VECCO CRITICAL MINERALS PROJECT

Julia Creek, North-West Queensland

Air Quality Assessment

Vecco Group

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1. INTRODUCTION

1.1 Overview

Trinity Consultants Australia (Trinity) was commissioned by Vecco Group Pty Ltd (Vecco Group) to provide air quality consultancy services for the proposed Vecco Critical Minerals Project (the Project).

The vanadium deposit is located in north-western Queensland. The deposit is 70 kilometres north of the township of Julia Creek. Access to the Project site is via Mt Isa, the nearest major centre and regional airport.

The Project area will be defined by three proposed mining lease applications (MLA) being an MLA for the mine, an MLA for infrastructure and an MLA for the access road, which will occupy a total area of 3,536 ha. The land within and surrounding the Project area is designated as 'Rural' zone under the McKinlay Shire Planning Scheme 2019. The existing land use of the Project area is low intensity cattle grazing. The Project location is shown in **Figure 1.1**.

1.2 Scope

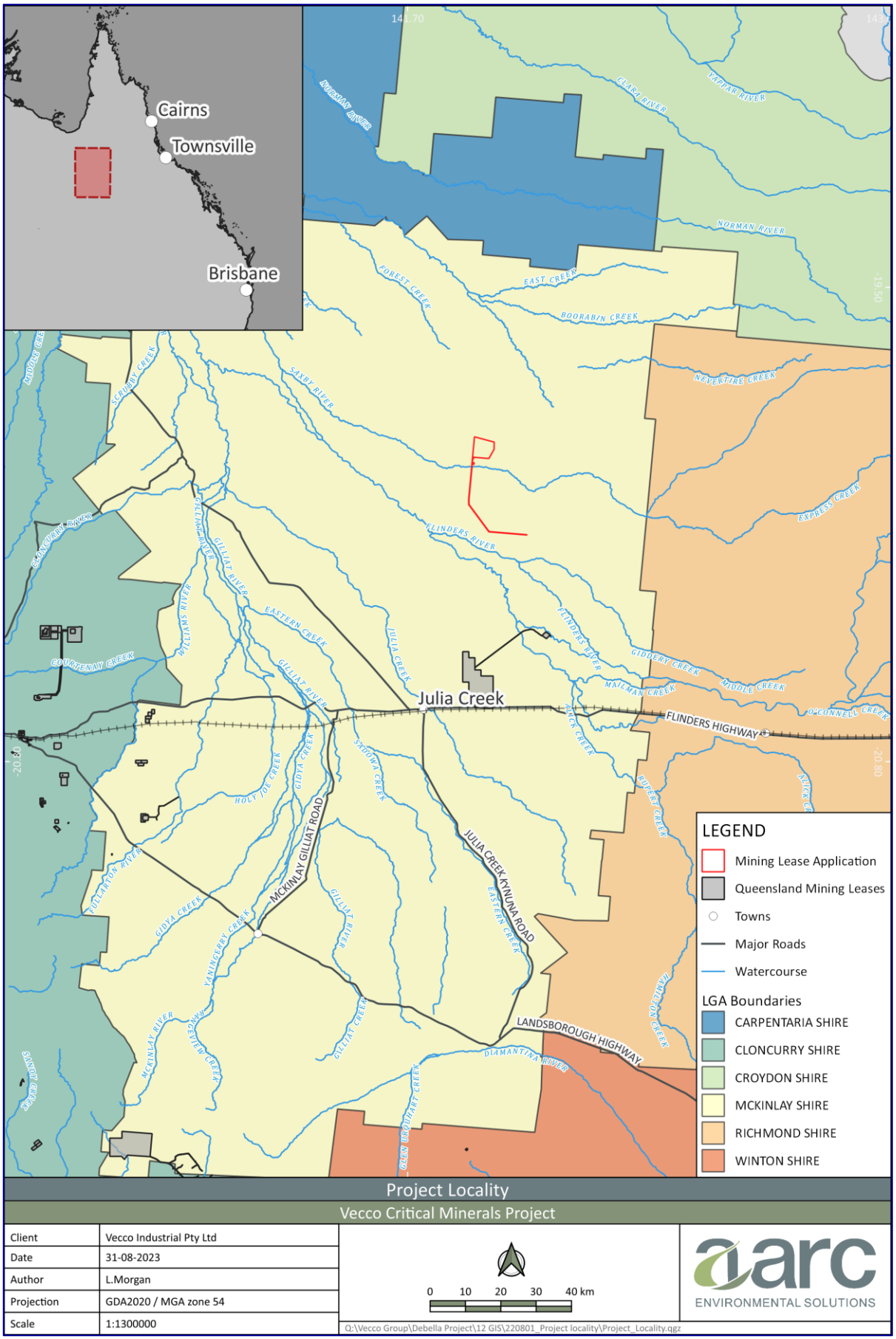
This report presents an assessment of the air quality impacts and greenhouse gas emissions associated with the proposed Project. It is to form an appendix to the application for a site-specific Environmental Authority (EA) for assessment by the Queensland Department of Environment and Science (DES).

This report is based on the following tasks:

- Review the Project and the associated potential air emissions.
- Review existing air quality monitoring data applicable to the Project site.
- Identify existing sensitive receptors and sensitive zones.
- Prepare a greenhouse gas inventory based on current National Greenhouse Accounts Factors, National Greenhouse and Energy Reporting (NGER) guidelines, and the FullCAM vegetation model. Discuss the relative scale and implications of these emissions compared to state and national emissions.
- Develop an emission inventory based on National Pollutant Inventory (NPI) and United States Environmental Protection Agency (USEPA) AP-42 literature for particulates less than 2.5 microns ($PM_{2.5}$), particulates less than 10 microns (PM_{10}), total suspended particles (TSP) and dust deposition.
- Model meteorological conditions using TAPM and CALMET.
- Model the dispersion of expected air pollutants based on proposed activities using Calpuff to estimate levels of the emissions reaching sensitive receptors and develop contours over the modelling domain for the worst-case scenarios.
- Analyse the results of meteorological and pollutant dispersion modelling, including cumulative impacts and compare results with the relevant air quality criteria designed to protect human health and wellbeing, and dust deposition guidelines designed for amenity purposes.
- Qualitatively assess the impacts during construction and closure of the mine.
- Provide recommendations on control measures and for monitoring and corrective actions.

To aid in the understanding of the terms in this report a glossary is included in **Appendix A**.

Figure 1.1: Vecco Critical Minerals Project Location and Other Mining Leases

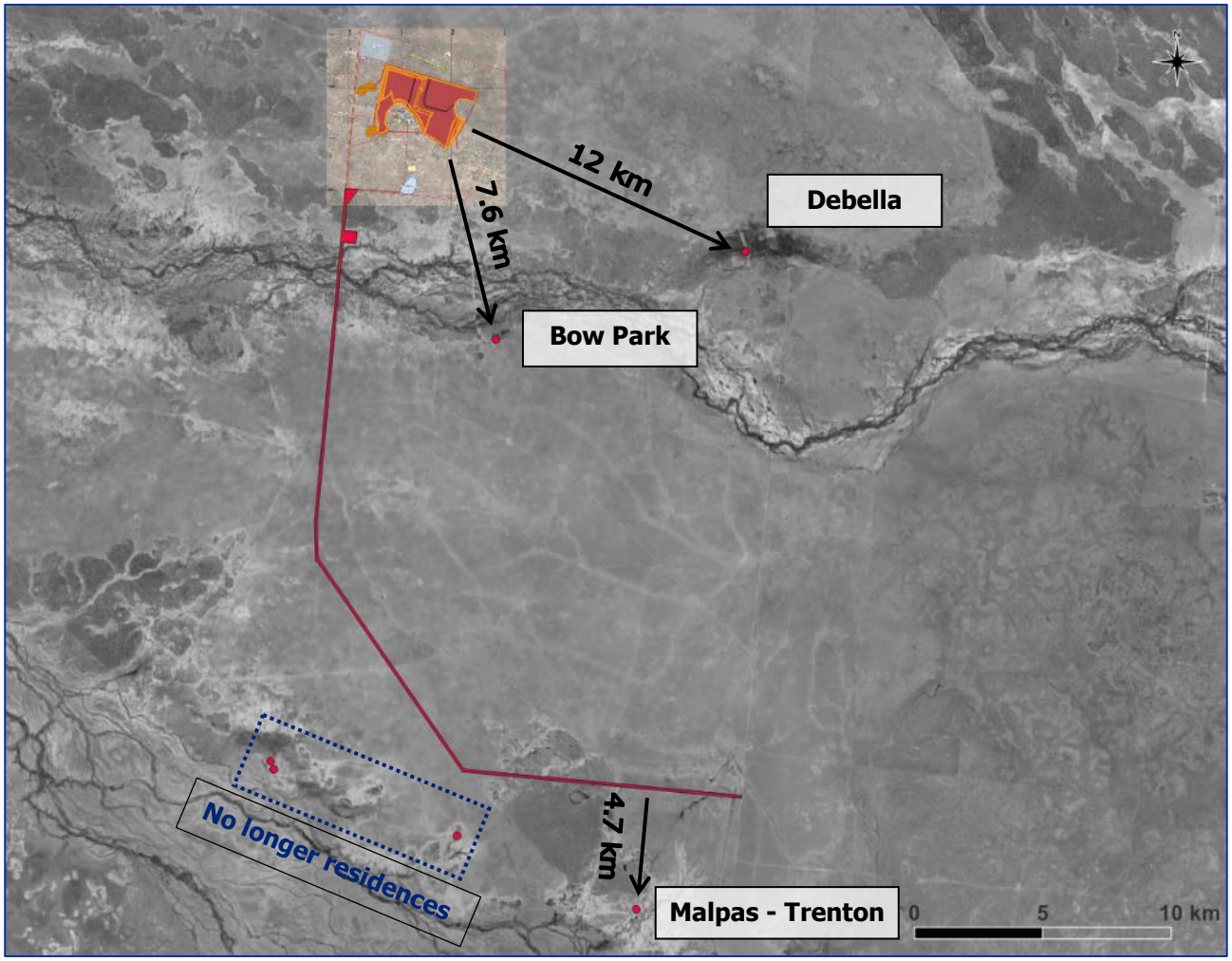


2. STUDY AREA DESCRIPTION

2.1 Overview

The Project site is located in a remote area approximately 70 kilometres north of Julia Creek in mid-northern Queensland. The nearest potential residential sensitive receptor is approximately 7.6 kilometres to the southeast of the mining area, located on the 'Bow Park' property. The Project location including the access road and nearby sensitive receptors are shown in **Figure 2.1**.

Figure 2.1: Location of Site and Sensitive Receptors (Image from Queensland Globe Overlay)



2.2 Identification of Existing Sensitive Receptors

The definition of a sensitive receptor required to be considered by operators of environmentally relevant activities is provided by the Department of Environment and Science (DES 2021). This definition is a place that could include but is not limited to:

- a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises;
- a motel, hotel or hostel;
- a kindergarten, school, university or other educational institution;
- a medical centre or hospital;

- a protected area under the Nature Conservation Act 1992, the Marine Parks Act 2004 or a World Heritage Area;
- a public park or garden; and
- a place used as a workplace including an office for business or commercial purposes.

Only two potential sensitive receptors were identified near the Project as listed in **Table 2.1**. There is also the Malpas-Trenton residence located 4.7 kilometres from the mine access road as shown in **Figure 2.1**. The Bow Park residence is located 6.4 kilometres from the access road.

Table 2.1: Potential Sensitive Receptors

Receptor ID	Receptor Description	Latitude	Longitude	Distance and Direction from Closest Mining Area
1 – Bow Park	Residential	-20.018064	141.933653	7.6 km SE
2 – Debella	Residential	-19.987765	142.028363	12 km E

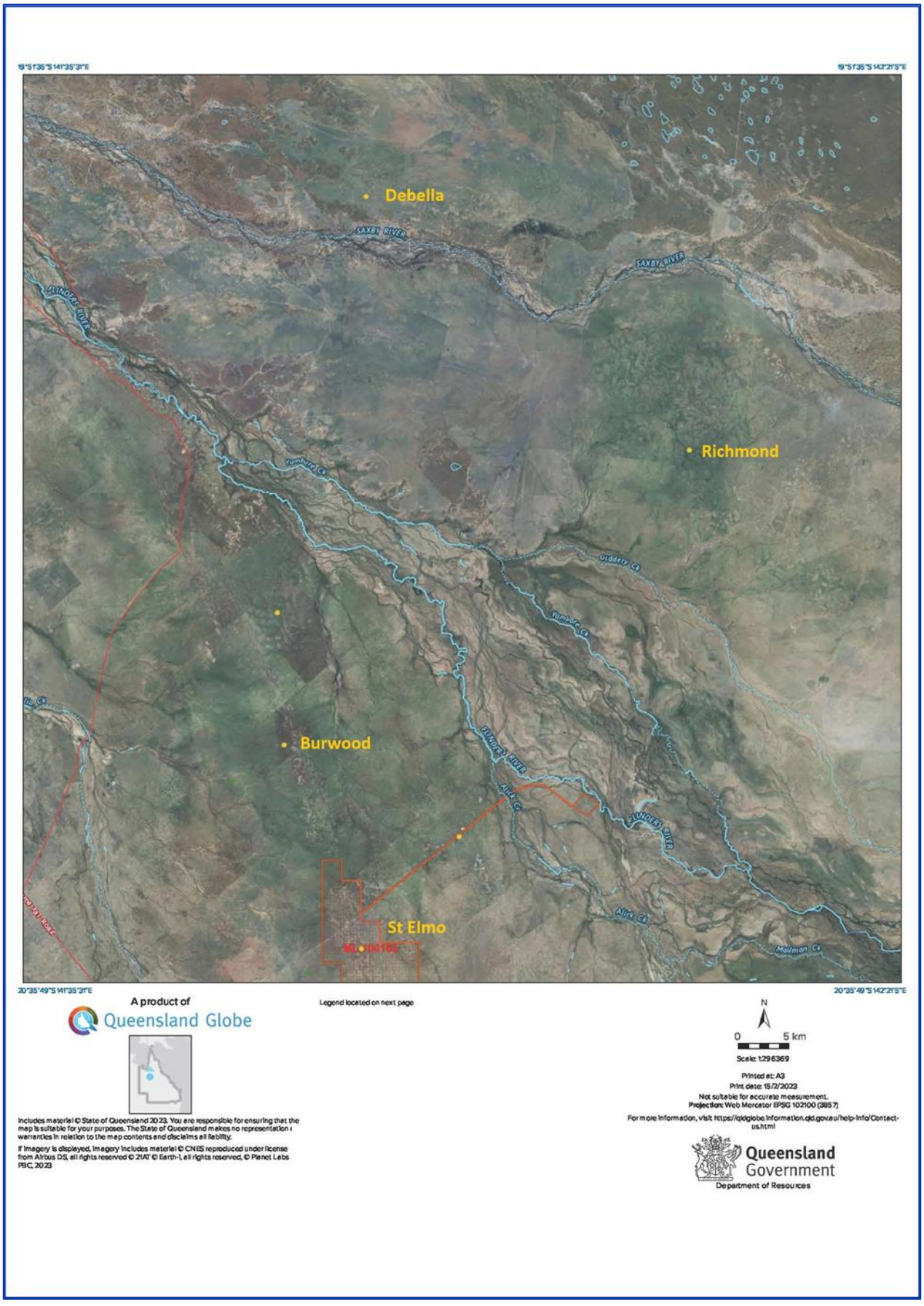
2.3 Description of the Existing Air Environment

A desktop survey of the surrounding area was conducted with no other existing air emission sources found, with the exception of grazing operations and their associated activities.

There are no current granted mining leases, local to the Project. There are several other exploration permits in the vicinity of the sensitive receptors held by Red OX Copper Pty Ltd, Currie Rose Vanadium, CMG_3 Pty Ltd, and Yappar Resources Pty Ltd. However, at the time of publication Trinity and AARC are not aware of any other operations proposed in the foreseeable future. Proposed mines and mineral resources in the vicinity on Queensland Globe include Richmond, Manfred and Burwood, all potential future vanadium mines as shown in **Figure 2.2**. The approved St Elmo mine is further south and the Richmond – Julia Creek Vanadium Project is on the Queensland Coordinated Projects map of proposed mines.

However, St Elmo and Richmond – Julia Creek are more than 60 kilometres away and no air quality impact is expected on the sensitive receptors identified within this assessment.

Figure 2.2: Potential Vanadium Mines in Vicinity



3. PROPOSED DEVELOPMENT

3.1 Project Overview

The information in this section has been provided to Trinity by Vecco.

The proponent of the Project is Vecco Industrial Pty Ltd (Vecco), a wholly owned subsidiary of Vecco Group Pty. Ltd. (Vecco Group).

Vecco is seeking to develop the Project to mine and process the vanadium deposit. The Project will target vanadium pentoxide (V_2O_5) and High Purity Alumina (HPA), along with minor quantities of Rare Earth Elements (REEs) also found within the MLA area. The life of mine (LOM) is expected to be approximately 36 years, which includes construction, operation, and rehabilitation. A conceptual Project layout is presented in **Figure 3.1**. The Project is a proposed greenfield operation that will consist of a shallow, open-cut mine that will process up to 1.9 Mtpa ROM feed to produce up to 5,500 to 6,000 tpa V_2O_5 and approximately 3,000 to 4,000 tpa HPA over an operational life of approximately 26 years.

Ore will be mined to an approximate depth of up to 35 metres. Processing will occur following on site crushing and screening of the ore. Mineral products will be packed in containers and transported by truck to Townsville, for secondary processing into battery electrolyte or export from the Port of Townsville to international markets.

3.2 Infrastructure

Project infrastructure will include:

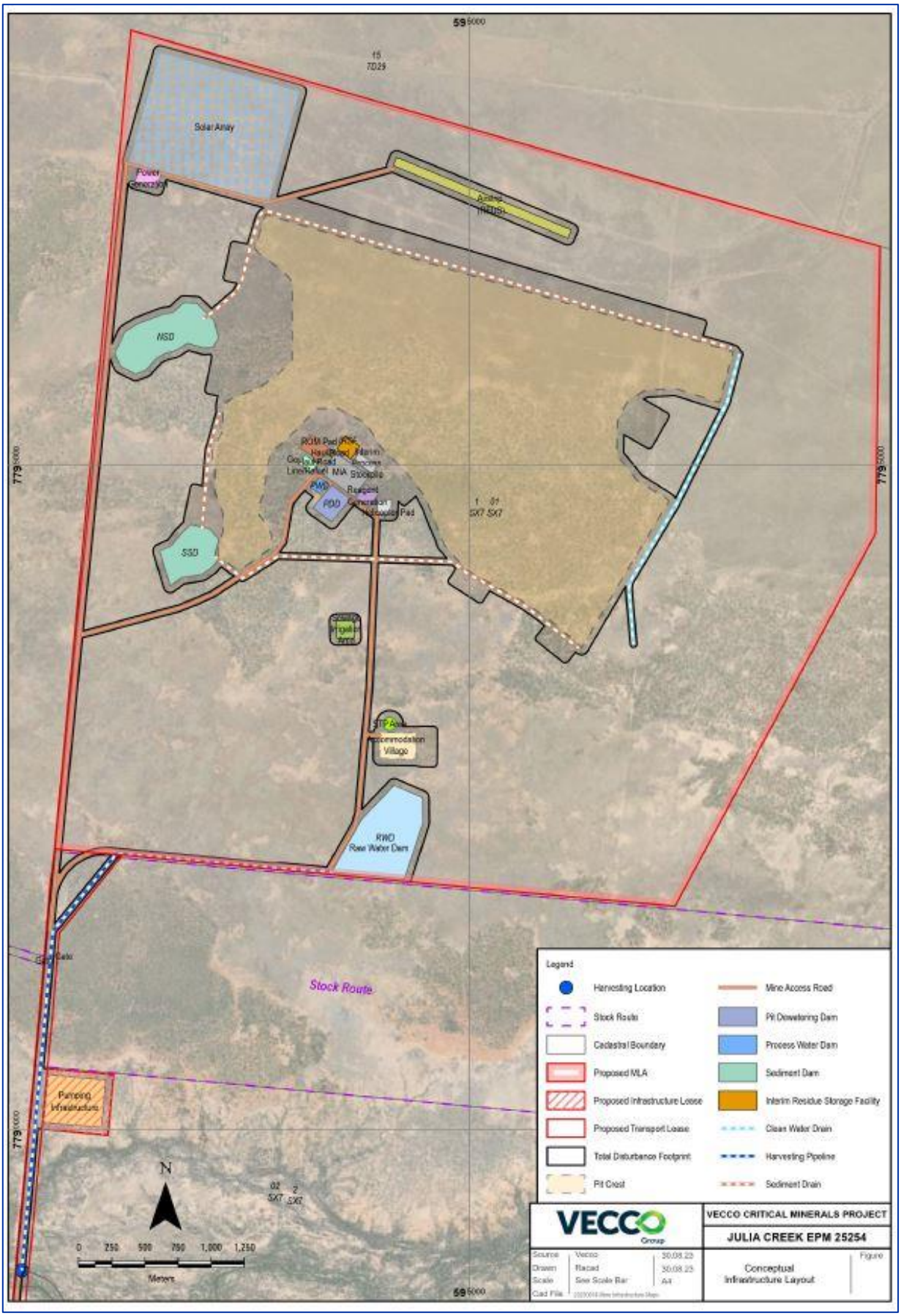
- open-cut mining of up to 1.9 Mtpa ROM ore over a period of 26 operational years;
- development of a mine infrastructure area (MIA) including, administration buildings, bathhouse, crib rooms, storage warehouse, workshop, fuel storage, refuelling facilities, wash bay, laydown area, and a helipad;
- development of mine areas (open-cut pits) and out-of-pit waste rock emplacements. This includes vegetation and soil stripping;
- construction and operation of a Mineral Processing Plant (MPP) and ore handling facilities adjacent to the MIA (including ROM ore and product stockpiles and rejects);
- construction and use of an access road from Punchbowl Road to the MIA;
- construction of an airstrip to provide access for the Royal Flying Doctors Service;
- construction of a 10 MW solar farm and associated energy storage system;
- installation of a raw water supply pumping system and pipeline to connect the Raw Water Dam to the Saxby River for water harvesting;
- construction of an on-site workers' village and associated facilities, including an adjacent sewage treatment plant (STP);
- other associated minor infrastructure, plant, equipment and activities;
- progressive establishment of soil stockpiles, laydown area and borrow pits (for road base and civil works). Material will be sourced from local quarries where required;
- mine operations using conventional surface mining equipment (excavators, front end loaders, rear dump trucks, dozers);
- strategic disposal of neutralised process rejects within the backfilled mining void;
- continued exploration and resource definition drilling on the MLA's;
- progressive development of internal roads and haul roads including a low level crossing over the Saxby River (designed for minimum impact on flow events) to enable access and product haulage;

- development of water storage dams and sediment dams, and the installation of pumps, pipelines, and other water management equipment and structures including temporary levees, diversions and drains; and
- progressive rehabilitation occurring at defined milestones through the operational life. All voids will be backfilled to natural surface, ensuring all rehabilitated landforms achieve sustainable post-mining land use on closure.

Existing regional infrastructure, facilities and services may be used to support the Project activities. These include the Townsville Port, the Aurizon rail network, Ergon's electricity network and the Flinders Highway.

The Project layout is shown in **Figure 3.1**. The following sections specify details of the Project that are relevant to the air quality and greenhouse assessment.

Figure 3.1: Project Layout



3.3 Mining Activities

3.3.1 Overview

The Project is based on typical truck and excavator operations. Mining will be carried out sequentially from mining panels. Once material is removed the exposed pit floor will be covered with neutralised, filtered, process residue (trucked from the MIA) before being backfilled to near surface level. The back-filled waste rock will then be sheeted with subsoils and topsoil for revegetation. Progressive rehabilitation will then be undertaken.

The mining operations are summarised as follows:

- Vegetation will be cleared.
- Topsoil will be removed, temporarily stockpiled and used progressively for rehabilitation activities.
- A single box cut will be excavated with waste rock, initially dumped in a single out-of-pit waste rock dump.
- As the mining face advances, neutralised residue will be trucked from the MIA to cover the pit floor and waste rock from the advancing face will be dumped in-pit, returning the mined land to natural surface level.
- Dozers will push material to back-fill the areas that have been previously mined.
- Excavators will side cast the rehandle overburden wedge.
- Excavators will load the mined ore into haul trucks to be transported from the pits to the ROM pad.
- Haul trucks will unload ROM ore at the ROM pad. All the ore from the ROM stockpiles will be rehandled to feed the processing plant using a front end loader to feed the ore onto a conveyor via a hopper.
- MPP residue will be dried, blended, neutralised, stockpiled, loaded and hauled back to the open-pit where it will be used to cover the exposed pit floor.
- Ore will be processed in the on-site plant incorporating beneficiation, roasting, leaching, filtration, solvent extraction, precipitation refining, HPA and REEs processes.
- Product will be transported out through the mine access road by road trucks such as B-double and A-triple.
- Maintenance and servicing of plant and equipment will be undertaken at the MIA.

3.3.2 Mine Sequencing

The mining sequencing plan is to target the lowest strip ratio area first. **Figure 3.2** presents a layout of the mining sequencing plan. Predicted material handling quantities over the 26 year operational life of the Project are provided in **Table 3.1**. The interim process stockpile near the ROM pad will only be used in the early years of the mine.

The life of the open-cut mine is estimated to be 36 years, including construction, operation (26 operational years), and active rehabilitation.

Figure 3.2: Mine Sequencing Plan (Period Progress Plot – Ore)

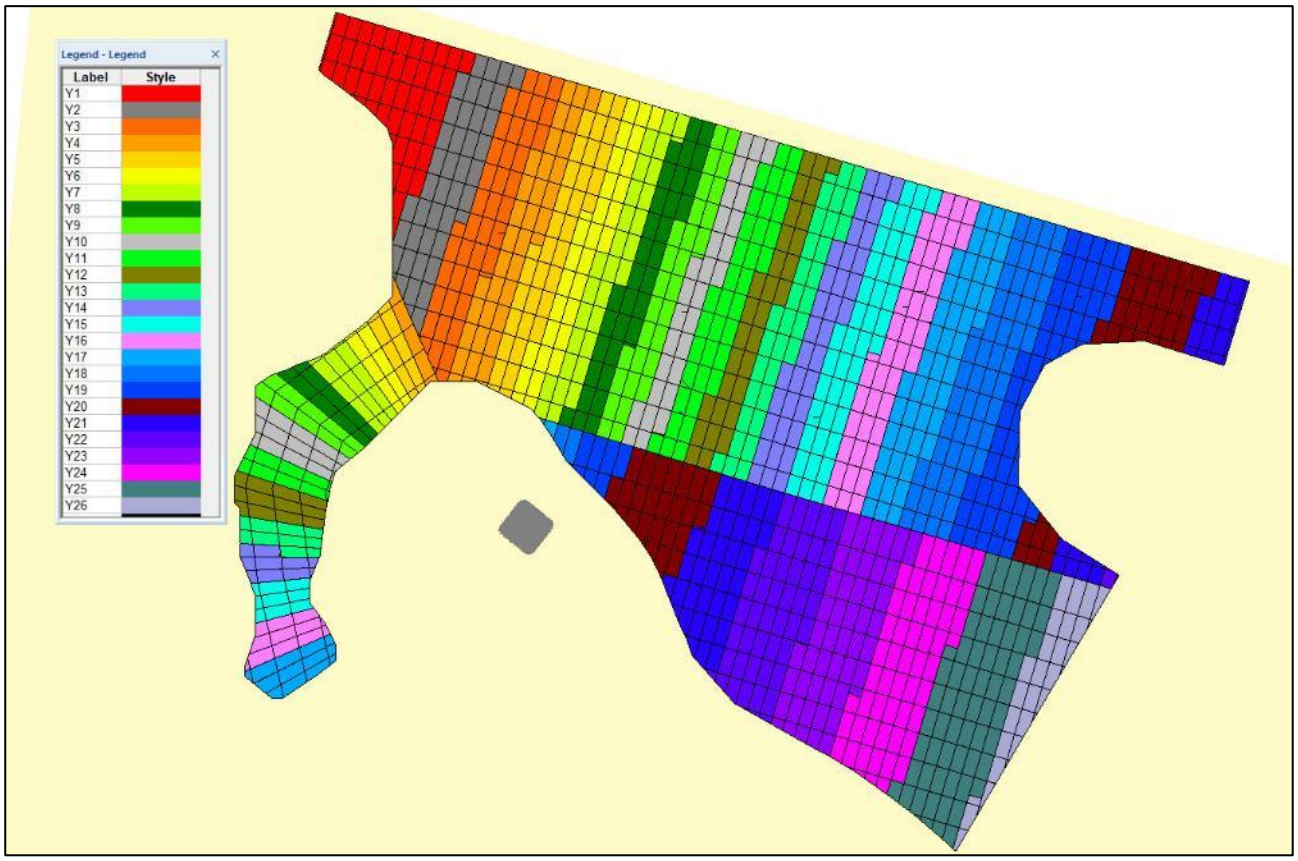


Table 3.1: presents the proposed schedule of materials to be handled over the life of the mine. The rejects quantities shown in the table are highly conservative as there will also be product HPA removed which wwill reduce waste quantities further.

Table 3.1: Indicative Material Handling Quantities Over the 26 Years of Operating Mine

Year	Topsoil removal (bcm)	Overburden (bcm)	Ore – ROM (t/period)	Product V_2O_5 (t/period)	Rejects (t/period)
0	162,000	2,200,000	-	-	-
1	62,000	2,122,000	1,900,000	9,290	1,890,710
2	58,000	1,930,000	1,900,000	9,610	1,890,390
3	63,000	1,980,000	1,900,000	9,200	1,890,800
4	59,000	1,929,000	1,900,000	8,960	1,891,040
5	61,000	1,996,000	1,900,000	8,620	1,891,380
6	60,000	2,001,000	1,900,000	8,710	1,891,290
7	57,000	1,966,000	1,900,000	8,490	1,891,510
8	62,000	2,072,000	1,900,000	8,190	1,891,810
9	65,000	2,002,000	1,900,000	8,250	1,891,750
10	54,000	2,154,000	1,900,000	8,180	1,891,820
11	67,000	2,129,000	1,900,000	8,090	1,891,910
12	59,000	2,181,000	1,900,000	8,320	1,891,680
13	63,000	2,387,000	1,900,000	8,530	1,891,470

Year	Topsoil removal (bcm)	Overburden (bcm)	Ore – ROM (t/period)	Product V_2O_5 (t/period)	Rejects (t/period)
14	65,000	2,475,000	1,900,000	8,680	1,891,320
15	67,000	2,758,000	1,900,000	8,760	1,891,240
16	79,000	3,040,000	1,900,000	8,880	1,891,120
17	83,000	3,181,000	1,900,000	8,710	1,891,290
18	85,000	3,403,000	1,900,000	8,680	1,891,320
19	75,000	3,341,000	1,900,000	8,640	1,891,360
20	90,000	3,552,000	1,900,000	8,440	1,891,560
21	79,000	3,628,000	1,900,000	8,230	1,891,770
22	69,000	3,749,000	1,900,000	7,290	1,892,710
23	73,000	3,829,000	1,900,000	6,890	1,893,110
24	81,000	3,613,000	1,900,000	6,910	1,893,090
25	94,000	3,604,000	1,900,000	7,730	1,892,270
26	12,000	921,000	524,000	2,520	521,480

3.3.3 Choice of Modelling Scenarios

The major determinant of air quality impacts over the life of the mine is the quantity of materials handled and the location of emission sources relative to the sensitive receptors. Estimated material handling quantities over the life of the mine is provided in **Table 3.1**.

One mine scenario has been considered as follows:

- Year 26 mine site layout as shown in **Figure 3.2** with Year 25 production rate.

The scenario was chosen to represent the likely worst-case impact at the nearest sensitive receptors 1 and 2. The emission sources are anticipated to be closest to the nearest receptors 1 and 2 during year 26 (EOM) of the mine. As the quantities of materials for year 26 are relatively low (based on a partial year) in comparison to other years within 25 years of the life of the mine, the quantities of materials handled for year 25, which are typical but erring on the higher side of the quantities of materials, were used. The combination of year 26 source locations with year 25 materials handled provides a worst-case scenario with a good balance between the proximity of emission sources to the sensitive receptors and amount of materials handled.

3.3.4 Mobile Plant and Production

The ore will be processed to produce high grade V_2O_5. The proposed fleet for the open-cut mining operations is presented in **Table 3.2**.

Table 3.2: Proposed Production Fleet

Equipment Model	Scenario Quantity	Application	Annual Target Work Hours
Komatsu PC1250 Excavator	2	Overburden removal	11,963
Komatsu HD605-7 Truck	5	Hauling/unloading of Overburden	23,919
Komatsu PC700 Excavator	1	Loading of Ore	4,077
Komatsu HD325-7 Truck	3	Hauling/unloading of Ore	13,256
Face Dozer	2	Ore on run-of-mine (ROM) pad/product	-

Equipment Model	Scenario Quantity	Application	Annual Target Work Hours
Stockpile Dozer/Dump Dozer	2	Pit and haul road establishment and maintenance	-
Grader	2	Overburden removal	-
Wheel Dozer	1	Rejects loading and general use	-
Water Truck	2	Dust control	-
Service Truck	1	Maintenance	-

3.4 Processing Plant

3.4.1 Processing overview

The Project has a hydrometallurgical processing plant designed to extract and refine vanadium and HPA and produce a REE concentrate. The vanadium extraction process is based on the capacity of sulphuric acid required to dissolve the vanadium contained within the iron oxides and clays within the orebody. Vanadium will be refined through selective solvent extraction. The basis for refinement of HPA is the utilisation of HCl (hydrochloric acid) to leach and precipitate an alumina chloride hexahydrate (ACH) through multiple purification stages.

Ore will be crushed to a nominal size for a reverse flotation process, utilising frothing agents to differentially float the calcite from the ore. This calcite-rich concentrate is transported to the process waste treatment for use in the neutralisation of residue material. The vanadium rich concentrate proceeds to drying and roasting in a rotary kiln. Concentrate is then cooled and conveyed to the leaching circuit. Leaching will be undertaken at up to 800° C via process heating (most likely steam injection). The material is then slightly cooled and conveyed for acid leaching through the addition of sulphuric acid. The barren residue will be filtered and washed to recover vanadium and sulphuric acid. This recovered leachate will then be partially neutralised before solvent extraction. A series of mixer settlers will extract the vanadium from the solution into an organic phase (with other impurities) and then a stripping solution will be utilised to selectively concentrate the vanadium into an aqueous phase for precipitation. Precipitation of ammonium metavanadate (AMV) involves crystallisation in stirred tanks with recycling as seed to enhance the recovery of AMV. A filtered product will be then calcined to generate a high purity V_2O_5 powder while recovering ammonia to generate AMV. Rare earth metals are beneficiated, leached and concentrated into a mixed carbonate product.

The concept level flowsheet presented in **Figure 3.3** and **Figure 3.4** summarises the current understanding, with the treatment of ROM ore through to the production of a bagged V_2O_5 product, a HPA product and REE concentrate. Several simplifications have been made to reflect current understanding and a full mass balance has not yet been prepared.

Figure 3.3: Process Flowsheet for V_2O_5 and HPA

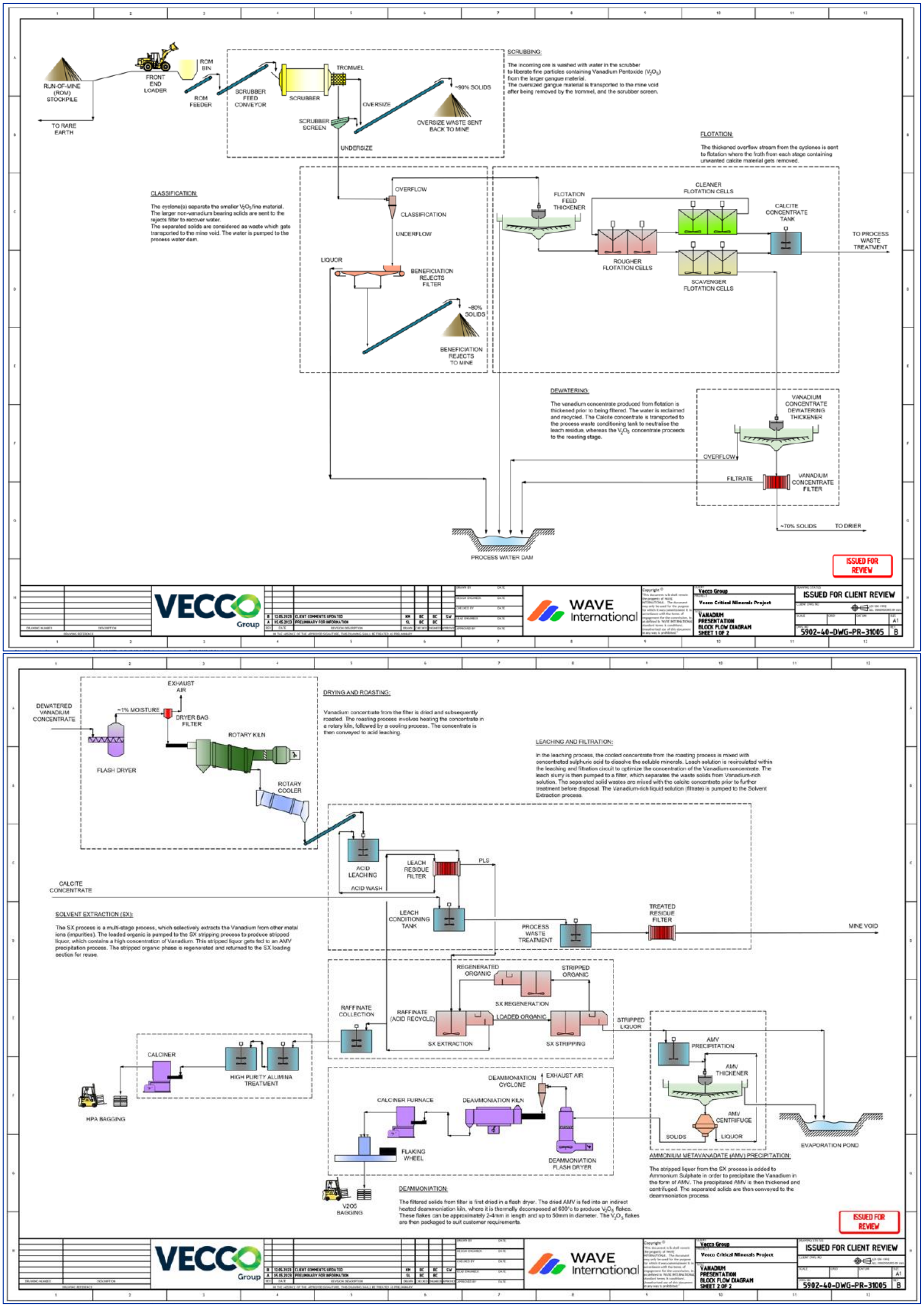
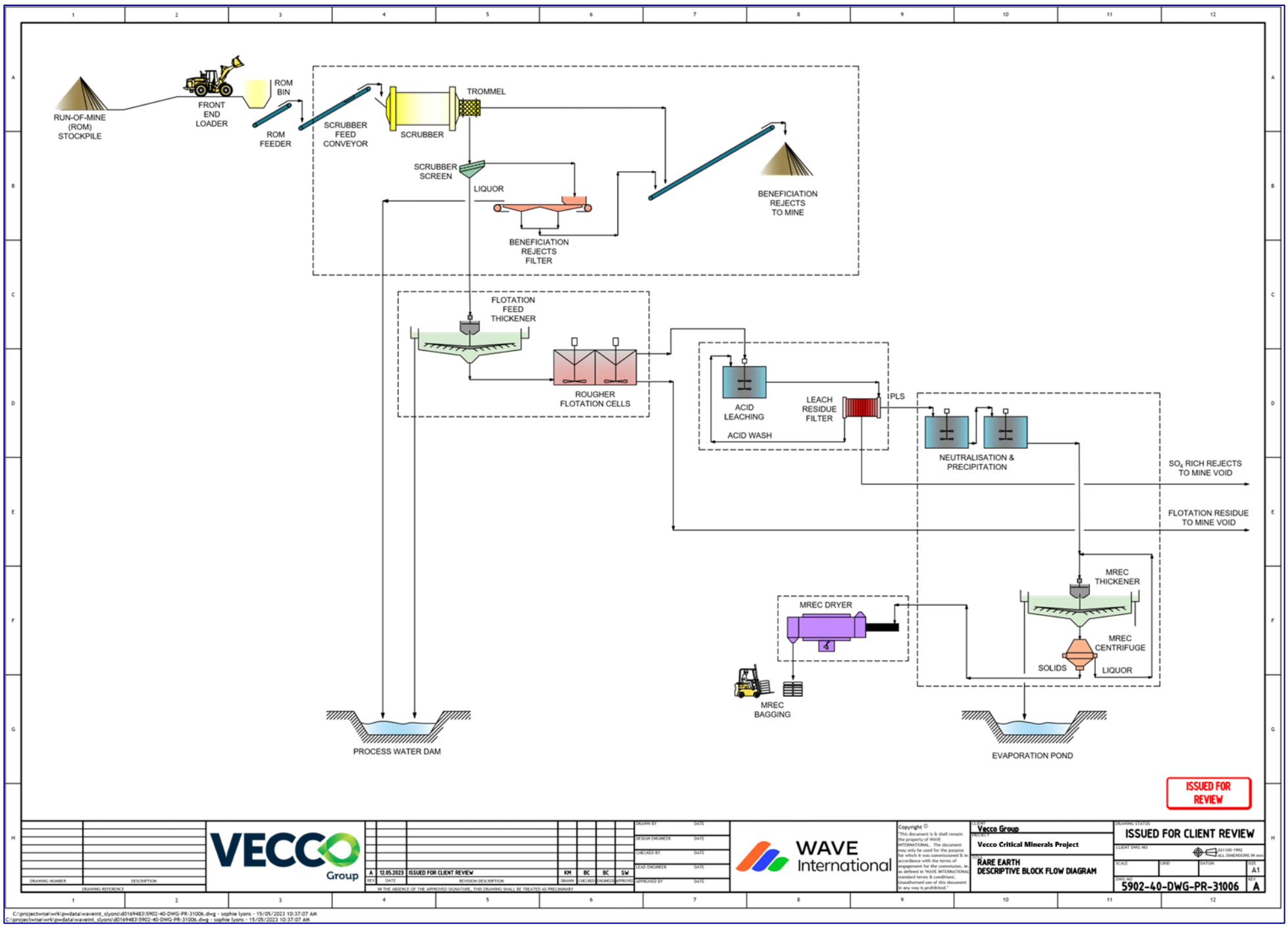


Figure 3.4: Process Flowsheet for REE



3.4.2 Scrubbing

- The scrubbing circuit will be designed to reduce the top size of the ore to below 5 millimetres.
- The scrubber will pre-condition the ore to disperse the clay material from the calcite and other gangue.
- The intention is not to generate fines for superior calcite rejection but also to ensure the liberation of vanadium.
- The incoming ore is washed with water in the scrubber to liberate the fine particles containing vanadium from larger gangue material. The oversized gangue material is transported to the mine void after being removed by the trommel and the scrubber screen.

3.4.3 Flotation

- A reverse flotation circuit has been devised where the calcite is floated off leaving the vanadium bearing minerals in the tail. This is critical in rejecting calcium. Calcium-rich concentrate is removed and transported to the process waste treatment for use in the neutralisation of the leach residue.
- Multiple stages of concentrate cleaning have shown that additional vanadium can be recovered.
- The flotation material will require thickening/filtration to minimise water going into leaching.

3.4.4 Roasting Plant

- Vanadium concentrate from the dryer bag filter will be dried and subsequently roasted. The roasting process involves heating the concentrate in a rotary kiln up to 800°C. Followed by a cooling process. The concentration is then conveyed to acid leaching.

3.4.5 Sulphuric Acid Leaching

- Contacting the ore with H_2SO_4 in stirred tanks will extract the vanadium as sulphate. This leach will also extract aluminium and iron as sulphates.
- Leaching will be operated in a counter-current fashion so that the most leached ore will contact the highest acid concentration.
- It will be operated at sufficient free acid concentration to secure fast kinetics and reduce residence time at atmospheric conditions to minimise energy.
- It will be operated at 20-25 wt% solids to manage viscosity.
- The leach slurry is pumped to a filter, which separates the waste solids and vanadium rich solution (filtrate).
- Separated solid waste will be finished with a counter current decantation (CCD) wash prior to further treatment for disposal.
- The vanadium-rich filtrate is pumped to the next step in processing, the solvent extraction process.

3.4.6 Solvent Extraction

- The leachate will be partially neutralised to be compatible with the solvent extraction organic. This can be achieved through the neutralisation with ore to minimise the costs of pH adjustment.
- Contacted with organic in multiple stages of extraction with an O:A ratio to be determined. Mextral 984 H (which is an aldoxime and oxime) is successful at extracting vanadium with low amounts of Fe / V.
- The vanadium rich organic phase will then be stripped in multiple stages with ammonia at an O: A ratio to be determined to remove vanadium into the stripped liquor. A 2.5% V/V ammonia solution has also been very successful at stripping vanadium from the organic, to produce a clean V-loaded strip solution.

3.4.7 Ammonium Metavanadate (AMV) Precipitation

- The stripped vanadium rich liquor will be then pH adjusted to promote precipitation of AMV (NH_4VO_3) while managing impurities. Precipitation of the AMV will be achieved in this process and yield and purity will be controlled through manipulation of pH and temperature seeding.

3.4.8 Calcination to V_2O_5

- The filtered AMV will be flash dried at 100° C and then submitted to an electric calciner which drives the temperature to 450° C. The AMV decomposes to V_2O_5 and ammonia (NH_3). Calcined V_2O_5 is the final product ready for packaging and transport. Ammonia is captured and recycled back to the start of the AMV precipitation.

3.4.9 High Purity Alumina (HPA)

- This process is shown as a side stream of raffinate from the solvent extraction process during vanadium processing.
- As described in **Figure 3.3**, the leach conditions promote the extraction of aluminium (Al) into a sulphate solution. This provides a rich source of Al for purification and concentration.
- The raffinate feed will first be neutralised in tanks and then subjected to acid leach using HCl to promote the extraction of aluminium into a chloride solution.
- The residual sulphate solution will provide a rich source of aluminium for purification and concentration. The solution will enter a calciner to produce the final product.
- The final product is calcined HPA which will then be ready for packaging and transport.

Waste from this process will be treated on-site and comprises part of the mixed residue material that will be disposed of on the pit floor.

3.4.10 Waste Management

The back end of the process involves the management of waste which is described below:

Residue Filtration

- This will be conducted to recover as much of the vanadium as possible after the CCD recovery of the vanadium.

Residue Neutralisation and Filtration

- The leached residue will be neutralised prior to disposal. This will be achieved through contact with the Ca rich concentrate (ground) from the flotation circuit (and/or TLB_A) in a series of stirred tanks.
- Final pH adjustment will be achieved through the addition of lime (calcined) from the Toolebuc formation (TLB_A).
- The neutralised residue will be filtered in large plate and frame filters.

Residual Disposal

- Filtered, neutralised residue will be co-disposed into the pit with other waste. The residue and mine waste will be mixed prior to disposal (mixing via a scrubber).
- The co-disposed residue will be trucked to the pit where it will be placed inside internal embankments which will contain the residue as it dries and compacts – potentially with additional mechanical assistance (dozing/ripping).
- As it meets compaction objectives, fresh residue can then be placed on top of compacted residue.

- A small ex-pit facility (the interim residue storage facility) will be used to manage any unplanned events affecting suitability for co-disposal.

3.4.11 Rare Earth Elements Processing Flowsheet

Beneficiation

- The mine material may be subjected to a water-based beneficiation process to concentrate the rare earths present in the apatite. The incoming ore is washed with water in the scrubber to liberate the fine particles containing REE from larger gangue material. This material will be screened and put through the beneficiation rejects filter where fine REE material will enter the flotation process.
- During the flotation process, the fines feed will be thickened and flotation cells will ensure froth containing calcite is floated off in each cell leaving the valuable REE bearing minerals.
- The waste from this process can be disposed into the mining pit. Water, if acidic will be treated prior to re-use or disposal.

Leaching

- Rare earths are extractable at modest leach conditions (pH=1, 90 degrees, 4-8 hour duration). As shown in **Figure 3.3**, it is anticipated that a sulphuric acid (H_2SO_4) leach will be utilised.
- The rare earths are now in liquor form as sulphates.
- The product will be thickened and filtered to recover the liquor and densify the residue.
- The residue will be washed and neutralised for disposal with vanadium waste residue.

Neutralisation and Precipitation

- The liquor will be sequentially neutralised with sodium carbonate and the impact will be the removal of calcium (Ca) and iron (Fe), further concentrating the rare earths fraction. These waste stream will be neutralised and also co-disposed with the vanadium waste.
- The precipitated rare earths concentrate will then be washed, filtered, dried and bagged for transportation.

3.4.12 Sulphuric Acid Plant

Due to the amount of sulphuric acid required and the availability of 98% acid in Queensland, Vecco will need to produce sulphuric acid.

Sulphur Preparation

- Sulphur will be received in bulk from Townsville, either trucked from Townsville or railed to Julia Creek and trucked in from Julia Creek. If railed to Julia Creek, there may be some storage at this location. Infrastructure discussions have commenced.
- Sulphur will be stored in an enclosed shed to prevent contamination and also loss of containment.

Acid Generation

- Sulphur will be melted in a spinning cup sulphur burner that includes atomisation of liquid sulphur prior to burning.
- A double adsorption, double catalysis oxidation process will produce SO_3(g) (sulphur trioxide), which will then be contacted with water to produce H_2SO_4(l) at 98.5 wt%.
- The concentrated sulphuric acid will then be diluted. This is an exothermic reaction which provides additional heat that will be used in the processing circuit (such as the leach circuit).

- Another potential by-product is high pressure steam for electricity generation and could complement the significant renewable supply that is planned for the site.

3.5 Construction and Commissioning

Prior to the operation of the Project, ancillary facilities will be constructed at the MIA which will include (but not be limited to) the processing plant, offices, solar farm, process waste facility and interim storage facility. The emissions from the construction phase will include dust emissions from clearing of land and material handling, and minor gaseous combustion emissions from mobile equipment. The emissions due to the construction activities are expected to be of similar nature, albeit minor in comparison to the mining operations emissions. Commissioning should include testing of processing plant air emission controls.

The activities will also be short-lived and are located relatively far from the sensitive receptors. Hence, emissions from these sources were not modelled in this assessment.

3.6 Decommissioning and Closure

Closure of the Project will include decommissioning of the facilities onsite. Emissions will be of similar nature to the construction activities and are likely minimal in comparison to mining operations, will be short-lived and located relatively far from the sensitive receptors. During this phase, the emissions from mining and processing will also cease and the closure of the Project will also include rehabilitation of the site which will involve revegetation of exposed areas and so will substantially reduce emissions. Emissions from these sources were not modelled in this assessment.

3.7 On-site Water Storage Facility

An on-site water storage facility (Raw Water Dam) will be constructed approximately 7 kilometres to the north-west of receptor 1. **Figure 3.1** shows the location of the raw water dam. A pump station will transfer the water to raw water dam at a rate of up to 112,320 ML per day during flow harvesting conditions. The pump station energy will be supplied by a 500 kW diesel generator approximately 7 kilometres from the nearest sensitive receptor.

3.7.1 Construction

The construction of the raw water dam is anticipated to use the following equipment: excavators, scrapers, front-end loaders/dozers, moxies/dump trucks, mobile cranes and forklifts. The construction activities would generate dust; however, this or any emissions would be substantially smaller in scale in comparison to the mining dust emissions. The area of the dam and related disturbance area is 40 hectares compared to the area of the mining lease being 3,536 hectares. Dust generated from the construction activities of the raw water dam is not likely to cause discernible impacts at the nearest sensitive receptor 7 kilometres away. The closest construction activity from receptor 1 would be the pipeline works which would be approximately 7 kilometres away to the north-west at the nearest point. Dust emissions from the pipeline works would be relatively minimal and would not be discernible at 7 kilometres away. Hence, the impacts from the construction activities have not been considered further in this report.

3.7.2 Operation

The main air emission sources of the raw water dam operation would be combustion gases from a 500 kilowatt pump generator. These emissions are not likely to cause discernible changes to the air quality at the nearest sensitive receptor 13 kilometres away. Hence, these emissions have not been considered further in this assessment.

Greenhouse gas emissions from the pump generators have been included in **Section 5.2**.

3.7.3 Decommissioning

The raw water dam and associated infrastructure will be decommissioned after approximately 26 years, or when mining activities have been completed and plant and structures decommissioned. The raw water dam will be retained in the final landform.

3.7.4 Off-site Product Haul Route

Product vanadium and HPA from the mine as well as sulphur to site will be hauled along a 35 kilometre mine access road south to south-east to the Punchbowl Road by road trucks such as B-double and A-triple.

Based on information provided by client:

- Product vanadium will be bagged.
- The length of the haul route is approximately 35 kilometres.
- The maximum annual quantity of product vanadium from site will be 9.61 kt/year.
- The maximum number of B double loads for hauling 5,589 m^3 product vanadium per year will be 0.36 per day.
- The maximum number of B double loads for hauling 5,714 m^3 product HPA per year will be 0.37 per day.
- The maximum number of A-triple loads for hauling 74 kt of sulphur to site for H_2SO_4 plant per year will be 4.5 per day.
- The nearest dwelling is located at Malpas-Trenton approximately 4.7 kilometres south from the haul route. This has been verified by Trinity using Google Earth aerial photography.

The maximum total truckloads of product removed from site and sulfur delivered to site is 5.3 loads per day. Based on the above information, the dust emissions from these haul trucks on the mine access road will be insubstantial and the likelihood of impacts at sensitive receptors approximately 4.7 kiometres from the route is negligible. Therefore, modelling of the dust emissions was not required.

3.8 Upset Conditions

Potential upset conditions may include the following:

- Water trucks may break down from time to time. However, the use of two water trucks is proposed and it is expected that one would suffice for water application most of the time, and this condition is not considered high risk. The mine should ensure routine spare parts are available on site to reduce down time duration and manage this risk.
- Processing plant air emission controls may fail. These controls should have pressure gauges to detect leaks, blockages and failures. The processing plant control system should be programmed to shutdown the plant when such failures occur. Routine spare parts should be kept on site to allow replacement before operations re-commence.

4. AIR QUALITY VALUES AND CRITERIA

4.1 Relevant Pollutants

This section identifies and assesses the contaminants anticipated to be released from point and diffuse sources and fugitive emissions anticipated within the area of the MLA. Quantitative details of these emissions are provided in **Sections 9.6 and 9.8.**

4.1.1 Particulates

The Project's operation would result in the emission of particulates characterised as:

- total suspended particulate matter (TSP);
- particulate matter with equivalent aerodynamic diameters of 10 µm or less (PM_{10}); and
- particulate matter with equivalent aerodynamic diameters of 2.5 µm and less ($PM_{2.5}$).

4.1.2 Gaseous Emissions

Anticipated emissions also include exhaust emissions from mobile equipment and stationary sources including power generation. From mining operations that apply standard control measures, combustion gases normally have substantially less air quality impact than particulates. Therefore, compliance with particulate criteria generally indicates compliance with criteria for gaseous pollutants. The modelling of mining operations has therefore been undertaken for particulate emissions. Dispersion of particulate and gaseous emissions from power generation has been modelled separately and includes the following species: acetaldehyde, benzene, carbon monoxide (CO), formaldehyde, oxides of nitrogen (NO_x), $PM_{2.5}$, PM_{10}, polycyclic aromatic hydrocarbons (PAHs), sulfur dioxide (SO_2), toluene and xylene.

Gaseous pollutants will also be emitted from processing operations onsite. Gaseous pollutants from processing operations are included in the emission inventory for the purpose of assessing whether dispersion modelling is required. The gaseous emission sources included in the emission inventory are:

- vapour emission of flotation reagent;
- SO_2, particulate and metals emissions from roasting ore;
- H_2SO_4 mist emissions from the leaching tanks;
- volatile organic compounds (VOCs) from evaporation of solvent used in solvent extraction; and
- ammonia (NH_3) emissions from the deammoniation plant.

4.2 State Legislative Instruments

4.2.1 Queensland Environmental Protection Policy

The relevant assessment criteria are the environmental values defined in the Environmental Protection (Air) Policy (EPP Air) 2019, under the Environmental Protection Act (1994).

The EPP Air provides objectives for air quality indicators (pollutants) that address health, the aesthetic environment, ecosystems and agriculture. The objectives relevant to this Project, the human health and wellbeing and aesthetic environment have been summarised in **Table 4.1**.

Table 4.1: Air Quality Criteria (EPP Air) for Health and Wellbeing

Air Quality Indicator	Period	Criteria (µg/m³)
$PM_{2.5}$	1 day	25
	1 year	8
PM_{10}	1 day	50
	1 year	25
total suspended particles (TSP)	1 year	90
vanadium in PM_{10}	1 day	1.1
sulphur dioxide (SO_2)	1 hour	570
	1 day	229
	1 year	57
carbon monoxide (CO)	8 hour	11,000
nitrogen dioxide (NO_2)	1 year	62
	1 hour	250
benzene	1 year	5.4
formaldehyde	1 day	54
	30 minutes (aesthetic environment)	109
toluene	1 year	400
	1 day	4,100
	30 minutes (aesthetic environment)	1,100
xylene (total of all isomers)	1 year	950
	1 day	1,200
arsenic and compounds	1 year	0.006
lead and compounds	1 year	0.5
manganese and compounds	1 year	0.16
nickel and compounds	1 year	0.02

Note that the EPP Air also contains a criterion for visibility reducing particles, but this is a measure of regional air quality and is not relevant to point sources. The impact of visible particles from point sources is addressed by the $PM_{2.5}$ criteria.

4.2.2 Department of Environment and Science (DES) Guideline

The Department of Environment and Science (DES) Guideline, version 4.04, (DES, 2021) for the Application requirements for activities with impacts to air, suggested that a short-term (24-hour average) TSP concentration at the sensitive receptor of greater than 90 µg/m³ may cause dust nuisance and so has advised the assessment of the short-term (24-hour average) maximum TSP impact to be undertaken and compared against the trigger levels provided in the *Good practice guide for assessing and managing the environmental effects of dust emissions* (NZ Ministry for the Environment, 2016) as shown in **Table 4.2.** The most recent 24-hour average trigger level for a residential area is 60 µg/m³ which is more stringent than the annual average TSP criterion of 90 µg/m³. The NZ Ministry for the Environment guide clearly states that these trigger levels are not meant for regulatory compliance purposes but are only applicable to monitoring data and for the purpose of alerting the operators into potentially taking additional dust control measures when triggered. Hence, the current trigger levels are well below those that may impact receptors.

Table 4.2: Suggested 24-Hour Trigger Levels for TSP (NZ Ministry for the Environment, 2016)

Sensitivity of Receiving Environment	High	Moderate	Low
Trigger Level (µg/m³)	60	80	100

Notes: *1. In general, all residential areas will be high sensitivity*

2. For managing chronic dust only

4.3 Other State Legislation

The EPP Air does not contain criteria for NH_3. Thus, in this assessment, the NH_3 criterion from the State Environment Protection Policy (Air Quality Management) of the Environment Protection Authority Victoria (VIC EPA, 2022) as presented in **Table 4.3** has been used in this assessment.

Table 4.3: Air Quality Criteria (VIC EPA, 2022)

Air Quality Indicator	Period	Criteria (µg/m^3)
NH_3	1 hour	3,200
	1 day	1,184
	1 year	70
acetaldehyde	1 hour	470
	1 year	9
H_2SO_4	1 hour	120
	1 year	1

4.4 Dust Deposition

Whilst there are no quantitative limits specified in legislation, there are guidelines designed to avoid nuisance caused by dust deposition fallout onto near horizontal surfaces.

The Department of Environment and Science (DES 2021) suggests the guideline that deposited matter averaged over one month should not exceed 120 mg/m^2/day (3.6 g/m^2/month). For extractive industries, it is the insoluble component of analysed dust that is used.

It should be noted that these values are a guideline for the level that may cause nuisance at a sensitive receptor such as a residence or sensitive commercial land use. It is not normally necessary to achieve this level at the boundary, but boundary measurement can assist in the assessment of whether there is risk of nuisance occurring or not.

4.5 Summary of Relevant Criteria

Table 4.4: Summary of Relevant Air Quality Criteria

Air Quality Indicator	Period	Criteria (µg/m^3)
$PM_{2.5}$	1 day	25
	1 year	8
PM_{10}	1 day	50
	1 year	25
TSP	1 year	90
vanadium in PM_{10}	1 day	1.1
SO_2	1 hour	570
	1 day	229
	1 year	57
arsenic and compounds	1 year	0.06
lead and compounds	1 year	0.5
manganese and compounds	1 year	0.16
nickel and compounds	1 year	0.02
NH_3	1 hour	3,200
	1 day	1,184
	1 year	70

Air Quality Indicator	Period	Criteria (µg/m^3)
H_2SO_4	1 hour	120
	1 year	1
acetaldehyde	1 hour	470
	1 year	9
dust deposition	30 days	120 mg/m^2/day

5. GREENHOUSE GAS EMISSIONS

5.1 Greenhouse Gas Regulatory Requirements

5.1.1 National Greenhouse and Energy Reporting (NGER)

The legislative framework for a national greenhouse and energy reporting system is established via:

1. the National Greenhouse and Energy Reporting Act 2007 (NGER Act) as amended 01 September 2021 (Department of the Environment and Energy, 2021)
2. the National Greenhouse and Energy Reporting Regulations 2008 (NGER Regulations) as amended 1 July 2021 (Department of the Environment and Energy, 2021)
3. the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (NGER Determination) as amended 1 July 2021 (Department of the Environment and Energy, 2021).

The *Estimating emissions and energy* series of guidelines (Clean Energy Regulator, 2023) provide additional guidance and commentary to assist in estimating greenhouse gas emissions for reporting under the NGER system. The emission factors used in these guidelines are consistent with those specified in the National Greenhouse Account Factors (DCCEEW 2022). The National Greenhouse Account Factors form the most appropriate standard for use in the prediction of emissions for impact assessment.

The NGER Act makes reporting mandatory for corporations whose energy production, energy use, or greenhouse gas emissions meet certain specified thresholds. These thresholds are detailed in the NGER Regulations. **Section 9.1.2** summarises the reporting thresholds.

The NGER Determination provides methods for the estimation and measurement of:

(1) greenhouse gas emissions;
(2) the production of energy; and
(3) the consumption of energy.

Greenhouse gas emissions are defined in Section 2.5 of the NGER Regulation as follows:

Emissions of greenhouse gas, in relation to a facility, means the release of greenhouse gas into the atmosphere as a direct result of:

(a) an activity, or series of activities (including ancillary activities) that constitute the facility (scope 1 emissions); and
(b) one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility (scope 2 emissions).

Coverage of scope 1 emission sources is given in Section 1.3 (4) of the NGER Determination by:

(a) fuel combustion, which deals with emissions released from fuel combustion;
(b) fugitive emissions from fuels, which deals with emissions mainly released from the extraction, production, processing and distribution of fossil fuels;
(c) industrial processes emissions, which deal with emissions released from the consumption of carbonates and the use of fuels as feedstock or as carbon reductants, and the emission of synthetic gases in particular cases; and
(d) waste emissions, which deal with emissions mainly released from the decomposition of organic material in landfill or other facilities, or wastewater handling facilities.

Scope 2 emissions are generally emissions that result from activities that generate power offsite for consumption onsite. The largest contributor to scope 2 emissions is consumption of electricity or steam.

Scope 3 emissions are those created downstream of the operation, specifically from the usage of the product produced by the operation.

5.1.2 Reporting Thresholds

This section is to determine operational requirements of the Project to report scope 1 and 2 emissions. Section 13 of the NGER Act sets reporting thresholds for the operation of a facility or corporations, as per the following excerpts:

(1) A controlling corporation's group meets a threshold for a financial year if in that year:

(a) the total amount of greenhouse gases emitted from the operation of facilities under the operational control of entities that are members of the group has a carbon dioxide equivalence of: ....

(iii) 50 kilotonnes or more; or

....

(b) the total amount of energy produced from the operation of facilities under the operational control of entities that are members of the group is:…

(iii)

(c) the total amount of energy consumed from the operation of facilities under the operational control of entities that are members of the group is:

....

(iii) 200 terajoules or more; or

(d) an entity that is a member of the group has operational control of a facility the operation of which during the year causes:

i) emission of greenhouse gases that have a carbon dioxide equivalence of 25 kilotonnes or more; or

ii) production of energy of 100 terajoules or more; or

iii) consumption of energy of 100 terajoules or more.

Note that within a corporation, incidental facilities may be reported as percentages of the total or otherwise estimated as per the NGER Regulations as updated by the National Greenhouse and Energy Reporting Amendment (Streamlining Reporting) Regulation 2013.

5.1.3 Greenhouse Gases

Gases addressed by the NGER Regulations are the six key greenhouse gases consistent with the Kyoto Protocol. These gases differ in their capacity to trap heat and contribute to the greenhouse effect. The capacity of each gas to contribute to global warming is referred to as its Global Warming Potential (GWP) relative to that of carbon dioxide. The GWP's of the six Kyoto greenhouse gases are provided in **Table 5.1.**

Because of the variation in GWP between different gases, the emission factors used to calculate greenhouse gas emissions from the Project are stated in terms of carbon dioxide equivalents (CO_2-e) and consider the various GWP's of the different greenhouse gases.

Table 5.1: Global Warming Potential of Greenhouse Gases

Greenhouse Gas	GWP (CO_2-e)
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265
Hydrofluorocarbons (HFC's)	116-12,400
Perfluorocarbons (PFC's)	6,630-11,100
Sulphur hexafluoride (SF_6)	23,500

Note: Source is Australian National Greenhouse Accounts, (DCCEEW 2022).

5.2 Greenhouse Gas Assessment

5.2.1 Methodology for Impact Assessment

The following data and assumptions were used in emission calculations:

- Fugitive gas emissions from the use of liquid fuels for the production fleet have been determined using Method 1 from the NGER Technical Guidelines (Department of the Environment and Energy, 2017).
- The diesel combusted onsite by mobile fixed mining equipment is calculated to be 5,082 kL over the 26 year operating life.
- Water for the process and for dust suppression will be provided by an onsite water storage facility supplemented by water extraction.

  Emissions resulting from the combustion of petrol are assumed to be insignificant for the purposes of this assessment.
- The processing plant will require 10 MW of electricity. It is currently proposed to generate this onsite using a mix of solar panels and heat produced by the sulphuric acid processing plant, in which case there will be no scope 2 emissions from consumption of purchased electricity from a grid.
- Non-combustion emissions from the processes are assumed to be not significant for the purposes of this assessment.
- The maximum greenhouse gas emission for the mine is anticipated to occur in Year 25 of the mine as this represents the maximum amount of overburden removal and number of equipment in operation. Hence, the greenhouse gas emission of the Project has been assessed using the Year 25 production and equipment schedules.

The mobile equipment anticipated to utilise diesel fuel is summarised in **Table 5.2**.

Table 5.2: Mobile Plant for Year 25

Equipment Type	Make	Model	Quantity
Excavator	Komatsu	PC1250	2
Excavator	Komatsu	PC700	1
Truck	Komatsu	HD605-7	5
Truck	Komatsu	HD325-7	3
Dump Dozer	-	-	2
Face Dozer	-	-	2
Grader	-	-	2
Rubber Tyre Dozer	-	-	1
Water cart	-	-	2
Service Truck	-	-	1

Other fixed or minor equipment may include integrated tool handler, crane, lighting plants, tyre handler and forklift.

5.3 Emissions from Vegetation Clearing

It is understood that there are four vegetation types to be cleared that have crown cover greater than 20%: 0.9 hectares of RE 2.3.17a; 443.8 hectares of 2.5.12a; 26.1 hectares of RE 2.5.1a and 47.8 hectares of 2.5.33b as presented in **Table 5.3**. Thus, this vegetation removal has been included in the inventory. Emissions from vegetation clearing were calculated using the Plot module of the FullCAM software (FullCAM Public Release

2020) (Department of Industry, Science, Energy and Resources). Only forests or woodlands with crown cover greater than 20 percent need to be assessed, a threshold specified by Department of the Environment and Energy (2019).

Spatial data (rainfall, evaporation, temperature, local tree species) was downloaded for latitude -19.958° longitude 141.892, a location within the proposed mining lease. For the purpose of this assessment, a worst-case clearing scenario was assumed: that all vegetation clearing was undertaken in one year. Each of the areas and vegetation types listed in **Table 5.3** was entered into FullCAM as a plot. These areas include regrowth vegetation that has a crown cover of greater than 20%. The default biomass values were used. No product recovery was assumed, which is an over-estimate and is a worst-case scenario for greenhouse gas emissions.

Table 5.3: Vegetation in the study Area with Crown Cover >20%

Regional ecosystem type	Vegetation type (both remnant and regrowth	Area to be cleared (ha)
2.3.17a	Eucalyptus microtheca low open woodland, commonly with Excoecaria parvufolia and Lysiphyllum	0.9359
2.5.12a	Eucalyptus pruinosa and/or Corymbia terminalis low woodland to low open woodland, commonly with Lysiphyllum cunninghamii.	443.7668
2.5.1a	Mixed woodland, including combinations of the species Lysiphyllum cunninghamii, Atalaya hemiglauca, Eucalyptus microneura, Grevillea striata, Acacia spp. and Archidendropsis basaltica.	26.0918
2.5.33b	Melaleuca viridiflora low open woodland to low woodland, occasionally with M. citrolens, M. stenostachya, Erythrophleum chlorostachys, Asteromyrtus symphyocarpa and Terminalia canescens.	47.7958
	Total to be cleared	518.6

Notes:
- *Source: Client data*

The decay or combustion of vegetation will emit both CO_2 and, in anaerobic conditions, CH_4. Literature provided by Department of Industry, Science, Energy and Resources and its predecessors, provide some factors for the proportion of non-CO_2 gases released by combustion, but not by decay. Therefore, this assessment assumes that the carbon is released as CO_2.

The results of the model simulation are shown in **Table 5.4**. Applying a conversion factor of 44 / 12 / 1000 converts these predicted values to kilotonnes CO_2-e. The annual peak emission from clearing over the life of the mine is estimated as 36.4 kt CO_2-e. During rehabilitation (post mine (5yrs)), 4.3 kt CO_2-e is estimated to be absorbed (sequestered).

Table 5.4: Carbon Emissions from vegetation clearing and Rehabilitation

Activity	1 year peak carbon change (tonnes)	1 year peak emission (kilotonnes CO_{2-e})	Total 5 year post mine carbon change (tonnes)	Total 5 year post mine emission (kilotonnes CO_2-$_e$)
Vegetation clearing	9,918 emission	+ 36.4	13,571 emission	+ 49.8

Activity	1 year peak carbon change (tonnes)	1 year peak emission (kilotonnes CO_{2-e})	Total 5 year post mine carbon change (tonnes)	Total 5 year post mine emission (kilotonnes CO_{2}-$_{e}$)
Rehabilitation	821 sink	- 3.0	1,183 sink	- 4.3

5.4 Liquid Fuel Combustion Emissions

Diesel fuel will be used primarily by mining equipment, fixed plant such as lighting rigs and pumps, and light vehicles. Power will likely be supplied by a 10 MW solar farm and associated energy storage system. Liquefied natural gas (LNG) will be used for the gas burner for the roaster kiln. Approximately 23,265 kL of LNG per year will be consumed for a maximum production of 9,600 tonnes per year. The diesel consumption for on-site light vehicles was estimated as 88 kL per year and for off-site haulage of products from site and supplies to site was estimated as 1.7 kL per year.

Greenhouse emission factors for liquid fuel consumption are shown in **Table 5.5**. Note that the emission factors are per kilolitre of fuel.

Table 5.5: Liquid Fuel Greenhouse Gas Emission Factors

Fuel Type	Energy Content (GJ/kL) [1]	Scope 1 Emission Factor (kg CO_2-e/GJ) [1, 2]	GHG Emission Factor (tonnes CO_2-e/ kL) [3]
Diesel oil (stationary engine)	38.6	70.2	2.71
Diesel oil (light vehicles)	38.6	70.41	2.72
Diesel oil (heavy vehicles – Euro IV or higher)	38.6	70.37	2.72
LNG	25.3	51.53	1.56

Notes: 1. Energy content of fuel is sourced from Table 3, Table 6 and Table 7 of DCCEEW (2022).
2. Emission factors include contributions from CO_2, CH_4 and N_2O.
3. GHG Emission Factor is the Energy Content multiplied by Scope 1 Emission Factor.

The greenhouse gas emission from fuel usage is calculated by multiplying the fuel consumption by the emission factor from the last column in **Table 5.5**. **Table 5.6** below present the total fuel consumption and the resultant emissions, with a total greenhouse gas emission of 54 kt CO_2-e from fuel combustion.

Table 5.6: Fuel Combustion Emission Summary

Activity	Total Fuel Consumed (kL)	Emission factor (t CO_2-e/kL) [1]	Total Emissions (kt CO_2-e)
Mobile plant diesel combustion	5,082	2.71	14
Fixed mining plant diesel combustion	299	2.72	1
Diesel oil (on-site light vehicles) (workers)	88 [2]	2.72	0.2
Off-site product and supplies transport	75	2.72	0.2
Water pump generators diesel combustion	1,011	2.72	3
LNG combustion	23,265	1.56	36
Total			**54**

*Notes: 1. Emission factors from **Table 5.5***
2. Fuel consumption rate based on rates in ATAP (2023)

5.5 Leakage Emissions from Storage and Tranfer of LNG

Assuming a tank volume capacity margin of 20% and a tank volume of 790 kL, which is equivalent to 20,000 GJ of LNG, the loss due to storage and transfer would be equivalent to (20,000 GJ x 0.0005 x 365 days) 3,650 GJ per year.

Amount of LNG stored on-site (5-days supply):

$$1{,}216{,}691\ \frac{GJ}{year} \times \frac{1\ year}{365\ days} \times 5\ days = 16{,}667\ GJ$$

$$16{,}667\ GJ \times \frac{1}{25.3\ GJ/kL} = 658\ kL$$

Tank volume (assuming 20% capacity margin):

$$658\ kL \times 1.2 = 790\ kL$$

Tank volume equivalent in GJ:

$$16{,}667\ GJ \times 1.2 = 20{,}000\ GJ$$

Amount of LNG emitted due to leakage:

$$790\ kL \times \frac{0.0005}{day} \times \frac{365\ days}{1\ year} = 144\ kL\ per\ year$$

$$\frac{144\ kL}{year} \times \frac{25.3\ GJ}{kL} \cong 3{,}650\ GJ\ per\ year$$

Table 5.7: **Natural Gas Leakage Summary**

Fuel Type	Energy Content (GJ)	Scope 1 Emission factor (kg CO_2-e/GJ) [1]	Total Emissions (kt CO_2-e)
LNG	3,650	377.8	1.4

Notes: 1. Emission factor from 3.81A of the Department of Climate Change (2017b). The emission factor is based on Queensland LNG composition of approximately 95% methane and 5% CO_2, resulting in contributions of 377 and 0.8 kg CO_2-e/GJ respectively.

5.6 Emissions from Exposure of Ore Body and Shale

It is understood that the vanadium rich shale have an average thickness of approximately 5 metres. Shale is an immature rock which has not generated and expelled hydrocarbons (Bradshaw et al, 2012). It is generally in the deeper, more mature sections where the conditions are suitable for oil generation, similar to shale gas. Shale is capable of storing carbon dioxide and to a lesser degree methane, however, this typically happens deep underground where there is higher pressure (Sherifa & Reza, 2018). Methane has been detected in mudlogs across most of the Toolebuc Formation deeper than 300 metres below ground level (Troup et al, 2018).

Based on the above information, it is likely that any greenhouse gas emissions from the exposure of shale to 35 metres below ground level will be negligible. In addition, progressive backfill and rehabilitation will be undertaken, which will minimise exposure duration of the shale.

5.7 Summary of Greenhouse Gas Emissions

Based on the emission calculations, the major source of greenhouse gas emissions is vegetation clearing. The annual peak emission from clearing over the life of the mine is estimated as 36 kt CO_2-e. A summary of the emissions breakdown is presented in **Table 5.8**.

Table 5.8: Greenhouse Gas Emissions

Activity	**Maximum Annual Emissions (kt CO_2-e)**
Vegetation cleared	36.4
Rehabilitation	- 3.0
Mobile plant diesel combustion	14
Fixed mining plant diesel combustion	1
Water pump generators diesel combustion	3
Diesel oil (on-site light vehicles) (workers)	0.2
Off-site product and supplies transport	0.2
LNG combustion	36
Scope 1 Fugitive emission from LNG storage and transfer	1.4
Total	**89**

The total scope 1 greenhouse gas emissions in 2021 - 2022 from Australian corporations that had to report to NGER was 307 megatonnes CO_2-e (Clean Energy Regulator 2023). The total emissions in 2020 from Queensland reported by the National Greenhouse Accounts 2020 based on United Nations Framework Convention on Climate Change (UNFCCC) accounting basis were 159.2 megatonnes CO_2-e (State and Territory Greenhouse Gas Inventories 2020 (DISER, 2022)). Based on the sum of the totals from each activity, emissions from the operation of the mine would be 89 kilotonnes CO_2-e or 0.03% of Australian NGER emissions and 0.06% of Queensland emissions.

5.8 Recommendations for Mitigation Measures

Best practice measures for reducing greenhouse gas emissions from mining have been published by Environment Australia (2002) and their practicality for this assessment is considered. Potential measures to minimise greenhouse gas emissions from the proposed development are outlined in the following subsections.

5.8.1 Equipment and Energy Efficiency

- Include energy efficiency as a criterion when selecting diesel and electric powered motors and other equipment for purchase, for example, variable speed drive pumps. This has potential for substantial reductions in electricity demand.
- Install energy efficient lighting and controls where practical. This has potential for small reductions in electricity demand.

5.8.2 Mine Planning

- Minimise vegetation clearing. This has potential for small reductions in emissions due to decay of vegetation.
- Where practical, reuse vegetation that has to be cleared as timber product or mulch for rehabilitation. This has potential for small reductions in emissions due to decay of vegetation.
- Rehabilitate the land as soon as practical. The subsequent growth of vegetation would provide an offset sink for CO_2.

5.8.3 Mine Operations

- Use production monitoring systems to minimise fuel burn rates and reduce the time when trucks are idling.
- Maintain electrical equipment to retain energy efficiency. This has potential for reductions in electricity demand.
- Maintain haul roads to minimise rolling resistance. This has potential for reductions in diesel consumption.
- Recycle water in the processing operations to reduce off site pumping requirements.
- Provide training for operators of mobile plants on how to minimise fuel consumption, including no unnecessary idling.
- Where suitable, use local personnel to reduce transport emissions. This has potential for reductions in transport fuel consumption.
- As far as practical, obtain construction materials and ongoing consumables from local suppliers to reduce fuel consumption.

5.8.4 New Technology

- Consider additional use of solar energy and other clean energy sources, including using solar panels to extend battery life at workshops, diesel lighting plant and at remote monitoring and control stations.

5.8.5 Management Systems

- Following completion of annual reporting, undertake an internal energy audit and energy mass balance to ensure that the activities are using best practice for minimisation of energy consumption.

6. REGIONAL CLIMATE

The proposed MLAs for the Project are located in north Queensland approximately 526 kilometres inland west-southwest from Townsville. The climate class nominated by the Bureau of Meteorology (2018) for this area is grassland with a hot climate and winter drought.

6.1 Weather Stations

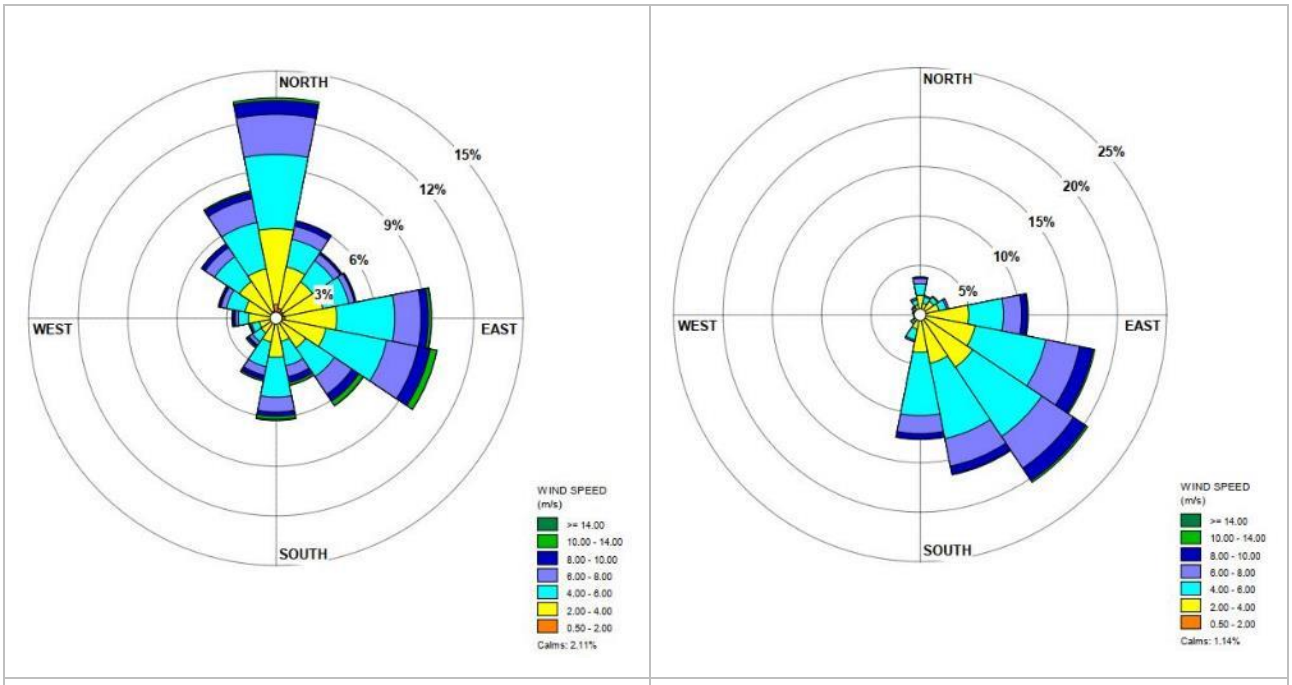
A search of the Bureau of Meteorology's weather station directory has revealed that the nearest rain gauge and the nearest public weather station to the site was at Julia Creek Post Office approximately 80 kilometres to the southwest of the site. The rain data were collected from 1912 to 2011. Wind data were recorded from 1948 to 2002 and temperature and humidity data were collected from 1965 to 2002.

The nearest rain gauge and the nearest public weather station that is currently operating is at Julia Creek Airport approximately 82 kilometres to the southwest of the site. The rain gauge was installed in 2002. Wind, temperature and humidity data have been collected since 2001.

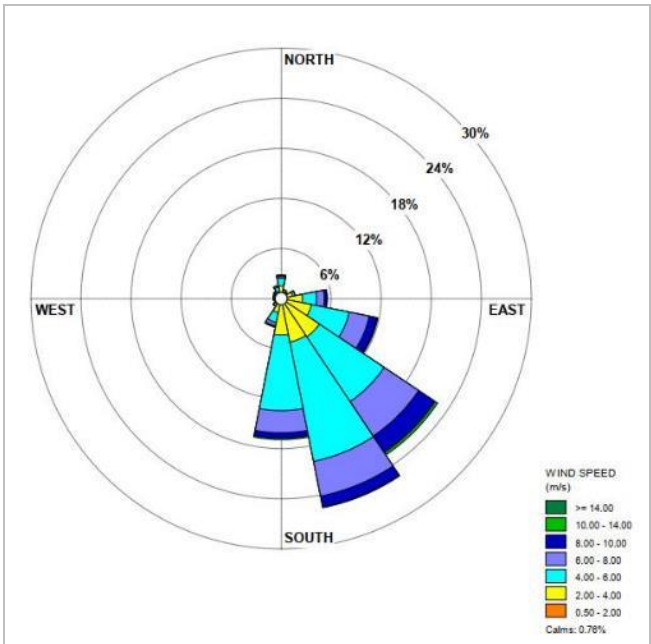
6.2 Existing Wind Records

Seasonal wind roses derived from Julia Creek Airport data from January 2015 until December 2021 are provided in **Figure 6.1**.

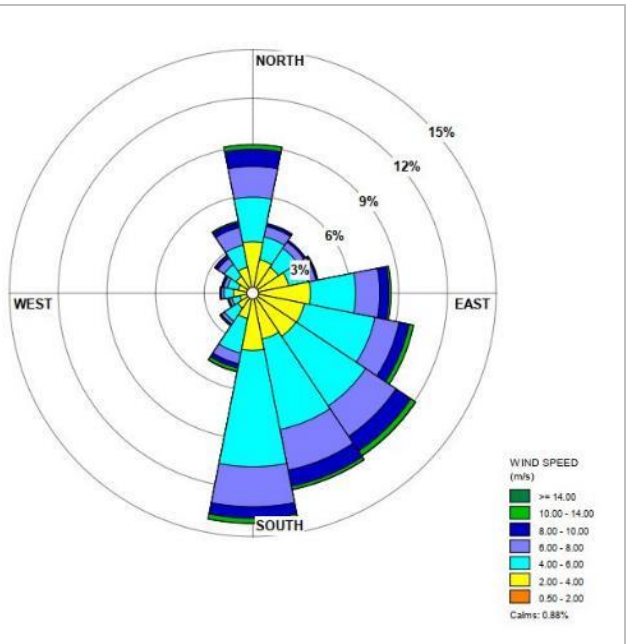
Figure 6.1: Seasonal wind roses (year 2015 – 2021)



Summer (December – February)	Autumn (March – May)



Winter (June – August)



Spring (September – November)

6.3 Existing Temperature and Rain

Long-term weather and climate data from the Julia Creek Airport weather station (site number: 029058) are summarised in **Table 6.1**.

Table 6.1: Climate Statistics for Julia Creek Airport for years 2001 to 2020

Month	Mean Daily Maximum Temperature (°C)	Mean Daily Minimum Temperature (°C)	Mean Monthly Rainfall (mm)	Highest Monthly Rainfall (mm)	Lowest Monthly Rainfall (mm)
Jan	37.7	24.1	130.2	572.6	12.8
Feb	37.1	23	109.9	482	2.6
Mar	36.4	21.3	76.9	290.8	0
Apr	34.4	17.8	12.4	113.2	0
May	30.7	13.6	8	69.8	0
Jun	27.1	9.9	16.1	147.2	0
Jul	27.5	9.0	8.5	104.6	0
Aug	29.6	9.7	3.8	19.2	0
Sep	34	14.4	2.9	23	0
Oct	37.5	18.5	10.1	62.6	0
Nov	39.1	21.8	27.7	66	0.2
Dec	39.9	23.9	56.7	166.2	4
Annual	34.2	17.3	455.7	857.6	220.6

6.4 Potential Future Changes to Climate

Future climate patterns may differ from the existing data due to global warming or other trends. The important parameters for dispersion are wind speed and direction, rain & humidity, and the frequency of elevated temperature inversions.

6.4.1 Wind

Prevailing wind patterns are determined by regional topography and land-sea interface, so it is unlikely that in the foreseeable future, these patterns will change even with global warming; however, to allow for minor fluctuations in wind patterns, contours can be smoothed to remove inward curves when recommending buffer zones.

Research into predicted changes in wind patterns due to climate change has been focussed on strong winds, with an increase in frequency of events. This could lead to increased wind-blown dust.

6.4.2 Rain & Humidity

Predicted changes in rainfall in North-west Queensland due to climate change are shown in **Table 6.2**. If rainfall is reduced, more water would be required for dust suppression or dust emissions would increase. Reduced rain and humidity would also cause a minor reduction in wet deposition of particles.

Note that the Queensland government's approach is to allow for a +25% increase in rainfall intensity when designing projects.

Table 6.2: Annual Rainfall Change Projections for North-West Queensland (Percentage Change)

Emissions Scenario	Projections for 2030 [Range – 5th to 95th percentile (median change) %]	Projections for 2050 [Range – 5th to 95th percentile (median change) %]	Projections for 2070 [Range – 5th to 95th percentile (median change) %]
Low Emissions (RCP 4.5)	-11 to +10 (-2)	-14 to +14 (-1)	-26 to +12 (-3)
High Emissions (RCP 8.5)	-19 to +13 (-3)	-24 to +18 (-0)	-24 to +19 (+1)

Notes:

1. Source: Queensland Government (2019)

2. RCP is Representative Concentration Pathways. RCP 4.5 assumes reduction in greenhouse gas emissions. RCP 8.5 assumes business as usual or no curbing of greenhouse gas emissions

6.4.3 Elevated Temperature Inversions

When temperature inversions are elevated above the ground at heights of 100 or 200 metres, a mixing layer is formed underneath and trapping of emissions within this layer can occur. This occurs most commonly in the mornings.

7. METEOROLOGICAL MODELLING

7.1 TAPM Meteorological Modelling

7.1.1 TAPM Fundamentals

The meteorological component of The Air Pollution Model (TAPM) was used to provide wind fields over the region. Wind speed and direction data from the nearest continuous monitoring station were assimilated into the model as described in **Section 7.1.3**.

The databases required to run TAPM are provided by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and include global and Australian terrain height data, vegetation and soil type datasets, sea surface temperature datasets and synoptic scale meteorological datasets.

The Australian terrain data are in the form of 9-second grid spacing (approximately 0.3 kilometres) and is based on data available from Geosciences Australia. Australian vegetation and soil type data are on a longitude/latitude grid at 3-minute grid spacing (approximately 5 kilometres) and is public domain data provided by CSIRO Wildlife and Ecology.

The synoptic scale meteorology dataset used is a six-hourly synoptic scale analysis on a longitude/latitude grid at 0.75 or 1.0-degree grid spacing (approximately 75 kilometres or 100 kilometres). The database is derived from US NCEP reanalysis synoptic product.

TAPM dynamically fits the gridded data for the selected region to finer grids including the influences of terrain, surface type and surface moisture conditions. It produces detailed fields of hourly estimated temperature, winds, pressure, turbulence, cloud cover and humidity at various levels in the atmosphere as well as surface solar radiation and rainfall.

7.1.2 TAPM Configuration

The year 2020 has been used as discussed in **Section 7.1.3**.

TAPM was setup using four nested 30 x 30 grids centred on latitude 19°58′ south, longitude 141°54′ east, which are coordinates within one kilometre of the source. The four nested grids were as follows:

- 900 km x 900 km with 30 km resolution
- 300 km x 300 km with 10 km resolution
- 90 km x 90 km with 3 km resolution
- 30 km x 30 km with 1 km resolution

Thirty (30) vertical levels were used with lower-level steps at 10, 25, 50, 75 and 100 metres up to 8 kilometres in altitude. This is greater than the normal number of vertical layers in order to provide better resolution of vertical layers. Boundary conditions on the outer grid were derived from the synoptic analysis. Non-hydrostatic pressures were ignored due to the gentle terrain and moderate resolution.

7.1.3 Observational Data Assimilation

Meteorological data from the BoM Julia Creek Airport station, located approximately 82 kilometres south-west from site, were available for assimilation into the model run. The percentage of wind conditions in each wind speed category of the five most recent years are presented in **Table 7.1**.

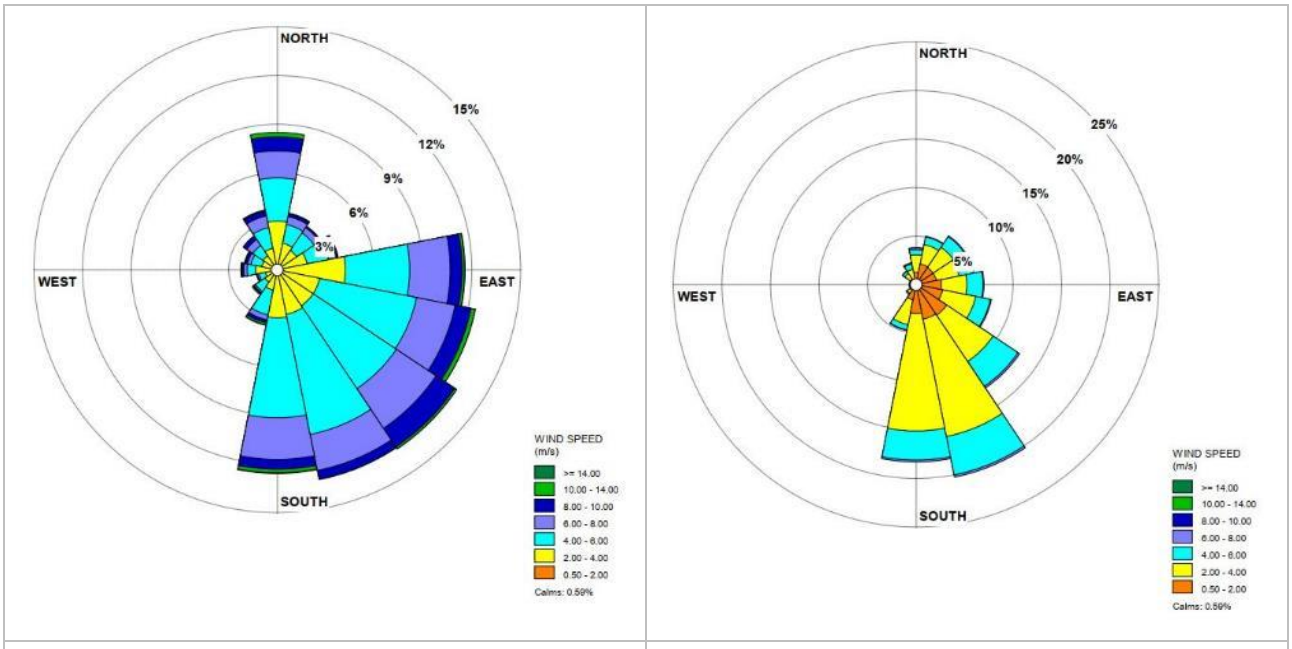
As shown in **Table 7.1**, the year 2020 at the Julia Creek Airport station experienced typical wind speed conditions, and more importantly near-calm and light-wind conditions. These conditions are critical for this assessment as the sources are at ground level and hence higher proportion of near calms will lead to more conservative results. Hence, the year 2020 was used.

Table 7.1: Percentage of Wind Conditions for Different Wind Speed Category

Year	Calm (0-0.5 m/s) (%)	0.5–2 m/s (%)	2-4 m/s (%)	4-6 m/s (%)
2021	0.6	1.6	24.7	41
2020	0.6	2.1	28.9	42.3
2019	0.2	1.4	25.6	45.4
2018	0.1	1.7	31.8	43
2017	2.2	10.1	42.5	30.6
Average	0.7	3.4	30.7	40.5

Meteorological data from the BoM Julia Creek Airport station for the period from 1 January to 31 December 2020 was available for assimilation into the model run. Trinity has analysed data from the BoM Julia Creek Airport station. TAPM was run without assimilation of this data and the wind rose for the same period. A comparison of wind rose of BoM Julia Creek Airport station and TAPM predicted data is shown in **Figure 7.1**. The two wind roses show a similar pattern with exactly same calm conditions. TAPM predicted a higher proportion of light wind conditions and winds from the south-east quarter.

Figure 7.1: Wind Rose of BoM Julia Creek Airport Weather Station Data and TAPM for year 2020



BoM Julia Creek Airport | TAPM

Statistical parameters were calculated to determine the relative agreements between data from the BoM Julia Creek Airport station and the TAPM prediction and are presented in **Table 7.2**. As shown, the Index of Agreement values are higher for u and v components of wind speed meaning there is good agreement between the datasets. Therefore, the observational data from the Julia Creek Airport station were included in the TAPM model for generating data for the Project.

Table 7.2: Statistical Agreement Between the Data from the BoM Julia Creek Station and TAPM

Statistical Parameter	Wind Speed	u-Component of Wind Speed	v-Component of Wind Speed
Root Mean Square Error (RMSE)	1.28	1.01	1.05
Index of Agreement	0.38	0.89	0.88

7.2 Topography and Land Use

Terrain data for the area surrounding the development was obtained from the Digital Elevation Model (DEM) 5 Metre Grid of Australia derived from LiDAR model, which represents a national 5 metre (bare earth) DEM that has been derived from some 236 individual LiDAR surveys between 2001 and 2015. Data for a 10 km x 10 km area (0.1 km spacing) has been extracted for use in the modelling.

The TERRAD value in CALMET is used to determine the radius of influence for terrain features within the model domain. The TERRAD value has been calculated based on the rule 'ridge-to-ridge divided by 2, rounded up' recommended by the NSW Office of Environment and Heritage (TRC, 2011). Based on an average ridge to ridge distance a TERRAD value of 1 kilometre has been adopted.

Land use data was also created based on the Queensland Government Land Use Dataset and satellite imagery and incorporated into the CALMET model. Where land use categories do not correspond with the CALMET land use input file categories, satellite imagery has been reviewed to determine the most appropriate land use category. **Figure 7.2** and **Figure 7.3** present the modelled terrain and land use in CALMET.

Figure 7.2: Modelled Terrain

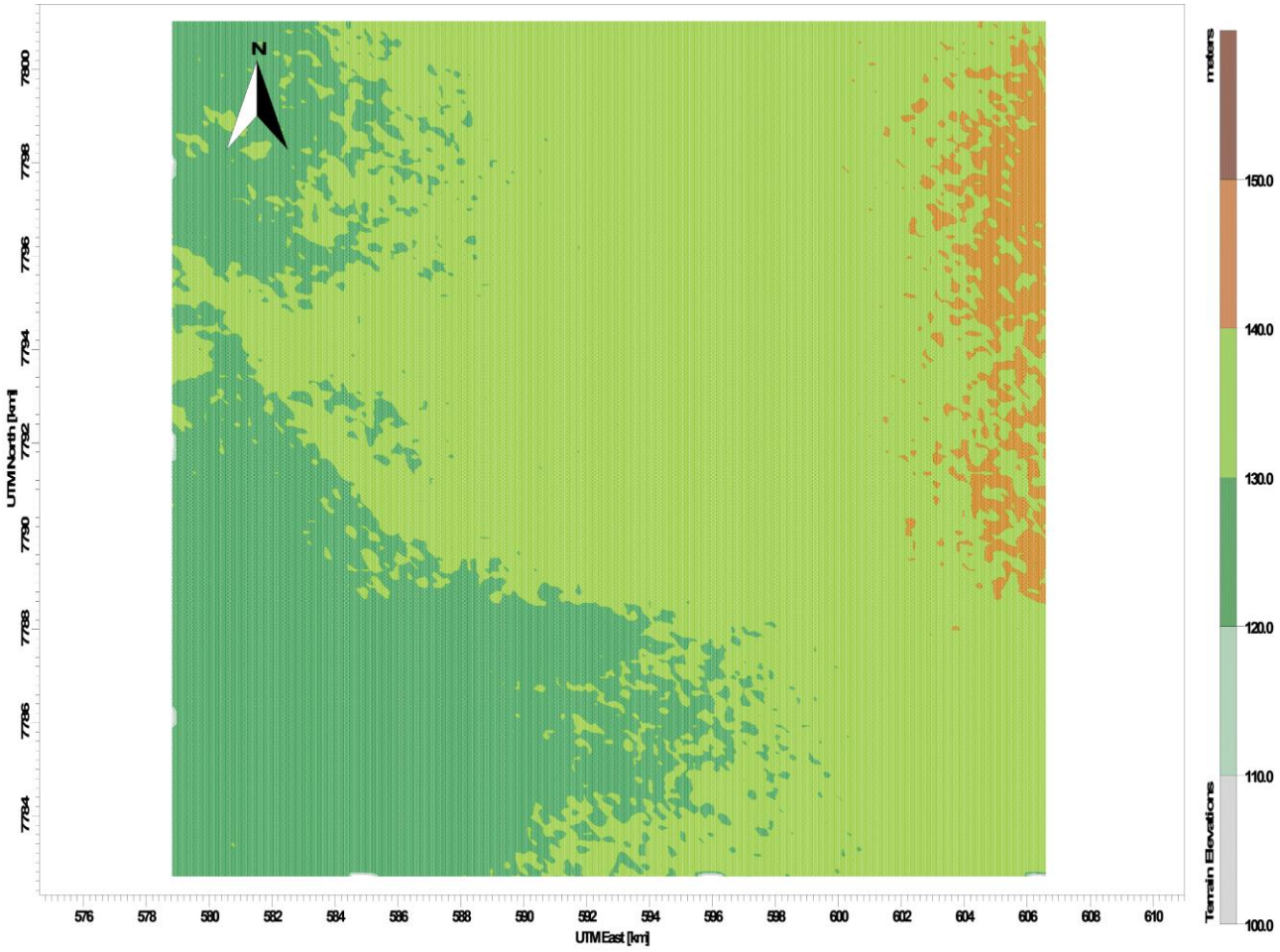
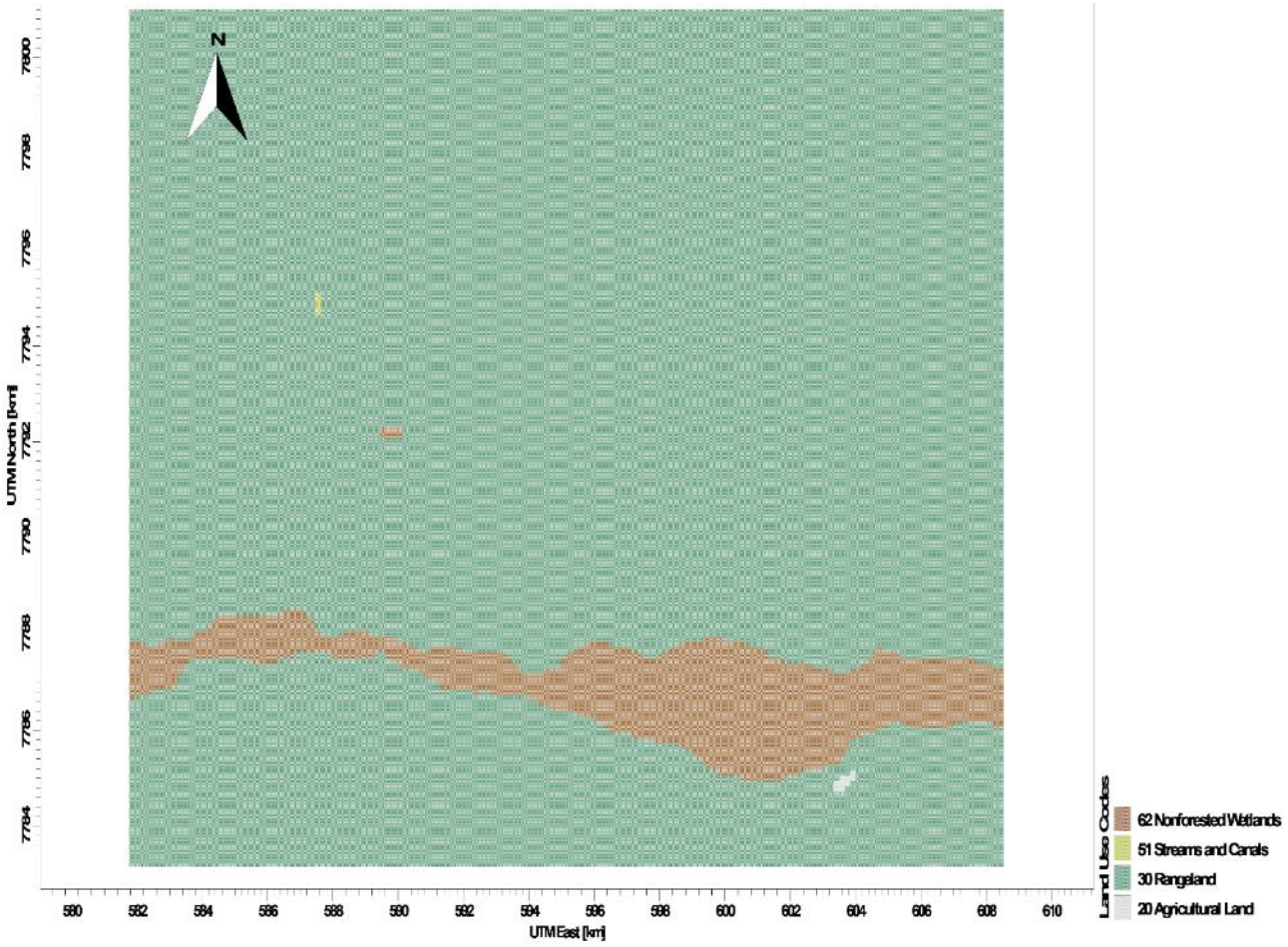


Figure 7.3: Modelled Land Use



7.3 Calmet Modelling Configuration

The Calmet configuration used is consistent with NSW OEH guidance (TRC, 2011).

The model was run over the full year of 2020 based on a 3-dimensional grid produced using the CALTAPM utility program to convert TAPM data to MM5 format suitable for CALMET to read. The CALMET grid was set to grid spacing of 50 metres and 70 by 70 grid points. Twelve vertical layers were modelled with cell face heights of 0, 20, 40, 80, 160, 300, 450, 650, 900, 1200, 1700, 2300, and 3200 metres. This is greater than the normal number of vertical layers to provide better resolution of vertical layers.

Mixing height calculation parameters were set to default values except the Coriolis parameter which was set to 4.96454E-05 as calculated from the Coriolis parameter equation:

$f = 2\ \Omega \sin(\phi)$, where:

F is the Coriolis parameter.

Ω is the Earth's rotation rate (2π/86400 or 7.29×10^{-5} rad·s^{-1}).

ϕ is the latitude which in this case is -19.958°.

Temperature prediction parameters were set to default. Divergence minimisation was used. Slope flow effects were included. The radius of influence of terrain features was set to 6 kilometres, approximately the distance between top to bottom of the most influential slope.

The output from CALMET was a three-dimensional grid of wind-field data for incorporation into CALPUFF.

7.4 Calmet Results

The frequency distributions of occurrences of winds for each direction sector and for each wind class (wind rose) as generated by Calmet are illustrated in **Figure 7.4**.

Figure 7.4: CALMET Site Predicted Wind Rose

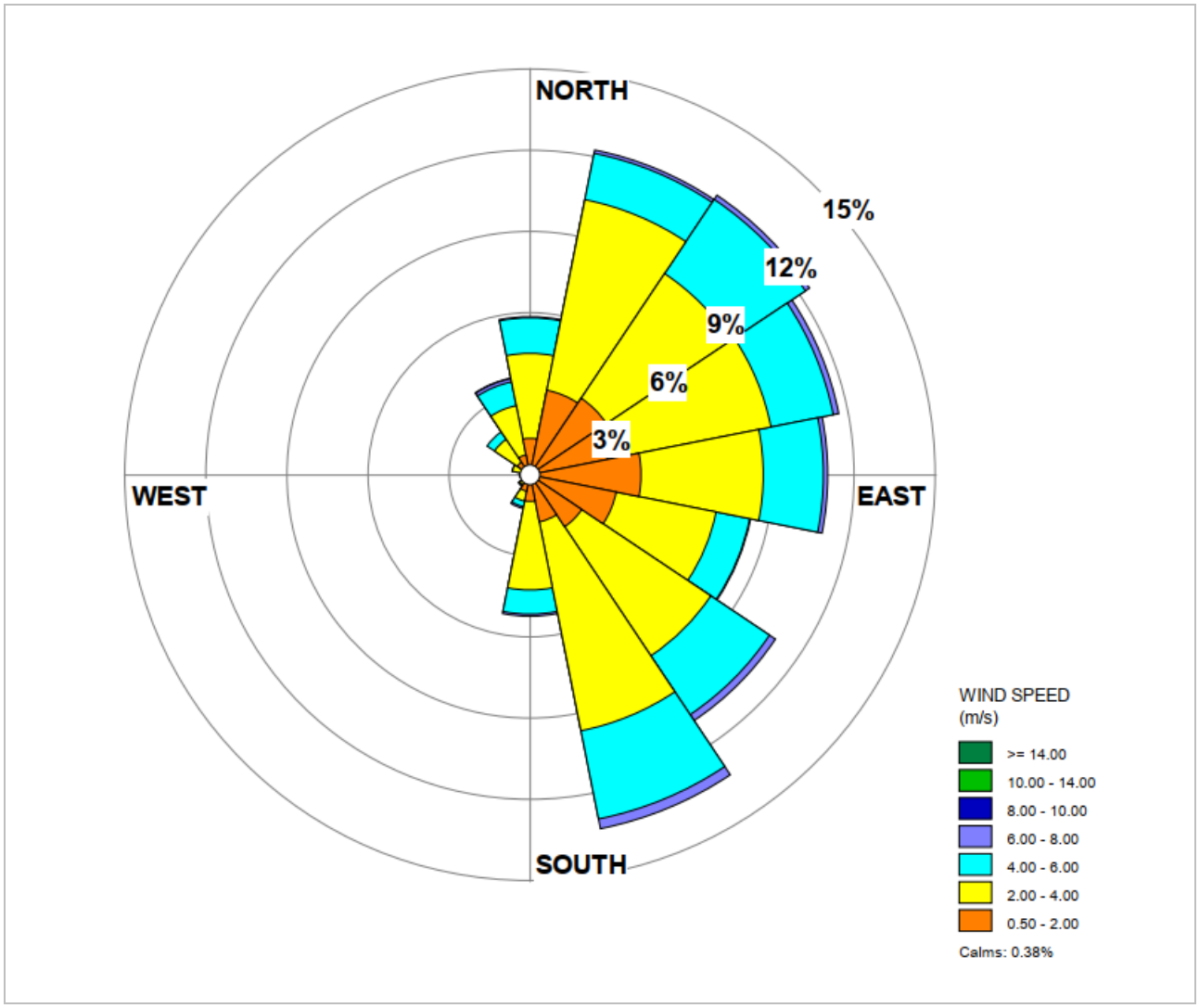


Figure 7.5 presents a plot showing predicted mixing heights for each hour of the day. As expected, higher mixing heights occur during the day period, while lower mixing heights occur during the night period when stable conditions are dominant and temperature inversions occur. In the morning, the mixing rises gradually, reaching an average of approximately 2 kilometres by the afternoon, then reforming near ground level again at nightfall.

Figure 7.5: CALMET Site Predicted Mixing Heights

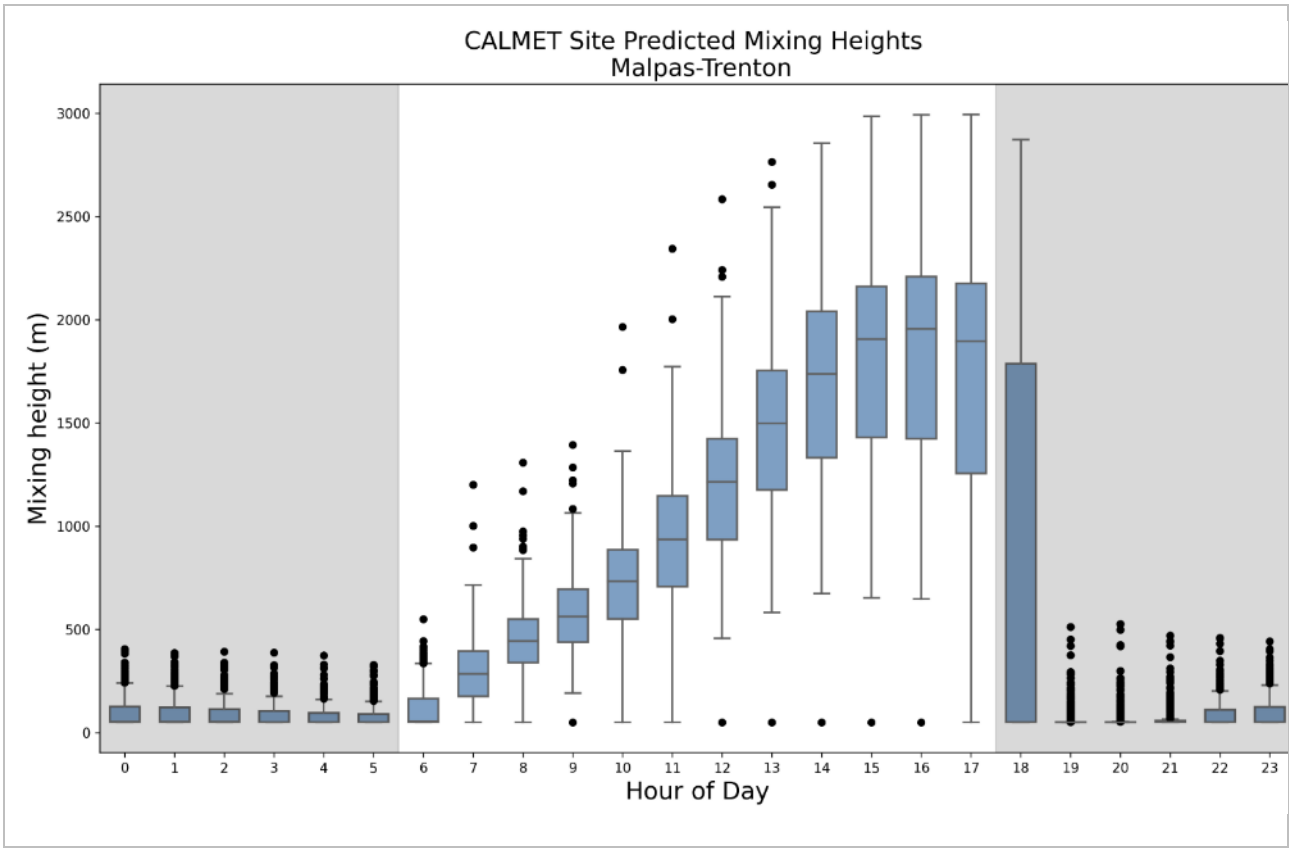
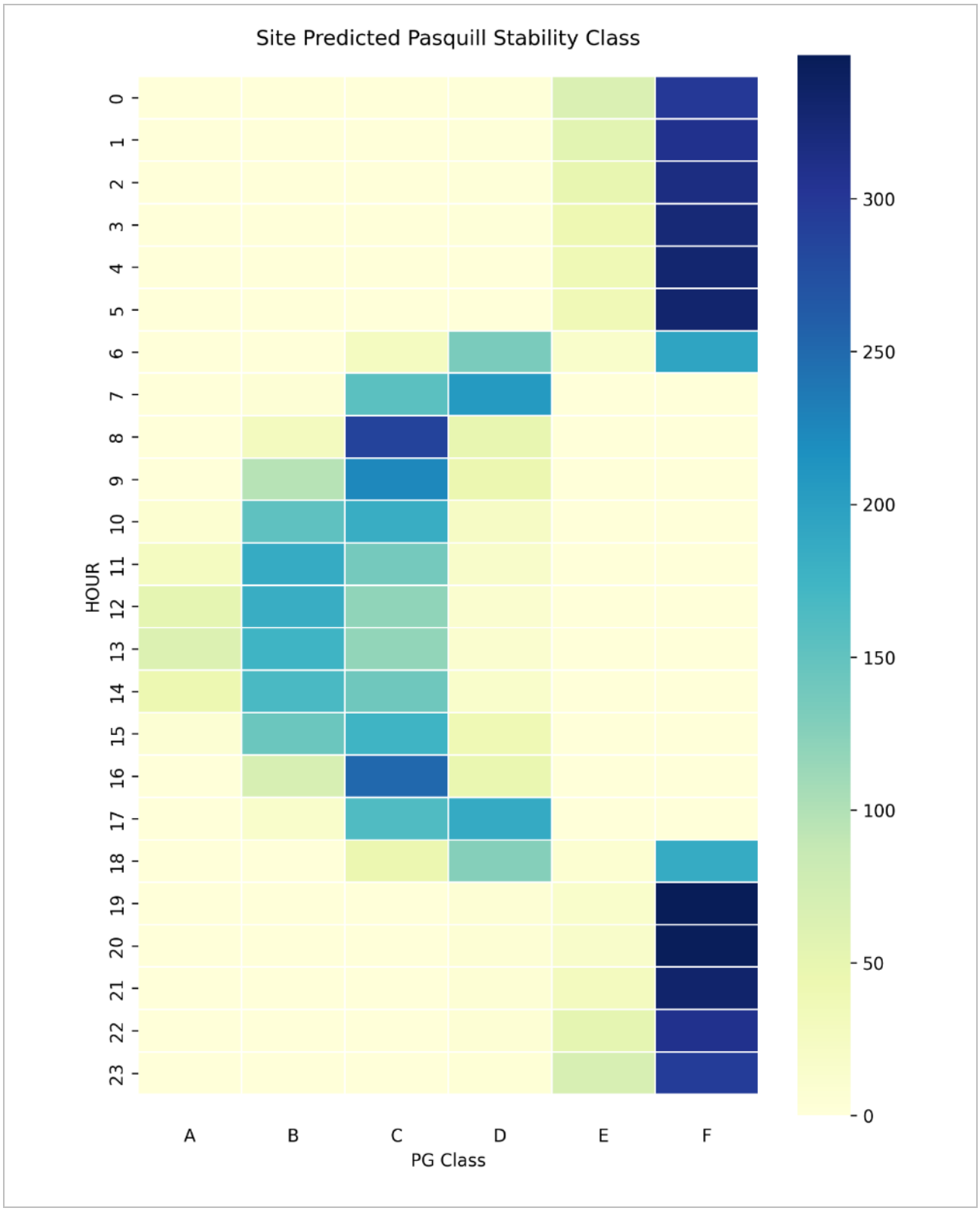


Figure 7.6 shows the frequency of stability classes throughout the day. Day time conditions are either neutral or unstable, whilst night time conditions are stable.

Figure 7.6: Diurnal Frequency of Stability Classes



8. EXISTING AIR QUALITY

8.1 Overview

Based on the rural nature of the regional area, it is expected that the air quality for the study area would be acceptable for the foreseeable future with possible exceptions including dust and particulates. The existing air quality would be influenced by wind-blown dust, sporadic traffic on unsealed roads as well as bushfires and controlled burning activities in the region. Saint Elmo Vanadium Project is located approximately 66 kilometres south-west from the current site location.

Monitoring data from similar locations have been used to represent the existing background. The estimated background concentrations have not been included in the modelling runs but are provided with the results so that the cumulative impact can be compared to criteria. In the absence of continuous monitoring data, it is recommended to use the 70th percentile as a background concentration for dispersion modelling.

The nearest location to the site with publicly available data is The Gap (Mount Isa) monitoring station operated by Department of Environment and Science (DES).

Historical reports of the DES data do not provide the 70th percentile. Recently data from 2010 has become freely available on the Queensland Government data website (https://data.qld.gov.au).

8.2 DES The Gap (Mount Isa)

The DES 'The Gap' monitoring station is the closest monitoring station located approximately 268 kilometres south-west of the Project. The monitoring station was established in 2009 and is located close to an operating mine and a large metal smelter and so the pollutant concentrations at this station is considered conservatively high for this project. **Table 8.1** shows the PM_{10} and SO_2 concentrations over the available period from 2010.

Table 8.1: Concentrations Recorded by the DES The Gap Station

Year	70th percentile 24-hour average PM_{10} concentration ($\mu g/m^3$)	Annual average PM_{10} concentration ($\mu g/m^3$)	70th percentile 1-hour average SO_2 concentration ($\mu g/m^3$)	70th percentile 24-hour average SO_2 concentration ($\mu g/m^3$)	Annual average SO_2 concentration ($\mu g/m^3$)
2010	10	9	0	2	9
2011	19	18	3	4	13
2012	22	19	3	3	11
2013	25	23	0	5	13
2014	22	20	3	6	10
2015	21	19	3	5	11
2016	19	17	3	7	12
2017	20	18	0	6	12
2018	25	24	3	3	10
2019	28	30	0	2	6
2020	21	20	3	5	11
Average [1]	**21**	**20**	**2**	**4**	**11**

Note: 1. The measured concentrations for 2009 were not included in the calculation of the average as the concentrations were substantially lower than all the other years and so were considered outliers.

Based on a typical ratio of PM_{10} to TSP around Australian mines being 0.39 (ACARP, 1999), the annual average TSP was estimated as 51 $\mu g/m^3$. Based on an assumed $PM_{2.5}$ to PM_{10} ratio of 0.25, the background 24-hour average $PM_{2.5}$ concentration was estimated as 5.25 $\mu g/m^3$ and the annual average $PM_{2.5}$ concentration as 5 $\mu g/m^3$.

8.3 DES Memorial Park (Gladstone)

Established in 2009, the Memorial Park station uses differential optical absorption spectroscopy (DOAS) equipment to monitor pollutants over a light path from the Entertainment Centre to Memorial Park. It is classified as a neighbourhood station.

The measured ozone (O_3), NO_2 and air toxics (organic pollutants) concentrations are presented in **Table 8.2**.

Table 8.2: Concentrations Recorded by the DES Memorial Park Station

Year	70th % 1h O_3 (ppm)	70th % 1h NO_2 (µg/m³)	Annual average NO_2 (µg/m³)	Annual average benzene (µg/m³)	70th % 1h toluene (µg/m³)	70th % 24h toluene (µg/m³)	Annual average toluene (µg/m³)	70th % 24h xylene (µg/m³)	Annual average xylene (µg/m³)	70th % 1h formadehyde (µg/m³)	70th % 24h formadehyde (µg/m³)
2010	i.d.	13	11	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
2011	0.019	6	6	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
2012	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
2013	0.024	13	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.	i.d.
2014	0.025	9	5	i.d.	7	6	6	45	41	3	2
2015	0.025	9	5	i.d.	9	8	7	47	44	3	3
2016	0.021	9	11	3	5	5	4	38	33	3	3
2017	0.024	9	4	4	9	9	7	25	22	4	4
2018	0.024	9	10	i.d.	10	9	8	22	20	4	4
2019	0.022	8	7	4	8	9	7	40	33	6	6
2020	0.022	6	4	3	7	7	6	33	30	6	6
Average	**0.023**	**9**	**7**	**4**	**8**	**8**	**6**	**36**	**32**	**4**	**4**

Note: i.d. = insufficient data

8.4 DES Boyne Island (Gladstone)

This station is located in the residential area of Boyne Island likely to be worst affected from industrial emissions according to modelling. CO data from this monitoring station is presented in **Table 8.3**.

Table 8.3: Concentrations Recorded by Queensland DES Boyne Island Monitoring Station

Year	70th % 8-hour CO (µg/m³)
2010	65
2011	115
2012	49
2013	72
2014	115
2015	115
2016	115
2017	115
2018	0
2019	72
2020	0
Average	**76**

8.5 Ammonia Concentration

Ambient ammonia concentration on a four-hectare grazed pasture in Australia was found to be between 12 to 28 µg/m^3 (Shah et al, 2006). Other grazed pastures and agricultural land fertilised with urea have been found to have higher ammonia concentrations, as expected (Shah et al, 2006). For this assessment, the background ammonia concentration for the site is assumed to be 28 µg/m^3.

8.6 Dust Deposition

The criterion for dust deposition in Queensland is generally based on the EHP guideline that insoluble deposited matter should not exceed 120 mg/m^2/day (3.6 g/m^2/month). Background dust deposition levels vary according to local sources. In rural agricultural or industrial areas, these are typically 50 mg/m^2/day and in urban areas these are typically 40 mg/m^2/day. The DES Mount Isa data published does not include dust deposition. Based on the dust deposition monitoring undertaken onsite, the dust deposition levels at the nearest sensitive receptors ranged from 4 to 59 mg/m^2/day. The maximum measured monthly dust deposition level of 59 mg/m^2/day has been used in this assessment as the background level.

8.7 DERM Runcorn Monitoring

Heavy metals and other pollutants were monitored from September 2009 to March 2010 near the Bradken Resources Foundry at Runcorn (Department of Environment and Resource Management (DERM) 2010). Arsenic, cadmium and aldehyde levels were found to be consistent with background. Other heavy metals increased when the wind blew from the foundry.

Sampling was completed at three sites. The proportion of time wind was flowing from the foundry was less at Bonemill Road and Selsey Street during metals sampling. The data summarised in **Table 8.4** is, for metals, the y-intercept from plots of concentration against wind for these two sites.

Table 8.4: Summary of DERM Runcorn Monitoring Results Most Relevant to Background

Pollutant	Annual Concentration (µg/m^3)
Arsenic (As)	0.001
Lead (Pb)	0.0005
Manganese (Mn)	0.01
Nickel (Ni)	0.002
Vanadium (V)	0

8.8 Other Pollutants

Background concentrations of H_2SO4 are not routinely monitored and are expected to be negligible.

8.9 Summary of Estimated Background Levels

Based on the discussions in the preceding sections, the expected background air quality for key pollutants has been summarised with the estimated concentrations listed in **Table 8.5**. These are well within the criteria contained in **Table 4.4**. It is anticipated that the criteria would only be exceeded during regional events such as bushfires or dust storms.

Since the monitoring period onsite is currently insufficient to cover multiple seasons, it is more appropriate to use the long-term Mount Isa data. Further, the Osiris site data obtained to date suggests that the suspended particulate concentrations in Mount Isa are higher than those onsite. Thus, it is conservative to use the Mount Isa suspended particulate data.

Table 8.5: Background Air Quality

Pollutant	Averaging Period	Concentration (µg/m³)
TSP	1 year	51
PM_{10}	24 hours	21
	1 year	20
$PM_{2.5}$	24 hours	5.3
	1 year	5.0
Dust deposition	30 days	59 mg/m²/day
vanadium in PM_{10}	1 day	0
SO_2	1 hour	2
	24 hours	4
	1 year	11
NH_3	3 minutes	28
H_2SO_4	3 minutes	0

9. DISPERSION MODELLING METHOD

9.1 Overview

As discussed in **Sections 3.5** and **3.6**, the emissions from the construction, commissioning, rehabilitation and closure of the Project will likely be minimal in comparison to emissions from mining operations. Therefore, these scenarios were not modelled in this assessment. Worst case operating conditions however have been incorporated into the assessment by the use of a high production schedule throughout the modelled calendar year which includes periods of adverse weather conditions.

In order to predict what happens to the pollutants after they are emitted to air, a mathematical model is used to simulate their dispersion and deposition. It is accepted by regulatory agencies that this type of modelling has associated uncertainties. These are normally addressed by using statistics over long simulation times and deriving emission rates based on published emission factors or data representing high emission conditions.

With sources close to ground level, the critical wind conditions tend to be near-calm i.e. low wind speeds. Gaussian plume models such as Ausplume and Aermod cannot model near-calm conditions and have low accuracy in light winds, especially in valleys where katabatic flows are present and where drainage flows turn to follow the valley. Calpuff, being a non-steady-state Lagrangian puff model, is able to simulate stagnation over time, which is critical in near-calm conditions. Its meteorological pre-processor Calmet performs diagnostic simulation of terrain effects on the wind field. It has a specific slope flow algorithm that predicts katabatic flows (Scire, J.S. & Robe, F.R., 1997).

Due to the low source height for emissions sources associated with the Project, the worst conditions may be near-calm conditions. In near-calm conditions there is little turbulent mixing and less dilution by incoming wind. Large sources (such as mine dust) can travel long distances (slowly) with only slight reduction in concentration. Windy conditions cause more emission of dust from some sources, but much greater mixing and dispersion of the dust before it travels far.

Thus Calpuff (Version 7.2.1) was chosen as the most appropriate model. The predictions undertaken for this assessment are based on the following method:

- The activity scenarios selected for modelling were based on the highest potential to cause impact to nearby sensitive receivers.
- Emission estimates were based on accepted methods and data consolidated by the National Pollutant Inventory (NPI) and the United States Environmental Protection Agency (USEPA) and calculated theoretical concentrations using the mass-balance method. The main emission calculation methods utilised are included in Appendix B and Section 11.8.
- Prediction of input meteorology was completed using TAPM developed by the CSIRO Division of Atmospheric Research. TAPM has a prognostic 3 dimensional meteorological component which can be used to generate hourly meteorological data for input into dispersion models. TAPM was run over a full representative year (2017) to include all seasons. It uses gridded terrain data at approximately 300 metre grid spacing to shape the windfields.
- TAPM input meteorology was enhanced using Calmet, the meteorological pre-processor for Calpuff. This fits the windfields to the terrain based on gridded terrain data at approximately 30 metre grid spacing.
- Particulate and gaseous concentrations and dust deposition were predicted using Calpuff.

9.2 Modelling Scenario

The modelling scenarios selected to predict emissions from the Project are presented in **Table 9.1.** The selected scenario is based on the year 25 production schedule as presented in **Table 3.1** using the year 26 (EOM) mine sequencing layout where the emission sources are anticipated to be closest to the nearest sensitive receptors 1 and 2. The number of excavators in pit are two plus one out of pit to load overburden to truck. The number of dozers is five (4 track dozers and 1 wheel dozer) in total, two in Pit, two on the dump

and one wheel dozer on the ROM pad. The number of trucks on site is anticipated to be eight, with five for hauling/unloading overburden and three for hauling/unloading ore. The emissions of other mobile equipment listed in **Table 3.2** such as grader are based on distance travelled or amount of materials handled. The emission rates determined for the modelled sources are presented in **Section 9.6**.

Table 9.1: Modelled Scenario of Materials Handled

Material handled	Annual Amount	Density (tonne/bcm)
Total overburden extracted	3,604,000 bcm	
Topsoil removed	94,000 bcm	1.6
Extracted ore	1,900,000 tonnes	2.1
Intermediate feed into roaster	7,730 tonnes	-
Product	4,496 tonnes	-
Rejects	1,892,270 tonnes	2.0

9.3 Calpuff Configuration

The three dimensional wind fields from Calmet were entered into Calpuff for the full year 2020. Calpuff was run over a smaller computational grid (11 kilometres x 8 kilometres) with spacing of 100 metres, and with receptors gridded over the same domain with a resolution of 100 metres.

Dry deposition was modelled with vegetation state set to active and stressed. Gravitational settling was included due to the large particle size in the dust being modelled.

Wind speed profile was set to the Industrial Source Complex (ISC) Rural exponents. Transitional plume rise and partial penetration of boundary layers were included. Briggs rise algorithm was used since the sources are not very hot.

The emissions were modelled as puffs and puff-splitting was turned off.

Dispersion coefficients were derived by the model using turbulence generated by micrometeorology. The Heffter curve was used to compute time-dependent dispersion beyond 550 metres. The partial plume height adjustment method was used to allow winds to approach hills as terrain increases.

The minimum turbulence velocity, sigma v, was set to 0.2 m/s.

For the purpose of calculating the influence of deposition, Calpuff only allows each particulate species to be characterised by a single mean diameter and standard deviation. Therefore, suspended TSP concentrations were modelled as three separate components: $PM_{2.5}$, coarse (between 2.5 and 10 microns) and "dust" (between 10 and 75 microns). Emission rates of the species "dust" were calculated as the difference between TSP and PM_{10} emissions from the inventory. Emission rates of the species "coarse" were calculated as the difference between PM_{10} and $PM_{2.5}$ emissions from the inventory. The predicted TSP results were then calculated as the sum of the model outputs for each of the three components. Similarly, dust deposition was predicted as the sum of the deposition of each of the three components.

9.4 Emission Inventory Calculations for Particulates

The emission rates entered into the dispersion modelling are based on the activity and source information provided as listed in **Section 3**. For the purpose of dispersion modelling, it has been conservatively assumed that product will be transported via road. **Appendix B** provides the calculation methods, for significant particulate sources.

Note that the NPI manual is designed for estimating total annual emissions. Some of the equations are based on annual averages of wind speed and rainfall. Using annual averages is not appropriate for dispersion modelling where maximum 24 hour concentrations may occur during dry, windy conditions.

Therefore, for this Project, rain has been removed from the emission calculations and emission rates are variable dependent on wind speed category.

9.5 Dust Control Measure

Emission controls proposed to be used to reduce particulate emissions that have been included in the dispersion modelling are presented in **Table 9.2**. The control efficiencies of these technologies are derived from Environment Australia (2012), Katestone (2011) and Department of Environmental Quality (2015).

Table 9.2: Dust Emission Controls

Emission Source	Control(s) Utilised	Control Efficiency Applied
Graders, and vehicles on unpaved roads	Water sprays	50%

In addition to **Table 9.2**, pit retention factors of 50% for TSP and 5% for PM_{10} were utilised for activities located within the pit. These factors are specified by Environment Australia (2012).

9.6 Summary of Emission Inventories

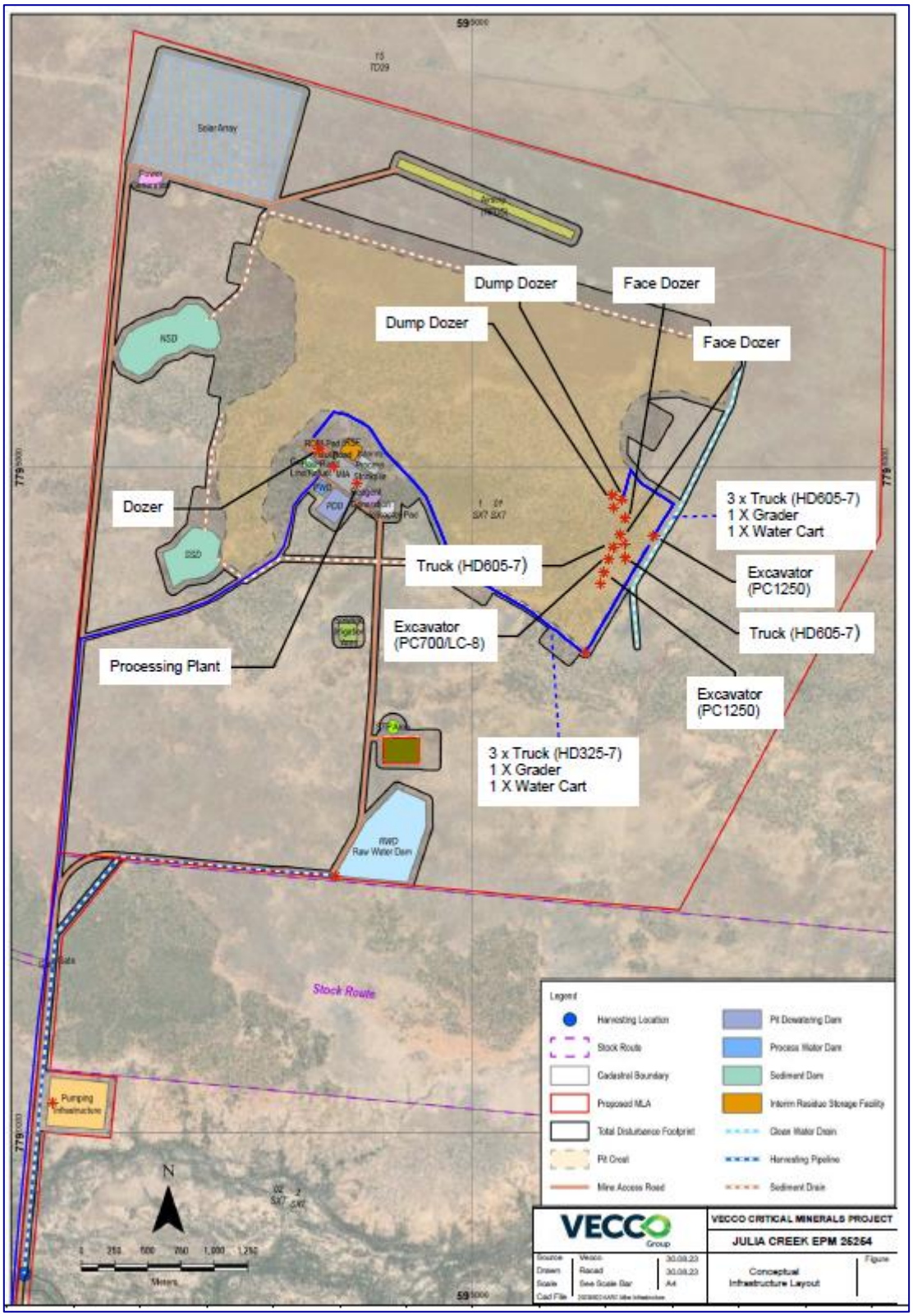
The total emission inventories for all sources are provided in **Table 9.3**. The modelled source locations are presented in **Figure 9.1**. These locations are those anticipated by Trinity, based on operating mine site experience, for mining years 25 and 26 (EOM).

Table 9.3: Modelled Total Controlled Emission Rates

Source	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Grader Out of pit	1,561	908	65
Grader Out of pit	1,561	908	65
Excavator for loading overburden	151	136	22
Excavator for loading overburden	151	136	22
Excavator for loading ore	151	71	3
Track dozer unloading ore (Dump dozer)	45,945	11,558	4,824
Track dozer unloading ore (Dump dozer)	45,945	11,558	4,824
Track dozer in Pit (Face dozer)	22,973	10,981	873
Track dozer in Pit (Face dozer)	22,973	10,981	873
Wheel dozer at ROM Pad (Rubber Tyre dozer)	45,945	11,558	4,824
Truck Unloading Overburden to Dump	101	48	7
Truck Unloading Overburden to Dump	101	48	7
Truck Unloading Overburden to Dump	101	48	7

Source	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Truck Unloading Overburden to Dump	101	48	7
Truck Unloading Overburden to Dump	101	48	7
Truck Unloading Ore to ROM pad	74	35	5
Truck Unloading Ore to ROM pad	74	35	5
Truck Unloading Ore to ROM pad	74	35	5
Drilling	2,391	1,256	190
Blasting	3,596	1,870	108
Mine trucks on unpaved roads out of pit (OB)	90,401	27,674	2,767
Mine trucks on unpaved roads in pit (Ore)	12,969	7,543	794
Mine trucks on unpaved roads out of pit (Ore)	249,650	76,423	7,642
Crushing, transfers to stockpiles	20,789	8,446	34
Total	**567,879**	**182,352**	**27,980**

Figure 9.1: Modelled Source Locations



9.7 Other Source Parameters

Other source parameters used in modelling are provided in **Table 9.4**.

Table 9.4: Other Source Parameters for considered scenario

Source	Easting (m) UTM	Northing (m) UTM	Effective height (m)	Horizontal spread (m)	Vertical spread (m)
Grader Out of pit	596445	7794644	4.4	1.0	1.0
Grader Out of pit	595591	7793801	4.4	1.0	1.0
Excavator for loading overburden	596349	7794499	6.0	1.2	1.4
Excavator for loading overburden	595974	7794227	6.0	1.2	1.4
Excavator for loading ore	596014	7794331	4.3	1.0	1.0
Track dozer unloading ore (Dump dozer)	596116	7794776	4.2	1.0	1.0
Track dozer unloading ore (Dump dozer)	596046	7794803	4.2	1.0	1.0
Track dozer in Pit (Face dozer)	596130	7794625	4.7	1.0	1.1
Track dozer in Pit (Face dozer)	596101	7794514	4.7	1.0	1.1
Wheel dozer at ROM Pad (Rubber Tyre dozer)	593852	7795154	4.1	1.0	1.0
Truck Unloading Overburden to Dump	596046	7794427	4.4	2.2	1.0
Truck Unloading Overburden to Dump	596321	7794857	4.4	2.2	1.0
Truck Unloading Overburden to Dump	596136	7794838	4.4	2.2	1.0
Truck Unloading Overburden to Dump	596503	7794726	4.4	2.2	1.0
Truck Unloading Overburden to Dump	596143	7794332	4.4	2.2	1.0
Truck Unloading Ore to ROM pad	593822	7795262	4.2	1.0	1.0
Truck Unloading Ore to ROM pad	596320	7794445	4.2	1.0	1.0
Truck Unloading Ore to ROM pad	594852	7794347	4.2	1.0	1.0
Drilling	596333	7794644	190	2.3	4.7
Hauling of overburden out of pit	various	various	5.0	46.0	10.0

Source	Easting (m) UTM	Northing (m) UTM	Effective height (m)	Horizontal spread (m)	Vertical spread (m)
Hauling of ore in pit	various	various	5.0	46.0	10.0
Hauling of ore out of pit	various	various	5.0	46.0	10.0
Crushing, transfers to stockpiles	593953	7795107	3.0	23.3	4.7

9.8 Emission Inventory for the Processing Plant

9.8.1 Overview

Emission inventory has been developed based on the process description presented in **Section 3.4**.

9.8.2 Modelling Scenarios

This study has considered all the stack emission sources associated with the proposed processing plant presented in **Table 9.5**. Modelling scenario is consistent with mining emissions as presented in **Section 9.2**. Sulfuric acid plant emissions are also modelled to estimate the cumulative effects.

9.8.3 Emissions Modelling for the Processing Plant

Within the overall process, a total of 5 stacks have been included which target the emissions sources as listed in **Table 9.5**, alongside the assumed stack location.

Table 9.5: Modelled Stack Locations

Equipment Name	Easting (m)	Northing (m)
Roasting Stack	594049	7794958
Calciner Stack	594058	7794929
Leach Scrubber Stack	594022	7794885
Ammonium Metavanadate (AMV) Precipitation Stack	594071	7794918
H_2SO_4 Plant Stack	593972	7795043

The sources were modelled as point sources with parameters presented in **Table 9.5**. The assumed temperature and velocity are conservative estimates. Building wake effect was modelled using the BPIP processor and the Prime algorithm. Rectangular structures with a height of 15 metres and a width of 15 meters were modelled to represent the processing plant under each source. The modelled source locations are presented in **Figure 9.2**.

The emission rates used for modelling have been estimated based on client provided information, National Pollutant Inventory (NPI), USEPA AP-42 literature and Environmental Authority P-EA-100119386 for similar processing activities. Highest emission rates have been adopted for modelling derived from different sources as mentioned above as a conservative approach. We assumed $PM_{2.5}$ is the same as PM_{10} in the absence of $PM_{2.5}$ emission speciation. Below are the key assumptions for emission rate calculations.

Table 9.6 shows the control measures associated with individual sources.

- 98% dust collector and baghouse recovery were assumed for all sources. 98% dust recovery was assumed for all ESP's. 95% vapour and particulate recovery were assumed for all gas scrubbers.
- The leach tanks should be fully enclosed; therefore, it was assumed that no particulates are produced from any of these units.
- Where TSP and PM_{10} in the PM_{10} fraction have not been provided by vendors or factored from other studies (Appendix B, NPI Manual for Alumina Refining); TSP was estimated based on the typical ratio of PM_{10} to TSP at Australian mines of 0.39 (ACARP, 1999). Vanadium (V_2O_5) in the PM_{10} fraction and other metal particulates was estimated based on the vendor provided assay count.
- Estimates of typical stack heights, diameters, exit velocities and volumetric flow rates through the stack were made according to project experience.

Table 9.6: Proposed control measures for the modelled sources

Equipment Name	Control Measure
Roasting Stack	ESP, Wet Scrubber
Calciner Stack	ESP, Wet Scrubber
Leach Scrubber Stack	Wet Scrubber
Ammonium Metavanadate (AMV) Precipitation Stack	Baghouse, Wet Scrubber
H_2SO_4 Plant Stack	Wet Scrubber

Table 9.7: Stack parameters

Stack Number	Name	Stack Diameter (m)	Stack Height (m)	Temperature (K)	Stack Velocity (m/s)	Flow Rate (Nm^3/s)
1	Roasting Stack	1.25	20	1073	3	0.94
2	Calciner Stack	1.25	20	1073	3	0.94
3	Leach Scrubber Stack	0.45	20	353	3	0.37
4	Ammonium Metavanadate (AMV) Precipitation Stack	0.45	20	323	3	0.40
5	H_2SO_4 Plant Stack	1.25	20	473	10	7.08

9.8.3.1 Roasting and Calcination

Roasting and calcination emissions have been calculated using the maximum amount of ore extracted 1,900,000 tonnes/year, maximum amount of final V_2O_5 product 4,496 tonnes/year and maximum amount of final HPA product 4,000 tonnes/year. The average composition of ore is shown in **Table 9.8.**

Table 9.8: Average ore composition

Species	Concentration (% wt)
V_2O_5	0.3
As	0.005
Pb	0.001
Mn	0.1
Ni	0.02
S	0.03

Table 9.9 presents estimated emission rates for the roasting and calcination process based on both theoretical calculations and based on approval conditions for the St Elmo vanadium processing plant (EA-100119386).

Table 9.9: Estimated Emission Rates for Roasting and Calcination

	Calculated Based on Literature			Calculated Based on P-EA-100119386	
Species	**Emission factor (kg/tonne product)**	**Emission rate (g/s)**	**Emission concentration (mg/Nm³)**	**Emission rate (g/s)**	**Emission concentration (mg/Nm³)**
PM_{10}	39[a]	0.1	6.8	0.3	19.5
TSP	100[b]	0.3	17.5	0.7	50
Vanadium in PM_{10} (as V_2O_5)		0.001	0.05	0.01	0.5
As		0.00001	0.001	0.001	0.04
Pb		0.000001	0.0001	0.0001	0.008
Mn		0.0003	0.02	0.01	0.8
Ni		0.0001	0.003	0.002	0.2
SO_2[c] (Roasting)		1.4	97.1		
SO2c (Calcination)		0.5	36.2		

[a] *ACARP, 1999*

[b] *Appendix B, NPI (2007), Emission Estimation Technique Manual for Alumina Refining Version 2.0*

[c] *Based on material balance, assuming all sulfur in the ore is converted to SO_2*

It is noted that except for SO_2 roasting and calcination emissions have been similar due to the lack of practical data and as a conservative approach. SO_2 emission rates have been readjusted based on the ratio of roasting and calcination SO_2 emission of similar operations. It is further noted that the above-presented emission rates include appropriate control efficiency. The highest emission rates from theoretical calculations and St Elmo approval conditions have been adopted for modelling.

9.8.3.2 Leaching

Leaching will be undertaken using H_2SO_4 solution in agitated tanks. The amount of H_2SO_4 mist that will be emitted from the tanks is calculated using the emission limits presented in P-EA-100119386. The derived SO_2 emission rate during the leaching process is 200 mg/Nm³ and 0.12 g/s.

9.8.3.3 De-ammoniation

The source of ammonia emissions will be the decomposition of NH_4VO_3. It is assumed that 3 tonnes of $(NH_4)_2SO_4$ will be consumed for every tonne of product. Based on the maximum potential production rate of 7,730 tonnes/year of V_2O_5, the amount of $(NH_4)_2SO_4$ consumed would be 23,190 tonnes/year. The ammonia emitted has been calculated as shown below:

$$\frac{51{,}000\ t\ (NH_4)_2SO_4}{year} x \frac{17.031\ \frac{g}{mol}\ NH_3}{132.14\ \frac{g}{mol}\ (NH_4)_2SO_4} x \frac{2\ mol\ NH_3}{1\ mol\ (NH_4)_2SO_4} = \frac{13{,}146\ t\ NH_3}{year}$$

A scrubber will be used to minimise ammonia emissions by up to 95%. **Table 9.10** shows the estimated emission rates for de-ammoniation process.

Table 9.10: De-ammoniation Emission Rates

Species	Emission factor (kg/tonne product)	Calculated Based on Literature		Calculated Based on P-EA-100119386	
		Emission rate (g/s)	Emission concentration (mg/Nm³)	Emission rate (g/s)	Emission concentration(mg/Nm³)
PM_{10}	39[a]	0.1	174.2	0.01	19.5
TSP	100[b]	0.3	446.7	0.03	50
Vanadium in PM_{10} (as V_2O_5)		0.0003	0.5	0.0003	0.5
NH_3		9.5	16,688.6	-	-

[a] *ACARP, 1999*

[b] *Appendix B, NPI (2007), Emission Estimation Technique Manual for Alumina Refining Version 2.0*

9.8.3.4 Sulfuric Acid Plant

A conservative estimate of the capacity required for the sulfuric acid plant is 773 tonnes/day (as 100% H_2SO_4). The emissions data (presented in **Table 9.11**) has been extracted from the technical summary report of the sulfuric acid plant manufacturer (Desmet Ballestra S.p.A., 2020).

The SO_2 emission rate was calculated as follows:

$$\frac{280\ mol\ SO_2}{10^6 mol\ gas}\ x\ \frac{1\ mol\ gas}{28.1\ g\ gas}\ x\ 18{,}507\ \frac{g\ gas}{s}\ x\ 64\ \frac{g\ SO_2}{mol} = 11.8\ \frac{g\ SO_2}{s}$$

As SO_3 has potential to form H_2SO_4, the emission for SO_3 and acid mist was assumed to be entirely composed of H_2SO_4. The emission rate was calculated as follows:

$$80\ \frac{mg\ SO_3}{Nm^3 gas}\ x\ 15\ \frac{Nm^3\ gas}{s}\ x\ \frac{1\ g}{1000\ mg}\ x\ \frac{98\ g\ H_2SO_4}{80\ g\ SO_3} = 1.2\ \frac{g\ H_2SO_4}{s}$$

Table 9.12 presents estimated emission rates for Sulfuric Acid Plant.

Table 9.11: Gaseous Emissions from Sulfuric Acid Plant

Species	Emission concentration
SO_2	280 ppm
SO_3 and acid mists	80 mg/Nm³

Table 9.12: Estimated Emission Rate

Species	Emission rate (g/s)	Emission concentration (mg/Nm³)
SO_2	11.8	555.4
SO_3 + acid mists (H_2SO_4)	1.2	55.6

9.8.4 Summary of Emission Inventories for Processing Plant

Table 9.13 and **Table 9.14** present particulate and gaseous emission rates for the processing plant and sulphuric acid plant.

Table 9.13: Particle and Metal Emissions from Processing Plant

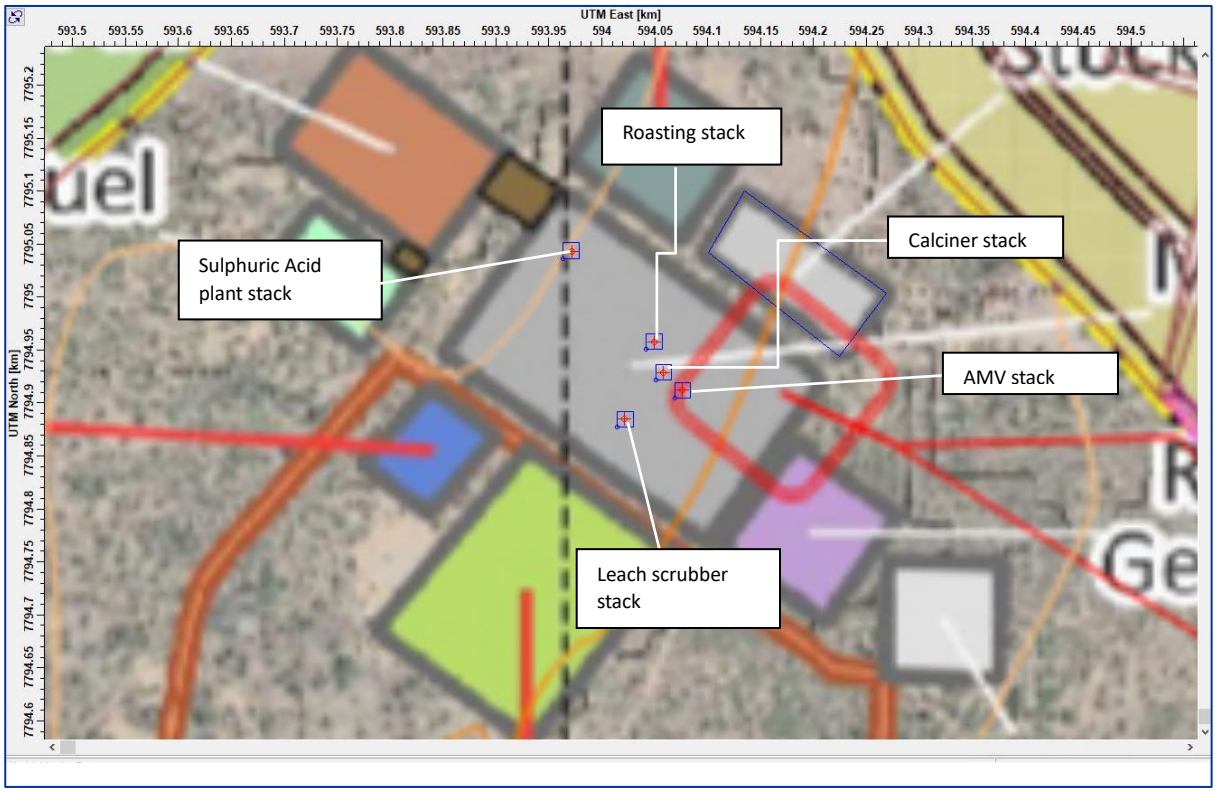
Stack Number	PM_{10}		TSP		Vanadium		As		Pb		Mn		Ni	
	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³
1	0.28	19.50	0.72	50.00	0.01	0.50	0.01	0.04	0.01	0.01	0.01	0.79	0.01	0.16
2	0.28	19.50	0.72	50.00	0.01	0.50	0.01	0.04	0.01	0.01	0.01	0.79	0.01	0.16
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	0.1	174.2	0.3	446.7	0.0003	0.50	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 9.14: Gaseous Emissions from Processing Plant

	NH_3	NH_3	SO_2	SO_2	SO_3	SO_3	H_2SO_4	H_2SO_4
Stack Number	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³	g/s	mg/Nm³
1	-	-	38.6	2665.9	0.002	0.14	-	-
2	-	-	38.6	2665.9	0.002	0.14	-	-
3	0.12	200	-	-	-	-	-	-
4	9.48	16,688.56	-	-	-	-	-	-
5	-	-	11.81	555.43	-	-	1.18	55.55

No-onsite power generation will take place; hence, power generation emissions have not been considered in this assessment.

Figure 9.2: Modelled Processing Plant stacks Locations



10. DISPERSION MODELLING RESULTS

10.1 Limitations

The uncertainties associated with this type of assessment are normally only dealt with in a qualitative manner, but include:

- emission estimation techniques;
- meteorological data variability; and
- inherent uncertainty in dispersion modelling.

This has been addressed by conservative assumptions that will over-predict the ambient concentrations including the following:

- Processing emission rates are based on a variety of highly conservative assumptions and in some cases are gross over-predictions of actual emission rates.
- Activities are assumed to operate throughout the day and year.
- The mining years with the closest disturbance footprint to the nearest sensitive receptors were used in this assessment.
- Within the footprint for the modelled scenario, the sources were modelled relatively close to receptors R1 (7.6km Southeast) and R2 (12km East) and the locations were modelled as unchanging throughout the year. However, a hypothetical receptor location R3 (4 km East) was considered to represent R2 because it was out of the modelled domain.
- Due to the presence of clay and siltstone, the silt content of haul roads was assumed to be high.
- The adopted background deposition and suspended concentrations are conservatively high.

10.2 Suspended Particulate Results

Predicted concentrations at the sensitive receptors from the proposed mining operations only, processing plant only and both mining operations and processing plant are presented in **Table 10.1, Table 10.2, Table 10.3,** respectively, along with the criteria. Predicted heavy metal concentrations from the processing plant are presented in **Table 10.4**. The estimated background levels are listed separately and not included in the predicted concentrations. The concentrations at all the receptors assessed are predicted to comply with all the relevant criteria.

Table 10.1: Predicted Suspended Particulate Concentrations Arising from Mining Operations Only

Receptor ID	Annual Average TSP ($\mu g/m^3$)	Maximum 24h Average PM_{10} ($\mu g/m^3$)	Annual Average PM_{10} ($\mu g/m^3$)	Maximum 24h Average $PM_{2.5}$ ($\mu g/m^3$)	Annual Average $PM_{2.5}$ ($\mu g/m^3$)	Dust Deposition ($mg/m^2/day$)
Criterion	90	50	25	25	8	120
Background	51	21	20	5.3	5.0	59
R1	0.10	2.1	0.10	0.5	0.01	17
R2 (Hypothetical location)	0.04	1.9	0.04	0.5	0.01	17

Table 10.2: Predicted Suspended Particulate Concentrations Arising from Processing Plant Only

Receptor ID	Annual Average TSP (µg/m³)	Maximum 24h Average PM_{10} (µg/m³)	Annual Average PM_{10} (µg/m³)	Maximum 24h Average $PM_{2.5}$ (µg/m³)	Annual Average $PM_{2.5}$ (µg/m³)	Maximum 24h Average V_2O_5 (µg/m³)
Criterion	90	50	25	25	8	1.1
Background	51	21	20	5.3	5	0
R1	0.015	0.28	0.006	0.28	0.006	0.009
R2 (Hypothetical location)	0.007	0.17	0.003	0.17	0.003	0.005

Table 10.3: Predicted Suspended Particulate Concentrations Arising from Minining Operations and Processing Plant

Receptor ID	Annual Average TSP (µg/m³)	Maximum 24h Average PM_{10} (µg/m³)	Annual Average PM_{10} (µg/m³)	Maximum 24h Average $PM_{2.5}$ (µg/m³)	Annual Average $PM_{2.5}$ (µg/m³)
Criterion	90	50	25	25	8
Background	51	21	20	5.3	5
R1	0.12	2.4	0.11	2.4	0.11
R2 (Hypothetical receptor)	0.05	2.1	0.04	2.1	0.04

Table 10.4: Predicted Heavy Metal Concentrations Arising from Processing Plant

Receptor ID	Annual Average As (µg/m³)	Annual Average Pb (µg/m³)	Annual Average Mn (µg/m³)	Annual Average Ni (µg/m³)
Criterion	0.006	0.5	0.16	0.02
Background	0.001	0.0005	0.01	0.002
R1	0.00016	0.00016	0.00016	0.00016
R2 (Hypothetical receptor)	0.00006	0.00006	0.00006	0.00006

10.3 Gas Concentration Results

The predicted gaseous emission concentrations at the sensitive receptors are shown in **Table 10.5** along with the criteria. The estimated background levels are listed separately and not included in the predicted concentrations. The predicted gaseous concentrations at the sensitive receptors are within the relevant criteria.

Table 10.5: Predicted Gaseous Particulate Concentrations Arising from Processing plant

Receptor ID	Maximum 1h Average NH_3 (µg/m³)	Maximum 24h Average NH_3 (µg/m³)	Annual Average NH_3 (µg/m³)	Maximum 1h Average SO_2 (µg/m³)	Maximum 24h Average SO_2 (µg/m³)	Annual Average SO_2 (µg/m³)	1h H_2SO4 (µg/m³)	Annual H_2SO4 (µg/m³)
Criterion	3,200	1,184	70	570	229	57	120	1
Background	28	-	-	2	4	11	0	-

Receptor ID	Maximum 1h Average NH_3 ($\mu g/m^3$)	Maximum 24h Average NH_3 ($\mu g/m^3$)	Annual Average NH_3 ($\mu g/m^3$)	Maximum 1h Average SO_2 ($\mu g/m^3$)	Maximum 24h Average SO_2 ($\mu g/m^3$)	Annual Average SO_2 ($\mu g/m^3$)	1h H_2SO4 ($\mu g/m^3$)	Annual H_2SO4 ($\mu g/m^3$)
R1	92	8	0.1	42	6	0.10	3.4	0.009
R2 (Hypothetical receptor)	231	12	0.1	39	3	0.04	3.3	0.003

11. DISCUSSION

11.1 Summary of Results

Table 11.1 includes results of predicted suspended particulate concentrations at the worst affected receptor (Receptor 1) from mining operations and processing plant emissions. The cumulative concentrations including the background in **Table 11.1** show that all the modelled receptors are predicted to be within the relevant criteria.It is evident that 24 hour average PM_{10} and annual average PM_{10} are the most critical pollutants with maximum predicted concentrations of 23 µg/m^3 and 20 µg/m^3, respectively. **Figure 11.1** and **Figure 11.2** present predicted ground level concentrations plus background contour plots for PM_{10} (24 hour) for mining operations and processing plant, respectively. It is also noted that the predicted concentrations are mostly due to background concentrations.

Table 11.1: Summary of Results for Minining Operations and Processing Plant for Receptor 1

Indicator	Prediction from Processing (µg/m^3)[a]	Prediction from Mining (µg/m^3)[b]	Background (µg/m^3)	Cumulative Prediction with Background (µg/m^3)[a+b]	Criterion (µg/m^3)
Annual average TSP	0.015	0.10	51	51	90
Maximum 24 h average $PM_{2.5}$	0.284	0.5	5.3	6	25
Annual average $PM_{2.5}$	0.006	0.01	5.0	5	8
Maximum 24 h average PM_{10}	0.284	2.1	21	23	50
Annual average PM_{10}	0.006	0.10	20	20	25
Dust Deposition (mg/m^2/day)	-	17	59	76	120 mg/m^2/day
Annual Average As	0.00016	-	0.001	0.001	0.06
Annual Average Pb	0.00016	-	0.0005	0.0007	0.5
Annual Average Mn	0.00016	-	0.01	0.01	0.16
Annual Average Ni	0.00016	-	0.002	0.002	0.02

Table 10.4 shows the predicted heavy metal concentrations are significantly lower than the relevant criteria at all receptors. Therefore, no adverse effects are expected from the proposed activity.

Table 11.2 shows the predicted gaseous emission concentrations at the worst affected receptor (Receptor 1) arising from the processing plant. The cumulative concentrations including background in **Table 11.2** show that all the modelled receptors are predicted to be within the relevant criteria. Annual average SO_2 is the closest to its criterion with an average predicted concentration of 11.1 µg/m^3, which is 20% of the relevant criterion of 57 µg/m^3. **Figure 11.5**, **Figure 11.4** and **Figure 11.5** present predicted ground level concentration including background contour plots for SO_2 (1 hour), SO_2 (24 hour) and SO_2 (Annual), respectively. Although the camp is not a sensitive receptor, due to the proximity to the processing plant, it is recommended that a monitoring plan be developed for sampling of SO_2 at the camp.

Table 11.2: Summary of Gaseous Results for Processing Plant for Receptor 1

Indicator	Prediction from Project (µg/m³)	Background (µg/m³)	Cumulative Prediction with Background (µg/m³)	Criterion (µg/m³)
Maximum 1h average SO_2	42	2	44	570
Maximum 24h average SO_2	6	4	10	230
Annual average SO_2	0.1	11	11.1	57
Maximum 1h average NH_3	92	28	120	3,200
Maximum 24h average NH_3	8	-	8	1,184
Annual average NH_3	0.1	-	0.1	70
1h H_2SO_4	2.5	0	2.5	33
Annual average H_2SO_4	0.009	-	0.009	1

Figure 11.1: Predicted PM_{10} (24 hour) Concentrations (µg/m^3) - Mining Operations

Criterion is 50 µg/m^3

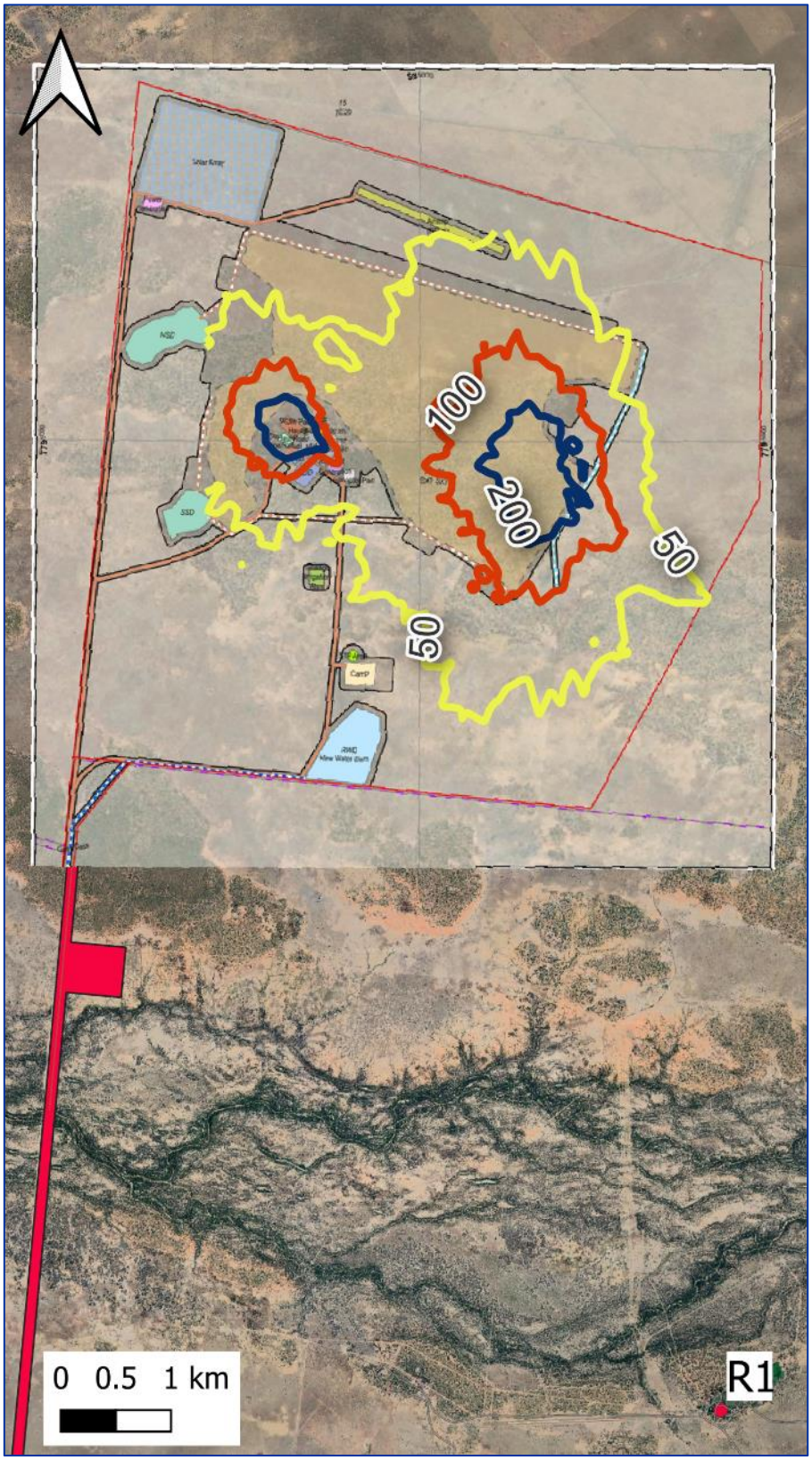


Figure 11.2: Predicted PM_{10} (24 hour) Concentrations (µg/m^3) - Processing Plant

Criterion is 50 µg/m^3

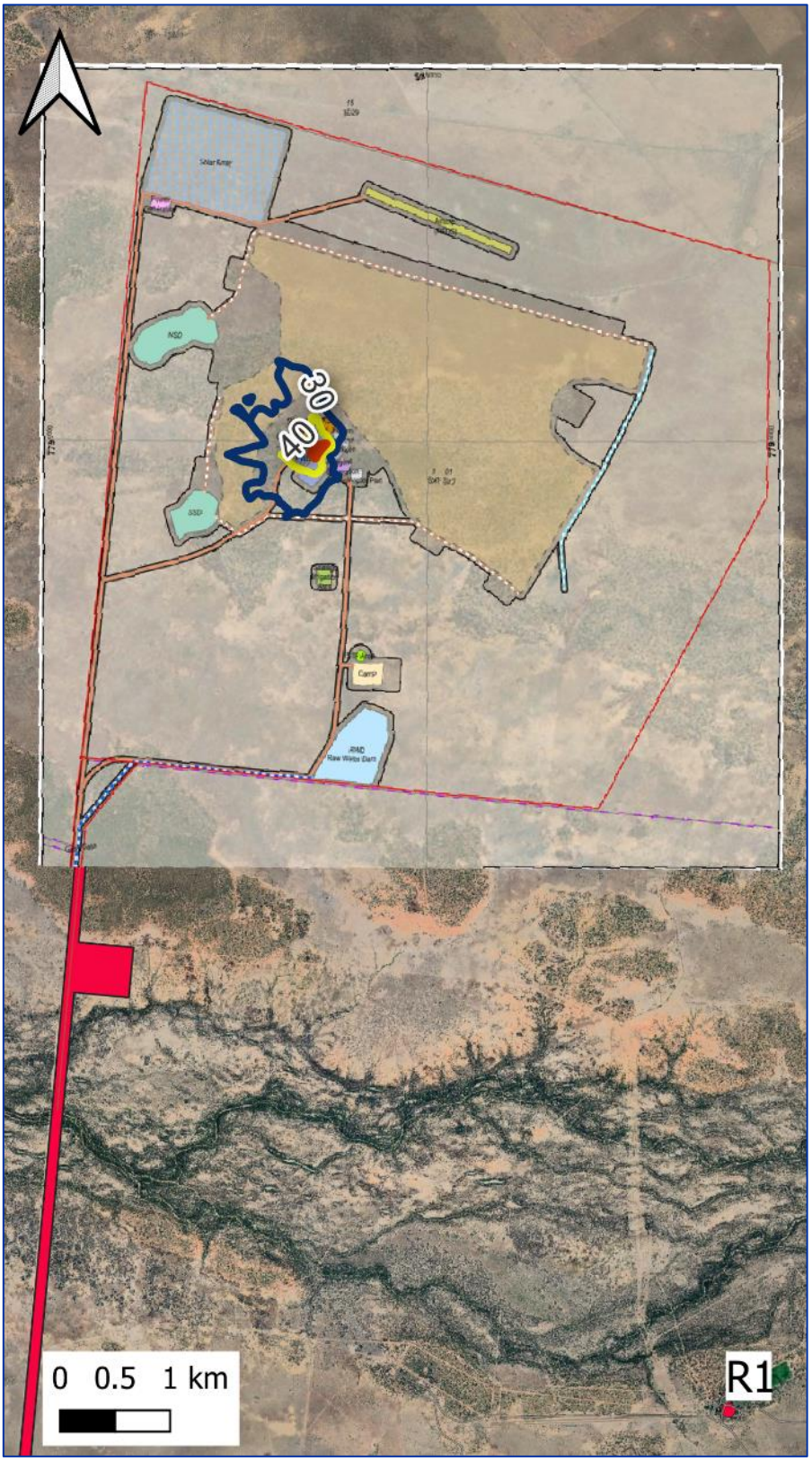


Figure 11.3: Predicted SO_2 (1 hour) Concentrations (µg/m^3)-Processing Plant

Criterion is 570 µg/m^3

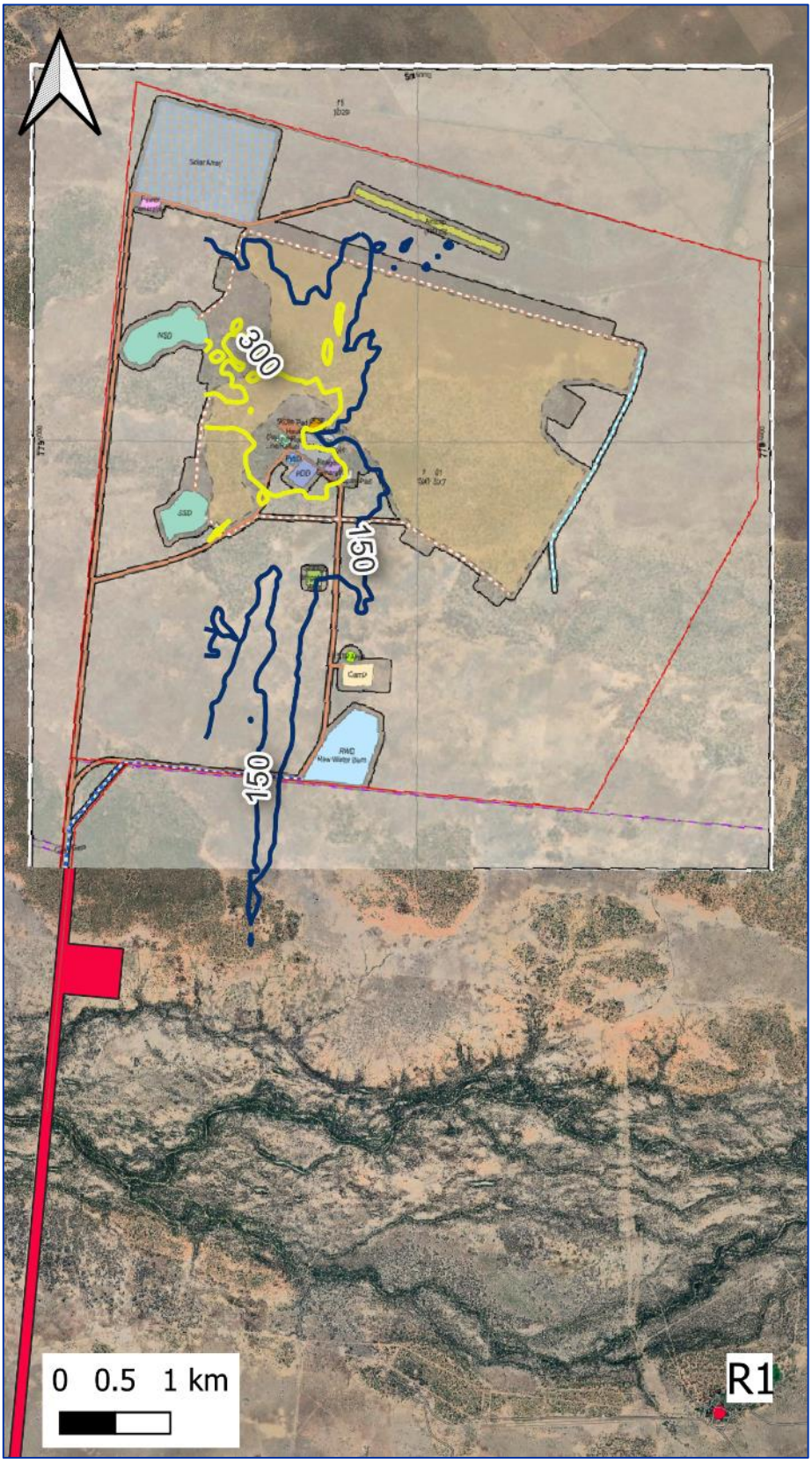


Figure 11.4: Predicted SO_2 (24 hour) Concentrations (µg/m^3)-Processing Plant

Criterion is 230 µg/m^3

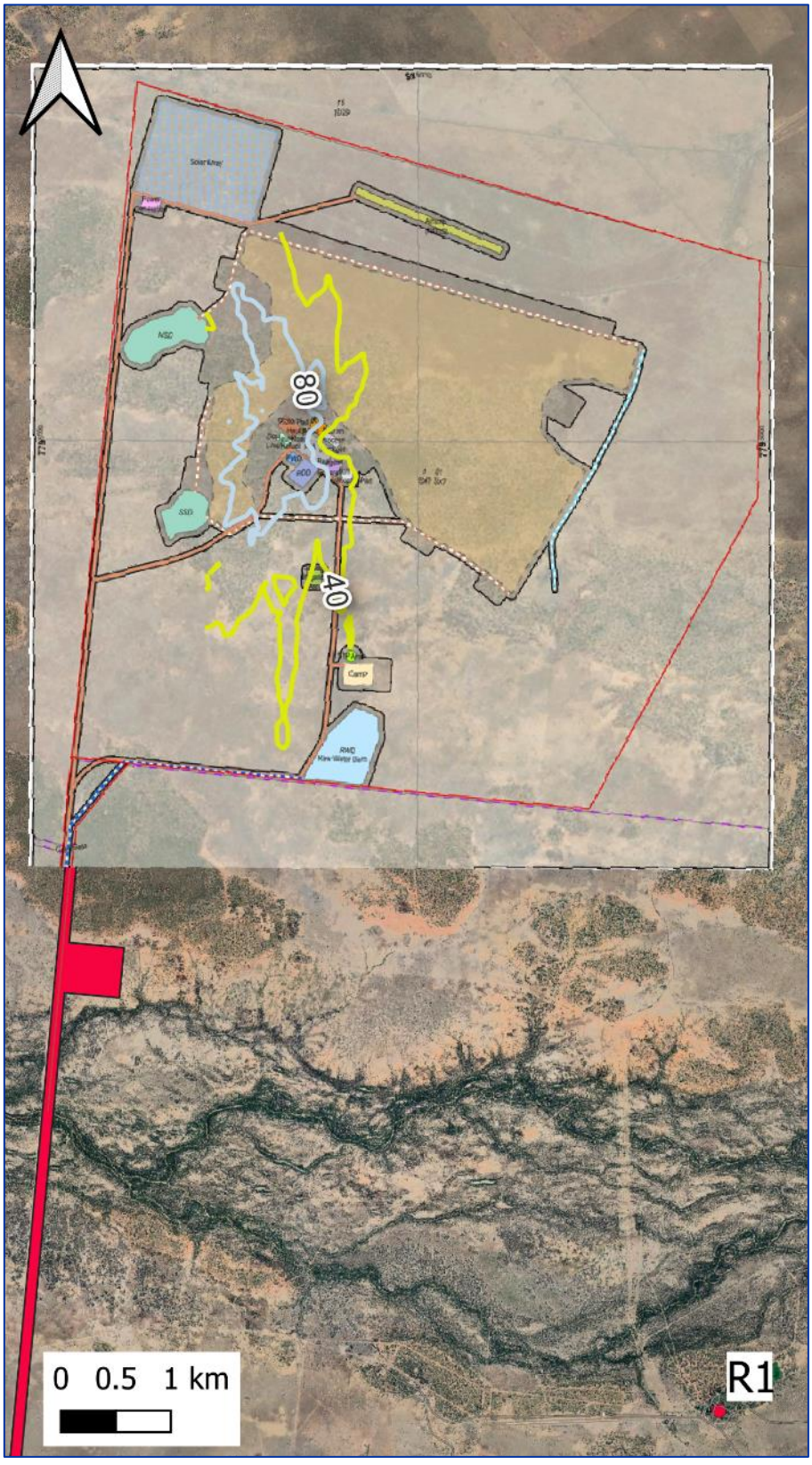
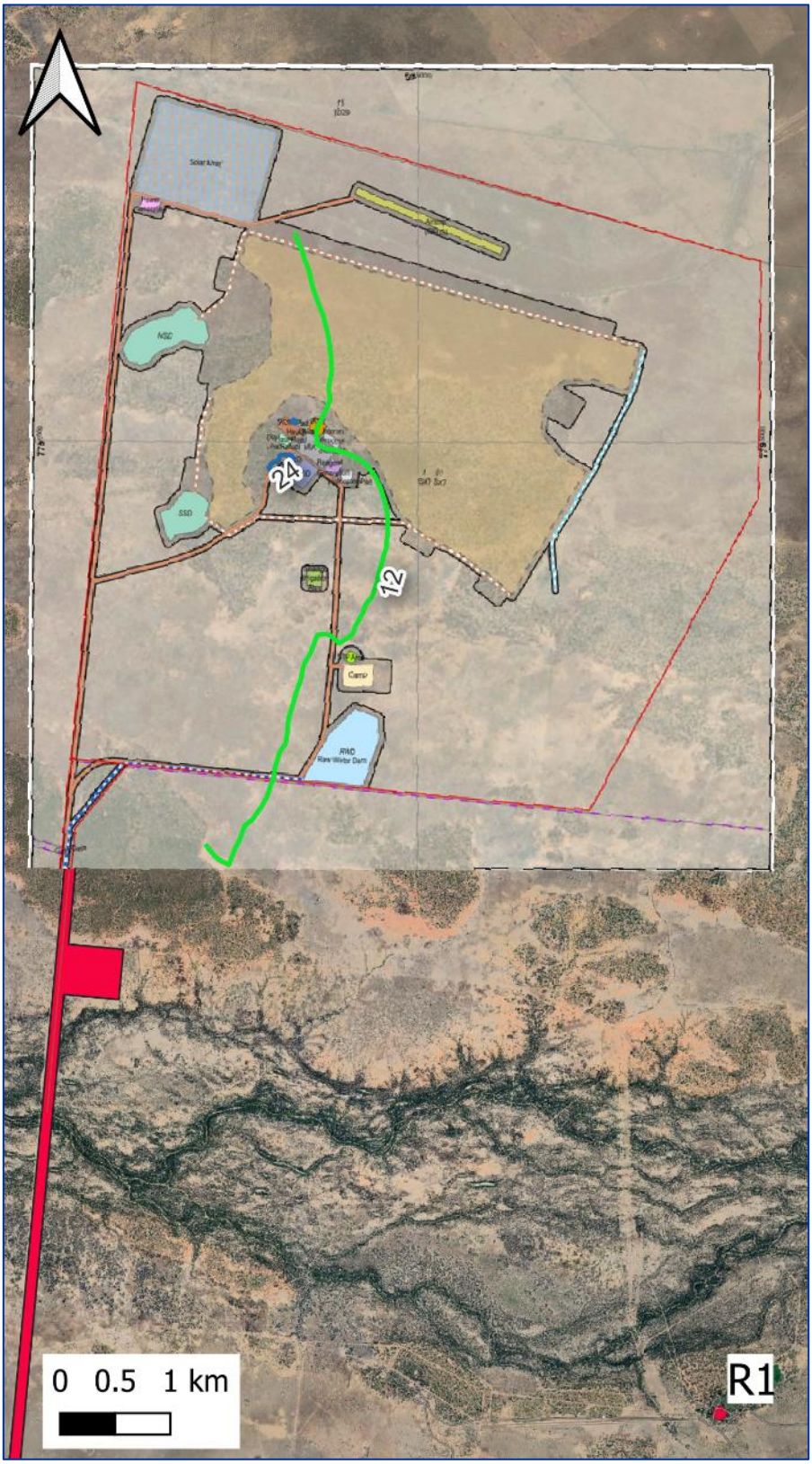


Figure 11.5: Predicted SO_2 (Annual Average) Concentrations (µg/m^3)-Processing Plant

Criterion is 57 µg/m^3



11.2 Recommended Dust Management Measures

The results have shown that predicted cumulative concentrations arising from mining operations are within the required criteria. Therefore, the assumed emission control measures should be adequate being water spraying on unpaved haul roads as specified in **Table 9.2**.

11.3 Recommended Process Control Measures

The results have shown that predicted cumulative concentrations arising from processing plant operations are within the required criteria. Therefore, the assumed emission control efficiencies should be adequate for proposed mining and processing plant operations. Those proposed control measures are presented in **Table 9.6** and **Section 9.8.3.**

As good practice, it is also recommended that a monitoring plan be developed by a certified air quality professional for sampling of SO_2 at the camp on site. Monitoring could involve passive samplers as a screening tool. This provides detail on long-term averages rather than short-term peaks. If results suggest potential exceedances of short-term peaks, continuous monitoring could be undertaken to measure peak data.

11.4 Conclusions

11.4.1 Air Quality

An air quality assessment has been conducted for the proposed Project. The results of the assessment are summarised as follows:

- Air quality cumulative impacts of the Project from both mining and processing plant operations are predicted to be within ambient criteria.
- Identified receptors are unlikely to be impacted by emissions from the mine if appropriate dust control measures are in place as recommended.

11.4.2 Greenhouse Gas Emissions

A greenhouse gas emissions assessment has been conducted for the proposed Project. The proposed development is estimated to contribute up to a maximum of 89 kilotonnes of scope 1 CO_2-e per year. Emissions from the operation of the mine will be 0.03% of Australian NGER emissions for the modelled worstcase year. This represents a small contribution to Australia's emission inventory.

REFERENCES

ACARP (1999), Fine Dust and the Implications for the Coal Industry, Report C7009.

ATAP (2023) Australian Transport Assessment and Planning, https://www.atap.gov.au/parameter-values/road-transport/appendix-e-detailed-fuel-consumption-coefficients-uninterrupted-flow, accessed 08/06/2023

Bradshaw, M.T., Borissova, I., Edwards, D.S., Gibson, G.M., Hashimoto, T., Nelson, G.J., Rollet, N. & Totterdell, J.M. (2012), Out of Gondwana, Shaping a Nation: A Geology of Australia, Richard Blewett, Australian National University Press, DOI: http://doi.org/10.22459.SN.08.2012.

Clean Energy Regulator (2023) https://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/Corporate%20emissions%20and%20energy%20data/corporate-emissions-and-energy-data-2021-22, accessed 07/06/2023

DCCEEW (2022), Australian National Greenhouse Accounts Factors, Australian Government Department of Climate Change, Energy, the Environment and Water.

Department of Environmental Quality (2015), Emission Factors for Paved and Unpaved Haul Roads, Guideline Memorandum, Department of Environmental Quality, State of Utah, 12 January, 2015.

Department of Environment and Energy (2019), Full Carbon Accounting Model, Australian National Greenhouse Accounts, Australian Government.

DES (2021), Guideline: Application requirements for activities with impacts to air, ESR/2015/1840 version 4.04, Queensland Department of Environment and Science.

Destmet Ballestra S.p.A. (2020), Sulfuric Acid Production Plant, Technical Summary #20146A Rev. 0, August 2020.

DISER (2022) https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-2020/state-and-territory-greenhouse-gas-inventories-2020-emissions, accessed 07/06/2023

Environment Australia (2002), Best Practice Environmental Management in Mining: Energy Efficiency & Greenhouse Gas Reduction.

Environment Australia (2012), National Pollutant Inventory Emission Estimation Technique Manual for Mining Version 3.1.

EPP(Air) (2019), Environmental Protection (Air) Policy, Queensland Government.

Katestone (2011), NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining, Katestone Environmental report KE1006953 for NSW Office of Environment and Heritage.

Multicom Resources Ltd (2023), Environmental authority P-EA-100119386 under Environmental Protection Act 1994.

NPI (2007), Emission Estimation Technique Manual for Alumina Refining Version 2.0.

New Zealand Ministry for the Environment (2016), Good Practice Guide for Assessing and Managing Dust, November 2016.

Scire J.S. & Robe F.R. (1997), Fine-Scale Application of the Calmet Meteorological Model to a Complex Terrain Site, Air and Waste Management Association's 90th Annual Meeting.

Shah, S., Westerman, P. & Arogo, J. (2006), Measuring Ammonia concentrations and Emissions from Agricultural Land and Liquid Surfaces: A Review, Journal of the Air & Waste Management Association, 56:7, 945-960.

Sherifa, C. & Reza, B. (2018), Carbon Dioxide Utilization and Sequestration in Kerogen Nanopores, Carbon Capture, Utilization and Sequestration, Ramesh K. Agarwal, IntechOpen, DOI: 10.5772/intechopen.78235, 12 September 2018.

TRC (2011), *Generic Guidance and Optimum Model Settings for the Calpuff Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessment of Air Pollutants in NSW, Australia'*, prepared for NSW Office of Environment and Heritage.

Troup, A., Edwards, S., Grigorescu, M., Dixon, O., Gopalakrishnan, S. & McKillop, M. (2018), Queensland Geological Record 2018-01, The shale oil potential of the Toolebuc Formation, Eromanga and Carpentaria basins, Queensland: Data and interpretation, Department of Natural Resources, Mines and Energy.

United States Environmental Protection Agency (2006), AP42 Compilation of Air Pollution Emission Factors, 5th Edition, Volume 1.

VIC EPA (2022), Guideline for assessing and minimising air pollution, Publication 1961.

APPENDIX A GLOSSARY

Parameter or Term	Description
BoM	Bureau of Meteorology
CCD	Counter current decantation
DES	Department of Environment and Science
EPA	Queensland Environmental Protection Act 1994
EPP (Air)	Queensland Environmental Protection (Air) Policy 2008
HPA	High purity alumina
kt/y	Kilotonnes per year
Multicom	Multicom Resource Ltd
mg/m_2/day	Milligrams per square metre per day
NEPM	National Environmental Protection (Ambient Air Quality) Measure
NH_3	Ammonia
NO_X	Oxides of nitrogen
NO_2	Nitrogen dioxide
NPI	National Pollutant Inventory
PSD	Particle size distribution
$PM_{2.5}$	Particulates suspended in air with aerodynamic diameter less than 2.5 microns
PM_{10}	Particulates suspended in air with aerodynamic diameter less than 10 microns
QLD	Queensland
ROM	Run of mine, referring to the ore removed from the pit.
tpa	tonnes per year

APPENDIX B EMISSION INVENTORY EQUATIONS FOR PARTICULATES

B-1 Loading to Trucks by Excavator

Equation 10 of Environment Australia (2012) has been used because it provides a method of varying emission rates with wind speed.

$$E = 0.0016\ k\ \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

where

E = Emission Factor with units kg/t of overburden
U = mean wind speed (m/s)
M = soil moisture content (%)
k = 0.74 for TSP
k = 0.35 for PM_{10}

B-2 Trucks Dumping

From equation 1 of USEPA (2006b):

E=0.0016 k (U/2.2)^1.3/(M/2)^1.4

where

E = Emission Factor with units kg/t of overburden

U = mean wind speed (m/s)

M = soil moisture content (%)

k = 0.74 for TSP

k = 0.35 for PM10

B-3 Wheel Dust Generation from Mine Vehicles on Unpaved Roads

From equation 1a of USEPA (2006c)

TSP

E=4.9×(s/12)^0.7 〖×(W/3)〗^0.45 {lb/VMT}

Where: E = Emission factor

s = Material silt content (%)

W = mean vehicle weight (tonnes)

Note – lb/VMT was converted to kg/VKT by multiplying lb/VMT by 0.2819

- vkt = vehicle kilometres travelled

PM_{10}

E=1.5×(s/12)^0.9 〖×(W/3)〗^0.45 {lb/VMT}

Where: E = Emission factor

s = Material silt content (%)

W = mean vehicle weight (tonnes)

Note – lb/VMT was converted to kg/VKT by multiplying lb/VMT by 0.2819

B-4 Grader

From Section A1.1.14 of Environment Australia (2012):

E=0.0034 × S^k

where

E = Emission factor with units kg/vkt (vkt = vehicle kilometre travelled)

k = 2.5 for TSP

k = 2.0 for PM10

S = Mean Vehicle Speed (km/h)

B-5 Wind Erosion from Un-vegetated and Unsealed Surfaces

Environment Australia (2012) provides an NPI method for estimating annual emissions of dust from wind erosion based on either a default value published in 1983 or an equation published in 1998, which has several variables including number of rain days and average wind speed; however dispersion modelling is normally based on hourly time-steps and using this equation, the model will predict a small quantity of wind-blown dust every hour of the year. In reality, peak emissions of wind-blown dust will occur only during high wind speeds conditions during dry periods. During low wind speed conditions when particulates from other sources can accumulate, wind-blown dust will be negligible. Thus using the NPI equations will lead to inaccurate and un-timely contribution of wind-blown dust to the peak 24 hour predictions.

ASK calculates variable wind-blown dust emissions from exposed surfaces based on equations 2 and 3 of USEPA (2006a), which combine to become:

$$E = k \times \left(58 \times (u^* - u_t^*)^2 + 25\,(u^* - u_t^*)\right)$$

Where: E = Emission factor with units g/m^2/disturbance hour
k = Constant (1.0 for TSP, 0.5 for PM_{10} and 0.075 for $PM_{2.5}$)
u^* = surface friction velocity (m/s)
u_t^* = threshold friction velocity (m/s)

The surface friction velocity can be calculated for different wind speed classes (at 10 metre anemometer height, based on Equations 13.2.5-6 and 13.2.5-7 of AP-42 (USEPA 2006a) using the following three factors:

- Based on Table 13.2.5-3 the ratio of surface wind to 10 metre approach wind over a steep stockpile area ranges from 0.2 to 1.1. Parts of the stockpile where the ratio is 0.2 will likely never be eroded by wind. Parts of the stockpile where the ratio is 0.6 will trigger rarely if ever for coal only. Overburden will only trigger when the ratio reaches 1.1, which is 4% of less of the stockpile. Coal will trigger when the ratio is 0.9 to 1.1, which occurs over 15% of the stockpile.
- Using equation 13.2.5-7, the surface friction velocity is one tenth of the surface wind.
- However these calculations are based on "fastest-mile" wind speeds, which approximate the fastest 1-minute mean wind speed (Graybeal 2006). The wind speeds used in modelling are one hour means. Ratios ("G60") of 1 minute means to one hour means are estimated by Ashcroft (1984) for different terrain types. For mostly open, fairly level terrain with a few buildings, G60 = 1.26.

Therefore, for overburden, the surface friction velocity is calculated as 1.1 x 0.1 x 1.26 times the 10 metre approach wind. For coal the ratio is assumed to be 0.6 x 0.1 x 1.26 x the 10 metre approach wind.

For each wind speed category, the geometric mean surface friction velocities are shown in **Table 15.1**.

Table B.1: Wind Speeds and Corresponding Surface Friction Velocities (m/s) for 4% of Exposed Earth and Overburden

Pasquill Wind Speed Class	Corresponding Surface Friction Velocities	Mean Surface Friction Velocity
0 – 1.54	0 – 0.21	0.11
1.54 – 3.09	0.21 – 0.43	0.30
3.09 – 5.14	0.43 – 0.71	0.55
5.14 – 8.23	0.71 – 1.14	0.90
8.23 – 10.80	1.14 – 1.50	1.31
> 10.80	> 1.50	1.52

The threshold friction velocity (Table 13.2.5-2, USEPA 2006a) for overburden is 1.02 m/s. The resultant emission rates for different Pasquill wind speed classes are given in **Table B.2**.

Table B.2: Wind Erosion Emission Rates for Exposed Surfaces

Source	Pasquill Wind Speed Class (m/s)	TSP (kg/ha/hour)	PM10 (kg/ha/hour)	PM2.5 (kg/m^2/hour)
Overburden dumps	5.15 – 8.23	0.1	0.05	3.5E-07
Overburden dumps	8.24 – 10.80	2.4	1.2	9.1E-06
Overburden dumps	> 10.80	5	2.5	1.9E-05

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