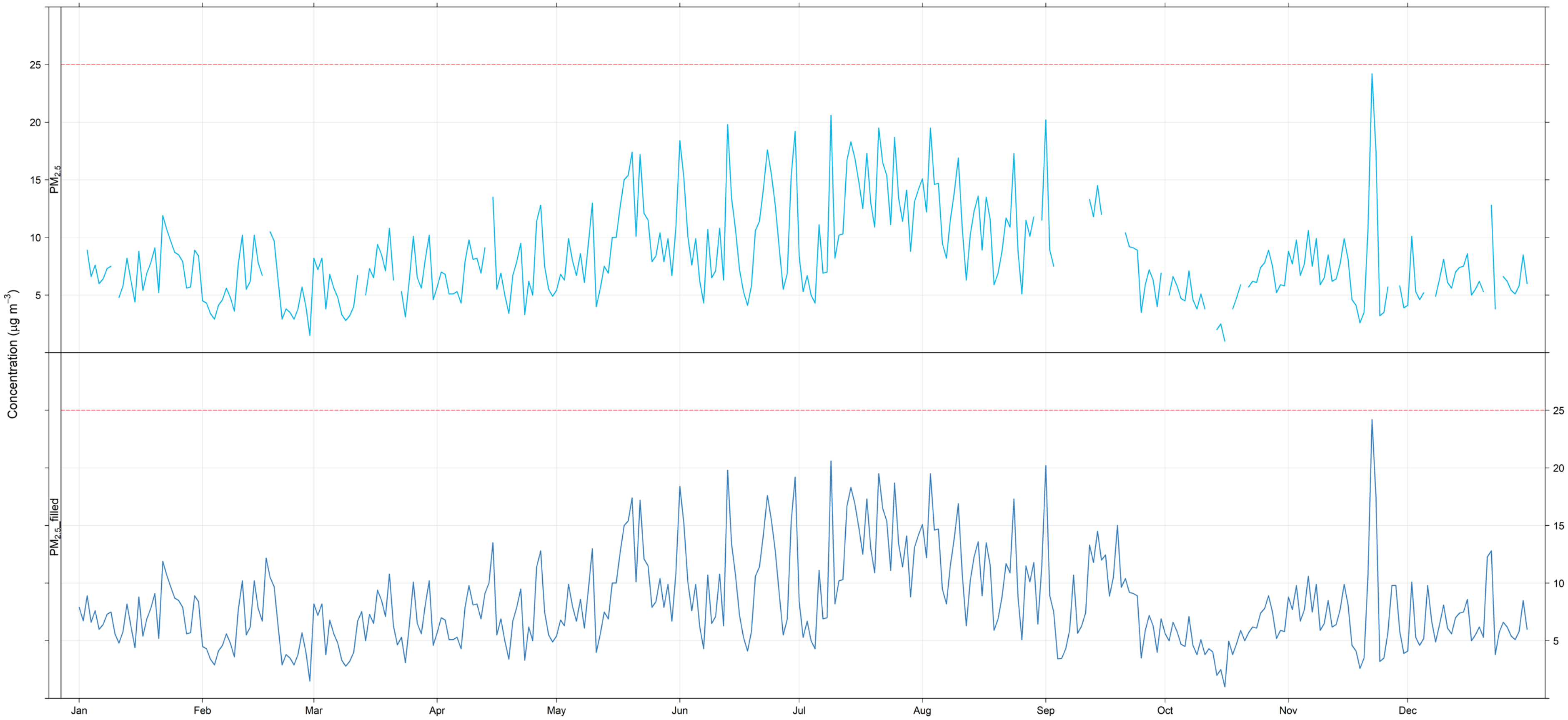

Figure B.6 Timeseries of 24-hour $PM_{2.5}$ concentrations – Tamworth 2018 (original and filled dataset)

Annexure C
Emissions inventory

EMM
creating opportunities

C.1 Introduction

Particulate matter emissions were quantified through the application of accepted published emission estimation factors, collated from United States Environmental Protection Agency (US EPA) AP-42 Air Pollutant Emission Factors (US EPA 1995) as follows:

- AP-42 Chapter 13.2.2 Unpaved roads (November 2006) – emission factor equation for wheel generated dust;
- AP-42 Chapter 13.2.4 Aggregate handling and storage piles (November 2006) – emission factor equation for material handling;
- AP-42 Chapter 11.9 Western Surface Coal Mines (October 1998) – emission factor equation for drilling and blasting and wind erosion from exposed areas; and
- AP-42 Chapter 11.19.2 – Crushed Stone Processing and Pulverised Mineral Processing (August 2004) – emission factors for crushing and screening.

Assumptions used to estimate emissions from diesel consumption are:

- the fleet comprised primarily of equipment with an engine power of 75-130 kW;
- a corresponding US EPA Tier 2 emission standards for PM of 0.2 g/kWh (US EPA 2016); and
- the PM emission standard is assumed to correspond to TSP and PM_{10}. $PM_{2.5}$ emissions are assumed to comprise 97% of PM_{10} emissions.

C.2 Project-related input data used for particulate matter emission estimates

The main inputs used in the emission estimates are summarised in Table C.1.

Table C.1 Inputs for emission estimation

Material properties	Value	Source of information
Unpaved road silt content (%)	5.0	Based on similar projects
Soil moisture (%)	13.5	Based on in-situ moisture content test results in the GI Factual report
Rock moisture (%)	4.1	Based on in-situ moisture content test results in the GI Factual report
Diesel consumption	3,901 kL/annum	Based on a total estimated diesel consumption of 9.752 ML for the project construction, with 40% of the total assumed for the peak construction years.
Average wind speed (m/s)	3.0	Calculated from CALMET at project site.
Average truck load (t)	40 t – slipway 28 t – quarry, borrow area	Based on specifications for Moxi trucks
Average truck gross mass (t)	55 t – slipway 38 t – quarry, borrow area8	Average of full and empty loads.

C.3 Particulate matter emissions inventory

The emissions inventory developed for the worst-case construction scenario is presented in Table C.2.

Table C.2 Dungowan Dam construction emission inventory inputs

Activities	Activity rate	Units	Emission Factors				Variables										Control	Control type
			TSP	PM10	PM2.5	Units												
Spillway																		
Stripping soil/OB	52,000	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Loading trucks with soil/OB	52,000	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Hauling soil/OB across spillway area	520	VKT/yr	2.23	0.57	0.06	kg/VKT	5.0	% silt content	0.4	km/return trip	1,300	Loads/y	50	Average weight (t)	40	Truck capacity (t)	0.75	Water sprays
Emplacement of soil/OB to temporary stockpile	52,000	t/y	0.0007	0.0003	0.00005	kg/t	3.0	Average wind speed (m/s)	13.5	Moisture content (%)								
Drilling	2,500	holes/y	0.59	0.3068	0.01770	kg/hole											0.7	Water injection
Blasting	25	blasts/y	6.96	3.6176	0.20871	kg/blast	1,000	Area of blast in m^2										
Ripping	2,663,348	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Screening/sizing	2,663,348	t/y	0.0125	0.0043	0.000025	kg/t											0.5	Water sprays
Rehandle to trucks	2,663,348	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Hauling rockfill from spillway to embankment placement	33,292	VKT/y	2.23	0.57	0.06	kg/VKT	5.0	% silt content	0.5	km/return trip	66,584	Loads/y	50	Average weight (t)	40	Truck capacity (t)	0.75	Water sprays
Exposed ground - spillway	8.0	Area (ha)	850	425	64	kg/ha/y												
Embankment emplacement																		
Stripping soil/OB	42,250	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								

Activities	Activity rate	Units	Emission Factors				Variables										Control	Control type
			TSP	PM10	PM2.5	Units												
Loading trucks with soil/OB	42,250	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Hauling soil/OB across embankment area	528	VKT/y	1.87	0.48	0.05	kg/VKT	5.0	% silt content	0.4	km/return trip	1,509	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Emplacement of soil/OB to temporary stockpile	42,250	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Trucks unloading rockfill from spillway	2,663,348	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Trucks unloading rockfill from quarry	276,000	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Truck unloading fill from borrow areas	130,000	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Import fill from external commercial source	21,429	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	3.0	km/return trip	7,143	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Unloading fill from external commercial source	200,000	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Excavator shaping/spreading	3,069,348	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Exposed ground - embankment	6.5	Area (ha)	850	425	64	kg/ha/y												
Rock quarrying																		
Pre-strip (n/a - completed in 2022)	7,475	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Drilling	2,500	holes/y	0.59	0.3068	0.01770	kg/hole											0.7	Water injection
Blasting	25	blasts/y	6.96	3.6176	0.20871	kg/blast	1,000	Area of blast in m^2										
Excavator ripping	276,000	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								

Activities	Activity rate	Units	Emission Factors			Units	Variables										Control	Control type
			TSP	PM10	PM2.5													
Crushing	82,800	t/y	0.0125	0.0012	0.00022	kg/t											0.5	Water sprays
Screening/sizing	82,800	t/y	0.0125	0.0043	0.000025	kg/t											0.5	Water sprays
Excavator loading trucks	276,000	t/y	0.0013	0.0006	0.00009	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Hauling from quarry to embankment placement	27,600	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	4.0	km/return trip	6,900	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Exposed ground - quarry	2.3	Area (ha)	850	425	64	kg/ha/y												
Borrow area																		
Pre-strip	16,250	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Excavator ripping	16,250	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Excavator loading trucks	130,000	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	13.5	Moisture content (%)								
Hauling from borrow to embankment placement	13,929	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	3.0	km/return trip	4,643	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Exposed ground	5.0	Area (ha)	850	425	64	kg/ha/y												
Concrete batch plant																		
Hauling from quarry to CBP	14,786	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	5.0	km/return trip	2,957	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Import aggregate from external commercial source	1,056	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	2.0	km/return trip	528	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Trucks unloading sand/aggregate	132,800	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Rehandle	132,800	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								

Activities	Activity rate	Units	Emission Factors				Variables										Control	Control type
			TSP	PM10	PM2.5	Units												
Transfer to hopper	132,800	t/y	0.0005	0.0002	0.00004	kg/t	2.4	Average wind speed (m/s)	4.1	Moisture content (%)								
Cement unloading	50,000	t/y	0.0005	0.00017	0.00002	kg/t												
Hauling from CBP to spillway	4,743	VKT/year	1.87	0.48	0.05	kg/VKT	5.0	% silt content	1.0	km/return trip	4,743	Loads/y	34	Average weight (t)	28	Truck capacity (t)	0.75	Water sprays
Stockpiles	0.02	Area (ha)	850	425	64	kg/ha/y												
Miscellaneous																		
Grader (road maintenance)	14,784	km/y	0.62	0.22	0.02	kg/km	8	speed of graders in km/h	1,848	grader hours								
Onsite diesel consumption	3,901	kl/annum	0.66	0.66	0.64	kg/kL												
Road realignment																		
Scraper	6,160	km/y	0.84	0.12	0.010	kg/VKT	5.0	% silt content	48.0	gross mass (t)	8	speed in km/h	770	grader hours			0.5	soil moisture
Rehandle	32,500	t/y	0.0006	0.0003	0.00005	kg/t	2.9	wind speed (m/s)	4	Moisture content (%)							0.5	soil moisture
Unloading gravel	57,500	t/y	0.0006	0.0003	0.00005	kg/t	2.9	wind speed (m/s)	4.1	Moisture content (%)								
Exposed ground wind erosion	5	Area (ha)	850	425	64	kg/ha/y											0.5	Water sprays

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