Council Meeting

Agenda

28 June 2023 at 6:30pm

Council Chamber, Town Hall, Sturt Street, Ballarat

CITY OF BALLARAT

The City of Ballarat acknowledges the Traditional Custodians of the land we live and work on, the Wadawurrung and Dja Dja Wurrung People, and recognises their continuing connection to the land and waterways. We pay our respects to their Elders past, present and emerging and extend this to all Aboriginal and Torres Straight Islander People.

This meeting is being broadcast live on the internet and the recording of this meeting will be published on Council's website www.ballarat.vic.gov.au in the days following the meeting.

Although every effort has been made to protect the privacy of the public, members of the public attending this meeting may be filmed. By remaining in the public gallery once the meeting commences, members of the public give their consent to being filmed, and for the recording of them to be made publicly available and used by council.

Information about broadcasting and publishing recordings of council meetings is available in council's Live Broadcasting and Recording of Council Meetings Procedure which is available on the council's website.

PUBLIC SUBMISSIONS

- Public representations may be made on any items listed on the agenda in a Council Meeting apart from those listed in the confidential section.

- Presentations must be submitted in writing, not more than 500 words by 2:00pm on the day of the relevant meeting:

    i. In the form approved; or

    ii. by email to Council's prescribed email address;.or

    iii. in person during normal office hours at the Council Offices at 25 Armstrong Street South, Ballarat.

- If a person submitting a presentation is not present in the gallery, their presentation will be read out subject to the time limits.

ORDER OF BUSINESS:

The next Meeting of the Ballarat City Council will be held on Wednesday 26 July 2023.

1. OPENING DECLARATION

Councillors:	*"We, the Councillors of the City of Ballarat, declare that we will carry out our duties in the best interests of the community, and through collective leadership will maintain the highest standards of good governance."*
Mayor:	*"I respectfully acknowledge the Wadawurrung and Dja Dja Wurrung People, the traditional custodians of the land, and I would like to welcome members of the public in the gallery."*

2. APOLOGIES FOR ABSENCE

3. DISCLOSURE OF INTEREST

4. MATTERS ARISING FROM THE MINUTES

5. CONFIRMATION OF MINUTES

6. PUBLIC QUESTION TIME

Note – all public representations will be heard before each item on the agenda.

QUESTION TIME

- Questions must be in English and must be 75 words or less and not include a preamble, other additional material, or multiple parts.
- Questions must be submitted via the form on Council's website, no later than 12:00pm on the day of the Council Meeting.
- **Please note:** no person may submit more than two questions at each meeting; questions may not be allowed if the time allotted for public question time has finished.
- If a person submitting a question is not present in the gallery during Public Question Time, their questions will be read out and a response provided at the meeting.

7. PETITIONS

7.1. GOVHUB PARKING

Division: Corporate Services
Director: John Hausler
Author/Position: Sarah Anstis – Statutory Compliance Officer

PURPOSE

1. To receive a written petition containing 53 signatories requesting Council to address the dire parking problems near the GovHub.

BACKGROUND

2. A petition was received on 7 June 2023 containing 53 signatures.

   The petition reads as follows:

   "We, the undersigned GovHub workers, petition the Council for urgent action to address the dire parking problems near the GovHub.

   The inability to obtain a parking space near the GovHub is having severe work/lifestyle balance impacts on GovHub workers, who are leaving home up to 1.5 hours earlier than their start time, to try to secure a parking space within reasonable walking distance. This is partially an issue for those with physical walking difficulties who cannot walk very far, but who are ineligible to use disabled parking.

   The GovHub has always been seen by Council as a way to increase support for CBD businesses. But this will only happen by providing parking as close to the CBD as possible, particularly for those who live out of town. Current inclement weather in Autumn, is a reminder that riding a bike to work is often not an option in Ballarat.

   Council must commit to providing new, creative parking solutions. We urge Council to:
   - *Require the Officeworks' expansion to include parking under the back of the building, as Bunnings does.*
   - *Increase parking for the hospital precinct, such as adding the extra floor for the Base helipad car park. This will then open up street parking west of Doveton Street for GovHub workers to use.*
   - *Provide a minibus (from the saving for the $200,000 per year lease freed by the loss of the Creswick Road car park site) to collect GovHub workers every 10 to 15 minutes from points along Doveton Street, Armstrong Stret, Lydiard Street, and Eastern Oval car park."*

KEY MATTERS

3. In accordance with Rule 3.7.4 c) the Chief Executive Officer must arrange for petitions to be submitted to the next practicable meeting following their receipt.

OFFICER RECOMMENDATION

4. That Council:

4.1 Note the petition be received; and

4.2 That the petition be referred to the Chief Executive Officer for consideration and response.

ATTACHMENTS

Nil

8. CHIEF EXECUTIVE OFFICER REPORT

8.1. CHIEF EXECUTIVE OFFICER REPORT

Division:	Executive Unit
Director:	Evan King
Author/Position:	Evan King – Chief Executive Officer

PURPOSE

1. The CEO's Operational Report highlights issues and outcomes affecting the organisation's performance as it delivers services and implements the Council's strategies and policy decisions.

BACKGROUND

2. The Council of the City of Ballarat is responsible for setting the municipality's strategic direction. The CEO of the City of Ballarat is the sole employee of the Council and is responsible for establishing the organisational structure and resource allocation to achieve the objectives set by the Council. This operational report provides greater detail about organisational activities and issues involved with service delivery.

KEY MATTERS

3. **Appointment of new City of Ballarat Director**
In early May, I informed City of Ballarat staff and the community of the appointment of Mr Martin Darcy to the newly created role of Director Economy, Experience and Commonwealth Games. Martin has the ideal mix of private and public sector experience to lead the City of Ballarat's newly formed business unit *Economy, Experience and Commonwealth Games* directorate. A key focus of this role will be driving reactivation, ongoing attraction and investment into Ballarat while also ensuring the Commonwealth Games provides a lasting legacy for our community. Mr Darcy began at the City of Ballarat on Wednesday 7 June.

4. **State Budget delivers a better Ballarat**
The City of Ballarat welcomed commitments in the State budget for a variety of key projects that will provide sweeping benefits for our community and the broader region. I was particularly pleased to see items such as the redevelopment of Sebastopol's Marty Busch Reserve, implementation of the Brown Hill Reserve Master Plan, the Continuous Voices Memorial and the Central Goldfields UNESCO World Heritage nomination. All these projects have strong local significance for the community and are projects that we have advocated for as an organisation in the lead up to the State Election.

   Key highlights for Ballarat in the 2023/24 State budget included:
   - $50 million for the Ballarat Station accessibility and safety upgrade
   - $8.6 million for Woodmans Hill Secondary College upgrades in Ballarat East
   - $8.4 million for Marty Busch Reserve Master Plan
   - $6 million for Stage 2 works at Federation TAFE

- $3.8 million for Championing Victoria's outstanding heritage (including the Central Goldfields UNESCO World Heritage joint bid involving 13 councils across the region)
- $1 million for Brown Hill Recreation Reserve Master Plan
- $500,000 towards the Continuous Voices Memorial
- A new PET scanner at Ballarat Base Hospital

5. **Toilet Strategy Consultation opens**

The community has been invited to have their say on how the City of Ballarat can improve public toilet facilities by completing a short survey. The feedback will help to inform a Draft Public Toilet Strategy and will be designed to meet the diverse needs of residents across the municipality. The strategy will establish a vision to provide high quality, inclusive and accessible public toilets that are safe, clean and cater for the needs of all residents and visitors.

The survey is available on the City of Ballarat's MySay page and two community pop-up sessions were held where the community could share their feedback direct to staff. A hard copy of the survey was also available at City of Ballarat sites, including Customer Service and Ballarat Libraries. The survey closes 5pm, 25 June. The Draft Public Toilet Strategy is expected to be presented to Council for consideration in August.

6. Strengthening Wendouree Community Recreation Precinct Project

On 10 May 2023, I was pleased to join the Community Sport Minister Ros Spence and Member for Wendouree Juliana Addison to unveil the Wendouree Community Recreation Precinct. The State Government contributed $7 million towards the project through its Local Sports Grant Program, the Federal Government contributed $1.3 million through the Local Roads and Community Infrastructure fund and the City of Ballarat contributed $1.885 million.

The newly created facilities include a new sports pavilion with female-friendly change rooms, community spaces for the Wendouree Neighbourhood Centre, Ballarat YMCA Youth Programs, a community kitchen, a new Men's Shed and a street soccer zone. With such extensive facilities on offer, it has become a neighbourhood centre for the Wendouree West community.

7. Opening of Victoria Park community sports pavilion

The Victoria Park community sports pavilion was officially opened on 10 May 2023 marking a significant day for community sport in Ballarat. Community Sport Minister Ros Spence and Member for Wendouree Juliana Addison joined the City of Ballarat Mayor, Councillors and officers to tour the $3.1 million pavilion, which is a key component of the $5.8 million Victoria Park Sport and Community Facility project. The broader project also included a significant upgrade of the area's soccer pitches, cricket nets and lighting, as well as inclusion of female-friendly change rooms.

The City of Ballarat contributed $5.2 million towards the community facility, with the State Government contributing a further $500,000 through the 2020-21 World Game Fund - Soccer and $100,000 through Sport and Recreation Victoria's Infrastructure Fund – Cricket. The facility is primarily used by the Lucas Cricket Club and the Victoria Park Football (Soccer) Club. It will also be available more broadly for other events that take place in Victoria Park such as disc golf, cycling events and other festivals and gatherings.

8. **Events in Ballarat**

Now in its 17th year, the 10-day **Ballarat Heritage Festival** ran from 19-28 May and provided the community with a unique opportunity to learn more about the city's rich heritage and unique stories with over 50 events on offer. About 20,000 attendees are estimated to have attended the festival bringing over $1 million in economic value to the region. Key events included the Tweed Ride, Craft Lab 23, Ballarat's Beard and Moustache competition, Candlelight Concerts, Vintage Car Show on Lydiard Street and the Heritage Harvest Weekend at Sovereign Hill. The annual festival was reported as being a "huge success, drawing thousands to the city's streets and attractions". The Festival certainly demonstrated that Ballarat is open for tourism business and is an excellent place to host unique and interesting events.

On 17 May, the City of Ballarat stood together with the LGBTIQA+ community by raising the Rainbow Flag in a special **International Day Against Homophobia, Biphobia and Transphobia (IDAHOBIT) flag raising**. The celebration forms part of the City of Ballarat's LGBTIQA+ Community Inclusion Plan 2022-2026, which strives to ensure all LGBTIQA+ people are visible, represented and able to safely participate in community life as they choose. This year, the event commemorated and celebrated the older members of Ballarat's LGBTIQA+ community and the challenges they face, while acknowledging how far we've come as society, as well as accepting that there is still work to be done to achieve equality.

The City of Ballarat marked a significant annual occasion for First Nations people by recognising **National Sorry Day** on Friday 26 May. A wreath will be laid in Queen Victoria Square and the Aboriginal flag was lowered to half-mast as part of the ceremony. The event was organised by the City of Ballarat's Social Inclusion team with the guidance of the Koorie Engagement Action Group (KEAG). The delivery of National Sorry Day is consistent with the City of Ballarat's Reconciliation Action Plan and Intercultural City Strategic Plan.

Ballarat rolled out the welcome mat to the **Western Bulldogs when they returned to town to host the Adelaide Crows on Saturday 20 May.** The Saturday afternoon fixture was the first of two Ballarat games in the 2023 season, with the Bulldogs returning in round 20 to host GWS Giants. The City of Ballarat values the Western Bulldogs continued support and their positive impact on the city. The existing partnership with the Western Bulldogs brings extraordinary benefits to Ballarat, including two AFL matches, at least one AFLW match, the Sons and Daughters of the West Health Programs, Youth Leadership Program, Bulldogs Read Program, and the Nallei Jerring Koori Youth Leadership Program.

OFFICER RECOMMENDATION

9. That Council:

9.1 Receive and note the CEO's Operational Report.

ATTACHMENTS

Nil

9. OFFICER REPORTS

9.1. PLP/2022/644 BALLARAT GOLD MINE TAILINGS DAM

Division: Development and Growth
Director: Natalie Robertson
Author/Position: Natalie Robertson - Director, Development and Growth

PURPOSE

1. The purpose of this report is to advise Council of Planning Permit Application No. PLP/2022/644.

2. This application seeks approval to construct a new Tailings Storage Facility (TSF) at Ballarat Gold Mine, 10 Woolshed Gully Drive, Mount Clear. This new facility, together with the creation of a new vehicle access point off Whitehorse Road, would be used in association with the existing earth and energy resources industry on site.

Summary

3. A summary of the application is provided below:

Application Number:	PLP/2022/644
Applicant:	Ideal Properties (Vic) Pty. Ltd.
Application Preamble:	Buildings and works for the development of a new Tailings Storage Facility (TSF) associated with the land use of earth and energy resources industry, creation of vehicle access and fencing
Subject Site:	10 Woolshed Gully Drive, Mount Clear
Restrictions on Title:	There are no covenants or restrictions registered on title A Plantation License does apply to the land
Zoning:	Farming Zone
Overlays:	• Bushfire Management Overlay • Environmental Significance Overlay – Schedule 5 (part) • Significant Landscape Overlay – Schedule 2 (part)
Aboriginal Cultural Heritage Sensitivity:	Not in an area of Aboriginal Cultural Heritage Sensitivity
Permit Triggers:	• Clause 35.07,Farming Zone – building and works • Clause 42.01,Environmental Significance Overlay - buildings and works (fencing) • Clause 52.29,Land Adjacent to Principal Road Network - creation of access (Whitehorse Road)
Number of Objections:	At the time of writing this report 53 objections had been received

Consultation Meeting:	A community information session was hosted by Ballarat Gold Mine (BGM) on 19 June 2023.
Key Considerations:	The following matters form the basis of this assessment: • Has the tailings storage facility been appropriately sited? • Have human health risks been appropriately considered? • Will the proposal have adverse environmental impacts? • Can noise and air quality be mitigated to an acceptable level? • Does the proposed access off Whitehorse Road lead to an inappropriate traffic outcome?
Officer Recommendation:	Council resolves to issue a Notice of Decision to Grant a Permit subject to conditions

Officer Direct or Indirect Interest

4. No officer involved in the preparation or review of this report has declared a general or material conflict of interest.

BACKGROUND

5. Ballarat Gold Mine (BGM) is an underground gold mining operation located in Woolshed Gully, Mount Clear. Ore from the underground mine is hauled to the on-site mill where it is processed and tailings are pumped as slurry to an existing on-site storage facility, commonly known as Tailings Storage Facility (TSF3).

6. The underground workings currently extend north from the application site to Ballarat Central (refer Figure 1) and remain within the approved mining license area.

7. TSF3 has been expanded several times and has now reached capacity and a temporary dry stack stockpile is currently in use while approval is sought for a new storage facility. This new facility will be known as Tailings Storage Facility 4 (TSF4).

8. Prior to applying for planning approval for TSF4, a Work Plan Variation (WPV) to mining tenement MIN4847 was required. This WPV was given statutory endorsement by Earth Regulation Resources (ERR) under the *Mineral Resources (Sustainable Development) Act 1990* (MRSD Act) on 10 August 2020.

9. The notice of Statutory Endorsement states:

   Operating hours are not specified in the statutory endorsed work plan variation and so must be specified in the planning permit. The risks posed by the works on site are found to be satisfactorily managed, with appropriate controls, to allow operation within any period of the day, evening or night and day.

   Following the issue of the planning permit you will need to lodge the statutory endorsed work plan variation together with the planning permit to Earth Resource Regulation. The endorsed work plan variation will then be approved.

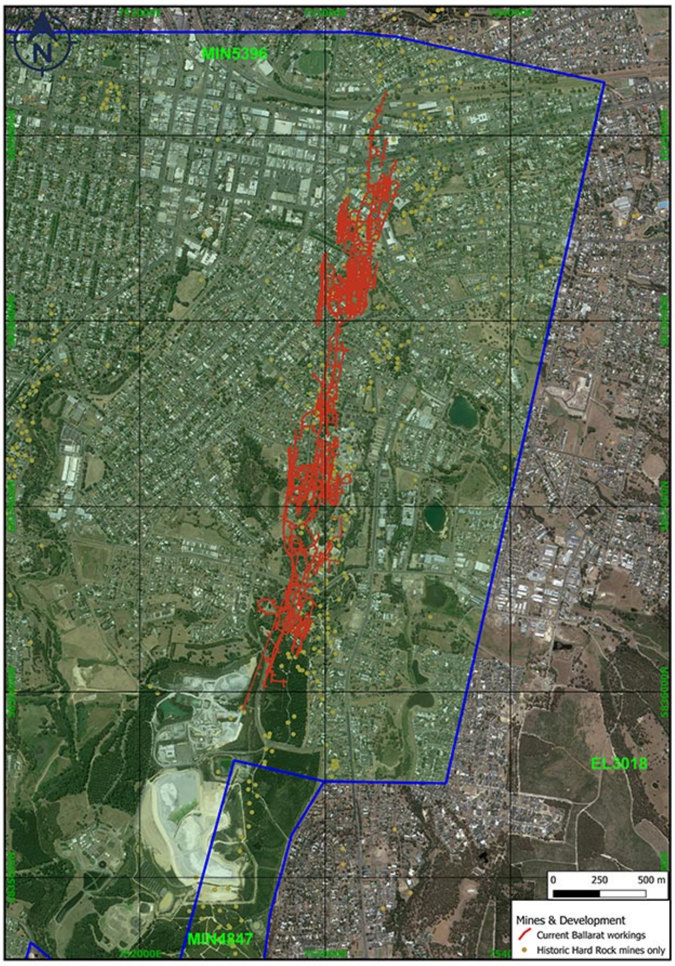

Figure 1 – BGM underground workings map. Red indicates workings and blue indicates license area (Source: BGM website)

<u>Subject Site and Surrounds</u>

10. The application site is known as 10 Woolshed Gully Drive, Mount Clear and is an irregular shaped property comprised of four parcels (refer Figure 2). The property is situated to the north of Whitehorse Road and west of Tinworth Avenue.

11. The site has a total area of approximately 117 hectares however that part the subject of this application is confined to the southern portion of the land, on Crown Allotment 10K of Crown Diagram 121210W. The works area is confined to approximately 43.5 hectares of the site.

12. Immediately to the north of the works area is TSF3, access tracks, a dam and part of the Yarrowee Plantation.

13. The site is within the Farming Zone (FZ) and is partially affected by the Environmental Significance Overlay - Schedule 5 (ESO5 - south eastern boundary) and Significant Landscape Overlay – Schedule 2 (SLO2 - western boundary).

14. The works area has formerly been used as a pine plantation authorised by Forestry License 100001R.

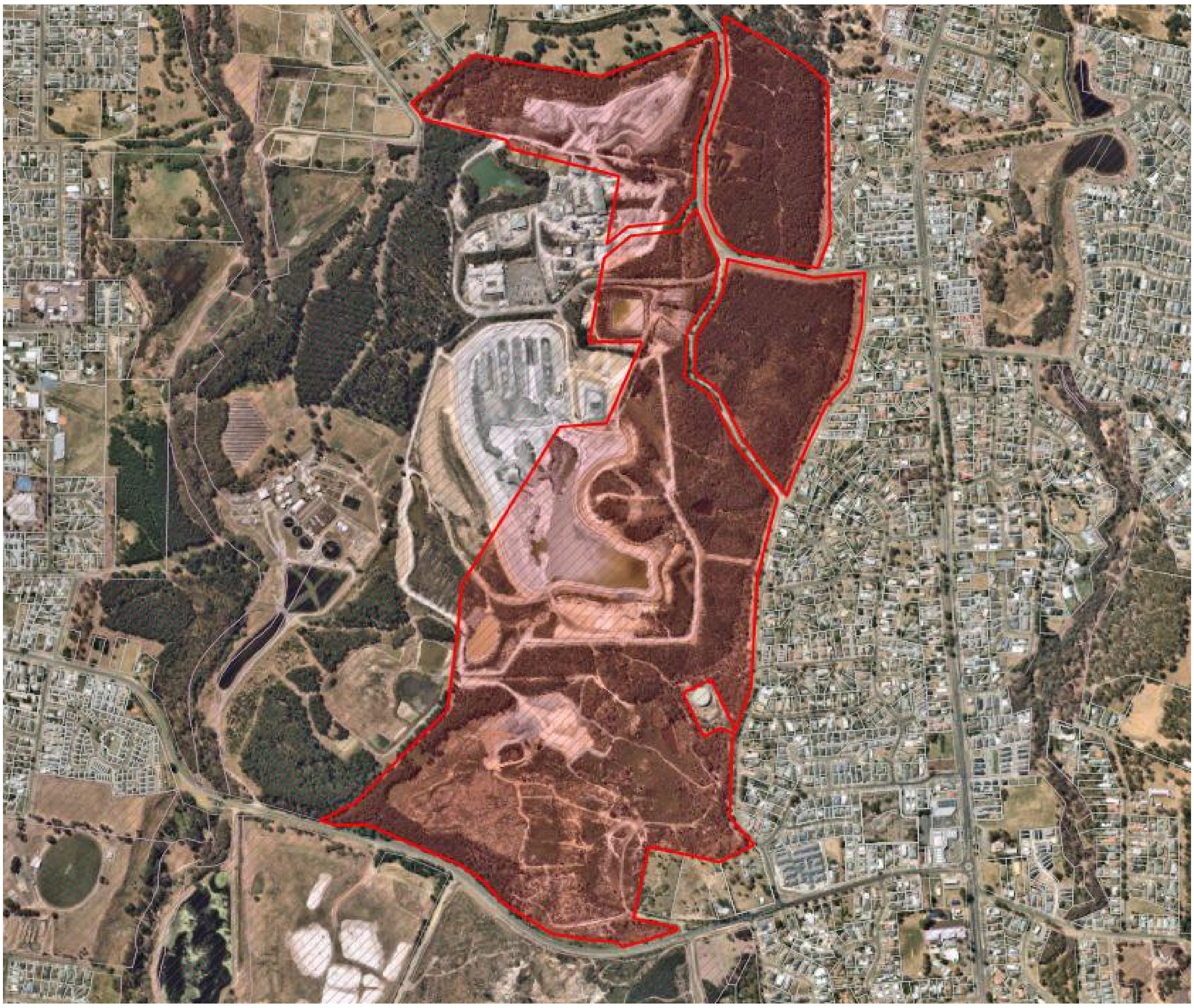

Figure 2 – Aerial view of subject site (Source: Intramaps)

15. The site is located within the urban boundary of Ballarat and is surrounded by a variety of zones, uses and development.

16. Land to the north and east is predominately located within the General Residential Zone (GRZ) along with an area of land zoned Public Conservation and Resource (PCRZ). This area primarily accommodates conventional housing along with an early learning centre and residential aged care facility.

17. To the west land is zoned Public Use - Services and Utility (PUZ1). Part of this land is owned and operated by BGM. The balance of the land accommodates the Ballarat South Wastewater Treatment Plant.

18. Land to the south is a mixture of Rural Living Zone (RLZ), Farming Zone (FZ) and Public Park and Recreation Zone (PPRZ). Whitehorse Road marks the southern boundary of the site.

19. Whitehorse Road forms part of a Transport Zone 2 (Principal Road Network) and is managed by the Department of Transport and Planning (DTP, formerly Department of Transport (DoT)).

Figure 3 – Aerial view of site showing works area boundary in red (Source: Application)

Figure 4 – Existing TSF3 (Source: Assessing officer site inspection, November 2022)

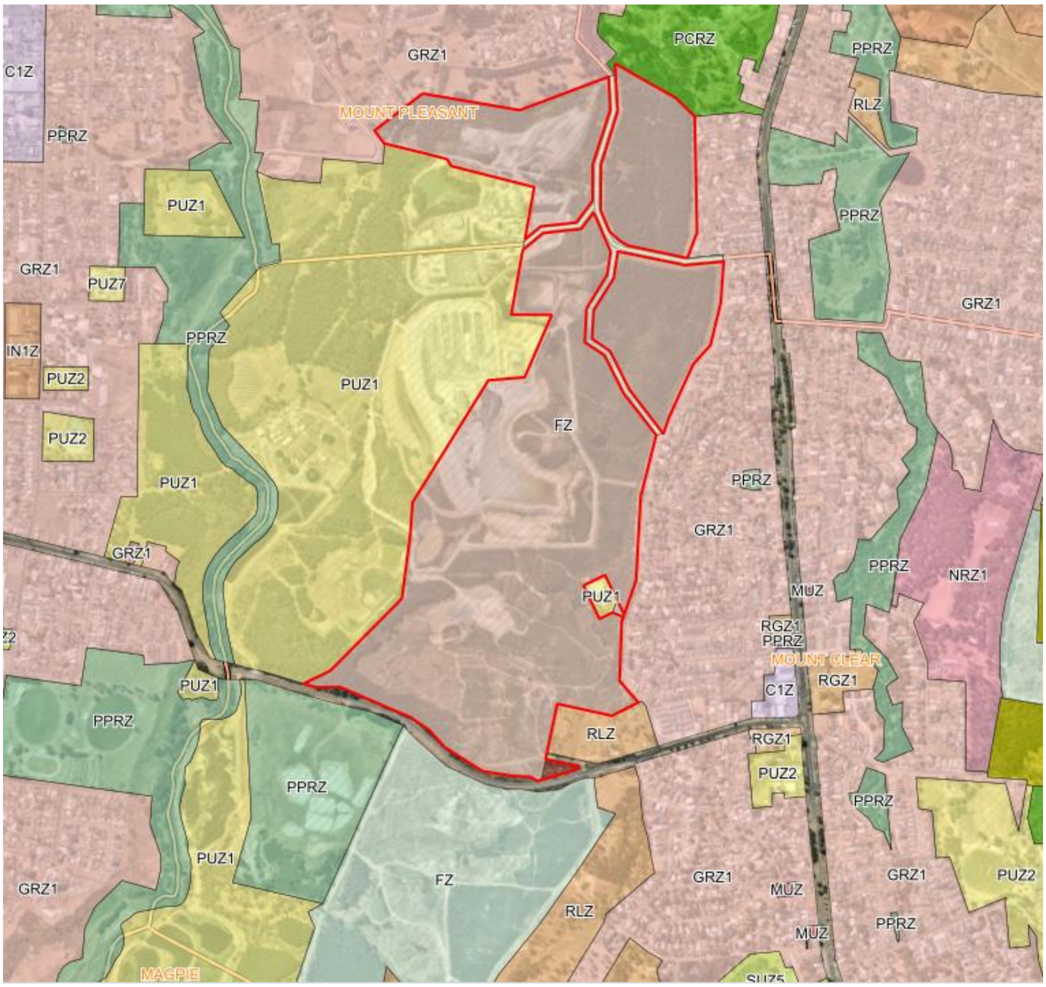

Figure 5 – Zone Map (Source: Intramaps)

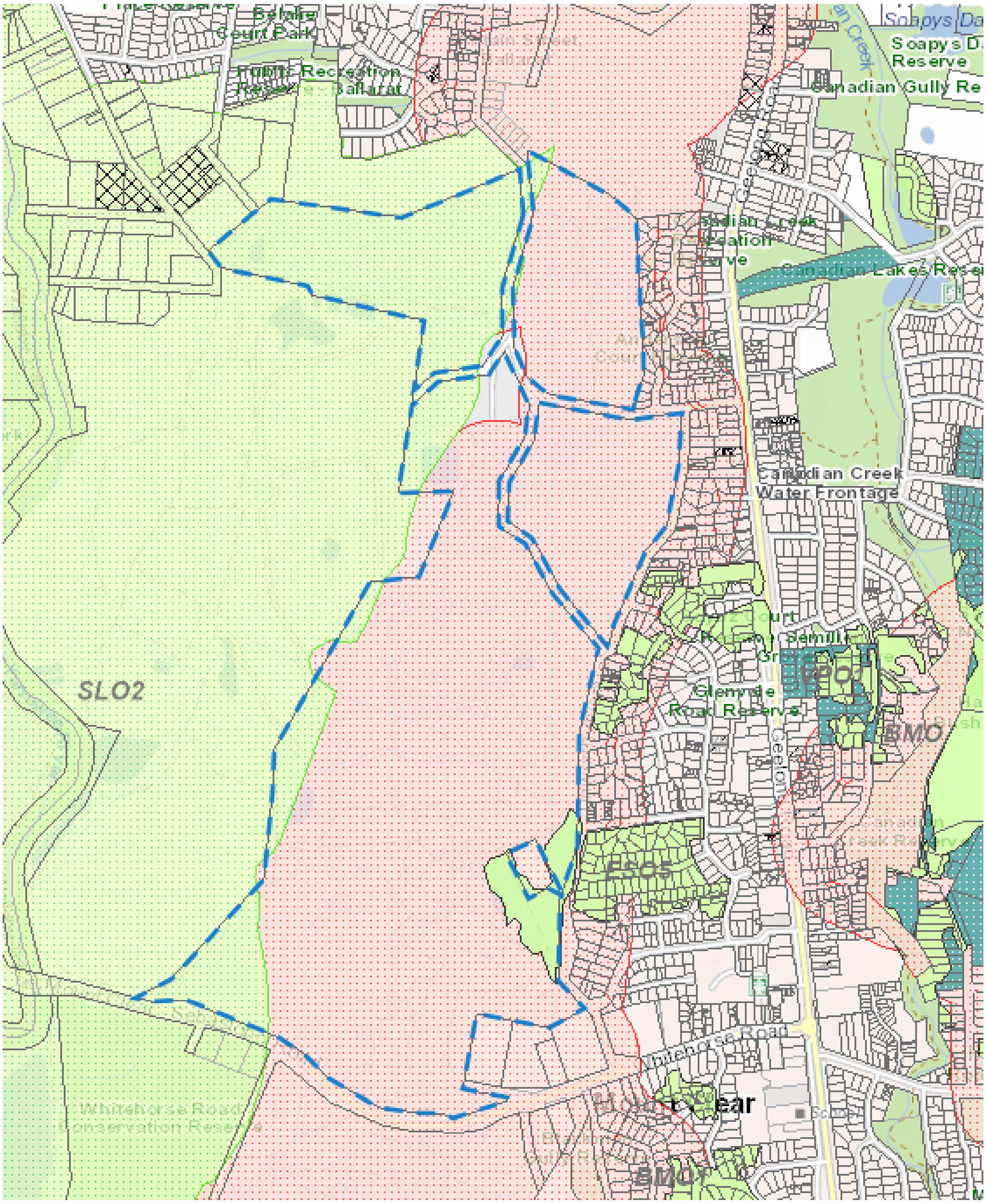

Figure 6 – Overlays applying to the site - ESO5, SLO2 and BMO (Source: VicPlan)

<u>Proposal</u>

20. This application seeks planning approval to construct a new Tailing's Storage Facility (TSF) on-site (TSF4). Together with a new vehicle access point off Whitehorse Road, TSF4 would be used in association with the existing earth and energy resources industry operating from the site.

TSF4

21. TSF4 is proposed to be located adjacent to the Whitehorse Road frontage of the site. This new facility will consist of an embankment standing to a maximum height of 35 metres and will provide tailings storage capacity of approximately 1.6 - 1.8 million cubic metres (Mm^3). This amounts to approximately 10 years of storage.

22. TSF4 would be constructed in six stages and include an emergency overflow spillway to the existing surge dam on site. Catch drains and sediment ponds downstream of the embankment are also proposed in order to capture sediment laden surface water runoff. Pumps will allow water to be transferred from sediment ponds to the surge dam.

23. TSF4 would be screened from view from Whitehorse Road by existing mature pines.

24. A 100 metre buffer to the closest residential properties along Tinworth Avenue and Whitehorse Road is intended to reduce visual and amenity impacts. No work will occur within this eastern buffer.

Figure 7 – Proposed TSF4 Footprint (Source: BGM Website)

Figure 8 – Proposed works area (Source: Assessing officer site inspection, November 2022)

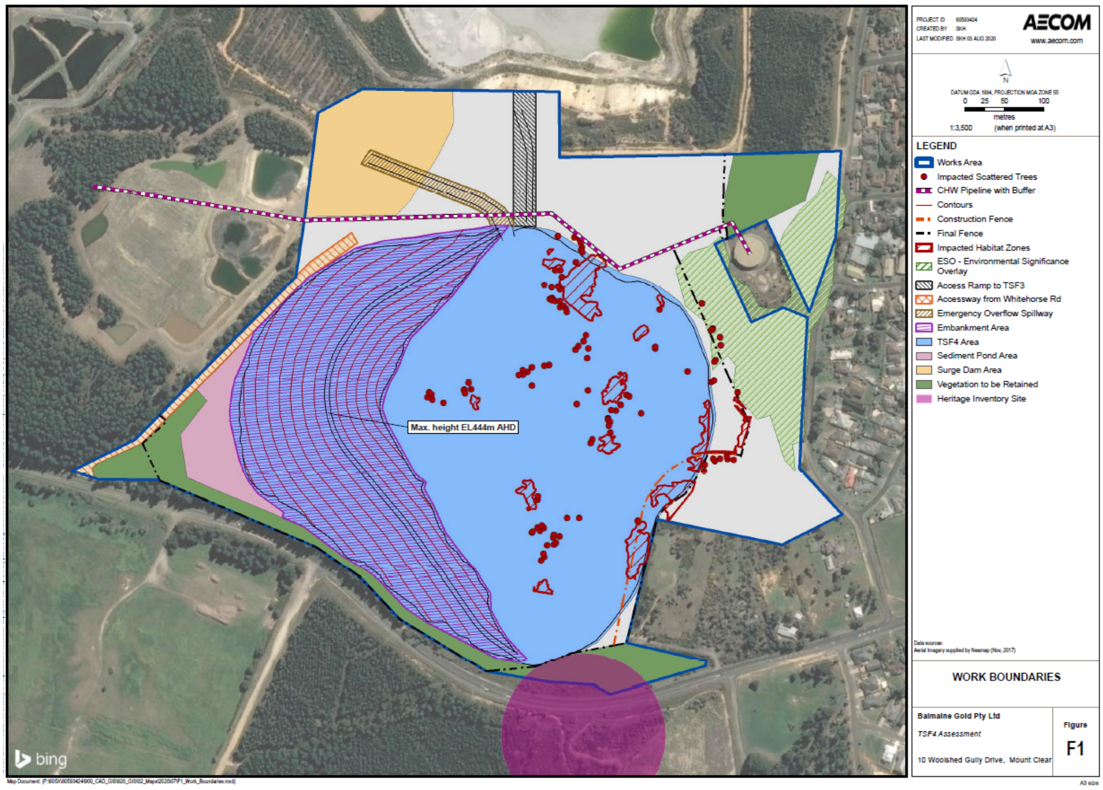

Figure 9 – Proposed site plan showing works area (Source: Application)

Access

25. A new vehicle access point is proposed off Whitehorse Road adjacent to the south-western corner of the site.

26. To facilitate this access, a new turning lane will be constructed along Whitehorse Road. Road widening is also required in order to enable passing vehicles to overtake slower exiting vehicles (refer Figure 10 below).

27. During each construction phase the access is proposed to be available between 7.00am and 6.00pm Monday to Friday.

28. Following the construction period and once TSF4 is operational, access is proposed to be available 24 hours a day, 7 days a week in order to accommodate on-site activities. Heavy vehicles will be restricted to using the new access from 7.00am to 6.00pm only Monday to Friday.

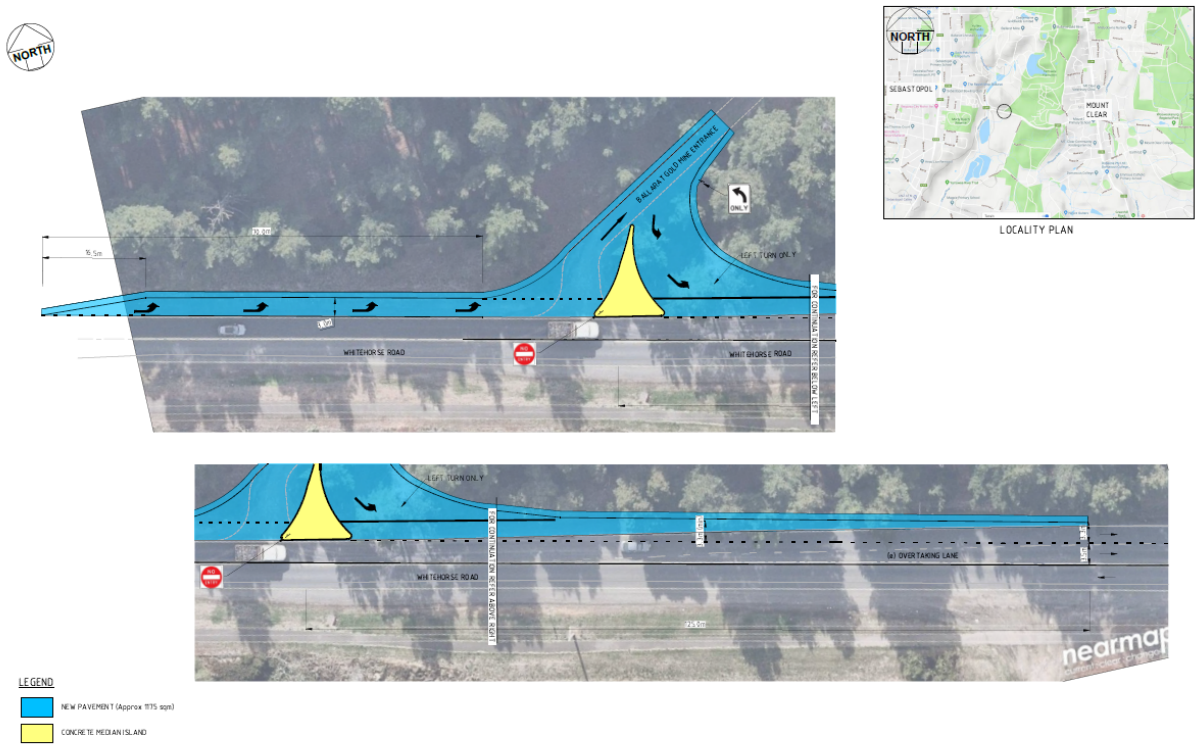

Figure 10 – Proposed access and road works (Source: Application)

Fencing

29. A new fence is proposed along the eastern, southern and part of the western boundary (as shown in Figure 7). The fence does not require a planning permit except for a small section which falls within ESO5.

30. The proposed fence will be 2.3 metres in height which includes the 1.8 metre high knuckle-to-barb mesh. It will be coloured black or dark green.

Vegetation Removal

31. To facilitate the construction of TSF4, native vegetation will be required to be removed. The footprint of TSF4 has been designed to largely avoid vegetation removal where possible, noting ES05 is located a short distance to the east of the facility.

32. Pursuant to Clause 42.01 (ESO) and Clause 52.17 (Native Vegetation) of the Ballarat Planning Scheme, an exemption relating to extractive industries applies. This exemption states the need to obtain a permit to remove native vegetation does not apply to:

    Native vegetation that is to be removed, destroyed or lopped to the minimum extent necessary to enable the carrying out of extractive industry in accordance with a work plan approved under the Mineral Resources (Sustainable Development) Act 1990 and authorised by a work authority under that Act.

33. The WPV includes conditions that relate to the off-setting of native vegetation to be removed and the protection of vegetation to be retained. As such, the abovementioned exemption is satisfied, and the removal of native vegetation does not form part of this assessment.

Planning Controls - Ballarat Planning Scheme

34. The following clauses are relevant in the consideration of this application:

Planning Policy Framework

- Clause 13.07-1S - Land Use Compatibility
- Clause 14.03-1S - Resource Exploration and Extraction
- Clause 17.01-1S - Diversified Economy
- Clause 17.01-1R - Diversified Economy – Central Highlands

Municipal Planning Strategy

- Clause 21.03 - Environmental and Landscape Values
- Clause 21.07 - Economic Development

Local Planning Policy Framework

- Clause 22.04 - Koala and Koala Protection (in relation to proposed fencing in ESO5 only)

Zone

- Clause 35.07 - Farming Zone

Overlays

- Clause 42.01 - Environmental Significance Overlay - Schedule 5
- Clause 42.03 - Significant Landscape Overlay - Schedule 2
- Clause 44.06 - Bushfire Management Overlay (no permit triggered by this control)

Other Provisions

- Clause 52.09 - Extractive Industry and Extractive Industry Interest Areas
- Clause 52.17 - Native Vegetation
- Clause 52.29 - Land Adjacent to the Principal Road Network
- Clause 65.01 - Approval of an Application or Plan

Planning Permit Triggers

35. A planning permit is required for the proposed works pursuant to:

- Clause 35.07 - Farming Zone – building and works
- Clause 42.01 - Environmental Significance Overlay – buildings and works (fencing)
- Clause 52.29 - Land Adjacent to Principal Road Network – creation of access

36. While not a planning permit trigger, Clause 52.09 (Extractive Industry and Extractive Industry Interest Areas) is the primary provision that guides the assessment of planning applications of this nature.

37. As previously stated, although native vegetation is required to be removed to accommodate the development, a permit is not required for this pursuant to Clauses 42.01 and 52.17 of the Ballarat Planning Scheme.

Consultation

Referrals

38. The following internal departments have been consulted:

Referral	Comment
Engineering	Consent – no conditions
Environmental Health	Consent – no conditions that are not already included

39. The following external authorities have been consulted:

Referral	Section 52 or 55	Comment
Department of Transport (now Department of Transport and Planning)	s55	Does not object to the grant of a permit subject to the following conditions: • *Prior to the occupation of the development hereby approved, the upgraded access to Whitehorse Road and associated roadworks must be constructed generally in accordance with the submitted Concept Plan (Revision B, dated July 2022 included in Traffic Impact Assessment Report dated 26 September 2022 prepared by Driscoll Engineering Services), to the satisfaction of and at no cost to the Head, Transport for Victoria.* • *Prior to the commencement of roadworks on Whitehorse Road, Functional Layout Plan(s), detailed design plan(s)s and associated technical plans and Road Safety Audit must be submitted to and approved by the Head, Transport for Victoria.*

40. It should be noted that Clause 52.09-3 of the Ballarat Planning Scheme states:

    Unless the referral authority is the Head, Transport for Victoria, the referral requirement in Clause 66 does not apply if a copy of a work plan or variation to an approved work plan accompanying the application was given to the referral authority under section 77TE of the Mineral Resources (Sustainable Development) Act 1990.

41. The WPV that accompanied the planning application was previously referred to:

    - Department of Environment, Land, Water and Planning (now DTP);
    - Southern Rural Water;
    - Central Highlands Water; and
    - Environment Protection Authority.

42. As these authorities were consulted as part of the WPV process and relevant conditions included via that process, the City of Ballarat was not required to refer the application again in accordance with Clause 52.09-3 as above.

Public Notification

43. The application has been advertised pursuant to Section 52 of the *Planning and Environment Act 1987* by:

    - Sending notices to the owners and occupiers of surrounding land (approximately 1,500 notices sent);
    - Placing six signs around the publicly accessible frontages of the site (Whitehorse Road and Tinworth Avenue); and

- Notice in the local newspaper

44. A total of 53 objections had been received at the time this report was written.

45. The below is a summary of the key themes raised by objectors:

- Health concerns;
- Environmental impacts (flora, fauna and water);
- Noise and dust impacts;
- Structural integrity/design of the facility;
- The facility's proximity to residential land uses and other sensitive uses;
- Traffic impacts; and
- The requirement for an Environmental Effects Statement (EES).

46. A community information session facilitated by BGM was held on 19 June 2023.

47. A response to the themes raised by objector is included in the following assessment.

Planning Assessment

48. The *Technical Guideline – Design and Management of Tailings Storage Facilities (April 2017)* prepared by the Department of Economic Development, Jobs, Transport and Resources provides the following definition of a tailing's storage facility:

    TSFs are built structures used to confine tailings. A TSF includes a dam or other structure and associated tailings delivery infrastructure. The primary purpose of a TSF is to safely contain tailings to achieve solid sedimentation and consolidation and to facilitate water recovery or removal without impacting on the environment. The nature of TSF design and operation is fundamentally different from a water dam in the way water is managed and in rehabilitation and closure.

49. Proposed TSF4 is required to enable the continued operation of BGM on the basis TSF3 has reached capacity.

50. In support of the application the following documents have been submitted:

- Planning report;
- Development plans;
- Copy of Statutory Endorsement of WPV;
- Copy of title;
- Visual impact assessment;
- Vegetation condition assessment;
- Noise assessment;
- Air quality assessment;
- Human Health Impact Assessment;
- Traffic impact assessment; and
- Road Safety Audit.

51. An assessment of the application is provided as follows. This assessment seeks to respond to the requirements of the Ballarat Planning Scheme and the concerns raised by objectors.

Is TSF4 appropriately located on the site and in relation to sensitive land uses?

52. The site is situated within the FZ and has been operating as a gold mine since the early 1990's in accordance with Planning Permit No. PA93/195, issued 22 September 1993 by the Shire of Buninyong. Historical photographs from 1994 shows established residential development immediately to the east of the site at this time.

53. This application does not seek to change the use of the land, it seeks only to undertake buildings and works in association with the existing lawful use of the site.

54. Clause 13.07-1S (Land Use Compatibility) seeks *to protect community amenity, human health and safety while facilitating appropriate commercial, industrial and infrastructure or other uses with potential adverse off-site impacts.*

55. On the basis the use of the land as an earth and energy resource industry is existing and lawful, the use of the site to accommodate additional mining infrastructure does not form part of this assessment.

56. TSF4 would be located a minimum 100 metres from the nearest residential receptors to the east and south-east. Importantly, this buffer area comprises a significant amount of vegetation and this will assist in visually screening the facility from nearby residential properties and also mitigating the potential spread of dust.

57. The proposed dam wall will be located on the western side of the site. The eastern edge of the facility will be built into the existing ground level. If a failure were to occur therefore, this would be along the western side of the facility, land opposite which is not used for residential purposes. There is no risk to the residential area to the east of the TSF failing as there is no dam wall here. To the west, land is zoned either PUZ1 or Public Park and Recreation Zone (PPRZ). The nearest residential property beyond this land is approximately 520 metres to the west.

58. Further details regarding the construction of the dam wall and the criteria applied when designing tailing's storage facilities appears below.

How has TSF4 been designed?

59. TSF4 has been deigned in accordance with:

    - *Earth Resources Regulation (ERR) 'Guidelines for Design and Management of Tailings Storage Facilities', April 2017;*
    - *Australian National Committee on Large Dams 'Guidelines on Tailings Dams', May 2012.*

60. The guidelines adopt a risk-based approach and recognise that larger dams create a larger risk. The guidelines establish a consequence category based on a range of factors, including the number of properties downstream at potential risk. In this instance the dam is 'Category High B' and has therefore been designed accordingly. This is the same category as TSF3.

61. As the consequence category is high, a corresponding high design criteria is required to make the probability of failure as low as reasonably possible. This includes:

    - Ensuring the dam can withstand a 1:1,000,000 Annual Exceedance Probability (AEP) flood event, with the critical duration of 5 hours with total 680 millimetres of rainfall;
    - Designing for a Maximum Credible Earthquake 1:10,000 year AEP and
    - Designing for flood handling capacity to safely store without spilling in a 1 in 100 year 72 hour rain event.

62. The emergency spillway is required in case of exceptional circumstances and has been designed based on the aforementioned flood criteria.

63. The existing surge dam and wetlands located south of TSF3 will also be used to accommodate any spillage from the proposed facility. This spillage would be captured by sediment ponds at the bottom of the dam wall and pumped to the surge dam to the north-west of the facility.

64. TSF4 has been conservatively designed using a staged raise construction phase. This minimises any geotechnical risks associated with foundation stability and liquefaction risk. A low permeability clay liner 800 millimetres thick will apply over the whole storage area.

65. The guidelines also require on-site monitoring and inspections on a daily basis, including the review of monitoring instruments. Monthly reviews and collection of data is also required. If this data reveals issues, then action would be undertaken in accordance with a mandatory Operation Manual or Emergency Response Plan.

66. A yearly report is also required to be produced for ERR setting out any such issues and the actions taken.

67. The final detailed design of TSF4 will be independently reviewed and sent to ERR and other key stakeholders.

<u>Have human health impacts been appropriately considered?</u>

68. The requirement to consider human health impacts in accordance with the Ballarat Planning Scheme is limited. The decision guidelines of Clause 52.09 (Extractive Industry and Extractive Industry Interest Areas) are also generally focused upon amenity and environmental impacts, not human health impacts. Notwithstanding this, there are references to human health at Clause 65.01 (Approval of an Application or Plan).

69. Tonkin + Taylor have prepared Human Health Risk Assessments (HHRA) for the construction and operation of TSF4. These assessments were prepared following the public notification process in order to respond to the concerns raised. Importantly, the HHRA is not a statutory requirement of the Ballarat Planning Scheme. The HHRA has been submitted on a voluntary basis.

70. As noted in the HHRA, it *has focused on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollutions, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust.*

71. The HHRA also states it *has considered the incremental risk from the construction and operation of TSF4 from changes in air quality (PM10, PM2.5, Respirable Crystalline Silica (RCS) and metals) and potential risks to human health through inhalation and deposition to water tanks (metals). The HHRA has been conducted in accordance with the relevant national and international guidelines as well as the relevant guidance from EPA Victoria.*

72. The HHRA is comprised of five components, as follows:

- Issue identification;
- Hazard assessment;
- Exposure assessment;
- Risk characterisation; and
- Uncertainty assessment

73. A conceptual site model (CSM) has been prepared which shows potential exposure pathways between TSF4 and sensitive receptors. 118 such receptors have been assessed including dwellings, aged care facilities, schools, kindergartens, childcare centres and recreational areas. It should be noted that identifying these receptors does not confirm a risk exists. The identification of these receptors confirms a potential risk of exposure exist.

74. The CSM identifies the main potential exposure pathways as:

- *Direct inhalation of dust, including PM10, PM2.5 and metals from the construction and operation of the TSF4;*
- *Potential infiltration of leachate into groundwater that may impact on the Yarrowee River; and*
- *Deposition of dust containing metals and run-off into rainwater tanks.*

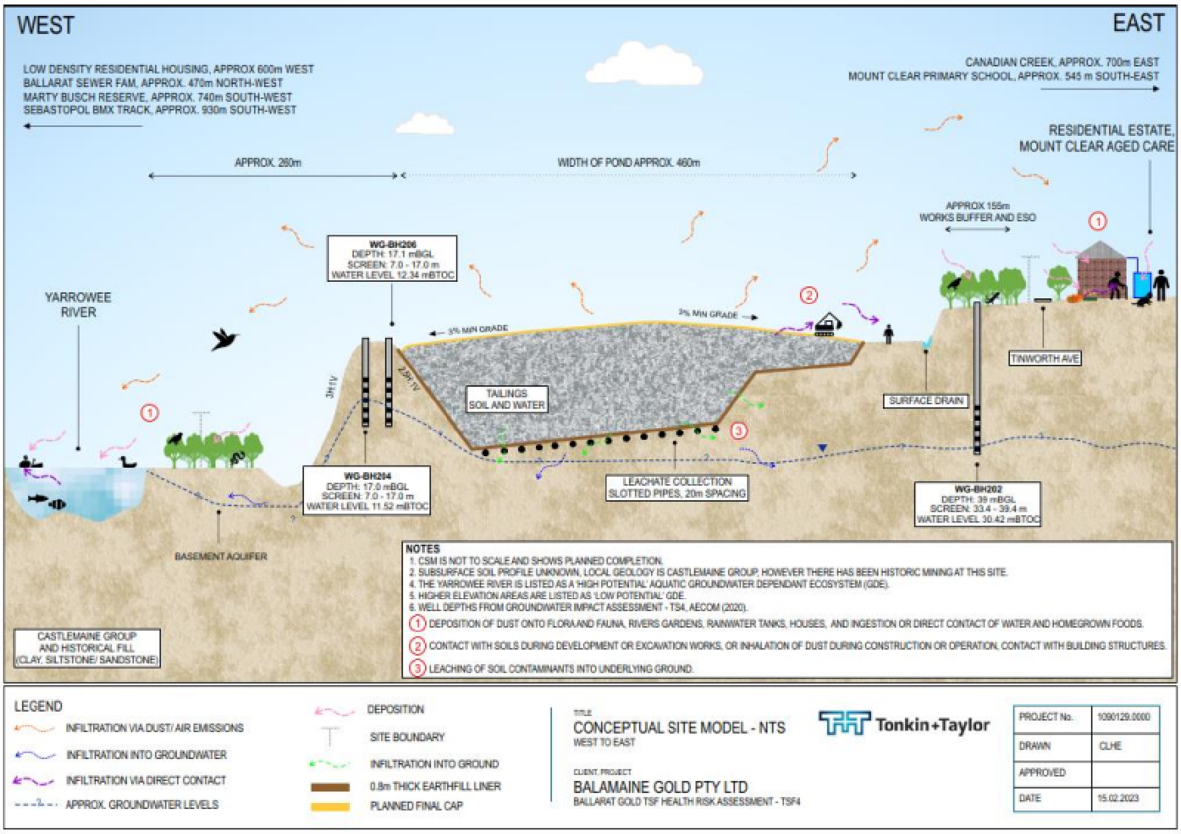

Figure 11 – Conceptual site model (Source: HRA)

75. The HHRA seeks to respond to the CSM and the concerns of objectors under four main themes. A summary of these themes and the applicant's response to each is provided below.

Human Health Risk – PM_{10} and $PM_{2.5}$

76. PM_{10} and $PM_{2.5}$ is also known as particulate matter and is a measurement of particles with a diameter of 10 micrometres or less or 2.5 micrometres or less.

77. The HHRA states:

A review conducted by the World Health Organization (WHO, 2013) concluded that both PM10 and PM2.5 are related to increases in mortality from respiratory and cardiovascular causes, hospital admissions and emergency department attendances for respiratory and cardiovascular causes including asthma, exacerbation of asthma, and increases in respiratory symptoms. In recent years, studies have provided much stronger evidence for the cardiovascular effects of particles, in particular PM2.5.

78. In order to understand the potential impacts of TSF4, Tonkin + Taylor have undertaken air dispersion modelling. The construction of TSF4 will occur over six stages. The first stage, known in the HHRA as Zone 1, will comprise 25 per cent of the total storage capacity of the facility. The remaining stages (Zones 2 - 6) will each comprise 15 percent of the total storage capacity. Modelling was completed for three scenarios as follows:

- *Construction of Zone 1 of TSF4 – this is the period of the largest earth movement activity;*

- *Construction of Zone 6 of TSF4 – this is the period when earth moving activities are closest to residential receptors; and*
- *Operation of TSF4 – this is a period of minimal emissions from TSF4 but includes ongoing operations of the site.*

79. The following mitigation measures have been incorporated into the modelling in order to satisfy the General Environmental Duty (GED) and to minimise the risk of impacts to human health and the environment:

- Watering of all areas where material is handled, including:
  - Waste rock stockpiles;
  - Transfer of rock to primary crusher;
  - Extraction and placement of TSF3 material on dry stack;
  - Disturbed area of dry stack until crust forms;
  - Extraction and placement of waste rock and soil material; and
  - Disturbed areas of waste rock and soil removal, placement until a crust has formed.

- All crushers fully enclosed;
- Sprinklers within ore conveying system;
- Baghouse used within concrete batching;
- Sprinklers used when receiving material for concrete batching; and
- Chemical sealants on haul roads with additional watering.

80. The HHRA then includes a risk characterisation that looks at matters such as potential increases in mortality, hospital admissions and emergency department visits across multiple suburbs of Ballarat as a result of the proposed facility.

81. The report concludes that:

- *The predicted number of attributable cases due to PM_{10} from construction and operation of the TSF4 for all areas assessed is low;*
- *The highest risk would be for hospital admissions for respiratory disease in people over 65 years of age in the Mount-Pleasant/Canadian area, with 6 additional admissions per 100 years attributable to PM_{10} from the construction and operation of the TSF4;*
- *The risks in all other areas and for all other health outcomes are lower than that predicted for hospital admissions for respiratory disease in people 65 years and older;*
- *The highest risk predicted for emergency department attendances for children with asthma is low for all areas with an additional 2 - 7 attendances per 1000 years predicted across all areas;*
- *It should be noted that the construction of each Zone of the TSF4 will be undertaken over a period of 10 to 12 months and the life of the TSF4 is 10 years. These timelines are shorter than those over which adverse health effects would be observed and as indicated by the results presented;*
- *The risks to the local population from PM_{10} from the proposed construction and operation of the TSF4 are very low and would not be detected in the population;*
- *The predicted number of attributable cases due to $PM_{2.5}$ from the construction and operation of the TSF4 are low for all areas assessed;*
- *The highest risk would be for hospital admissions for pneumonia and bronchitis in people over 65 years of age with 7 additional admissions per 100 years attributable to $PM_{2.5}$ from the construction and operation of the TSF4;*

- *The risks for all other health outcomes for all areas assessed are lower than that predicted for hospital admissions for pneumonia and bronchitis in people 65 years and older; and*
- *Risks to the local populations from $PM_{2.5}$ from the proposed construction and operation of the TSF4 are very low and would not be detected in the population.*

Metals

82. Separate to particulate matter, the HHRA also considers the effects of metals during both the construction and operation of TSF3. The metals considered are identified below and can have a range of health effects.

Metal	
Antimony	Vanadium
Arsenic	Cadmium
Lead	Chromium VI and VIII
Barium	Zinc
Manganese	Cobalt
Nickel	Strontium

Figure 12 – Metals assessed (Source: HRA)

83. An exposure assessment and risk characterisation has been undertaken and the HHRA concludes that *all hazard quotients for all scenarios are well below the acceptable limit of 1. A hazard quotation of 0.1 is considered negligible by enHealth, WHO and USA EPA. All hazard quotients are well below 0.1 indicating that all potential risks from exposure to metals from the construction and operation of TSF4 are negligible.*

84. The HHRA then states *all carcinogenic risk levels are several orders of magnitude below 1x10-5 even at the most impacted receptors. enHealth, consistent with WHO guidance, considers that risks below 1x10-6 are negligible. All carcinogenic risks calculated for the metals associated with the construction and operation of the TSF4 are well below this level. The risk is therefore considered to be negligible*

Respirable Crystalline Silica

85. The Work Safe Victoria website identifies crystalline silica as *a natural mineral found in stone products such as reconstituted stone, granite and sandstone.* It notes that silica dust can be harmful when it is inhaled.

86. In considering the risks around Respirable Crystalline Silica (RCS) the HHRA states conservative assumptions have been applied. To calculate the hazard quotients, the HHRA states *health-based guidelines of the Californian EPA Office of Health Hazard Assessment have been adopted.* These guidelines state 3µg/m3 is an annual average and have been adopted by the EPA as an air quality assessment criteria.

87. The HHRA concludes *all hazard quotients for all receptors for all areas are well below 1 and within acceptable risk levels adopted by enHealth (2012). The hazard quotients are also below the negligible risk level of 0.1.*

Groundwater

88. The HHRA also considers impacts upon groundwater. The potential for groundwater to be contaminated by leachate from TSF4 and impacts on recreational users of the Yarrowee River was raised by objectors. The HHRA includes a review of groundwater monitoring and potential exposure pathways. The HHRA notes *if there is no complete exposure pathway, then there is no potential risk to human health.*

89. A leachate collection system will be installed as part of TSF4. This system is designed to collect leachate from the floor of the facility. From here, the leachate would be pumped from the facility via an above-ground pipe. The TSF also includes a drain at the bottom of the embankment to catch any seepage.

90. As noted in the HHRA, the main pathway for groundwater impacts is the subsurface migration of impacted water from TSF4. There is also a possibility that contaminated groundwater may be discharged to surface waters such as the Yarrowee River.

91. There are 16 groundwater bores located within one kilometre of the facility. 10 bores are identified as ‘groundwater investigation’ or ‘observation’. None of the bores are identified as being a source of potable water.

92. Tonkin + Taylor have assessed groundwater monitoring data obtained by BGM between 2020 and 2023. In response to this data, the HHRA states:

    Based on the analysis conducted above, the risk of health impacts from exposure to groundwater from the site and potential impacts on users of the Yarrowee River from the construction and operation of the TSF4 is considered to be low. The proposed leachate management system would reduce the risk of leachate building to the point where seepage through the clay liner would occur. It is also unlikely that a sufficient volume of rainwater would infiltrate through the cap post-closure to re-saturate the tailings and leach into groundwater. Overall, the risk of contaminated water impacting groundwater is considered low.

    In addition, the hydraulic conductivity of the basement aquifer is very low, suggesting that in the event that there is leakage to groundwater, groundwater flow is likely to be an ineffective pathway for contaminant transport. There are no clear exposure pathways for people to be exposed to groundwater in either the Cavil Formation or Basement aquifers. There are no groundwater bores downgradient of the site that are not on industrial land. The existing bores can’t be accessed by the public therefore there are no direct exposure pathways.

    Groundwater quality results suggest that the existing TSF3 is not impacting groundwater quality downgradient of the mine. Based on the results of the ground water monitoring, the downgradient water quality is similar, if not better, than the upgradient quality. This indicates that the current mine operations, including the TSF3, is not impacting on groundwater in the area. As the proposed TSF4 is based on the same construction principles as TSF3, it is reasonable to assume that the potential impacts to groundwater would be similar for both operations. In addition, the ore being mined will be the same or similar to that currently being processed meaning that any impact on groundwater quality would be similar to that currently observed. If groundwater was to enter the Yarrowee River, there would be no impact from the mine and the TSF4 above that from background groundwater. The groundwater from the downgradient wells meets the recreational water guidelines for arsenic which means that if it did discharge to surface waters it would not pose a risk to human health through recreational use.

Will the proposal have adverse environmental impacts?

93. The proposal will result in topographical changes to the site. As a result, there is anticipated to be an increase in sediment from surface run-off and a settlement pond will be required to be constructed downstream of the TSF4 embankment. In addition, an existing surge dam and wetland system on site will be used to accommodate run-off.

94. As previously noted, the removal of native vegetation is not a matter for consideration. Notwithstanding this, a Vegetation Condition Assessment has been submitted in support of the application. This assessment is based upon the footprint of the proposed buildings and works.

95. The Vegetation Condition Assessment includes a detailed koala habitat assessment in the area defined by ESO5. This is on the basis a security fence is proposed in this area. The assessment concludes that *the vegetation in the ESO5 area did not qualify as any category of koala habitat and did not facilitate the safe movement of koalas between breeding populations or vacant preferred land. More specifically, the area of ESO5 that is to be impacted by the proposed fence contains a low-quality patch of vegetation that has previously been disturbed and does not contain trees that would provide the necessary food resources for koalas.*

96. The provisions of Clause 22.04 (Koala and Koala Habitat Protection) remain relevant however when considering the proposed fencing. Clause 22.04 states *fencing in areas of, or adjoining areas of koala habitat, must:*

- *Provide a minimum of 300mm between the bottom of the fence and ground level to allow koalas to move underneath the fence;*
- *Facilitate easy climbing by koalas. This could include use of:*
  - *chain mesh fences; or*
  - *solid fences with timber posts on both sides and spaced at regular intervals; or*
  - *open post and rail; or*
  - *post and wire fences, without the use of barbed wire.*
- *Effectively contain dogs in and exclude koalas from a dog compound. Dog compounds should be restricted to a location within a designated building envelope/works area and away from trees, to prevent koalas from entering the compound.*

97. The proposed fencing within ES05 does not satisfy the above requirements and therefore amendments are required. These amendments can be captured by way of conditions to ensure compliance with the provisions of Clause 22.04.

98. In relation to other native vegetation within the works area, this was found to be of a patchy nature due to forestry planting, multiple fire events and ongoing mining activities. The removal of vegetation on site has been considered as part of the WPV process and appropriate conditions, such as vegetation offsets, have been included.

99. The potential impacts on groundwater have been considered previously in this report.

Can noise and air quality be mitigated to an acceptable level?

100. A Noise Impact Assessment has been prepared by Broner Consulting. This assessment provides an analysis of the changes in predicted noise levels as a result of the construction and operations of TSF4.

101. Noise modelling was undertaken, including topographical details and dominant noise sources. The modelling was undertaken for both the construction and operational phases of the facility. Importantly, the construction phase will include operations between 7.00am and 6.00pm only whilst the operational phase will generate activities 24 hours a day.

102. Receiver locations for the modelling have been based on existing monitor points forming part of the existing mining license approvals (MIN4847 and MIN5396), including residential receptors. TSF4 will sit across the two mining licenses, each of which has different approved noise limits. The noise limits vary depending on the location and time of day.

103. The Noise Impact Assessment concludes as follows:

This report details the construction operational equipment that is to be used and the sound power level of the proposed equipment. Noise level predictions were conducted for two scenarios of the construction equipment (eastern and western edges of the TSF4). It was found that the predicted noise levels at critical receiver locations are well below the Approved Noise Limits. Therefore, it is predicted that the construction and operation of a proposed new tailings storage facility (TSF4) will not cause any additional noise impact.

104. An Air Quality Assessment has also been prepared in support of the application. This assessment considers potential impacts as a result of both the construction and operational phases of TSF4.

105. The air quality assessment considers compliance against *State Environment Protection Policy (Air Quality Management) 2001 (SEPP [AQM])* and the related *Environment Protection Authority Victoria's (EPAV) Publication 1191 - Protocol for Environmental Management, State Environment Protection Policy (Air Quality Management) – Mining and Extractive Industries (December 2007).*

106. The assessment focuses upon matters such as PM_{10}, $PM_{2.5}$ and RCS and overlaps with the HHRA. For a mining operation, particulate matter is emitted from a number of extractive activities, including disturbance of soil and rock, traffic on haul roads, movement of overburden, blasting/drilling and wind-blown dust from exposed surfaces.

107. In the assessment of air quality factors, including land use, terrain, climate and meteorology, existing air quality and sensitive receptor locations are taken into consideration.

108. Three modelling scenarios were investigated as part of the assessment and are described as follows:

- *Scenario 1 – existing operations. This scenario is based on operations at the mine utilising the existing TSF3 tailings dam;*
- *Scenario 2 – future TSF4 operations. This scenario is based on future operations at the mine utilising the proposed TSF4 tailing dam. The existing TSF3 tailings dam would not be operational under this scenario; ·*
- *Scenario 3 – TSF4 construction. This scenario is based on activities involved with the construction of the proposed TSF4 tailings dam. Operations would continue as per normal during construction of TSF4 and therefore all activities included in Scenario 1 were also included in Scenario 3. Modelled construction activities for*

this scenario are based on Stage 2 construction works, which have a higher total excavation volume than Stage 1 and would therefore experience higher emission rates. The Stage 2 footprint would also bring construction activities closer to sensitive receptors to the south and east of TSF4. Emission rates were calculated based on eight months construction duration. Stage 2 is likely to be constructed over a longer period than eight months and therefore the modelled construction intensity is likely to be greater than reality. Estimated emission rates were applied to all hours of the model (five years) conservatively.

109. The following is a summary of each of the scenario's key findings:

- *Scenario 1 (existing operations) - cumulative 24-hour concentrations for both PM_{10} and $PM_{2.5}$ were predicted to be well below criteria. Project contributions were predicted to be up to 43% (24- hour PM_{10}) and 11% (24-hour $PM_{2.5}$) of their respective criteria;*
- *Scenario 2 (future TSF4 operations) - cumulative 24-hour concentrations for both PM_{10} and $PM_{2.5}$ were predicted to be well below criteria. Project contributions were predicted to be up to 45% (24- hour PM_{10}) and 11% (24-hour $PM_{2.5}$) of their respective criteria; ·*
- *Scenario 3 (TSF4 construction) - cumulative 24-hour concentrations for both PM_{10} and $PM_{2.5}$ were predicted to be below criteria at all sensitive receptors. Project contributions were predicted to be up to 58% (24-hour PM_{10}) and 12% (24-hour $PM_{2.5}$) of their respective criteria; and*
- *Respirable crystalline silica (as $PM_{2.5}$) concentrations were predicted to be well below the criterion for all scenarios.*

110. Importantly, dust mitigation measures currently exist on site, including (but not limited to):

- The maintenance of dust control efficiency on primary haul roads through watering;
- Covering truck loads when leaving the site;
- Applying water spray to excavation activities during high dust/wind events; and
- Minimising the size of disturbed areas and rehabilitate as soon as possible.

111. The Air Quality Assessment identified that current dust mitigation measures being implemented on site were acceptable for all operational activities, however it is recommended that a Dust Management Plan be drafted to ensure these strategies remain in place and that dust impacts to surrounding receptors are controlled to an acceptable level during the construction phase also.

112. A condition would be included on any planning permit issued reflecting this recommendation.

<u>Does the proposed access lead to an inappropriate traffic outcome?</u>

113. The proposed vehicle access in the south-western corner of the site would extend off the Principal Road Network (as defined by the TZ) and this is managed by DTP, not the City of Ballarat.

114. In support of the proposed access, a Traffic Impact Assessment and Road Safety Audit has been submitted.

115. The application was referred to DTP who has consented to the proposal subject to conditions.

116. The use of the new access is proposed to be restricted (via hours) depending upon the size of the vehicle entering/exiting the site. Conditions to this effect will be included upon any permit issued.

117. As the road is managed by DTP and no objection has been raised by this authority, it is considered that the proposed access is acceptable and will not lead to an inappropriate traffic outcome.

<u>Other matters</u>

Visual Amenity

118. A Visual Impact Assessment was prepared by Hansen Partnership in support of the application.

119. This assessment provides a detailed analysis of the existing landscape character and values associated with the study area followed by an assessment of potential impacts.

120. Two landscape character precincts have been identified within the study area, these being described as 'Yarrowee Valley Landscape Character' and 'Urban Landscape Character.'

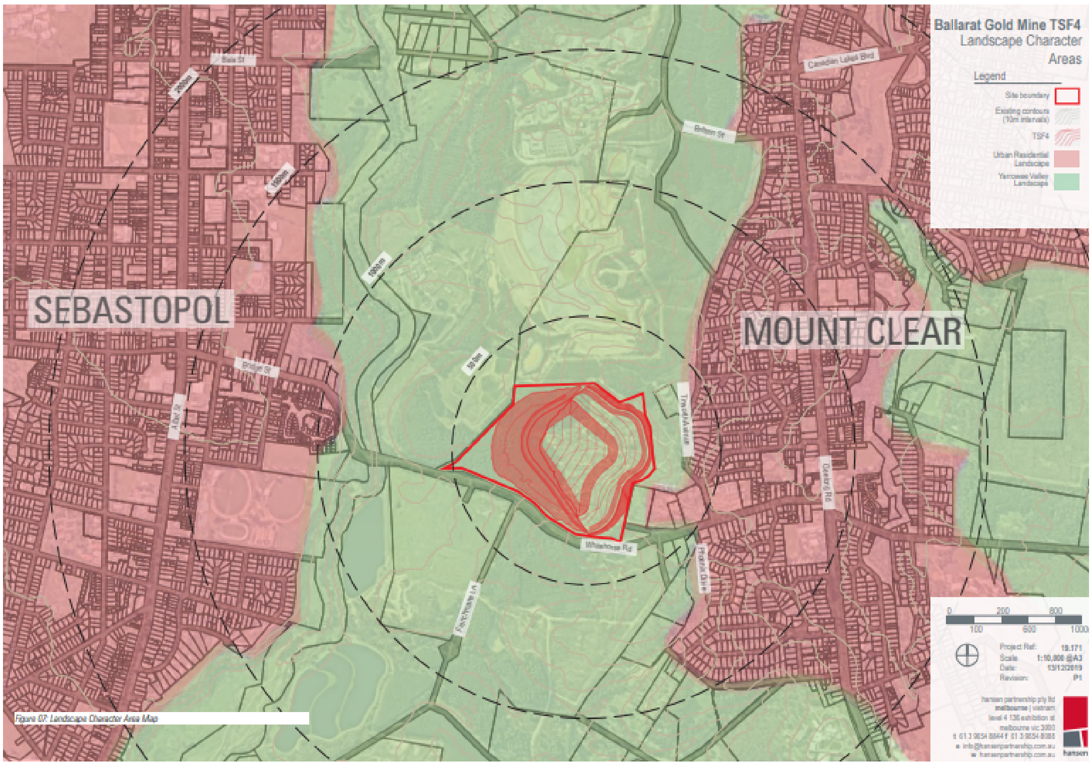

Figure 13 – Landscape character map (Source: Visual Impact Assessment)

121. Following the identification of the character precincts, an assessment of the landscape values of each was then undertaken. This allowed for an assessment of visual impacts from four representative viewpoints.

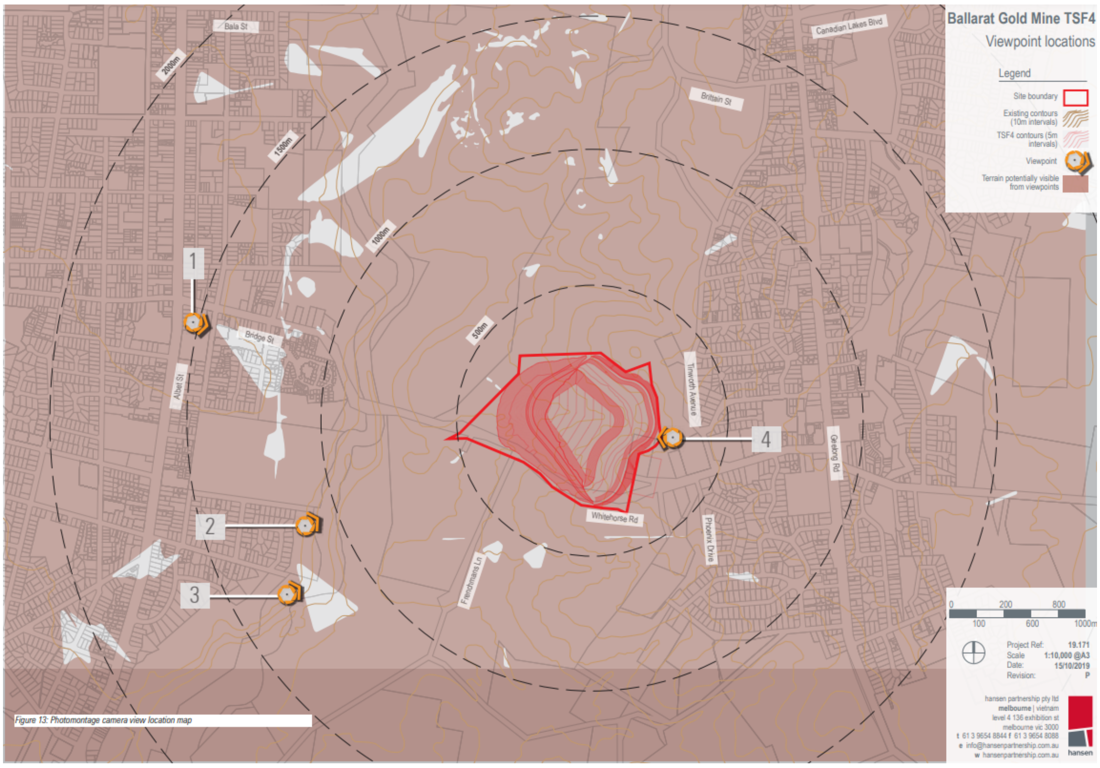

Figure 14 – Viewpoint locations (Source: Visual Impact Assessment)

122. For each viewpoint, visual character and anticipated visual impacts have been considered and a related statement has been provided as to whether or not mitigation measures are necessary. For all four view locations TSF4 is considered visually acceptable, and no mitigation measures are therefore necessary.

Requirements for an Environmental Effects Statement (EES)

123. ERR has previously provided Statutory Endorsement of the WPV. To secure this status, ERR was required to consult other agencies, such as the Department of Environment, Land, Water and Planning (now DTP) and the EPA. These authorities did not raise any objections to the proposal and have included conditions now forming part of the Statutory Endorsement.

124. Based on the previous review of the WPV by relevant agencies, which by way of Statutory Endorsement has considered the thresholds for requiring an Environmental Effects Statement (EES), Officers remain of the view the threshold for requiring such has not been met.

Conclusion

125. It should be acknowledged that the requirement for Council's to consider mining applications is a complex and challenging one, generally outside the typical scope of expertise. Notwithstanding this and having considered the City of Ballarat's ambit of discretion in this case, it is considered that the matters which require planning approval represent an appropriate outcome.

126. Importantly, the use is existing and as such cannot be considered. This is a point of contention for many objectors who are of the view a buffer zone should exist. Due to the historic nature of development in this area however, no such off-site buffer can be provided.

127. That said, an on-site buffer zone of approximately 100 metres to the nearest residential property to the east will be maintained. In accordance with recommended permit conditions, this area will be required to be planted out in order to provide added visual screening and to also assist with mitigating any spread of dust from the site.

128. As previously noted, objectors have raised a number of health-related concerns. These concerns are evidence-based and require careful consideration. The applicant's HHRA seeks to respond to these concerns and concludes that the impacts of particulates and metals as well as the impact of the proposal upon groundwaters will be negligible.

129. Given these juxtaposed views, and recognising that Council's ambit of discretion is limited in this case, it is considered that prior to the commencement of any development on site, an amended HHRA should be submitted for further consideration. This HHRA should include an updated methodology and quantitative data regarding the potential health risks associated with PM10, PM2.5 and metals to surrounding sensitive receptors.

130. This updated HHRA will then be independently peer reviewed to verify the conclusions put forward by the applicant and to ensure that the potential health impacts of the facility are fully known and understood and appropriate mitigation and monitoring measurers are applied. The development will not be permitted to commence until such time as all agreed measures and actions are implemented.

OFFICER RECOMMENDATION

131. That Council:

131.1 Having considered all the matters required under Section 60 of the *Planning and Environment Act 1987*, resolves to issue a Notice of Decision to Grant a Planning Permit in accordance with the Ballarat Planning Scheme in respect of the land known and described as 10 Woolshed Gully Road, Mount Clear, for *buildings and works for the development of a new tailings storage facility, associated with the land use of earth and energy resources industry and creation of access.*

Proposed Conditions

1 Amended Plans Required

Before the building and works commence, amended plans must be submitted to and approved in writing by the Responsible Authority. When approved, the plans will be endorsed and will then form part of the permit. The plans must be drawn to scale with dimensions and emailed to planninginfo@ballarat.vic.gov.au with the planning reference number. The plans must be generally in accordance with the development plans prepared by Aecom dated 03 August 2020 but modified to show:

(a) Fencing details for the area of fence within the Environmental Significance Overlay – Schedule 5 in compliance with Clause 22.04 of the Ballarat Planning Scheme;

(b) The opportunity for additional shrubs and trees to be planted around the permitter of the facility in accordance with Clause 52.09-6 of the Ballarat Planning Scheme and as per the requirements of Condition 14 of this permit;
(c) Locations of parking opportunities for vehicles (including trucks) being utilised in the construction and operational phases of Tailing Storage Facility 4 (TSF4) in accordance with Clause 52.09-6 of the Ballarat Planning Scheme; and
(d) Each of the stages of construction in accordance with Condition 4 of this permit.

The plans must be to the satisfaction of the Responsible Authority.

2 No Changes

The buildings and works hereby approved as shown on the endorsed plans and/or described in endorsed documents shall not be altered or modified without the prior written consent of the Responsible Authority, unless the alteration(s) and/or modification(s) comply with an exemption contained in the Ballarat Planning Scheme and do not result in non-compliance with any mandatory requirements.

3 TSF4 Structural Integrity

Prior to the commencement of works in association with the construction of TSF4, a copy of the detailed design plans, including a statement from an independent reviewer confirming the acceptability of these designs, must be submitted to the Responsible Authority. The statement must confirm that the detailed design is in accordance with relevant design guidelines (including ANCOLD) and that the proposed clay liner, along with under drainage systems will minimise any seepage to groundwater to an acceptable level.

4 Construction Stages

Prior to the commencement of the building and works hereby approved an overall staging plan showing each stage of construction must be submitted to and approved in writing by the Responsible Authority.

Prior to the commencement of each stage of construction, an individual stage plan must be submitted to and approved in writing by the Responsible Authority. The plan must detail:

- The location of the proposed works;
- Final construction details, including embankment heights, cut off trenches, spillway(s) etc.;
- Associated infrastructure, such as drains, pumps etc.;
- Pond volume/capacity; and
- Any required sediment ponds.

5 Operating Hours of TSF4

Once construction is complete, TSF4 may operate up to 24 hours a day provided:

- Noise limits within the two mining licenses, MIN4847 and MIN5396 are not exceeded; and
- Noise limits do not exceed those set out in EPA Publication 1826.4: Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues

6 <u>Dust Management Plan</u>

Prior to the commencement of the building works hereby approved, a Construction Dust Management Plan (CDMP) must be prepared by a suitably qualified consultant and submitted to and approved in writing by the Responsible Authority.

The CDMP must consider the Air Quality Assessment prepared by Aecom (March 2020) and be developed to ensure mitigation strategies are in place and that dust impacts on surrounding receptors are controlled to an acceptable level during the construction period.

The CDMP will be required to be independently peer reviewed by a suitably qualified consultant selected by the Responsible Authority. All costs associated with the peer review will be met by the permit holder.

7 <u>Construction Management Plan</u>

Prior to the commencement of the building works hereby approved, a Construction Management Plan (CMP) must be submitted to and approved in writing by the Responsible Authority The Plan must detail:

(a) Hours of construction to accord with Local Laws;

(b) Methods to contain dirt and mud within the site and the method and frequency of clean up procedures;

(c) Management of parking of construction machinery and workers vehicles to prevent adverse impacts to nearby properties and public roadways;

(d) Management of heavy vehicles, site deliveries and traffic management in the vicinity of the site to ensure routes to and from the land minimise disruption to nearby residential properties;

(e) Measures to minimise noise and other amenity impacts from mechanical equipment, including idling trucks and construction activities, especially outside of daytime hours where this is permitted;

(f) The provision of adequate environmental awareness training for all on-site contractors and sub-contractors; and

(g) A liaison officer for contact by the public and the Responsible Authority in the event of relevant queries or problems experienced.

All works on the land must be undertaken in accordance with the endorsed CMP to the satisfaction of the Responsible Authority.

Where the construction phase is to be carried out in stages, staged CMPs may be submitted and must be approved prior to the commencement of each relevant stage.

Each management plan must set out the matters noted in (a) to (g) above as relevant to that stage as well as any other mitigation measures considered necessary to manage the potential effects generated by the buildings and works associated with that stage as considered relevant by the Responsible Authority.

8 **Mitigation Measures**

The mitigation measures that have been adopted in the air dispersion modelling and described in Section 8.2 of the *Ballarat Gold TSF4 Health Risk Assessment Technical Report* prepared by Tonkin + Taylor June 2023 must be implemented on-site at all times.

9 **Amenity**

The buildings and works must be managed so that the amenity of the area is not detrimentally affected, through the:

a. transport of materials, goods or commodities to or from the land;
b. appearance of any building, works or materials;
c. emission of noise, artificial light, vibration, smell, fumes, smoke, vapour, steam, soot, ash, dust, waste water, waste products, grit or oil;
d. presence of vermin or otherwise;

In the event of any nuisance being caused to the neighbourhood by activities related to the use and development the Responsible Authority may direct, in writing, such actions or works, as deemed appropriate, to eliminate or mitigate such nuisance be undertaken.

10 **The Head of Transport Ref: PPR 41151/22**

1. Prior to the occupation of the development hereby approved, the upgraded access to Whitehorse Road and associated roadworks must be constructed generally in accordance with the submitted Concept Plan (Revision B, dated July 2022 included in Traffic Impact Assessment Report dated 26 September 2022 prepared by Driscoll Engineering Services), to the satisfaction of and at no cost to the Head, Transport for Victoria.

2. Prior to the commencement of roadworks on Whitehorse Road, Functional Layout Plan(s), detailed design plan(s)s and associated technical plans and Road Safety Audit must be submitted to and approved by the Head, Transport for Victoria.

11 **Use of Access**

The access off Whitehorse Road hereby approved must only be utilised during the following times:

During construction:

- 7.00am to 6.00pm Monday to Friday

During operation:

- 24 hours a day Monday to Sunday except for heavy vehicles (in excess of 10 tonnes) which will be restricted to 7.00am to 6.00pm Monday to Friday.

unless with the prior written approval of the Responsible Authority

12 Native Vegetation Removal

No vegetation removal is to occur until the Work Plan (currently known as Work Plan Variation PLN-001406) is approved under the Mineral Resources (Sustainable Development) Act 1990 and authorised by a work authority under the Act.

13 Maintenance of Vegetation

Prior to the commencement of the building works hereby approved, a Vegetation Maintenance Plan (VMP) must be submitted to and approved in writing by the Responsible Authority. The VMP must be prepared for the area of the site to the south of TSF3 known as the 'works area' and include:

- Details of all vegetation to be retained;
- Details of additional planting as per Conditions 1 and 14 of this permit;
- Measures that will be put in place to protect vegetation and associated tree protection zones during both the construction and operational phases;
- A maintenance regime for all vegetation, including watering, inspections, management of pest species and replacement of planted dead vegetation; and
- Measures that will be taken to protect and preserve the visual barrier to the east and south of TSF4, including the timing of any required replacement plantings.

14 Revegetation plan

Notwithstanding the requirements of Condition 13 and unless with the written consent of the Responsible Authority, prior to the commencement of Stage 1 of the development hereby approved, a revegetation plan making use of all other practically available land around the perimeter of the Tailings Storage Facility must be submitted to and be approved in writing by the Responsible Authority. The objective of this plan is to provide as extensive as reasonably possible screening of the facility when viewed from outside the site.

The plan must include details of all species to be provided, including maximum heights at maturity and maintenance measures.

The planted vegetation subject to the approved revegetation plan must be maintained to the satisfaction of the Responsible Authority.

15 Amended HHRA

Prior to the commencement of the Tailings Storage Facility hereby approved, the applicant must submit to and have approved in writing by the Responsible Authority an amended Human Health Risk Assessment (HHRA). This HHRA must be generally in accordance with the HHRA submitted in support of the application prepared by Tonkin & Taylor entitled Ballarat Gold TSF4, Health Risk Assessment Technical Report (June 2023) but amended to include an updated methodology and quantitative data regarding the potential health risks associated with PM10, PM2.5 and metals to surrounding sensitive receptors.

Should upon receipt of this amended HHRA the Responsible Authority be of the view that an independent peer review is required all costs associated with this review will be met by the applicant.

Once endorsed, the amended HHRA will then form part of the permit. All agreed mitigation measures set out in the endorsed amended HHRA must be implemented to the satisfaction of the Responsible Authority prior to the first use of TSF4 and maintained in perpetuity to ensure ongoing compliance with the objectives and standards of the amended HHRA.

Where ongoing monitoring of mitigation measures is required in accordance with the endorsed amended HHRA, the applicant must submit to the Responsible Authority all monitoring data upon request. Should this monitoring data again require an independent peer review, the costs associated with this will be met by the applicant. Any required rectification works/actions to ensure mitigation measures remain effective must be implemented without delay to the satisfaction of the Responsible Authority and a statement confirming such rectification works/actions have been carried out submitted to the Responsible Authority. All costs associated with any required rectification works/actions must be met by the applicant.

16 **Permit Expiry**

This permit will expire if one of the following circumstances applies:

(a) The building and works hereby approved are not started within five years of the date of this permit;
(b) The building and works hereby approved are not completed within ten years of the date of this permit.

The responsible authority may extend the periods referred to if a request is made in writing before the permit expires or within six months afterwards (for a request to extend the time to commence the building and works) or twelve months after the permit expires (for a request to extend the time to complete the building and works).

Notes:

The Head of Transport Note

No work must be commenced in, on, under or over the road reserve without having first obtaining all necessary approval under the Road Management Act 2004. Please contact the Head, Transport for Victoria, Department of Transport about working within the road reserve prior to commencing any works.

Heritage Note

Under the terms of the Heritage Act 2017 there is blanket protection for all historical archaeological sites in Victoria, including sites that are not included in the Victorian Heritage Register or Heritage Inventory. Section 123 of the Act stipulates that it is an offence to knowingly or negligently disturb any historical archaeological site unless Consent has been obtained from the Executive Director, Heritage Victoria. Penalties apply.

If historical archaeological remains, including artefacts, are uncovered at any time during works, it is necessary for all activities to cease and for the City of Ballarat and Heritage

Victoria to be notified immediately. In this case, a program of archaeological investigations and recording may be required in consultation with Heritage Victoria.

Cultural Heritage

Should the discovery of Aboriginal cultural heritage be discovered during the course of the building and works, the discovery must be reported to First Peoples – State Relations. First Peoples – State Relations can be contacted on 1800 762 003.

ATTACHMENTS

1. Governance Review [**9.1.1** - 2 pages]
2. PL P 2022644 10 Woolshed Gully Mount Clear Human Health Impact Assessment (HHI A) [**9.1.2** - 46 pages]
3. PL P 2022644 10 Woolshed Gully Mount Clear Health Risk Assessment Technical Report (HR A) [**9.1.3** - 158 pages]
4. PL P 2022644 10 Woolshed Gully Drive Mount Clear Planning Report [**9.1.4** - 67 pages]
5. PL P 2022644 10 Woolshed Gully Drive Mount Clear Appendix J Air Quality Assessment [**9.1.5** - 53 pages]
6. PL P 2022644 10 Woolshed Gully Drive Mount Clear Appendix I Noise Assessment [**9.1.6** - 14 pages]
7. PL P 2022644 10 Woolshed Gully Drive Mount Clear Appendix G Visual Impact Assessment [**9.1.7** - 62 pages]
8. PL P 2022644 10 Woolshed Gully Drive Mount Clear Appendix B Workplan Variation [**9.1.8** - 199 pages]
9. PL P 2022644 10 Woolshed Gully Drive Mount Clear Appendix A Development Plans [**9.1.9** - 5 pages]

ALIGNMENT WITH COUNCIL VISION, COUNCIL PLAN, STRATEGIES AND POLICIES

1. This report aligns with Council's Vision, Council Plan, Strategies and Policies.

COMMUNITY IMPACT

2. As noted in the officer report, objectors have raised a number of health-related concerns. These concerns require careful consideration. The applicant's HHRA seeks to respond to these concerns and concludes that the impacts of particulates and metals as well as the impact of the proposal upon groundwaters will be negligible.

3. The requirement for Council's to consider mining applications is a complex and challenging one, generally outside the typical scope of expertise. Notwithstanding this and having considered the City of Ballarat's ambit of discretion in this case within the Ballarat Planning Scheme, it is considered that the matters which require planning approval represent an appropriate outcome.

CLIMATE EMERGENCY AND ENVIRONMENTAL SUSTAINABILITY IMPLICATIONS

4. This amendment does not raise any direct climate emergency issues or environmental sustainability implications.

ECONOMIC SUSTAINABILITY IMPLICATIONS

5. The tailings storage facility is required to allow the continued operation of Ballarat Gold Mine and without it may mean the site can no longer operate.

FINANCIAL IMPLICATIONS

6. If applicable, the cost of running a VCAT hearing is already included within the Statutory Planning Unit's approved budget.

LEGAL AND RISK CONSIDERATIONS

7. The Planning and Environment Act 1987 (the Act) sets out the framework for the use, development, and protection of land in Victoria in the present and long-term interests of all Victorians.

HUMAN RIGHTS CONSIDERATIONS

8. It is considered that the report does not impact on any human rights identified in the *Charter of Human Rights and Responsibilities Act 2006.*

COMMUNITY CONSULTATION AND ENGAGEMENT

9. A community information session hosted by Ballarat Gold Mine occurred on 19 June 2023.

GENDER EQUALITY ACT 2020

10. There are no gender equality implications identified for the subject of this report.

CONFLICTS OF INTEREST THAT HAVE ARISEN IN PREPARATION OF THE REPORT

11. Council officers affirm that no general or material conflicts need to be declared in relation to the matter of this report.

PROCUREMENT COLLABORATION

(For Contracts Only)

REPORT

Tonkin+Taylor

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Document control

Title: Human Health Risk Assessment TSF4 - Planning Permit Application					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
May 2023	1	Draft	[redacted]	[redacted]	[redacted]
May 2023	2	Final	[redacted]		[redacted]

Distribution:

[redacted]	1 electronic copy
[redacted]	1 electronic copy
[redacted]	1 electronic copy
[redacted]	1 electronic copy

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Executive summary

Tonkin & Taylor Pty Ltd (T+T) has been engaged by [redacted] (in Administration) [redacted] to undertake a Human Health Risk Assessment (HRA) for the construction and operation of the Tailings Storage Facility (TSF4) at the Ballarat Gold Mine. The HRA was requested by Ballarat City Council to address concerns raised by the community through the public consultation phase of the Planning Permit Application for the TSF4.

The HRA has focussed on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollution, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust. This report describes both the short-term and long-term health effects associated with these pollutants.

The HRA assesses the potential risk from PM_{10} and $PM_{2.5}$, metals in the dust and Respirable Crystalline Silica (RCS). All risks are very low and below acceptable risk levels. In many cases, such as the metals and RCS, the potential risks are below negligible risk levels established by enHealth, WHO and the US EPA.

The HRA shows that if the mitigation measures that have been adopted in the air dispersion modelling and described in Section 8.2 are implemented at the site, the TSF4 can be constructed and operated without posing an unacceptable risk to the health of the local community.

1 Introduction

Tonkin & Taylor Pty Ltd (T+T) has been engaged by [redacted] (in Administration) [redacted] to undertake a Human Health Risk Assessment (HRA) for the construction and operation of the Tailings Storage Facility (TSF4) at the Ballarat Gold Mine. The HRA was requested by Ballarat City Council to address concerns raised by the community through the public consultation phase of the Planning Permit Application for the TSF4.

The HRA focusses on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollution, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust. This report describes both the short-term and long-term health effects associated with these pollutants.

This work has been carried out in accordance with our proposal dated 21 April 2023.

2 Scope of work

The HRA has considered the incremental risk from the construction and operation of TSF4 from changes in air quality (PM_{10}, $PM_{2.5}$, Respirable Crystalline Silica (RCS), metals) and potential risk to human health through inhalation, and deposition to water tanks (metals). The HRA has been conducted in accordance with the relevant national and international guidelines as well as the relevant guidance from EPA Victoria. These include enHealth Guidelines for Assessing Human Health Risks from Environmental Hazards (2012) and EPA Victoria Guideline for the Assessment and Management of Air Pollution in Victoria (2022). Reference is also made to World Health Organization and US Environmental Protection Agency acceptable risk levels for cancer causing substances.

The issues identification stage is important to identify the key issues of importance to stakeholders including the local community. These issues have largely been identified in the objections received to date with the Planning Application.

The hazard identification stage includes a review of the current understanding of the health effects associated with the pollutants of concern that will be used as the basis of the health risk assessment. At this stage it is assumed that the key pollutants to be considered include PM_{10}, $PM_{2.5}$, respirable crystalline silica (RCS) and metals, in particular arsenic from the tailings through discharge to air and deposition into rainwater tanks.

The exposure assessment phase provides an assessment of the sensitivity of the potentially exposed populations. This assessment includes the residential population of the suburbs surrounding the proposed TSF4 location. This includes population and socioeconomic information obtained from the Australian Bureau of Statistics (ABS) as well as baseline health data obtained from the Victorian Department of Health.

The exposure assessment considers all exposure pathways which may include direct inhalation exposures as well as deposition of dust and potential impacts on the quality of water in rainwater tanks.

The risk characterisation stage calculates an estimate of the incremental risk from the emissions from the construction and operation of the proposed TSF4 within the potentially exposed populations. The risk characterisation combines the information from the previous stages in the HHRA to provide an estimate of the number of people that may be affected by emissions from the construction and operation of the TSF4.

During the review of the objections to the Planning Application, concerns were raised about the potential leakage from the tailings dam on groundwater and eventually the Yarrowee River and users of the river. To address these concerns, a review of potential exposure pathways through groundwater and subsequently any impacts on the Yarrowee River has been undertaken. To inform this a review of the groundwater assessment previously undertaken as part of the Planning process has been undertaken.

3 Methodology

A HRA aims to quantify the potential health effects arising from exposure to, in this case, air pollution. Conservative safety margins are built into a risk assessment analysis to ensure protection of public health. Consideration of the most vulnerable subgroups within the population is part of the risk characterisation process.

For air quality risk assessments, the key health effects that are considered include increases in mortality and morbidity (e.g., hospital admissions for respiratory disease) which have been associated with exposure to air pollution in population-based epidemiological studies.

The Australian guidance for conducting HRAs is set out in the enHealth Guidelines for Assessing Human Health Risks from Environmental Hazards (2012). This HRA was undertaken in accordance with the enHealth Guidelines which comprises five components as outlined below:

a **Issue Identification** – Identifies issues that can be assessed through a risk assessment and assists in establishing a context for the risk assessment;

b **Hazard Assessment** – Identifies hazards and health endpoints associated with exposure to hazardous agents and provides a review of the current understanding of the toxicity and risk relationship of the exposure of humans to the hazards;

c **Exposure Assessment** – Identifies the groups of people who may be exposed to hazardous agents and quantifies the exposure concentrations;

d **Risk Characterisation** – Provides the quantitative or qualitative evaluation of potential risks to human health. The characterisation of risk is based on the concentration response relationship and the assessment of the magnitude of exposure; and

e **Uncertainty Assessment** – Identifies potential sources of uncertainty and qualitative discussion of the magnitude of uncertainty and expected effects on risk estimates.

The enHealth (2012) guideline has been applied to assess the potential risks to the health of the local community from air quality arising from the proposed construction and operation of the proposed TSF4.

For air pollution, in addition to the enHealth Guideline, EPA Guideline for Assessing and Minimising Air Pollution in Victoria (the EPA Guideline) (EPA, 2022) provides technical guidance and a framework for assessing and controlling risks associated with air pollution. The Guideline also includes guidance on how to conduct risk assessments for air quality in Victoria. These guidelines have also been considered in conducting the HRA for the proposed TSF4.

The EPA Guideline (EPA, 2022) provides advice on conducting risk assessments for air quality. The approaches recommended by EPA differ depending on the type of pollutant. For air toxics and other non-criteria pollutants, the use of hazard indices for threshold pollutants and incremental lifetime cancer risk (ILCR) estimates is recommended, consistent with enHealth (2012).

Air dispersion modelling was undertaken to provide data for the HRA. This modelling assumed a number of mitigation measures agreed with Balmaine Gold to minimize any off-site impacts and associated health risks. It is anticipated that these measures will be included in the Planning Permit for the TSF4. The risks assessed in this HRA are the residual risks post application of these mitigation measures. The mitigation measures are described in Section 8.2.

4 Population health profile

To establish the baseline characteristics relevant to the HRA, baseline population data and health profiles have been determined for the area surrounding the mine and the proposed area for the TSF4. This information enables identification of any underlying issues in the local community that may make them susceptible to changes in air pollution arising from the construction and operation of the TSF4.

The baseline health status and demographics of the potentially exposed community is important to understand as it can impact on the sensitivity of the population to the adverse effects of air pollution. People in older age groups (>65 years of age), with existing diseases such as respiratory and cardiovascular disease, people with asthma, children (<15 years) and people in low socioeconomic groups all fall into groups that are more sensitive to the effects of environmental pollution.

The study area potentially affected by changes in air quality from the construction and operation of the TSF4 include Mount Clear, Mount Pleasant, Canadian, Mount Helen and Sebastapol which are suburbs of the city of Ballarat. Baseline population data has been obtained from the Australian Bureau of Statistics' (ABS) Census of Population and Housing (2021) for Mount Clear-Mount Helen, Sebastapol-Redan, Mount Pleasant and Ballarat. This data has been compared with the data for Melbourne and Victoria as a whole.

4.1 Population profile

4.1.1 Age profile

The most recently published census data from the ABS in 2021 for the areas being assessed in this HHRA are summarised in **Table 4.1.** Data for Melbourne and Victoria are included for comparison purposes.

Table 4.1: Age profile of Mount Clear, Sebastopol, City of Ballarat, Melbourne and Victoria

	Mt. Clear	Sebastopol	Ballarat	Melbourne	Victoria
Total population (persons)	3,671	10,194	113,763	4,917,750	6,503,491
Females (%)	52	53	52	51	51
Males (%)	48	47	48	49	49
Age groups					
0 -14 (%)	20	18	19	18	18
15 – 64 (%)	61	61	62	67	65
≥ 65 (%)	19	21	19	15	17
Median age (years)	37	39	39	37	38

Note: Source ABS 2021 Census

As can be seen from **Table 4.1** the age profile of Mt. Clear and Sebastopol is very similar to that of Ballarat, Melbourne and Victoria as a whole. There is a slightly higher percentage of people >65 years of age in Mt. Clear, Sebastopol and Ballarat compared to Melbourne and Victoria. People greater than 65 years of age are known to be more vulnerable to the effects of air pollution.

4.1.2 Health profile

The baseline health statistics for the study area, which includes the suburbs adjacent to the mine, have been obtained from ABS 2021 Census data. **Table 4.2** and **Table 4.3** summarise the health indicators (prevalence of certain health conditions) and socio-economic factors for the study area, Melbourne and Victoria. The health indicators shown in **Table 4.2** are those that have been identified in population-based studies to be impacted by exposure to air pollution.

Table 4.2: Health indicators Study Area, Melbourne and Victoria

Health Indicator	Mount Clear – Mount Helen	Sebastopol - Redan	Canadian – Mount Pleasant – Golden Gully	City of Ballarat	Melbourne	Victoria
Asthma	10.2%	14%	12.7%	11.4%	7.9%	8.3%
Cancer (including remissions)	3.4%	4%	3%	3.4%	2.5%	2.8%
Diabetes	4.2%	7.2%	5.3%	5.2%	4.5%	4.7%
Heart Disease	4.1%	6%	3.8%	4.7%	3.3%	3.7%
Lung Conditions	1.8%	4.1%	2.4%	2.4%	1.2%	1.5%
Stroke	0.7%	1.7%	1.1%	1.2%	0.8%	0.9%

Note: ABS 2021 Census

The data in **Table 4.2** show that the prevalence of health conditions impacted by air pollution are lower in Mount Clear – Mount Helen than in the surrounding suburbs and the City of Ballarat. The prevalence is slightly higher for Sebastopol – Redan and Canadian – Mount Pleasant – Golden Gully compared to Ballarat. All areas in the study area have higher prevalence of disease than Melbourne and Victoria. This data suggests that the population in the study area and Ballarat more broadly may be more sensitive to the effects of air pollution.

Table 4.3 summarises the socioeconomic status (SES) of the suburbs within the study area, Ballarat, Regional Victoria and Victoria as a whole. Low SES is a known risk factor that can make the exposed population more vulnerable to the effects of air pollution. This is largely due to the fact that people within these groups usually have poorer health status than people within higher SES areas. They may also have poorer access to medical care. In addition, they usually live in areas that are more polluted (e.g., near major roads or near industry).

There are several indices of social deprivation used to assess SES in Australia. One commonly used are the Socio-Economic Indexes for Areas (SEIFA) index. The SEIFA index is a measure of relative social disadvantage and takes into account 20 variables to assess relative social disadvantage. The lower the SEIFA index the greater the level of disadvantage. The index is relative to a score of 1000 which is considered as the Australian average.

The SEIFA Index of Relative Socio-Economic Advantage/Disadvantage is derived from attributes such as low income, low educational attainment, high unemployment, jobs in relatively unskilled occupations and variables that broadly reflect disadvantage rather than measuring specific aspects of disadvantage (e.g. Indigenous and separated/divorced). At the advantage end of the scale, households with high incomes, high education levels, large dwellings, high numbers of motor vehicles, spare bedrooms and professional occupations contribute to a higher score.

Table 4.3: Socio-Economic Factors – Study Area, Ballarat, Regional Victoria and Victoria

Socioeconomic Indicators	Mount Clear – Mount Helen	Sebastopol - Redan	Mt Pleasant - Canadian - Golden Point	City of Ballarat	Regional Victoria	Victoria
Unemployment rate in June 2021	5.5%	6.5%	6.1%	4.7%	4.1%	5%
SEIFA Index of Relative Socio-economic Disadvantage (based on Australian average score = 1000) in 2021	1023	882	974.8	985.7	985	1010
Percentage of low income households in 2021	25.5%	25.5%	25.5%	26.7%	26.7%	21%
People who left school at year 10 or below.	14.1%	20.5%	15.3%	16.5%	18.3%	12.3%

The key indicator in **Table 4.3** is the SEIFA index which is the relative indicator of socioeconomic advantage/disadvantage. The SEIFA index for Mount Clear – Mount Helen is higher than the SEIFA index for the other areas including Ballarat and Victoria as a whole. This shows that Mount Clear – Mount Helen is less disadvantaged that the other locations. Sebastopol – Redan has a lower SEIFA index indicating a higher level of disadvantage than other areas shown in **Table 4.3**. The data in **Table 4.3** shows that, based on socioeconomic status, Mount Clear – Mount Helen may be less vulnerable to the effects of air pollution compared to Ballarat, Regional Victoria and Victoria as a whole while Sebastopol – Redan may be more vulnerable.

5 Conceptual site model

A conceptual site model (CSM) has been prepared for the site **(Figure 5. 1)** A CSM shows all the potential exposure pathways between the source (the TSF4) and sensitive receptors. This doesn't necessarily mean that there is a risk posed but that there is the potential for exposure. The risk is dependent on whether the source-receptor pathway is complete or not and the concentration of the pollutant that may occur at sensitive receptors.

The CSM identifies the main potential exposure pathways as follows:

- Direct inhalation of dust, including PM_{10}, $PM_{2.5}$ and metals, from the construction and operation of the TSF4.
- Potential infiltration of leachate into groundwater that may impact on the Yarrowee River.
- Deposition of dust contaning metals and run-off into rainwater tanks.

These exposure pathways have been assessed in this HRA.

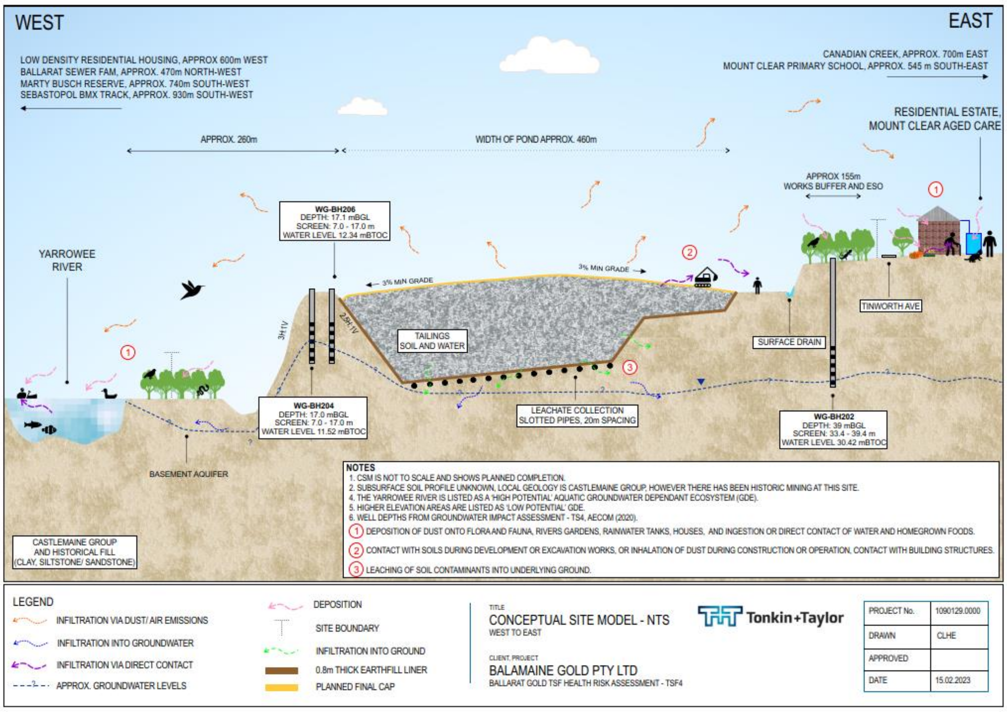

Figure 5. 1: Conceptual Site Model for Construction and Operation of the Ballarat Gold TSF4

6 Sensitive Receptors

A large number of sensitive receptors, 118 in total, have been assessed in this HRA. The location of the sensitive receptors is shown in **Figure 6. 1**. The sensitive receptors include residential areas, aged care facilities, schools and kindergartens, childcare centres, and recreational areas. In regard to residential activities, the assessment has focused on the most impacted locations in the neighbouring suburbs. It is not practical, or necessary, to consider the effects at all houses in the neighbouring suburbs as the effects will be less than at the most-impacted locations.

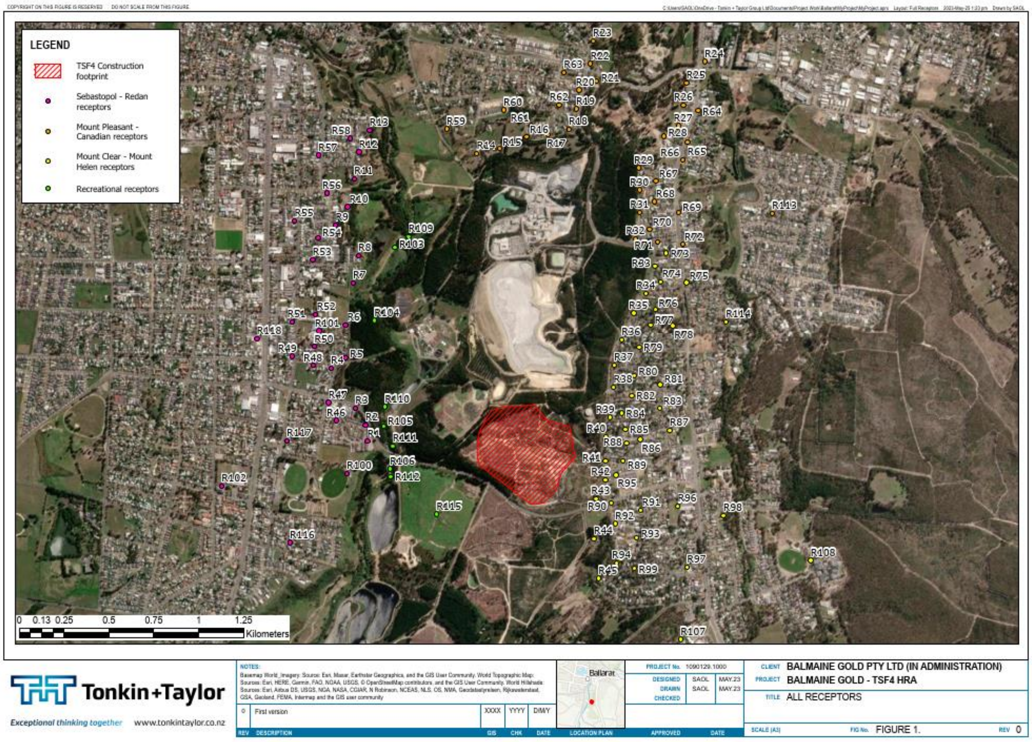

Figure 6. 1 Locations of Sensitive Receptors Assessed in the HRA

[redacted]

Table 6. 1 shows all receptors considered in this HRA.

Although the calculations presented in the following sections have focussed on the most impacted receptors in each area considered, risks to all the identified receptors in Table 6. 1 have been assessed. The focus on the most impacted receptor represents the worst case risk with all other risks being lower.

Table 6. 1: Locations and types of Sensitive Receptors used in the HRA

Receptor Number	Address	Type
1	[redacted]	Residential
2		Residential
3		Residential
4		Residential
5		Residential
6		Residential
7		Residential
8		Residential
9		Residential
10		Commercial
11		Residential
12		Residential
13		Residential
14		Residential
15		Residential
16		Residential
17		Residential
18		Residential
19		Residential
20		Residential
21		Residential
22		Residential
23		Residential
24		Hotel
25		Residential
26		Residential
27		Residential
28		Residential
29		Residential
30		Residential
31		Residential
32		Residential
33		Residential
34		Residential
35		Residential
36		Residential

Receptor Number	Address	Type
37	[redacted]	Residential
38		Residential
39		Residential
40		Residential
41		Residential
42		Residential
43		Residential
44		Residential
45		Residential
46		Residential
47		Residential
48		Residential
49		Residential
50		Residential
51		Residential
52		Residential
53		Residential
54		Residential
55		Residential
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59		Residential
60		Residential
61		Residential
62		Residential
63		Residential
64		Residential
65		Residential
66		Residential
67		Residential
68		Residential
69		Residential
70		Residential
71		Residential
72		Residential
73		Residential
74		Residential
75		Residential
76		Residential
77		Residential
78		Residential
79		Residential

Receptor Number	Address	Type
80	[redacted]	Residential
81		Residential
82		Residential
83		Residential
84		Residential
85		Residential
86		Residential
87		Residential
88		Residential
89		Residential
90		Residential
91		Residential
92		Residential
93		Residential
94		Residential
95		Residential/Aged Care Facility
96		School
97		Early education centre
98		Playground
99		Playground
100		Playground
101		School
102		Early education centre
103		Walking track
104		Walking track
105		Walking track
106		Walking track
107		School
108		School
109		River
110		River
111		River
112		River
113		Residential
114		Residential
115		Walking track
116		Residential
117		Residential
118		Residential

7 Issues identification

The key issues raised by submitters to the Planning Permit Application public consultation have been addressed in the HRA. The main issues raised with respect to health include:

- Potential health effects from dust including PM_{10}, $PM_{2.5}$ and metals (in particular arsenic);
- Proximity to sensitive receptors such as the aged care facilities, schools and childcare facilities;
- Proximity to residential receptors – proposed TSF4 too close;
- Potential health effects on sensitive populations such as children and people over 65 years of age;
- Potential impact on the users of the Yarrowee River through leakage or seepage from the tailings dam or through windblown dust;
- Potential contamination of drinking water with arsenic; and
- Impacts on people with pre-existing health conditions such as lung disease and cancer.

These issues have been addressed in the following section of the HRA:

- Health Effects of PM_{10} and $PM_{2.5}$ – Section 8.
- Health effects of metals – Section 9.
- Health effects of respirable crystalline silica – Section 10.
- Impacts on groundwater and the Yarrowee River – Section 11.

8 Health Risk Assessment – PM_{10} and $PM_{2.5}$

8.1 Hazard Assessment

The health effects of particles linked to ambient exposures have been well studied and reviewed by international agencies (NEPC, 2010; USEPA, 2004, 2009, 2012, 2019; WHO, 2021, 2013, 2006; OEHHA, 2000). Most information comes from population-based epidemiological studies that find increases in daily mortality, as well as increases in hospital admissions and emergency room attendances, and exacerbation of asthma associated with daily changes in ambient particle levels. In recent years, there has been an increasing focus on the association between exposure to particles and cardiovascular outcomes. In addition to studies on the various size metrics for particles, research has also investigated the role of particle composition in the observed health effects.

Several studies conducted in Australia show adverse effects of both PM_{10} and $PM_{2.5}$ on mortality and morbidity outcomes (e.g. Simpson et al., 2005a, b; Barnett et al., 2005, 2006) similar to those observed in overseas studies. The effects observed in the Australian studies appear to be greater per 1 $\mu g/m^3$ increase in PM than those observed in the US and Europe but are comparable to the results of Canadian studies.

A review conducted by the World Health Organization (WHO, 2013) concluded that both PM_{10} and $PM_{2.5}$ are related to increases in mortality from respiratory and cardiovascular causes, hospital admissions and emergency department attendances for respiratory and cardiovascular causes including asthma, exacerbation of asthma, and increases in respiratory symptoms. In recent years, studies have provided much stronger evidence for the cardiovascular effects of particles, in particular $PM_{2.5}$.

Birth cohort studies from Europe and elsewhere have found associations between $PM_{2.5}$ and respiratory infections and asthma in young children. Reduced lung function is also linked to $PM_{2.5}$ exposure. Associations with birth outcomes such as low-birth-weight, preterm birth and small gestation age at birth have also been found with long-term exposure to $PM_{2.5}$. These outcomes may affect a child's development later in life. The USEPA (2012) also identified several recent studies that showed associations between long-term exposure to $PM_{2.5}$ and respiratory morbidity including hospital admissions and respiratory symptoms as well as the incidence of asthma. Studies of reproductive and developmental effects also provided evidence for long-term exposure to $PM_{2.5}$ and reduced birth weight.

With respect to short-term effects, the USEPA (2012) found that there were important new studies that increase the evidence for an association between $PM_{2.5}$ and mortality and morbidity outcomes and strengthen the previous US EPA conclusion that there is a causal association between short-term exposure to $PM_{2.5}$ and these outcomes. Associations were found for hospital admissions and emergency department attendances for all cardiovascular and respiratory causes as well as cause specific outcomes, in particular asthma.

The Australian Child Health and Air Pollution Study (ACHAPS), which used a similar study design as that used in the Southern Californian Children's Health Study, was conducted to inform the review of the particle standards in the Ambient Air Quality NEPM (Standing Council on Environment and Water (SCEW, 2011). The results of a cross-sectional study of approximately 4,000 Australian school children aged 7-11 years showed varied results for the particulate matter exposures used in ACHAPS. PM_{10} was associated with a decline in lung function (Forced Expiratory Volume in 1 second - FEV_1) post-bronchodilator use and increase in exhaled NO (nitrous oxide, an indicator of airway inflammation), but no overall increase in current respiratory symptoms. $PM_{2.5}$ was associated with an adverse effect on lung function (measured as Forced Vital Capacity (FVC)), post-bronchodilator use and on exhaled NO, with no overall effects on current symptoms, but showed increased risk of lifetime wheezing, asthma, and asthma medication use, and current asthma, use of asthma inhalers and itchy rash in non-atopic children.

8.2 Exposure assessment

Air dispersion modelling was undertaken by T+T to provide inputs to the HRA. Modelling has been completed using the AERMOD dispersion model which is the regulatory dispersion model for use in Victoria. Emissions have been estimated using a combination of the emission factors contained in the National Pollutant Inventory (NPI) and the equivalent industry reporting materials from the US EPA (known as AP-42) where these provided more recent emission factors. Meteorological modelling has been completed for the site to provide a representative meteorological dataset.

Construction of the Tailings Facility 4 (TSF4) is proposed to occur over six stages. The first stage, known as Zone 1, will comprise 25% of the total storage capacity of TSF4. The remaining stages, known as Zones 2 to 6 will comprise 15% each of the total storage capacity of TSF4.

The modelling was completed for three scenarios:

- Construction of Zone 1 of TSF4 – this is the period of the largest earth movement activity;
- Construction of Zone 6 of TSF4 – this is the period when earth moving activities are closest to residential receptors; and
- Operation of TSF4 – this is a period of minimal emissions from TSF4 but includes ongoing operations of the site.

The modelling for each of the scenarios above include the contribution from the existing operations at the mine. The modelling is for the incremental change from the construction and operation of the TSF4 and well as the contribution from the existing operation. It does not include regional background air quality data.

Table 8. 1 shows the processes that have been considered in the modelling of the scenarios.

Table 8. 1: Processes considered in the modelling of each Scenario

Process	Zone 1 Construction	Zone 6 Construction	TSF4 Operation
North Prince Ventilation Shaft	✓	✓	✓
Diesel Generators 1 - may be used at the commencement of TSF4 operations	✗	✓	✓
Ore handling and processing	✓	✓	✓
Dry stacking of TSF3 whilst Zone 1 of TSF4 is constructed to allow ongoing operations	✓	✗	✗
Extraction, movement and placement of waste rock from current rehab area to embankment	✓	✗	✗
Movement and placement of waste rock from underground to embankment	✗	✓	✗
Extraction, movement and placement of soils from TSF4 excavation area to embankment	✓	✓	✗
Extraction and movement of soils from TSF4 to off-site which cannot be reused within the embankment	✓	✓	✗
Concrete batching plant activities	✓	✓	✓

The following mitigation measures have been adopted in the modelling in accordance with reducing the emissions so far as reasonably practicable as required to meet the General Environmental Duty (GED) to minimise the risk of harm to human health and the environment:

- Watering of all areas where material is handled including:
    - Waste rock stockpiles;
    - Transfer of rock to primary crusher
    - Extraction and placement of TSF3 material on dry stack;
    - Disturbed area of dry stack until crust forms;
    - Extraction and placement of waste rock and soil material;
    - Disturbed areas of waste rock and soil removal, placement until a crust has formed.
- All crushers fully enclosed.
- Sprinklers within ore conveying system.
- Baghouse used within concrete batching.
- Sprinklers used when receiving material for concrete batching.
- Chemical sealants on haul roads with additional watering

In addition, waste rock movements will be limited. Only rock required to construct the TSF4 will be brought to the surface of the mine and this will be transported directly to the TSF4 location. The waste rock will be wet (3-5% moisture) and transported directly from underground to the TSF4 area.

Figure 8. 1 shows the 24-hour PM_{10} concentrations for the most affected receptor for all 3 scenarios. In conducting the air dispersion modelling a year of meteorological data had to be selected. A review of the BOM meteorological data for Ballarat, including rainfall, showed that 2018 was the year with the lowest rainfall. This means that there is a higher risk of dust generation due to lower rainfall and therefore will lead to worst case emission estimates. The air dispersion modelling takes

into account the emissions from all sources on site through the construction and operation of the TSF4, the mitigation measures (described above) and the meteorological data to predict daily and annual changes in PM_{10} and $PM_{2.5}$ at every sensitive receptor listed in **Table 6. 1**. **Figure 8. 1** shows the data for the receptor that is predicted to have the highest PM_{10} levels during the construction and operation of the TSF4.

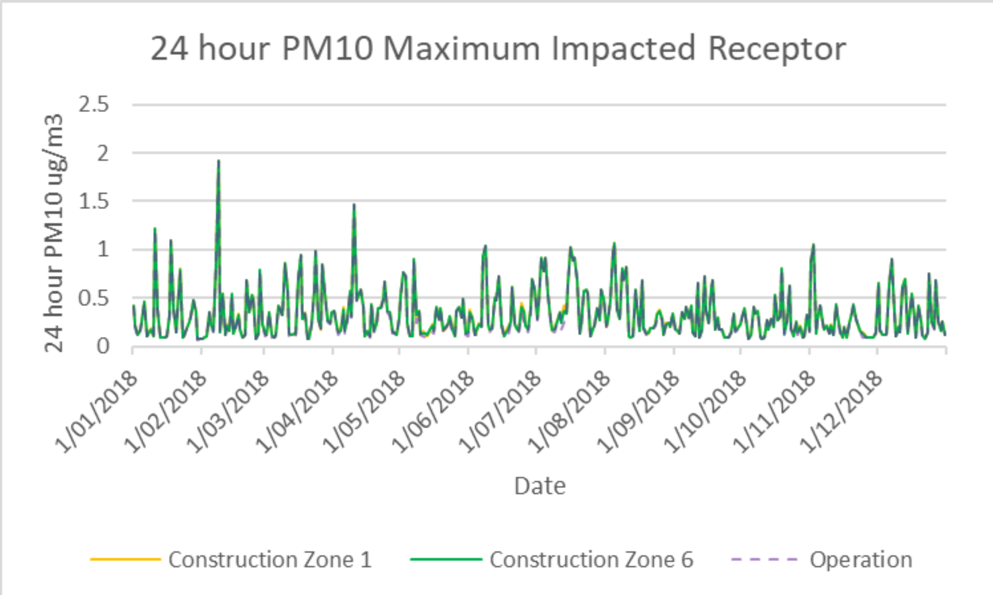

Figure 8. 1: 24-hour PM_{10} concentrations most affected receptor

The Environment Reference Standard (ERS) for PM_{10} is 50 µg/m^3. As can be seen from **Figure 8. 1** the 24 hour PM_{10} concentrations are small compared to the ERS, even at the most impacted receptor. According to the EPA Guideline for the Assessment and Management of Air Pollution in Victoria (GAMAPV, 2022), an incremental increase in PM levels of less than 4% of the air quality standard is considered to be a negligible risk and no further assessment is required. The maximum predicted 24 hour PM_{10} concentration at the most affected receptor is 4% of the ERS. For all other receptors the predicted PM_{10} concentrations are less than 4% and would be considered by EPA to be negligible.

The data for the most affected receptors have been used in this HRA, for both PM_{10} and $PM_{2.5}$.

8.3 Risk characterization

The health risk calculations have been undertaken to assess the potential increases in mortality, hospital admissions and emergency department visits. Local population data was used to calculate the number of attributable health outcomes due to the incremental increase in PM_{10} and $PM_{2.5}$ for each scenario.

As described in Section 8.1, epidemiological studies have shown that a wide range of health effects are associated with exposure to PM. Australian studies (NEPC, 2012; EPHC 2006) have found associations between $PM_{2.5}$ and PM_{10} levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality;
- increases in hospital admissions for respiratory disease and cardiovascular disease; and
- increases in emergency room attendances for asthma.

These health outcomes have been assessed in this health risk assessment for the relevant age groups.

Although no studies specifically investigating the long term effects of exposure to PM on health have been conducted in Australia, there have been several international studies that have shown strong associations between long-term exposure to PM_{10} and $PM_{2.5}$ and increases in mortality. On the basis of the findings of these studies, long-term mortality has also been assessed.

There are several groups within the general population that have been identified as being more vulnerable to the effects of air pollution. These include:

- the elderly;
- people with existing cardiovascular and respiratory disease;
- people with asthma;
- low socio-economic groups; and
- children.

Compared to healthy adults, children are generally more sensitive to air pollutants as their exposure is generally higher. The reasons for this are that children inhale more air per minute and have a larger contact lung surface area relative to their size compared to adults. Other factors that increase the potential for exposure in children are that children generally spend more time outdoors and more time exercising.

Studies have shown that people who have a low socioeconomic status (SES) also form a group within the population that is particularly vulnerable to the effects of air pollution.

To calculate the number of people that might be affected by air pollution, exposure-response functions for each outcome being assessed are required. These functions are a measure of the change in the health outcome within the population for a given change in PM_{10} or $PM_{2.5}$ concentration for example a 1% increase per 10 $\mu g/m^3$ increase in pollutant concentration.

The exposure-response functions in **Table 8. 2** and **Table 8. 3** have been taken from Australian studies and in particular two multicity meta-analyses (Simpson et al., 2005; EPHC, 2011). The use of Australian meta-analyses is consistent with the NHMRC (2006) and NEPC (2011) recommendations for selecting exposure-response functions.

The exposure-response functions for long-term exposure to PM_{10} and $PM_{2.5}$ have been taken from the American Cancer Society study (HEI, 2009). This study is considered by the WHO as the most reliable study to assess long-term effects of air pollution. The use of these values is also consistent with the recommendations made by NHMRC (2006) and NEPC (2011).

Table 8. 2 Exposure response functions for PM_{10} for selected health outcomes

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in PM_{10}
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.004
Daily all-cause mortality(non-accidental) all ages	24 hours	0.002
Daily mortality cardiovascular disease all ages	24 hours	0.002
Hospital Admissions respiratory disease 65+ years	24 hours	0.003
Hospital Admissions cardiac disease 65+ years	24 hours	0.002
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.0013
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits asthma 1-14 years	24 hours	0.015

Source: EPHC (2011) and HEI (2009)

Table 8. 3 shows the exposure response functions used for $PM_{2.5}$.

Table 8. 3 Exposure response functions for $PM_{2.5}$ for selected health outcomes

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in $PM_{2.5}$
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.006
Annual cardiopulmonary mortality 30+	Annual average	0.014
Annual mortality ischemic heart disease 30+ years	Annual average	0.024
Annual mortality lung cancer 30+ years	Annual average	0.014
Daily all-cause mortality (non-accidental) all ages	24 hours	0.0023
Daily mortality cardiovascular disease - all ages	24 hours	0.0013
Hospital Admissions respiratory disease 65+ years	24 hours	0.004
Hospital Admissions cardiac disease 65+ years	24 hours	0.005
Hospital Admissions cardiovascular disease 65+ years	24 hours	0.003
Hospital Admissions ischemic heart disease 65+ years	24 hours	0.004
Hospital Admissions COPD 65+ years	24 hours	0.004
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.005
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits asthma 1-14 years	24 hours	0.0015

Source: EPHC (2011) and HEI (2009)

Using the predicted annual average and 24-hour average PM_{10} and $PM_{2.5}$ concentrations for the most affected receptors, the population in each of these locations for the each of the suburban areas assessed (Mount Pleasant- Canadian, Mount Clear – Mount Helen, Sebastopol-Redan) and the exposure response function in **Table 8. 2** and **Table 8. 3**, the health effects attributable to PM_{10} and $PM_{2.5}$ been calculated using the following equation:

Number of attributable cases = exposure response function (Change in health outcome) per 1µg/m³ increase in PM x PM concentration x baseline health incidence rate/ 100,000 population x actual population

The annual average concentrations have been used to calculate the long-term health risks. The daily concentrations predicted for each day of the year have been used to calculate the short-term health risks.

In this assessment it is assumed that the data for the maximum impacted receptor point is representative of the whole population of each of the suburbs that have been assessed. This is a conservative assumption that will provide an overestimate of the risk to the whole population as the PM levels decrease with distance from the mine site.

For each scenario the number of attributable cases is shown **Table 8. 4** (PM_{10}) and **Table 8. 5** ($PM_{2.5}$). The number of attributable cases is the increase in the number, for example hospital admissions for respiratory disease that may arise from exposure to PM specifically from the construction and operation of the TSF4.

Table 8. 4: Attributable Health Outcomes (additional cases per year) due to PM_{10} from the Construction and Operation of TSF4

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian			
All-cause mortality 30+years (long-term)	0.06	0.06	0.06
Daily mortality all causes all ages	0.03	0.03	0.03
Daily mortality cardiovascular disease all ages	0.009	0.009	0.009
Hospital admissions respiratory disease 65+ years	0.07	0.07	0.07
Hospital admissions cardiac disease 65+ years	0.06	0.06	0.06
Hospital admissions respiratory disease 15-64 years	0.05	0.05	0.05
Emergency Department visits asthma 1-14 years	0.007	0.007	0.007
Mount Clear – Mount Helen			
All-cause mortality 30+years (long-term)	0.03	0.03	0.02
Daily mortality all causes all ages	0.01	0.02	0.009
Daily mortality cardiovascular disease all ages	0.004	0.005	0.003

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Hospital admissions respiratory disease 65+ years	0.03	0.04	0.02
Hospital admissions cardiac disease 65+ years	0.03	0.03	0.02
Hospital admissions respiratory disease 15-64 years	0.02	0.03	0.01
Emergency Department visits asthma 1-14 years	0.004	0.005	0.003
Sebastopol - Redan			
All-cause mortality 30+years (long-term)	0.02	0.01	0.01
Daily mortality all causes all ages	0.008	0.007	0.006
Daily mortality cardiovascular disease all ages	0.002	0.002	0.002
Hospital admissions respiratory disease 65+ years	0.02	0.02	0.02
Hospital admissions cardiac disease 65+ years	0.02	0.02	0.01
Hospital admissions respiratory disease 15-64 years	0.01	0.01	0.009
Emergency Department visits asthma 1-14 years	0.002	0.001	0.001

As can be seen in **Table 8. 4**, the predicted number of attributable cases due to PM_{10} from construction and operation of the TSF4 for all areas assessed is low. The highest risk would be for hospital admissions for respiratory disease in people over 65 years of age in the Mount-Pleasant-Canadian area, with 6 additional admissions per 100 years attributable to PM_{10} from the construction and operation of the TSF4. The risks in all other areas and for all other health outcomes are lower than that predicted for hospital admissions for respiratory disease in people 65 years and older.

The highest risk predicted for emergency department attendances for children with asthma is low for all areas with an additional 2-7 attendances per 1000 years predicted across all areas.

It should be noted that the construction of each Zone of the TSF4 will be undertaken over a period of 10 to 12 months and the life of the TSF4 is 10 years. These timelines are shorter than those over which adverse health effects would be observed and as indicated by the results presented in **Table 8. 4** the risks to the local population from PM_{10} from the proposed construction and operation of the TSF4 are very low and would not be detected in the population.

As can be seen from **Table 8. 5**, similar to PM_{10}, the predicted number of attributable cases due to $PM_{2.5}$ from the construction and operation of the TSF4 are low for all areas assessed. The highest risk would be for hospital admissions for pneumonia and bronchitis in people over 65 years of age with 7 additional admissions per 100 years attributable to $PM_{2.5}$ from the construction and operation of the TSF4. The risks for all other health outcomes for all areas assessed are lower than that predicted for hospital admissions for pneumonia and bronchitis in people 65 years and older.

As shown in **Table 8. 5**, the risks to the local populations from $PM_{2.5}$ from the proposed construction and operation of the TSF4 are very low and would not be detected in the population.

Table 8. 5: Attributable Health Outcomes (additional cases per year) due to $PM_{2.5}$ from the Construction and Operation of TSF4

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian			
All-cause mortality 30+years (long-term)	0.04	0.04	0.04
Cardiopulmonary mortality 30+years (long-term)	0.04	0.04	0.04
Ischemic Heart Disease 30+ years (long-term)	0.03	0.03	0.03
Lung cancer mortality 30+ years (long-term)	0.006	0.006	0.006
Daily mortality all causes all ages	0.02	0.02	0.02
Daily mortality cardiovascular disease all ages	0.003	0.003	0.003
Hospital admissions respiratory disease 65+ years	0.04	0.04	0.04
Hospital admissions cardiac disease 65+ years	0.06	0.06	0.06
Hospital admissions pneumonia and bronchitis 65+ years	0.07	0.07	0.07
Hospital admissions cardiovascular disease 65+ years	0.01	0.01	0.01
Hospital admissions respiratory disease 15-64 years	0.02	0.02	0.02
Emergency Department visits asthma 1-14 years	0.003	0.003	0.003
Mount Clear – Mount Helen			
All-cause mortality 30+years (long-term)	0.02	0.02	0.02
Cardiopulmonary mortality 30+years (long-term)	0.02	0.02	0.02
Ischemic Heart Disease 30+ years (long-term)	0.01	0.01	0.01
Lung cancer mortality 30+ years (long-term)	0.003	0.003	0.002
Daily mortality all causes all ages	0.007	0.007	0.007
Daily mortality cardiovascular disease all ages	0.001	0.001	0.001
Hospital admissions respiratory disease 65+ years	0.01	0.01	0.01
Hospital admissions cardiac disease 65+ years	0.03	0.03	0.02
Hospital admissions pneumonia and bronchitis 65+ years	0.03	0.03	0.03
Hospital admissions cardiovascular disease 65+ years	0.005	0.005	0.005

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Hospital admissions respiratory disease 15-64 years	0.008	0.008	0.008
Emergency Department visits asthma 1-14 years	0.002	0.002	0.002
Sebastopol - Redan			
All-cause mortality 30+years (long-term)	0.01	0.01	0.01
Cardiopulmonary mortality 30+years (long-term)	0.01	0.01	0.01
Ischemic Heart Disease 30+ years (long-term)	0.009	0.009	0.008
Lung cancer mortality 30+ years (long-term)	0.002	0.002	0.002
Daily mortality all causes all ages	0.005	0.005	0.005
Daily mortality cardiovascular disease all ages	0.001	0.001	0.001
Hospital admissions respiratory disease 65+ years	0.01	0.01	0.01
Hospital admissions cardiac disease 65+ years	0.02	0.02	0.02
Hospital admissions pneumonia and bronchitis 65+ years	0.03	0.03	0.03
Hospital admissions cardiovascular disease 65+ years	0.005	0.004	0.004
Hospital admissions respiratory disease 15-64 years	0.006	0.006	0.006
Emergency Department visits asthma 1-14 years	0.001	0.001	0.001

9 Metals

9.1 Hazard assessment

Beyond the impacts of the dust itself, particles can also carry potentially toxic elements including metals, which convey additional health risks (e.g., Csavina et al., 2012). Once solubilised, these contaminants can be transferred directly into the blood stream where a range of toxic effects have been documented, including carcinogenicity (for arsenic, cadmium, chromium and nickel), neurological effects (lead and mercury) and renal damage (chromium, cadmium and mercury) (Dreary et al., 2021).

The transition metals (cobalt, copper, nickel and zinc) are also of concern due to their ability to generate reactive oxygen species within the body, and iron bearing minerals and oxides are known to cause lung inflammation (Entwistle et al., 2019). The mining and processing of ore in semi-arid regions tends to generate metalloid-containing dust, where arid conditions increase risks of dust generation and distribution (Ettler et al., 2019).

There is not a clear correlation between metal(loid) loads and particle size, which can be influenced by mineralogical composition and the source of contamination (Ettler et al., 2019), and the pathway of metal contaminants from mining activities into the indoor residential environment remains poorly understood (Entwistle et al., 2019). The community health impact of metals present in house dust on residents near mine sites has been studied by Zota et al., (2011; 2016). These studies have looked at the metal concentrations in indoor dust and biomarkers in children less than 2 years of age.

Children in this age group are more vulnerable to the impact of contaminants in house dust as they spend more time on the floor and have significant hand to mouth behaviours. The study showed that there was a correlation in blood lead in children with dust from the mine site known to contain lead. Other metals, such as manganese, arsenic and cadmium were at lower levels and did not differ significantly from levels in homes away from the mine site.

A number of metals have been identified as being present in the tailings and soil associated with the with the construction and operation of the TSF4 as well as the current mine operations. These are summarised in **Table 9. 1**.

Table 9. 1: Metals Assessed for Construction and Operation of Proposed TSF4

Metal	
Antimony	Vanadium
Arsenic	Cadmium
Lead	Chromium VI and VIII
Barium	Zinc
Manganese	Cobalt
Nickel	Strontium

These metals have a range of health effects from non-cancer respiratory effects (e.g. shortness of breath, coughing, and wheezing), effects on the cardiovascular and central nervous systems, gastrointestinal effects, through to cancer.

9.2 Exposure Assessment

Calculated emission rates for total suspended particles (TSP) and particulate matter (PM_{10} and $PM_{2.5}$) were used as input to the dispersion model to predict the deposition rate and ambient air concentration of heavy metals at sensitive receptors described in Section 6 of this report. The model results were scaled by the proportion of heavy metals from laboratory analysis of solid samples of waste rock, mine tailings, surface and subsoil within the TSF4 area and applying the proportion to the modelled results of TSP, PM_{10} and $PM_{2.5}$. For concrete batching activities heavy metal concentrations were not available, with emission factors for metals from the United States Environmental Protection Agency (US EPA) used instead.

To assess the potential health risk from metals, the metals concentrations in the PM_{10} fraction have been used. **Table 9. 2** summarises the maximum PM_{10} metal concentrations – both 24 hour and annual average – for the most affected receptors in each of the areas assessed in this HRA. These values have been used in the risk characterization for both cancer and non-cancer risks. For the operation scenario, the tailings are wet and therefore there are no emissions from metals. The metals shown in **Table 9. 2** and subsequent tables for the operation scenario arise from the dust from the haul roads and other earth moving activities. For all metals marked '-', this means that they are not present in the dust on the site.

Table 9. 2: Maximum PM_{10} Metal Concentrations (µg/m^3)

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian				
Antimony	Annual	0.000000036	0.000000027	-
	24 hours	0.0000011	0.00000036	-
Arsenic	Annual	0.0000030	0.0000017	0.000031
	24 hours	0.000047	0.000020	0.00018
Barium	Annual	0.00000043	0.00000029	-
	24 hours	0.000012	0.0000038	-
Cadmium	Annual	0.000000017	0.0000000055	-
	24 hours	0.00000030	0.000000073	-
Chromium	Annual	0.00000021	0.00000016	-
	24 hours	0.0000061	0.0000022	-
Cobalt	Annual	0.00000015	0.00000014	0.0000019
	24 hours	0.0000040	0.0000017	0.000011
Lead	Annual	0.00000025	0.00000018	-
	24 hours	0.0000074	0.0000024	-
Manganese	Annual	0.0000022	0.0000035	0.000078
	24 hours	0.000036	0.000043	0.00046
Nickel	Annual	0.00000021	0.00000014	-
	24 hours	0.0000050	0.0000018	-
Strontium	Annual	0.00000052	0.00000040	-
	24 hours	0.000017	0.0000053	-
Vanadium	Annual	0.00000018	0.00000011	-
	24 hours	0.0000050	0.0000015	-
Zinc	Annual	0.00000046	0.00000064	0.000013
	24 hours	0.000010	0.0000079	0.000078
Mount Clear – Mount Helen				
Antimony	Annual	0.00000032	0.00000044	-
	24 hours	0.0000044	0.0000040	-
Arsenic	Annual	0.000012	0.000014	0.000016

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
	24 hours	0.00014	0.00011	0.00027
Barium	Annual	0.0000035	0.0000047	-
	24 hours	0.000047	0.000043	-
Cadmium	Annual	0.000000070	0.000000088	-
	24 hours	0.00000093	0.00000081	-
Chromium	Annual	0.0000017	0.0000023	-
	24 hours	0.000023	0.000021	-
Cobalt	Annual	0.0000012	0.0000015	0.0000010
	24 hours	0.000016	0.000014	0.000017
Lead	Annual	0.0000020	0.0000028	-
	24 hours	0.000028	0.000025	-
Manganese	Annual	0.000012	0.000014	0.000042
	24 hours	0.00014	0.00012	0.00069
Nickel	Annual	0.0000012	0.0000017	-
	24 hours	0.000017	0.000015	-
Strontium	Annual	0.0000048	0.0000066	-
	24 hours	0.000066	0.000060	-
Vanadium	Annual	0.0000014	0.0000018	-
	24 hours	0.000019	0.000017	-
Zinc	Annual	0.0000033	0.0000040	0.0000070
	24 hours	0.000039	0.000032	0.00012
Sebastopol - Redan				
Antimony	Annual	0.000000068	0.000000035	-
	24 hours	0.0000013	0.00000073	-
Arsenic	Annual	0.0000027	0.0000016	0.0000060
	24 hours	0.000071	0.000036	0.000069
Barium	Annual	0.00000074	0.00000037	-
	24 hours	0.000014	0.0000078	-
Cadmium	Annual	0.000000015	0.0000000069	-
	24 hours	0.00000035	0.00000015	-

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
Chromium	Annual	0.00000036	0.00000018	-
	24 hours	0.0000068	0.0000039	-
Cobalt	Annual	0.00000026	0.00000016	0.00000037
	24 hours	0.0000055	0.0000034	0.0000043
Lead	Annual	0.00000043	0.00000022	-
	24 hours	0.0000083	0.0000046	-
Manganese	Annual	0.0000028	0.0000023	0.000015
	24 hours	0.000082	0.000060	0.00018
Nickel	Annual	0.00000027	0.00000014	-
	24 hours	0.0000053	0.0000029	-
Strontium	Annual	0.0000010	0.00000052	-
	24 hours	0.000019	0.000011	-
Vanadium	Annual	0.00000029	0.00000015	-
	24 hours	0.0000056	0.0000031	-
Zinc	Annual	0.00000074	0.00000053	0.0000026
	24 hours	0.000018	0.000013	0.000029

9.3 Risk characterization

The purpose of the risk characterization is to estimate potential risks associated with exposure to the metals in the dust from the proposed construction and operation of the TSF4. For the assessment of health effects where there is a known threshold for effect, the predicted short-term or annual average metal concentration is compared to the health-based guideline values. The ratio of the predicted level to the guideline is termed the hazard quotient (HQ) (enHealth, 2012):

HQ = predicted metal concentration / health-based guideline

The hazard quotients associated with predicted metal concentrations have been estimated for all sensitive receptors considered in this HRA.

The risks presented in the following sections have been calculated using data from the air quality modelling that has been conducted assuming adoption of the mitigation measures outlined in the Section 8.2. Both non-carcinogenic and carcinogenic risks have been assessed as applicable. For non-carcinogenic risks, both short-term and long-term, the air quality guidelines shown in **Table 9.3** have been used to calculate the hazard quotients. For the carcinogenic metals – arsenic, cadmium, chromium VI, lead and nickel – the Californian EPA Office Environmental Health Hazard Assessment (OEHHA) unit risk factors have been used to calculate the incremental lifetime cancer risk from the construction and operation of the TSF4. A unit risk factor is the increase in cancer per 1 μg/m^3 increase in carcinogenic substance in air. The enHealth acceptable risk level of 1x10^{-5} has been used to assess the incremental lifetime cancer risk from these activities. This acceptable risk level is also used by WHO and the USEPA. A cancer risk of $1x10^{-6}$ (1 case in 1 million population) is considered negligible by all these agencies.

9.3.1 Non-carcinogenic risks

Table 9. 3 shows the air quality guidelines used in the risk assessment for the metals.

Table 9. 3: Non-carcinogenic risks

Metals	Health Based Air Quality Guidelines (µg/m³)	Health Based Air Quality Guidelines Sources
Arsenic	1-hour – 0.2 Annual average – 0.015	OEHHA chronic reference exposure level REL (2015)
Antimony	24-hours – 1 Annual average – 0.3	ATSDR inhalation minimal risk level (MRL) (2022)
Barium	1-hour – 5 Annual average – 0.5	TCEQ ESL
Cadmium	Annual average – 0.02	OEHHA chronic reference exposure level
Chromium VI	Annual average – 0.2	OEHHA chronic reference exposure level
Chromium III	8-hour – 0.12 Annual average – 0.06	OEHHA Acute reference exposure level OEHHA chronic reference exposure level
Cobalt	24-hours – 0.095 Annual average – 0.0017	TCEQ 24 hours AMCV health (2017) TCEQ long-term AMCV health (2017)
Lead	Annual average – 0.5	EPA Victoria ERS 26 May 2021
Manganese	24-hours average – 0.17 Annual average – 0.09	OEHHA 8-hour reference exposure level REL (2015) OEHHA chronic reference exposure level REL (2015)
Nickel	8-hours – 0.06 Annual average – 0.014	OEHHA acute reference exposure level REL (2015) OEHHA chronic reference exposure level
Strontium	24-hours – 20 Annual average – 2	TCEQ short-term ESL (2003) TCEQ long-term ESL (2003)
Vanadium	24-hours – 0.31 Annual average – 0.066	TCEQ 24-hour health (2021) TCEQ long-term AMCV health (2021)
Zinc	1 hour – 20 Annual average – 2	TCEQ short-term ESL (2010) TCEQ long-term ESL (2010)

The hazard quotients for non-carcinogenic risks for the metals for the most affected receptors are shown in **Table 9. 4** for the construction scenarios and operation of the TSF4**.**

Table 9. 4: Acute and Chronic Hazard Quotients for Metals – Construction and Operation TSF4

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Mount Pleasant – Canadian						
Antimony	0.00000023	0.000000071		0.000000072	0.000000053	
Arsenic	0.00024	0.00010	0.000182	0.00020	0.00011	0.00204
Barium	0.0000025	0.00000076		0.00000086	0.00000057	
Cadmium				0.00000085	0.00000027	
Chromium III	0.000013	0.0000046		0.0000035	0.0000027	
Chromium VI				0.0000010	0.00000080	
Cobalt	0.000020	0.0000084	0.00018	0.0000073	0.0000068	0.0000068
Lead				0.00000051	0.00000035	
Manganese				0.000025	0.000038	0.000038
Nickel	0.000025	0.0000091		0.000015	0.000010	
Strontium	0.00000084	0.00000027		0.00000026	0.00000020	
Vanadium	0.00000025	0.000000075		0.000000088	0.000000056	
Zinc	0.00000051	0.00000039	0.000078	0.00000023	0.00000032	0.00000032

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Mount Clear – Mount Helen						
Antimony	0.00000088	0.00000081		0.00000064		
Arsenic	0.00071	0.00057	0.00027	0.00079		0.00109
Barium	0.0000095	0.0000086		0.0000069	0.0000094	
Cadmium				0.0000035	0.0000044	
Chromium III	0.000048	0.000044		0.000028	0.000038	
Chromium VI				0.0000084	0.000011	
Cobalt	0.000078	0.000068	0.00027	0.000060	0.000077	0.000077
Lead				0.0000041	0.0000055	
Manganese				0.000133	0.00015	0.00015
Nickel	0.000084	0.000077		0.000089	0.000119	
Strontium	0.0000033	0.0000030		0.0000024	0.0000033	
Vanadium	0.00000093	0.00000085		0.00000068	0.00000092	
Zinc	0.0000020	0.0000016	0.00012	0.0000016	0.0000020	0.000002

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Sebastopol – Redan						
Antimony	0.00000026	0.00000015		0.00000014	0.000000069	
Arsenic	0.00035	0.00018	0.000069	0.00018	0.00011	0.00040
Barium	0.0000028	0.0000016		0.0000015	0.00000074	
Cadmium				0.00000076	0.00000035	
Chromium III	0.000014	0.0000081		0.0000060	0.0000031	
Chromium VI				0.0000018	0.00000092	
Cobalt	0.000028	0.000017	0.000069	0.000013	0.0000078	0.0000078
Lead				0.00000087	0.00000044	
Manganese				0.000031	0.000026	0.000026
Nickel	0.000027	0.000014		0.000019	0.0000097	
Strontium	0.00000095	0.00000055		0.00000051	0.00000026	
Vanadium	0.00000028	0.00000015		0.00000015	0.000000073	
Zinc	0.00000092	0.00000063	0.000029	0.00000037	0.00000027	0.00000027

As shown in **Table 9. 4**, all hazard quotients for all scenarios are well below the acceptable limit of 1. A hazard quotient of 0.1 is considered negligible by enHealth, WHO and US EPA. All HQs in **Table 9. 4** are well below 0.1 indicating that all potential risk from exposure to metals from the construction and operation of the TSF4 are negligible.

The hazard quotients for the individual metals have not been summed. It is only possible to sum the hazard quotients if the health effects associated with exposure to the metals are the same. Given that all the HQs in **Table 9. 4** are orders of magnitude below the acceptable and negligible risk levels, even if they were summed the risk would still be negligible.

9.3.2 Cancer risks

The carcinogenic risks for arsenic, cadmium, chromium VI, lead and nickel are shown in **Table 9. 5**. The annual average PM_{10} concentrations modelled as part of the air dispersion modelling undertaken for this HRA have been used to calculate the annual average metal concentrations.

As can be seen from **Table 9. 5** all carcinogenic risk levels are several orders of magnitude below $1x10^{-5}$ even at the most impacted receptors. enHealth, consistent with WHO guidance, considers that risks below $1x10^{-6}$ are negligible. All carcinogenic risks calculated for the metals associated with the construction and operation of the TSF4 are well below this level. The risk is therefore considered to be negligible. The cancer risk estimate for arsenic is an overestimate of the risk as it has assumed that all the arsenic is bioavailable. Even with this conservative assumption the risk is still considered to be negligible.

Table 9. 5: Cancer risks from the Construction and Operation of TSF4 – Most Affected Receptors

Scenario	Cancer Risk				
	As	Pb	Cd	Ni	Cr VI
Mount Pleasant – Canadian					
Construction Zone 1	$9.8x10^{-9}$	$3.1x10^{-12}$	$7.2x10^{-11}$	$4.6x10^{-11}$	$3.1x10^{-8}$
Construction Zone 6	$4.9x10^{-9}$	$2.1x10^{-12}$	$2.3x10^{-11}$	$2.9x10^{-11}$	$2.4x10^{-8}$
Operations	$1x10^{-7}$				
Mount Clear - Mount Helen					
Construction Zone 1	$3.9x10^{-8}$	$2.4x10^{-11}$	$2.9x10^{-10}$	$2.9x10^{-10}$	$2.5x10^{-7}$
Construction Zone 6	$4.5x10^{-8}$	$3.3x10^{-11}$	$3.7x10^{-10}$	$3.8x10^{-10}$	$3.4x10^{-7}$
Operations	$5.4x10^{-8}$				
Sebastopol - Redan					
Construction Zone 1	$8.8x10^{-9}$	$5.2x10^{-12}$	$6.4x10^{-11}$	$6.2x10^{-11}$	$5.4x10^{-8}$
Construction Zone 6	$5.3x10^{-9}$	$2.6x10^{-12}$	$2.9x10^{-11}$	$3.1x10^{-11}$	$2.8x10^{-8}$
Operations	$2x10^{-8}$				

OEHHA (2015) recommends that in conducting a cancer risk assessment a 10-fold factor be added to the risk estimates for children. This is to account for a greater vulnerability due to the developmental stages during childhood. Even with a 10-fold in risk to account for this, the cancer risk for all the metals and all areas assessed are below negligible risk levels.

10 Respirable Crystalline Silica

10.1 Hazard assessment

Respirable crystalline silica (RCS) can bioaccumulate in the lungs and cause respiratory disease. Large bioaccumulated loads of RCS in the lung can cause a build-up of connective tissue, termed silicosis, a specific form of pneumoconiosis. Silicosis is an irreversible and progressive condition. The majority of the epidemiological evidence of adverse health effects associated with exposure to RCS comes from occupational studies. There are limited studies of communities exposed to RCS.

Exposure to RCS at levels that appear not to cause silicosis can cause chronic bronchitis and chronic obstructive airways disease. An increased susceptibility to tuberculosis occurs in workers with silicosis. Epidemiological studies have also revealed an excess prevalence of autoimmune diseases like scleroderma, rheumatoid arthritis and systemic lupus erythematosus associated with exposure to RCS.

There are several epidemiological studies that have been conducted in communities close to gold mines in Johannesburg, South Africa. The findings of these studies have shown mixed results. A study by Kootbodien et al. (2019) found no association between non-occupational exposures and tuberculosis but did find an association with occupational exposures. A further study by Iyaloo et al. (2020) found that people living within 500 m of a gold mine had increases in adverse respiratory health effects such as upper respiratory symptoms, wheeze and chronic obstructive airways disease, associated with exposure to crystalline silica compared to communities living further away (>1.5 km). Chronic bronchitis and tuberculosis risks did not differ significantly among groups.

RCS has been classified by the International Agency for Research into Cancer (IARC) as a category 1 carcinogen as it has been shown to cause cancer in humans. It is accepted that RCS does not directly cause DNA damage. It is believed that inflammatory processes in the lung are the driving force for carcinogenicity rather than direct DNA damage. It is generally accepted that an inflammation-based mechanism as described in IARC (1997) is a likely mechanism responsible for the induction of lung cancer associated with exposure to RCS. It is accepted that inflammation and development of silicosis occurs before the development of lung cancer and that there is a threshold, or safe level, below which silicosis does not develop.

10.1.1 Exposure assessment

The modelling undertaken for this HRA has used the conservative assumption that the predicted $PM_{2.5}$ concentrations were 100% RCS. This will lead to an overestimate of risk posed by the increase in RCS due to the proposed construction and operation of the TSF4.

Table 10. 1: Maximum Annual Average RCS concentrations

Receptor	Scenario	Annual Average RCS (µg/m^3)
Mount Pleasant - Canadian	Construction Zone 1	0.14
	Construction Zone 6	0.14
	Operation	0.14
Mount Clear – Mount Helen	Construction Zone 1	0.08
	Construction Zone 6	0.08
	Operation	0.08
Sebastopol - Redan	Construction Zone 1	0.03
	Construction Zone 6	0.03
	Operation	0.03

10.1.2 Risk characterization

The purpose of the risk characterization is to estimate potential residual risks associated with exposure to RCS from the proposed Project. For the assessment of health effects where there is a known threshold for effect, the predicted annual average RCS concentration is compared to the health based guideline values. The ratio of the predicted level to the guideline is termed the hazard quotient (HQ) (enHealth, 2012):

HQ = predicted RCS concentration / health based guideline

The hazard quotients associated with predicted RCS concentrations have been estimated for the most impacted receptors for each of the areas assessed. Using the most impacted receptors is indicative of the highest risk posed to the potentially exposed population. All other risks from exposure to RCS will be lower. The hazard quotients shown in **Table 10. 1** have been calculated for both the increment from the construction and operation of the TSF4.

In calculating the hazard quotients, the health based guideline has been adopted from the Californian EPA Office of Health Hazard Assessment (OEHHA). The OEHHA guideline is 3 µg/m^3 as an annual average. This guideline has been established to protect against silicosis. This guideline has also been adopted by EPA as an Air Quality Assessment Criteria.

Table 10. 2: Hazard quotients for Respirable Crystalline Silica

Year	Hazard Quotient Project Increment alone
Mount Pleasant - Canadian	
Construction Zone 1	0.05
Construction Zone 6	0.05

Year	Hazard Quotient Project Increment alone
Operation	0.05
Mount Clear – Mount Helen	
Construction Zone 1	0.03
Construction Zone 6	0.03
Operation	0.03
Sebastopol - Redan	
Construction Zone 1	0.01
Construction Zone 6	0.01
Operation	0.01

As can be seen from **Table 10. 2** all hazard quotients for all receptors for all areas are well below 1 and within acceptable risk levels adopted by enHealth (2012). The hazard quotients are also below the negligible risk level of 0.1.

11 Impacts on groundwater

The potential for groundwater to be contaminated by leachate from the TSF4 and impacts on recreational users of the Yarrowee River was raised by the community during the consultation on the Planning Permit Application. This section reviews the groundwater monitoring conducted by Balmaine Gold and the potential exposure pathways for exposure to recreational users of the river. If there is no complete exposure pathway, then there is no potential risk to human health.

11.1 Hydrogeological setting

The AECOM groundwater impacts report[1] set out the hydrogeological setting of the proposed TSF4, which is summarised as follows:

- The proposed TSF4 is located in Whitehorse Gully, an ephemeral drainage line east of the Yarrowee River, with a surface elevation of 465 m AHD in the east to 400 m AHD in the west.
- The proposed TSF4 site is underlain by Castlemaine Group (marine turbiditic sandstone, siltstone, mudstone, black shale and minor granule conglomerate), with Whitehorse Gully Deep Leads originally present as thin alluvial deposits in the gullies, but heavily modified during historic mining activities and now present as hummocky deposits throughout the gullies.
- There are two hydrogeological units underlying the proposed TSF4:
  - Calivil Formation, located within the Whitehorse Gully Deep Leads (i.e., localised to gullies within the proposed TSF4 area). This unit has limited connection with the underlying Basement aquifer and is considered to be a perched groundwater system.

[1] AECOM, March 2020. *Groundwater impact assessment – TSF4*. Prepared for Castlemaine Goldfields Pty Limited. AECOM reference: 60593424.

  - Basement aquifer within the Castlemaine Group (undifferentiated sedimentary basement rocks). Low-yielding weathered siltstones and sandstones with largely north-south fracture orientations.
- Hydraulic conductivity within the Basement aquifer was reported by AECOM to be highly variable at a local scale, and dependent on faulting or fracturing of the bedrock. Site-specific conductivity results reported by AECOM were 0.005 m/day for the Basement aquifer.
- Groundwater flows from east to west, with the groundwater table present as a subdued reflection of the surface topography.
- Recharge of the Basement and Cavil Formation aquifers occurs largely via infiltration of rainfall.
- Local flow systems may discharge to the Yarrowee River, while intermediate and regional flow systems likely discharge further down the catchment.
- Leachate in the landfill located adjacent to the southern boundary of the proposed TSF4 is lower than the groundwater at the proposed TSF4 site.

11.2 Conceptual site model for groundwater

The source of potential impacts to groundwater that could impact on human health is water contaminated by the leachate from the tailings. This could occur either leachate from the TSF or the post-closure infiltration of rainwater into the TSF re-saturating the tailings and subsequent leakage of leachate.

As described in the AECOM report, a leachate collection system will be installed as part of the construction of TSF4. The system is designed to collect leachate from the floor of the TSF, which would be pumped out of the facility via an above-ground pipe which would not penetrate the walls of the embankment. The design includes a toe drain located at the bottom of the embankment to catch any seepage of rainfall infiltration through the downgradient wall of the TSF.

According to the AECOM report, post-closure, the TSF will be de-saturated. In this context, it is unlikely that the volume of water from rainfall that infiltrates the cap and saturate the tailings would be sufficient to cause leaching through the clay liner resulting in an impact on groundwater.

As shown in the CSM for the site (Section 5 of this report), the main pathway for groundwater impacts is the subsurface migration of impacted water from TSF4 into groundwater.

The low site-specific hydraulic conductivity presented in the AECOM report suggests a reduced risk of groundwater impact from contaminated water infiltration.

There is also the possibility that any contaminated groundwater may be discharged to surface waters such as the Yarrowee River.

11.2.1 Groundwater bores

A search of the Victorian groundwater bore database was carried out by T+T in May 2023. A total of 16 groundwater bores are recorded as being located within 1 km of the proposed TSF4. Of these bores:

- 10 bores have a reported use of ‘groundwater investigation’ or ‘observation’.
- Three bores have a reported use of ‘domestic and stock’, however these bores are all located within the boundaries of either the mine or the adjacent water treatment plant, and it is considered likely that the bores have been miscategorised.

- One bore has a reported use of 'commercial' and is located adjacent to the water treatment plant.
- One bore has a reported use of 'irrigation' and is located adjacent to an area of mine stockpiling.
- One bore does not have a recorded use and is located approximately 500 m east (up gradient) of the proposed TSF4 site.

None of the identified bores have a reported use for potable water. The bores identified for domestic or stock uses are located on industrial land and are unlikely to be used for drinking water.

There are no known users of the Cavil Formation aquifer, and as this aquifer is highly localised (limited to the gullies in the proposed TSF4 footprint) and perched and it is unlikely that people will be in contact with the water from this aquifer. As detailed in the AECOM report, the Cavil Formation will be removed during construction of TSF4 removing this as a potential groundwater source.

11.3 Groundwater quality

The results of groundwater monitoring conducted by Balmaine Gold between 2020 and 2023 from groundwater wells in the vicinity of existing TSF3 and proposed TSF4 were provided to T+T. These results were assessed against the following health-based criteria to assess whether impacts from the existing TSF3 have impacted groundwater quality and may pose a risk to human health:

- To assess water quality for use as drinking water: ADWG 2022[2] health criteria.
- To assess water quality for use as irrigation water: ANZECC 2000[3] Irrigation Long Term trigger levels.
- To assess water quality for use for water-based recreation: ADWG 2022 health criteria with a factor of 10 applied (as specified in the Assessment of Site Contamination NEPM, ASC NEPM amended 2013).

The most stringent criteria are the drinking water criteria and therefore, provided these criteria are met, the criteria for irrigation water and water-based recreation will also be met.

The locations of all wells were not able to be determined from the information provided, however it is known that three wells (BEB9, VMB4 and VMB5) are located east (upgradient) of TSF3 and are therefore considered to be representative of background groundwater quality. As a conservative approach, all other groundwater wells have been assumed to be downgradient of TSF3.

Table 11. 1 shows the analytes that exceeded each of the health-based assessment criteria for both the background (upgradient) and other groundwater wells.

Table 11. 1: Analytes exceeding the adopted health-based assessment criteria

Assessment criteria	Background wells	Other wells
Drinking water	Cadmium Nickel	Nickel

[2] NHMRC, NRMMC, 2011 (updated September 2022). *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.
[3] ANZECC & ARMCANZ, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Assessment criteria	Background wells	Other wells
Irrigation	pH Nitrogen Cobalt Iron Nickel Manganese	pH Nitrogen Cobalt Iron Nickel Manganese
Water-based recreation	Chloride pH Total dissolved solids Iron Manganese Zinc	pH Total dissolved solids Ammonia Chloride Iron Zinc Manganese

Table 11. 1 shows that all analytes that exceed the assessment criteria in downgradient wells also exceed the assessment criteria in the background wells, suggesting that the exceedances are representative of background water quality and are unlikely to be indicative of impacts from TSF3.

Figure 11. 1 shows the data from arsenic concentrations from both the upgradient and downgradient wells. From **Figure 11. 1**3it can be seen that the upgradient concentrations of arsenic are higher or similar to the downgradient wells indicating that the operation of the current TSF3 is not impacting groundwater quality on the site.

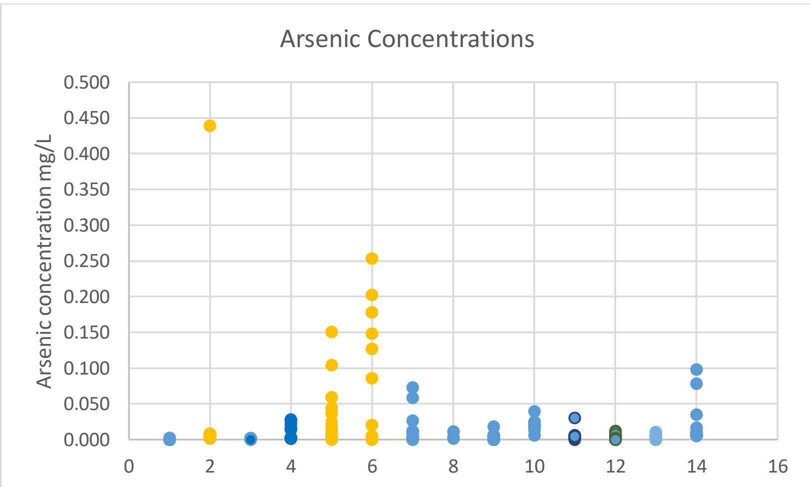

Figure 11. 1: Arsenic concentrations in upgradient (in yellow) and downgradient groundwater wells at Balmaine Gold site

The AECOM assessment states that tailings in TSF3 are enriched with arsenic and sulfate. The groundwater quality data indicates that there were no exceedances of the adopted health-based criteria for arsenic or sulfate in either the upgradient or downgradient wells. It is noted that the ADWG do not provide a health-based guideline for sulfate as there is insufficient data to set a health guideline. For this assessment the aesthetic criterion for sulfate (with a factor of 10 applied) was adopted to assess water quality for water-based recreation.

The range of concentrations of sulfate and arsenic in the groundwater results between 2020 and 2023 are show in **Table 11. 2**. Higher concentrations of both sulfate and arsenic were reported in the upgradient wells.

Table 11. 2: Range of concentrations of indicator analytes at upgradient and downgradient wells

Analyte	Upgradient wells (mg/L)	Downgradient wells (mg/L)
Sulfate (as SO_4)	28 – 435	2 – 299
Arsenic	0.001 – 0.253	0.001 – 0.098

The results shown in **Table 11. 2**. The ADWG for arsenic is 0.01 mg/L. This is exceeded for both upgradient and downgradient wells. The resulting recreational water quality guideline would be 0.1 mg/L (10x ADWG) which is exceeded in the upgradient wells. The results shown in **Table 11. 2** indicate that the operation of the TSF3 does not lead to contamination of the groundwater at the site. If the downgradient groundwater data was to discharge to the Yarrowee River, or other surface water bodies in the area, contact with the groundwater would not pose a risk to human health through recreational contact as the concentration of arsenic meet the recreational water quality guidelines.

11.4 Summary

Based on the analysis conducted above, the risk of health impacts from exposure to groundwater from the site and potential impacts on users of the Yarrowee River from the construction and operation of the TSF4 is considered to be low. The proposed leachate management system would reduce the risk of leachate building to the point where seepage through the clay liner would occur. It is also unlikely that a sufficient volume of rainwater would infiltrate through the cap post-closure to re-saturate the tailings and leach into groundwater. Overall, the risk of contaminated water impacting groundwater is considered low.

In addition, the hydraulic conductivity of the Basement aquifer is very low, suggesting that in the event that there is leakage to groundwater, groundwater flow is likely to be an ineffective pathway for contaminant transport.

There are no clear exposure pathways for people to be exposed to groundwater in either the Cavil Formation or Basement aquifers. There are no groundwater bores downgradient of the site that are not on industrial land. The existing bores can't be accessed by the public therefore there are no direct exposure pathways.

Groundwater quality results suggest that the existing TSF3 is not impacting groundwater quality downgradient of the mine. Based on the results of the ground water monitoring, the downgradient water quality is similar, if not better, than the upgradient quality. This indicates that the current mine operations including the TSF3 is not impacting on groundwater in the area. As the proposed TSF4 is based on the same construction principles as TSF3 it is reasonable to assume that the potential impacts to groundwater would be similar for both operations. In addition, the ore being mined will be the same or similar to that currently being processed meaning that any impact on groundwater quality would be similar to that currently observed. If groundwater was to enter the Yarrowee River, there would be no impact from the mine and the TSF4 above that from background groundwater. The groundwater from the downgradient wells meets the recreational water guidelines for arsenic which means that if it did discharge to surface waters it would not pose a risk to human health through recreational use.

12 Conclusions

A human health risk assessment has been undertaken to assess the potential impacts of emissions from the construction and operation of the TSF4 at the Ballarat Gold Mine on the local community. The HRA has been conducted to address issues raised by the local community and to inform Ballarat City Council's decision on the Planning Permit for the TSF4.

The HRA assesses the potential risk from PM_{10} and $PM_{2.5}$, metals in the dust and RCS. All risks are very low and below acceptable risk levels. In many cases, such as the metals and RCS, the potential risks are below negligible risk levels established by enHealth, WHO and the US EPA.

The HRA shows that if the mitigation measures that have been adopted in the air dispersion modelling and described in Section 8.2 are implemented at the site, the TSF4 can be constructed and operated without posing an unacceptable risk to the health of the local community.

In addition, Balmaine Gold has installed two real-time monitors for a dust management program for the site. Both PM_{10} and $PM_{2.5}$ plus meteorological data with results reported at the quarterly ERC meetings. The dust management plan has a tiered response process that is based on trigger concentrations that are set well below the PM standards. This approach requires additional use of water on roads and dust sources if windy/dry conditions are forecast. If the interim triggers are exceeded, additional water will be applied, traffic is slowed and if that does not reduce the dust levels, activities are stopped until weather conditions improve. This reactive dust management approach will further minimise any off-site impacts and any associated health risks.

13 References

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14 Applicability

This report has been prepared for the exclusive use of our client [redacted], with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of a Planning Permit Application for the construction and operation of the TSF4 and that Ballarat City Council as the responsible authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Pty Ltd
Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Pty Ltd by:
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REPORT

Tonkin+Taylor

Ballarat Gold TSF4 Health Risk Assessment Technical Report

Planning Permit Application

Prepared for
Balmaine Gold Pty Ltd
Prepared by
Tonkin & Taylor Pty Ltd
Date
June 2023
Job Number
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Executive summary

Tonkin & Taylor Pty Ltd (T+T) has been engaged by Balmaine Gold Pty Ltd (in Administration) (Balmaine Gold) to undertake a Human Health Risk Assessment (HRA) for the construction and operation of the Tailings Storage Facility (TSF4) at the Ballarat Gold Mine. The HRA was requested by Ballarat City Council to address concerns raised by the community through the public consultation phase of the Planning Permit Application for the TSF4.

The HRA has focussed on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollution, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust. This report describes both the short-term and long-term health effects associated with these pollutants.

The HRA assesses the potential risk from PM_{10} and $PM_{2.5}$, metals in the dust and Respirable Crystalline Silica (RCS). All risks are very low and below acceptable risk levels. In many cases, such as the metals and RCS, the potential risks are below negligible risk levels established by enHealth, WHO and the US EPA.

The HRA shows that if the mitigation measures that have been adopted in the air dispersion modelling and described in Section 8.2 are implemented at the site, the TSF4 can be constructed and operated without posing an unacceptable risk to the health of the local community.

1 Introduction

Tonkin & Taylor Pty Ltd (T+T) has been engaged by Balmaine Gold Pty Ltd (in Administration) (Balmaine Gold) to undertake a Human Health Risk Assessment (HRA) for the construction and operation of the Tailings Storage Facility (TSF4) at the Ballarat Gold Mine. The HRA was requested by Ballarat City Council to address concerns raised by the community through the public consultation phase of the Planning Permit Application for the TSF4.

The HRA focusses on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollution, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust. This report describes both the short-term and long-term health effects associated with these pollutants.

This work has been carried out in accordance with our proposal dated 21 April 2023.

2 Scope of work

The HRA has considered the incremental risk from the construction and operation of TSF4 from changes in air quality (PM_{10}, $PM_{2.5}$, Respirable Crystalline Silica (RCS), metals) and potential risk to human health through inhalation, and deposition to water tanks (metals). The HRA has been conducted in accordance with the relevant national and international guidelines as well as the relevant guidance from EPA Victoria. These include enHealth Guidelines for Assessing Human Health Risks from Environmental Hazards (2012) and EPA Victoria Guideline for the Assessment and Management of Air Pollution in Victoria (2022). Reference is also made to World Health Organization and US Environmental Protection Agency acceptable risk levels for cancer causing substances.

The issues identification stage is important to identify the key issues of importance to stakeholders including the local community. These issues have largely been identified in the objections received to date with the Planning Application.

The hazard identification stage includes a review of the current understanding of the health effects associated with the pollutants of concern that will be used as the basis of the health risk assessment. At this stage it is assumed that the key pollutants to be considered include PM_{10}, $PM_{2.5}$, respirable crystalline silica (RCS) and metals, in particular arsenic from the tailings through discharge to air and deposition into rainwater tanks.

The exposure assessment phase provides an assessment of the sensitivity of the potentially exposed populations. This assessment includes the residential population of the suburbs surrounding the proposed TSF4 location. This includes population and socioeconomic information obtained from the Australian Bureau of Statistics (ABS) as well as baseline health data obtained from the Victorian Department of Health.

The exposure assessment considers all exposure pathways which may include direct inhalation exposures as well as deposition of dust and potential impacts on the quality of water in rainwater tanks.

The risk characterisation stage calculates an estimate of the incremental risk from the emissions from the construction and operation of the proposed TSF4 within the potentially exposed populations. The risk characterisation combines the information from the previous stages in the HHRA to provide an estimate of the number of people that may be affected by emissions from the construction and operation of the TSF4.

During the review of the objections to the Planning Application, concerns were raised about the potential leakage from the tailings dam on groundwater and eventually the Yarrowee River and users of the river. To address these concerns, a review of potential exposure pathways through groundwater and subsequently any impacts on the Yarrowee River has been undertaken. To inform this a review of the groundwater assessment previously undertaken as part of the Planning process has been undertaken.

3 Methodology

A HRA aims to quantify the potential health effects arising from exposure to, in this case, air pollution. Conservative safety margins are built into a risk assessment analysis to ensure protection of public health. Consideration of the most vulnerable subgroups within the population is part of the risk characterisation process.

For air quality risk assessments, the key health effects that are considered include increases in mortality and morbidity (e.g., hospital admissions for respiratory disease) which have been associated with exposure to air pollution in population-based epidemiological studies.

The Australian guidance for conducting HRAs is set out in the enHealth Guidelines for Assessing Human Health Risks from Environmental Hazards (2012). This HRA was undertaken in accordance with the enHealth Guidelines which comprises five components as outlined below:

a **Issue Identification** – Identifies issues that can be assessed through a risk assessment and assists in establishing a context for the risk assessment;

b **Hazard Assessment** – Identifies hazards and health endpoints associated with exposure to hazardous agents and provides a review of the current understanding of the toxicity and risk relationship of the exposure of humans to the hazards;

c **Exposure Assessment** – Identifies the groups of people who may be exposed to hazardous agents and quantifies the exposure concentrations;

d **Risk Characterisation** – Provides the quantitative or qualitative evaluation of potential risks to human health. The characterisation of risk is based on the concentration response relationship and the assessment of the magnitude of exposure; and

e **Uncertainty Assessment** – Identifies potential sources of uncertainty and qualitative discussion of the magnitude of uncertainty and expected effects on risk estimates.

The enHealth (2012) guideline has been applied to assess the potential risks to the health of the local community from air quality arising from the proposed construction and operation of the proposed TSF4.

For air pollution, in addition to the enHealth Guideline, EPA Guideline for Assessing and Minimising Air Pollution in Victoria (the EPA Guideline) (EPA, 2022) provides technical guidance and a framework for assessing and controlling risks associated with air pollution. These guidelines have also been considered in conducting the HRA for the proposed TSF4.

The EPA Guideline (EPA, 2022) provides advice on conducting risk assessments for air quality. The approaches recommended by EPA differ depending on the type of pollutant. For air toxics and other non-criteria pollutants, the use of hazard indices for threshold pollutants and incremental lifetime cancer risk (ILCR) estimates is recommended, consistent with enHealth (2012).

Air dispersion modelling was undertaken to provide data for the HRA (Appendix A). This modelling assumed a number of mitigation measures agreed with Balmaine Gold to minimize any off-site impacts and associated health risks. It is anticipated that these measures will be included in the Planning Permit for the TSF4. The risks assessed in this HRA are the residual risks post application of these mitigation measures. The mitigation measures are described in Section 8.2.

4 Population health profile

To establish the baseline characteristics relevant to the HRA, baseline population data and health profiles have been determined for the area surrounding the mine and the proposed area for the TSF4. This information enables identification of any underlying issues in the local community that may make them susceptible to changes in air pollution arising from the construction and operation of the TSF4.

The baseline health status and demographics of the potentially exposed community is important to understand as it can impact on the sensitivity of the population to the adverse effects of air pollution. People in older age groups (>65 years of age), with existing diseases such as respiratory and cardiovascular disease, people with asthma, children (<15 years) and people in low socioeconomic groups all fall into groups that are more sensitive to the effects of environmental pollution.

The study area potentially affected by changes in air quality from the construction and operation of the TSF4 include Mount Clear, Mount Pleasant, Canadian, Mount Helen and Sebastapol which are suburbs of the city of Ballarat. Baseline population data has been obtained from the Australian Bureau of Statistics' (ABS) Census of Population and Housing (2021) for Mount Clear-Mount Helen, Sebastapol-Redan, Mount Pleasant and Ballarat. This data has been compared with the data for Melbourne and Victoria as a whole.

4.1 Population profile

4.1.1 Age profile

The most recently published census data from the ABS in 2021 for the areas being assessed in this HHRA are summarised in **Table 4.1.** Data for Melbourne and Victoria are included for comparison purposes.

Table 4.1: Age profile of Mount Clear, Sebastopol, City of Ballarat, Melbourne and Victoria

	Mt. Clear	Sebastopol	Ballarat	Melbourne	Victoria
Total population (persons)	3,671	10,194	113,763	4,917,750	6,503,491
Females (%)	52	53	52	51	51
Males (%)	48	47	48	49	49
Age groups					
0 -14 (%)	20	18	19	18	18
15 – 64 (%)	61	61	62	67	65
≥ 65 (%)	19	21	19	15	17
Median age (years)	37	39	39	37	38

Note: Source ABS 2021 Census

As can be seen from **Table 4.1** the age profile of Mt. Clear and Sebastopol is very similar to that of Ballarat, Melbourne and Victoria as a whole. There is a slightly higher percentage of people >65 years of age in Mt. Clear, Sebastopol and Ballarat compared to Melbourne and Victoria. People greater than 65 years of age are known to be more vulnerable to the effects of air pollution.

4.1.2 Health profile

The baseline health statistics for the study area, which includes the suburbs adjacent to the mine, have been obtained from ABS 2021 Census data. **Table 4.2** and **Table 4.3** summarise the health indicators (prevalence of certain health conditions) and socio-economic factors for the study area, Melbourne and Victoria. The health indicators shown in **Table 4.2** are those that have been identified in population-based studies to be impacted by exposure to air pollution.

Table 4.2: Health indicators Study Area, Melbourne and Victoria

Health Indicator	Mount Clear – Mount Helen	Sebastopol - Redan	Canadian – Mount Pleasant – Golden Gully	City of Ballarat	Melbourne	Victoria
Asthma	10.2%	14%	12.7%	11.4%	7.9%	8.3%
Cancer (including remissions)	3.4%	4%	3%	3.4%	2.5%	2.8%
Diabetes	4.2%	7.2%	5.3%	5.2%	4.5%	4.7%
Heart Disease	4.1%	6%	3.8%	4.7%	3.3%	3.7%
Lung Conditions	1.8%	4.1%	2.4%	2.4%	1.2%	1.5%
Stroke	0.7%	1.7%	1.1%	1.2%	0.8%	0.9%

Note: ABS 2021 Census

The data in **Table 4.2** show that the prevalence of health conditions impacted by air pollution are lower in Mount Clear – Mount Helen than in the surrounding suburbs and the City of Ballarat. The prevalence is slightly higher for Sebastopol – Redan and Canadian – Mount Pleasant – Golden Gully compared to Ballarat. All areas in the study area have higher prevalence of disease than Melbourne and Victoria. This data suggests that the population in the study area and Ballarat more broadly may be more sensitive to the effects of air pollution.

Table 4.3 summarises the socioeconomic status (SES) of the suburbs within the study area, Ballarat, Regional Victoria and Victoria as a whole. Low SES is a known risk factor that can make the exposed population more vulnerable to the effects of air pollution. This is largely due to the fact that people within these groups usually have poorer health status than people within higher SES areas. They may also have poorer access to medical care. In addition, they usually live in areas that are more polluted (e.g., near major roads or near industry).

There are several indices of social deprivation used to assess SES in Australia. One commonly used are the Socio-Economic Indexes for Areas (SEIFA) index. The SEIFA index is a measure of relative social disadvantage and takes into account 20 variables to assess relative social disadvantage. The lower the SEIFA index the greater the level of disadvantage. The index is relative to a score of 1000 which is considered as the Australian average.

The SEIFA Index of Relative Socio-Economic Advantage/Disadvantage is derived from attributes such as low income, low educational attainment, high unemployment, jobs in relatively unskilled occupations and variables that broadly reflect disadvantage rather than measuring specific aspects of disadvantage (e.g. Indigenous and separated/divorced). At the advantage end of the scale, households with high incomes, high education levels, large dwellings, high numbers of motor vehicles, spare bedrooms and professional occupations contribute to a higher score.

Table 4.3: Socio-Economic Factors – Study Area, Ballarat, Regional Victoria and Victoria

Socioeconomic Indicators	Mount Clear – Mount Helen	Sebastopol - Redan	Mt Pleasant - Canadian - Golden Point	City of Ballarat	Regional Victoria	Victoria
Unemployment rate in June 2021	5.5%	6.5%	6.1%	4.7%	4.1%	5%
SEIFA Index of Relative Socio-economic Disadvantage (based on Australian average score = 1000) in 2021	1023	882	974.8	985.7	985	1010
Percentage of low income households in 2021	25.5%	25.5%	25.5%	26.7%	26.7%	21%
People who left school at year 10 or below.	14.1%	20.5%	15.3%	16.5%	18.3%	12.3%

The key indicator in **Table 4.3** is the SEIFA index which is the relative indicator of socioeconomic advantage/disadvantage. The SEIFA index for Mount Clear – Mount Helen is higher than the SEIFA index for the other areas including Ballarat and Victoria as a whole. This shows that Mount Clear – Mount Helen is less disadvantaged that the other locations. Sebastopol – Redan has a lower SEIFA index indicating a higher level of disadvantage than other areas shown in **Table 4.3**. The data in **Table 4.3** shows that, based on socioeconomic status, Mount Clear – Mount Helen may be less vulnerable to the effects of air pollution compared to Ballarat, Regional Victoria and Victoria as a whole while Sebastopol – Redan may be more vulnerable.

5 Conceptual site model

A conceptual site model (CSM) has been prepared for the site **(Figure 5.1)** A CSM shows all the potential exposure pathways between the source (the TSF4) and sensitive receptors. This doesn't necessarily mean that there is a risk posed but that there is the potential for exposure. The risk is dependent on whether the source-receptor pathway is complete or not and the concentration of the pollutant that may occur at sensitive receptors.

The CSM identifies the main potential exposure pathways as follows:

- Direct inhalation of dust, including PM_{10}, $PM_{2.5}$ and metals, from the construction and operation of the TSF4.
- Potential infiltration of leachate into groundwater that may impact on the Yarrowee River.
- Deposition of dust contaning metals and run-off into rainwater tanks.

These exposure pathways have been assessed in this HRA.

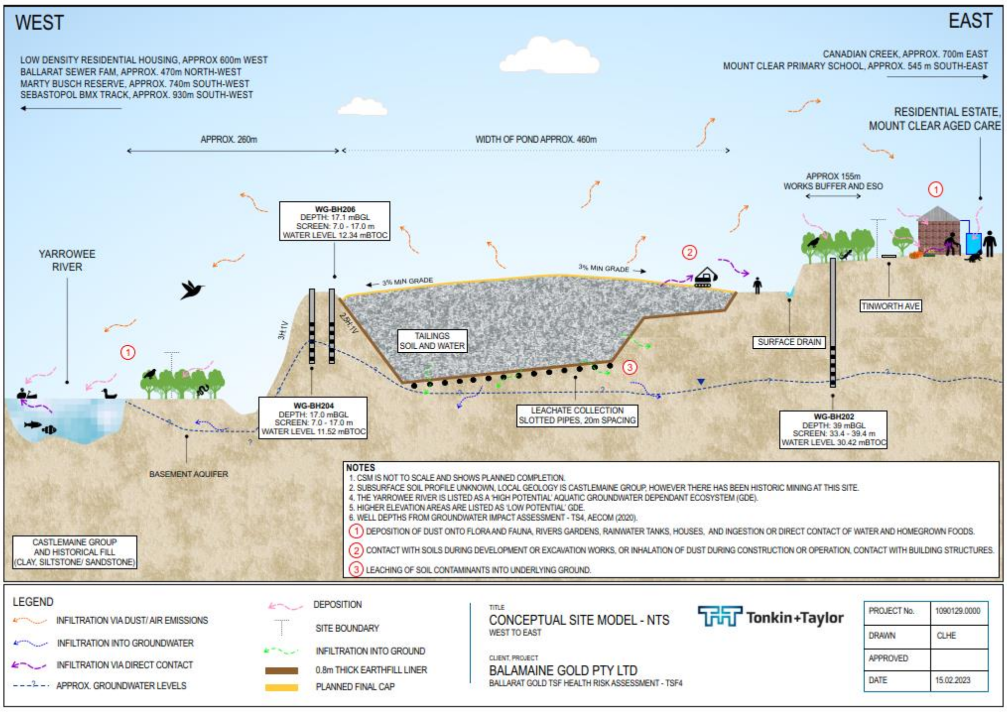

Figure 5.1: Conceptual Site Model for Construction and Operation of the Ballarat Gold TSF4

6 Sensitive Receptors

A large number of sensitive receptors, 118 in total, have been assessed in this HRA. The location of the sensitive receptors is shown in **Figure 6.1**. The sensitive receptors include residential areas, aged care facilities, schools and kindergartens, childcare centres, and recreational areas. In regard to residential activities, the assessment has focused on the most impacted locations in the neighbouring suburbs. It is not practical, or necessary, to consider the effects at all houses in the neighbouring suburbs as the effects will be less than at the most-impacted locations.

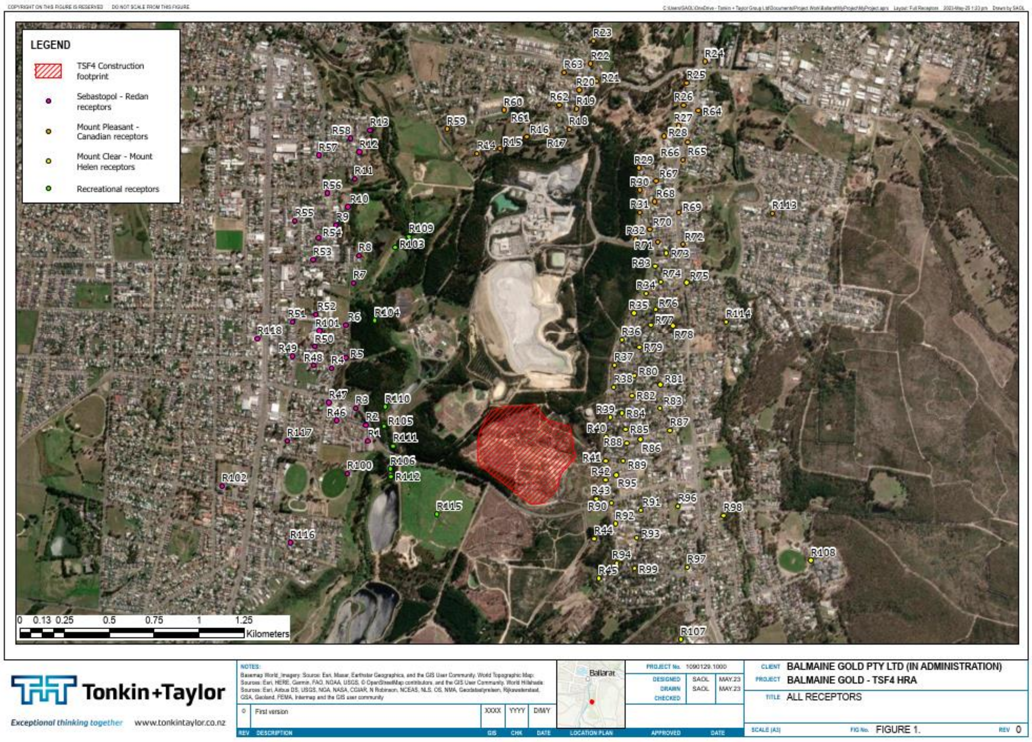

Figure 6.1: Locations of Sensitive Receptors Assessed in the HRA

Table 6.1 shows all receptors considered in this HRA.

Although the calculations presented in the following sections have focussed on the most impacted receptors in each area considered, risks to all the identified receptors in Table 6.1 have been assessed. The focus on the most impacted receptor represents the worst case risk with all other risks being lower.

Table 6.1: Locations and types of Sensitive Receptors used in the HRA

Receptor Number	Address	Type
1	[redacted]	Residential
2		Residential
3		Residential
4		Residential

Receptor Number	Address	Type
5	[redacted]	Residential
6		Residential
7		Residential
8		Residential
9		Residential
10		Commercial
11		Residential
12		Residential
13		Residential
14		Residential
15		Residential
16		Residential
17		Residential
18		Residential
19		Residential
20		Residential
21		Residential
22		Residential
23		Residential
24		Hotel
25		Residential
26		Residential
27		Residential
28		Residential
29		Residential
30		Residential
31		Residential
32		Residential
33		Residential
34		Residential
35		Residential
36		Residential
37		Residential
38		Residential
39		Residential
40		Residential
41		Residential
42		Residential
43		Residential
44		Residential
45		Residential
46		Residential
47		Residential
48		Residential

Receptor Number	Address	Type
49	[redacted]	Residential
50		Residential
51		Residential
52		Residential
53		Residential
54		Residential
55		Residential
56		Residential
57		Residential
58		Residential
59		Residential
60		Residential
61		Residential
62		Residential
63		Residential
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81		Residential
82		Residential
83		Residential
84		Residential
85		Residential
86		Residential
87		Residential
88		Residential
89		Residential
90		Residential
91		Residential
92		Residential

Receptor Number	Address	Type
93	[redacted]	Residential
94		Residential
95		Residential/Aged Care Facility
96		School
97		Early education centre
98		Playground
99		Playground
100		Playground
101		School
102		Early education centre
103		Walking track
104		Walking track
105		Walking track
106		Walking track
107		School
108		School
109		River
110		River
111		River
112		River
113		Residential
114		Residential
115		Walking track
116		Residential
117		Residential
118		Residential

7 Issues identification

The key issues raised by submitters to the Planning Permit Application public consultation have been addressed in the HRA. The main issues raised with respect to health include:

- Potential health effects from dust including PM_{10}, $PM_{2.5}$ and metals (in particular arsenic);
- Proximity to sensitive receptors such as the aged care facilities, schools and childcare facilities;
- Proximity to residential receptors – proposed TSF4 too close;
- Potential health effects on sensitive populations such as children and people over 65 years of age;
- Potential impact on the users of the Yarrowee River through leakage or seepage from the tailings dam or through windblown dust;
- Potential contamination of drinking water with arsenic; and
- Impacts on people with pre-existing health conditions such as lung disease and cancer.

These issues have been addressed in the following section of the HRA:

- Health Effects of PM_{10} and $PM_{2.5}$ – Section 8.
- Health effects of metals – Section 9.

- Health effects of respirable crystalline silica – Section 10.
- Impacts on groundwater and the Yarrowee River – Section 11.

8 Health Risk Assessment – PM_{10} and $PM_{2.5}$

8.1 Hazard Assessment

The health effects of particles linked to ambient exposures have been well studied and reviewed by international agencies (NEPC, 2010; USEPA, 2004, 2009, 2012, 2019, 2022; WHO, 2021, 2013, 2006; OEHHA, 2000). Most information comes from population-based epidemiological studies that find increases in daily mortality, as well as increases in hospital admissions and emergency room attendances, and exacerbation of asthma associated with daily changes in ambient particle levels. In recent years, there has been an increasing focus on the association between exposure to particles and cardiovascular outcomes. In addition to studies on the various size metrics for particles, research has also investigated the role of particle composition in the observed health effects.

In 2021 WHO conducted a review of the Global Air Quality Guidelines (WHO, 2021). As part of this review WHO commissioned systematic reviews of the epidemiological studies on the short-term and long-term health effects of PM_{10} and $PM_{2.5}$ (Orellano et al., 2020, Chen and Hoek, 2020). The study by Chen and Hoek (2020) found that the evidence base for adverse health effects associated with long-term exposure to PM_{10} and $PM_{2.5}$ has increased substantially compared to the previous global WHO evaluation in 2006. They further concluded that there is clear evidence that both $PM_{2.5}$ and PM_{10} are associated with increased mortality from all causes, cardiovascular disease, respiratory disease, and lung cancer for long-term exposure. The combined hazard ratios (HRs) for natural-cause mortality are 1.08 (95%CI:1.06, 1.09) per 10 µg/m^3 increase in $PM_{2.5}$, and 1.04 (95%CI:1.03, 1.06) per 10 µg/m^3 increase in PM_{10}. The authors stated that there was no clear evidence of a threshold for effect and that if one did exist it was at a very low level.

The review conducted by Orrellano et al (2021) found evidence of a positive association between short-term exposure to PM_{10}, $PM_{2.5}$ and all-cause mortality, cardiovascular, respiratory and cere-brovascular mortality. These results were robust through several sensitivity analyses. The authors concluded that in general, the level of evidence was high, meaning that they could be confident in the associations found in this study.

A study by Cong et al., (2019) investigated the associations between PM_{10} and $PM_{2.5}$ and daily mortality in 652 cities globally. The results of this study showed that on average, an increase of 10 µg/m^3 in the 2-day moving average of PM_{10} concentration, which represents the average over the current and previous day, was associated with increases of 0.44% (95% confidence interval [CI], 0.39 to 0.50) in daily all-cause mortality, 0.36% (95% CI, 0.30 to 0.43) in daily cardiovascular mortality, and 0.47% (95% CI, 0.35 to 0.58) in daily respiratory mortality. The corresponding increases in daily mortality for the same change in $PM_{2.5}$ concentration were 0.68% (95% CI, 0.59 to 0.77), 0.55% (95% CI, 0.45 to 0.66), and 0.74% (95% CI, 0.53 to 0.95). These associations remained significant after adjustment for gaseous pollutants. Associations were stronger in locations with lower annual mean PM concentrations and higher annual mean temperatures. The pooled concentration–response curves showed a consistent increase in daily mortality with increasing PM concentration, with steeper slopes at lower PM concentrations. The authors concluded that the data showed independent associations between short-term exposure to PM_{10} and $PM_{2.5}$ and daily all-cause, cardiovascular, and respiratory mortality in more than 600 cities across the globe.

Several studies conducted in Australia show adverse effects of both PM_{10} and $PM_{2.5}$ on mortality and morbidity outcomes (e.g., Simpson et al., 2005a, b; Barnett et al., 2005, 2006) similar to those observed in overseas studies. The effects observed in the Australian studies appear to be greater per 1 µg/m^3 increase in PM than those observed in the US and Europe but are comparable to the results of Canadian studies.

A review conducted by the World Health Organization (WHO, 2013) concluded that both PM_{10} and $PM_{2.5}$ are related to increases in mortality from respiratory and cardiovascular causes, hospital admissions and emergency department attendances for respiratory and cardiovascular causes including asthma, exacerbation of asthma, and increases in respiratory symptoms. In recent years, studies have provided much stronger evidence for the cardiovascular effects of particles, in particular $PM_{2.5}$.

Birth cohort studies from Europe and elsewhere have found associations between $PM_{2.5}$ and respiratory infections and asthma in young children. Reduced lung function is also linked to $PM_{2.5}$ exposure. Associations with birth outcomes such as low-birth-weight, preterm birth and small gestation age at birth have also been found with long-term exposure to $PM_{2.5}$. These outcomes may affect a child's development later in life. The USEPA (2012) also identified several recent studies that showed associations between long-term exposure to $PM_{2.5}$ and respiratory morbidity including hospital admissions and respiratory symptoms as well as the incidence of asthma. Studies of reproductive and developmental effects also provided evidence for long-term exposure to $PM_{2.5}$ and reduced birth weight.

With respect to short-term effects, the USEPA (2012) found that there were important new studies that increase the evidence for an association between $PM_{2.5}$ and mortality and morbidity outcomes and strengthen the previous US EPA conclusion that there is a causal association between short-term exposure to $PM_{2.5}$ and these outcomes. Associations were found for hospital admissions and emergency department attendances for all cardiovascular and respiratory causes as well as cause specific outcomes, in particular asthma. These findings were confirmed in the more recent reviews (USEPA, 2019;2022).

A number of studies reported by WHO (2013) and USEPA (2012, 2019, 2022) linking long-term exposures have examined additional health outcomes apart from the previously identified respiratory and cardiovascular outcomes. These outcomes include atherosclerosis, adverse birth outcomes and childhood respiratory disease. Studies have also shown possible links between long-term exposure to $PM_{2.5}$ and neurodevelopment and cognitive function, as well as other chronic conditions such as diabetes. In recent years, the evidence for a link between exposure to particles and diabetes has been strengthened.

The Australian Child Health and Air Pollution Study (ACHAPS), which used a similar study design as that used in the Southern Californian Children's Health Study, was conducted to inform the review of the particle standards in the Ambient Air Quality NEPM (Standing Council on Environment and Water (SCEW, 2011). The results of a cross-sectional study of approximately 4,000 Australian school children aged 7-11 years showed varied results for the particulate matter exposures used in ACHAPS. PM_{10} was associated with a decline in lung function (Forced Expiratory Volume in 1 second - FEV_1) post-bronchodilator use and increase in exhaled NO (nitrous oxide, an indicator of airway inflammation), but no overall increase in current respiratory symptoms. $PM_{2.5}$ was associated with an adverse effect on lung function (measured as Forced Vital Capacity (FVC)), post-bronchodilator use and on exhaled NO, with no overall effects on current symptoms, but showed increased risk of lifetime wheezing, asthma, and asthma medication use, and current asthma, use of asthma inhalers and itchy rash in non-atopic children.

8.1.1 Studies near mining operations

Mining related activities generate dust that can be dispersed through air movement over large distances (e.g., Entwistle et al., 2019). In this way contaminants can spread quickly compared to other media such as soil, water and biota (e.g., Csavina et al., 2012). PM_{10} can pass through the throat and nose and cause serious health effects on the heart and lungs (NSW Ministry of Health, 2015), although fine ($PM_{2.5}$) and ultrafine ($PM_{0.1}$) particles have greatest system toxicity (Schraufnagel et al., 2019a). The health impacts of mine dust on nearby communities have been extensively documented in the literature, however impacts are highly site specific (e.g., Guney et al., 2017), determined by the composition of dust as influenced by local geology and industrial processes (e.g. Ettler et al., 2019). Australian research suggests that region-specific emission estimation techniques are necessary to inform predictions and decision making around open-cut mining, due to the strong influence of regional conditions and specific mining activities on particle size fractioning and characteristics of emitted particulates (Richardson et al., 2018).

Particle size plays a large role in determining the health impacts of mine dust, as does their chemical composition, solubility, shape, structure and surface area (Entwistle et al., 2019). While fine particles (<4 µm) often deposit in the alveoli, larger particles tend to be trapped in the mucus lining of airways (Dreary et al., 2021) and can enter the gastrointestinal pathway (Entwistle et al., 2019). This difference in deposition determines the residence time of the particle in the body, and the capacity for extraction of associated contaminants as particles interact with different bodily fluids, pH, and assimilation processes (Dreary et al., 2021).

Mine dusts can impact on the health of nearby communities through numerous pathways including inhalation and ingestion through contact with contaminated soil, crops or water (e.g., Ettler et al., 2019). Children are particularly sensitive to health impacts due to frequent hand-to-mouth behaviour (Entwistle et al., 2019). The health status of individuals in the community is also important, as organs already damaged by disease and lifestyle are likely to have increased susceptibility (Schraufnagel et al., 2019a). The community health impacts of mine dust is further influenced by their interactions with other determinants of disease including economic, cultural and environmental factors (Lewis et al., 2017) and social and psychological stressors (Entwistle et al., 2019) occurring at multiple scales.

Several UK cohort studies have investigated the impact of proximity to coal mining sites on children's respiratory health due to local concern about the health impacts of PM_{10} generated by opencast mining processes related to overburden, soil and diesel. These studies did not find strong evidence of an association between residential proximity to opencast mines and prevalence of respiratory illness (Pless-Mulloli et al., 2001); however, increased exposure to PM_{10} near coal mines resulted in significantly more respiratory consultations at General Practitioners (1.5 vs 1.1 per person per year) (Pless-Mulloli et al., 2000). A systematic review of populations near coal mines across the US, Europe and China found consistent evidence of an increased risk of mortality and/or morbidity across a wide spectrum of circulatory, respiratory, genitourinary and metabolic diseases, in addition to eye, skin and perinatal conditions (Cortes-Ramirez et al., 2018). It should be noted that all of these studies were conducted in small communities, with participants ranging from 1,400 to approximately 5,000 people.

The Cortes-Ramirez (2018) review found that, within the last three decades, epidemiological studies have increasingly investigated the impacts of coal mining on the general populations in proximity to coal mining. Studies referred to in this review using data from hospital records of these populations have found higher rates of morbidity and mortality due to respiratory diseases and cancer, and measures of biomarkers have evidenced greater exposures to environmental contaminants associated with the mining activities. Significant risk measures of mortality were found in 13 studies of mortality including cancers, diseases of the circulatory system, diseases of the respiratory system, diseases of the genitourinary system, and external causes of morbidity.

Recently two studies have been conducted near gold mining operations (Ng et al., 2019; Morais et al., 2019) in Brazil. A study of arsenic from multiple exposure pathways in a gold mining town in Brazil by Ng et al. (2019) included contribution of arsenic (As) through the diet, 38 surface soil/dust samples from residential/commercial dwellings and roadside locations, and 600 airborne dust samples including PM_{10} and total suspended particulates (TSP). The study found that exposure to arsenic was dominated by ingestion of food and water. The contribution of inhaled As was found to be ≤3% of the total daily intake (0.7 and 2.4% in adults and children, respectively), even with the assumption of 100% bioavailability. Arsenic concentration in air in the PM_{10} fraction collected between 2011-2013 found mean arsenic concentrations within 3-5 ng/m^3. The predicted cancer risk from inhalation of dust was determined to be $7.3x10^{-6}$ and $2.2x10^{-5}$ for adults and children, respectively. The authors concluded that dietary exposure was the major contributor to arsenic intake as opposed to the dust via ingestion and inhalation.

The findings of Ng et al. (2019) were in agreement with those by Morais et al. (2019), who reported that As intake from inhalation was minimal (<0.01%) when compared to total arsenic intake considering food and water ingestion in the same study area in Brazil used in the study by Ng et al (2019). Morais et al (2019) found that the largest contribution to arsenic intake was through dietary exposure. The predicted cancer risk contribution by inhalation of arsenic in the PM_{10} fraction was $3.92x10^{-6}$.

Pearce et al. (2012) reported that increasing soil arsenic levels were associated with small but significant increases in past cancer risk in more socioeconomically disadvantaged areas in the goldfields region of Victoria. The study, however, did not provide any details on the specific exposure pathways considered. Excess risks for all cancers in males (RR 1.21 with 95% CI, 1.15-1.27) and females (RR 1.08 (1.03-1.14)) were observed when comparing standardised incidence ratios (SIRs) in the uppermost soil arsenic quintile (54 to 299 mg/kg As) to the lowest quintile (12 to 25 mg/kg As) in more disadvantaged areas. Although not reported in this study, according to the data in the Victorian soil database As levels in Ballarat would fall into the lowest quintile. Increased risks were observed for male leukaemia (1.55 (95th CI: 1.15-2.14)), melanoma (95th CI: 1.52 (1.25-1.85)), colon (1.18 (95th CI: 95th CI: 1.01-1.38) and prostate (1.23 (1.11-1.37)) cancers, and female melanoma (1.29 (1.08-1.55)) and colon (1.21 (1.02-1.44)) cancers. Increasing trends across quintiles of soil arsenic were also detected. The results showing an association between soil arsenic and melanoma, male leukaemia, and prostate cancer confirm those initially reported by Hinwood et al. (1999) in Victoria. No evidence of a strong association between soil arsenic and lung cancer was obtained by either Hinwood et al. (1999) or Pearce et al. (2012).

A more recent study conducted in the US (Bedawai et al ,2022) to evaluate the possible association of skin cancer with source of tap water did not find a relationship between the incidence of melanoma and exposure to arsenic among US adults. After adjusting for age and race/ethnicity, the adjusted odds ratio of participants with >50 µg/L of total urinary arsenic for melanoma or nonmelanoma skin cancer was 1.87 (95% CI, 0.58-6.05) and 2.23 (95% CI, 1.12-4.45) times higher compared with no cancer, respectively. Participants with nonmelanoma skin cancer had 2.06 increased odds of reporting a nonmunicipal water source compared with participants without cancer. The authors concluded that non-municipal water sources were associated with nonmelanoma skin cancer.

In a pilot study in South Africa of a relatively small sample size, Iyaloo et al. (2020) related respiratory health and exposure to dust from gold mine tailings storage facilities using two measures of exposure: exposure group, based on distance lived from the tailings facility – high (n=93) (home <500m from storage facilities), moderate (n=133) (500m – 1.5 Km), and low (n=84) (>15 km, control group); and cumulative exposure index (CEI) derived from exposure group and number of years of residence in each exposure group. Participants were interviewed about respiratory symptoms and had chest X-rays and spirometry. No subject had radiological features of silicosis. Results were adjusted for confounding factors age, sex, a smoking history, occupational history of exposure to vapours, gas, dust or fumes; exposure to biomass fuels; tuberculosis and socio-economic status. Using multivariate logistic regression, significantly high adjusted odds ratios (AORs) for high relative to low exposure group for upper respiratory symptoms (AOR: 2.76, 95% CI: 1.28-5.97), chest wheezing (AOR: 3.78; 95% CI: 1.60-8.96), and spirometry-diagnosed chronic obstructive pulmonary disease (COPD) (AOR: 8.17; 95% CI: 1.01 – 65.85). Similar findings were observed for the high relative to medium exposure group, but no significant associations were found for the medium versus low exposure group.

In India, Shenoy and Kutty (2020) investigated the association between exposure to PM_{10} and respiratory symptoms in a sample of 258 women between 18- and 60-years old living in a gold mining town for over 3 years. The area near the mine had exceptionally high PM_{10} concentrations with average PM_{10} concentration of 1.49 ± 0.74 mg/m^3. Respiratory symptoms were assessed using the American Thoracic Society questionnaire and measurements of lung function including forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), peak expiratory flow rate (PEFR), and FEV1/FVC% using a computerized spirometer. The study found that PM_{10} was associated with respiratory symptoms - complaints of cough were 34%, breathlessness 31%, phlegm 30%, and asthma 20%. Indicators of lung function were significantly reduced - FVC, FEV1, and PEFR were 1.3 ± 0.5 L/s, 1.25 ± 0.49 L/s, and 2.6 ± 1.2 L/s, respectively. FEV/FEV1 was 93.65 ± 9.27%. The authors concluded that the PM_{10} levels measured in this study were associated with increases in respiratory symptoms and significantly decreased lung function in the local female population.

Overall, the findings of the studies summarised above indicate that there are potential health effects from dust arising from mining operations.

8.2 Exposure assessment

Air dispersion modelling was undertaken by T+T to provide inputs to the HRA. Modelling has been completed using the AERMOD dispersion model which is the regulatory dispersion model for use in Victoria. Appendix A provides the detailed approach and assumptions used in the dispersion modelling undertaken to inform this HRA. Emissions have been estimated using a combination of the emission factors contained in the National Pollutant Inventory (NPI) and the equivalent industry reporting materials from the US EPA (known as AP-42) where these provided more recent emission factors. Meteorological modelling has been completed for the site to provide a representative meteorological dataset.

Construction of the Tailings Facility 4 (TSF4) is proposed to occur over six stages. The first stage, known as Zone 1, will comprise 25% of the total storage capacity of TSF4. The remaining stages, known as Zones 2 to 6 will comprise 15% each of the total storage capacity of TSF4.

The modelling was completed for three scenarios:

- Construction of Zone 1 of TSF4 – this is the period of the largest earth movement activity;
- Construction of Zone 6 of TSF4 – this is the period when earth moving activities are closest to residential receptors; and
- Operation of TSF4 – this is a period of minimal emissions from TSF4 but includes ongoing operations of the site.

The modelling for each of the scenarios above include the contribution from the existing operations at the mine. The modelling is for the incremental change from the construction and operation of the TSF4 and well as the contribution from the existing operation. It does not include regional background air quality data.

Table 8.1 shows the processes that have been considered in the modelling of the scenarios.

Table 8.1: Processes considered in the modelling of each scenario

Process	Zone 1 Construction	Zone 6 Construction	TSF4 Operation
North Prince Ventilation Shaft	✓	✓	✓
Diesel Generators 1 - may be used at the commencement of TSF4 operations	✗	✓	✓
Ore handling and processing	✓	✓	✓
Dry stacking of TSF3 whilst Zone 1 of TSF4 is constructed to allow ongoing operations	✓	✗	✗
Extraction, movement and placement of waste rock from current rehab area to embankment	✓	✗	✗
Movement and placement of waste rock from underground to embankment	✗	✓	✗
Extraction, movement and placement of soils from TSF4 excavation area to embankment	✓	✓	✗
Extraction and movement of soils from TSF4 to off-site which cannot be reused within the embankment	✓	✓	✗
Concrete batching plant activities	✓	✓	✓

The following mitigation measures have been adopted in the modelling in accordance with reducing the emissions so far as reasonably practicable as required to meet the General Environmental Duty (GED) to minimise the risk of harm to human health and the environment:

- Watering of all areas where material is handled including:
  - Waste rock stockpiles;
  - Transfer of rock to primary crusher
  - Extraction and placement of TSF3 material on dry stack;
  - Disturbed area of dry stack until crust forms;
  - Extraction and placement of waste rock and soil material;
  - Disturbed areas of waste rock and soil removal, placement until a crust has formed.
- All crushers fully enclosed.
- Sprinklers within ore conveying system.
- Baghouse used within concrete batching.
- Sprinklers used when receiving material for concrete batching.
- Chemical sealants on haul roads with additional watering

In addition, waste rock movements will be limited. Only rock required to construct the TSF4 will be brought to the surface of the mine and this will be transported directly to the TSF4 location. The waste rock will be wet (3-5% moisture) and transported directly from underground to the TSF4 area.

Figure 8.1 shows the 24-hour PM_{10} concentrations for the most affected receptor for all 3 scenarios. In conducting the air dispersion modelling a year of meteorological data had to be selected. A review of the BOM meteorological data for Ballarat, including rainfall, showed that 2018 was the year with the lowest rainfall. This means that there is a higher risk of dust generation due to lower rainfall and therefore will lead to worst case emission estimates. The air dispersion modelling takes into account the emissions from all sources on site through the construction and operation of the TSF4, the mitigation measures (described above) and the meteorological data to predict daily and annual changes in PM_{10} and $PM_{2.5}$ at every sensitive receptor listed in **Table 6.1**. **Figure 8.1** shows the data for the receptor that is predicted to have the highest PM_{10} levels during the construction and operation of the TSF4.

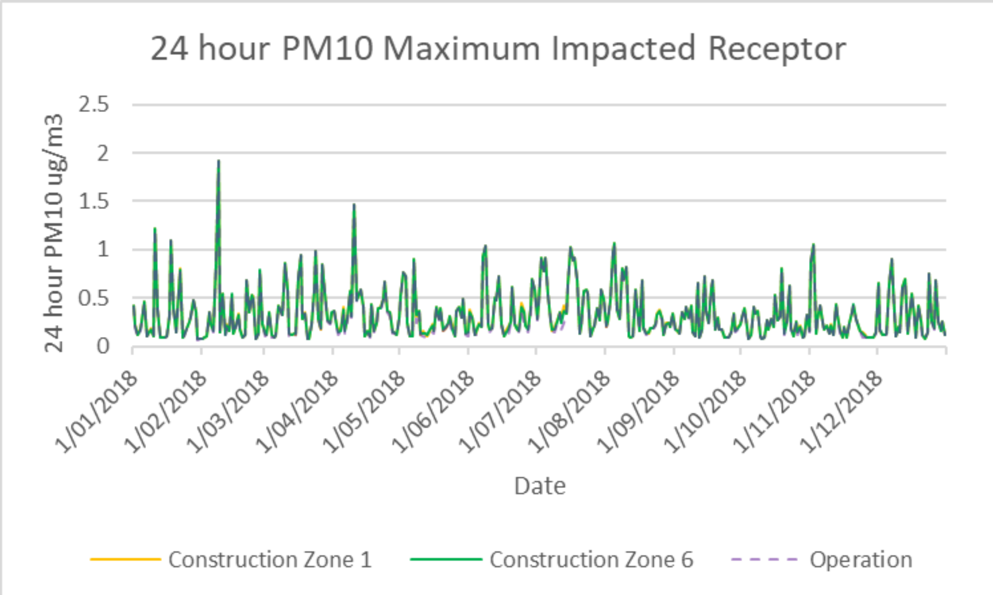

Figure 8.1: 24-hour PM_{10} concentrations most affected receptor

The Environment Reference Standard (ERS) for PM_{10} is 50 µg/m^3. As can be seen from **Figure 8.1** the 24 hour PM_{10} concentrations are small compared to the ERS, even at the most impacted receptor. According to the EPA Guideline for the Assessment and Management of Air Pollution in Victoria (GAMAPV, 2022), an incremental increase in PM levels of less than 4% of the air quality standard is considered to be a negligible risk and no further assessment is required. The maximum predicted 24 hour PM_{10} concentration at the most affected receptor is 4% of the ERS. For all other receptors the predicted PM_{10} concentrations are less than 4% and would be considered by EPA to be negligible.

The data for the most affected receptors have been used in this HRA, for both PM_{10} and $PM_{2.5}$. **Table 8.2** and **Table 8.3** shows the maximum 24-hour and annual average PM_{10} and $PM_{2.5}$ data for each of the receptors shown in **Table 6.1**.

Table 8.2: Maximum predicted 24-hour PM_{10} and $PM_{2.5}$ at Sensitive Receptors for each scenario

Receptor Number	Maximum 24-hr PM_{10} Zone 1 Construction	Maximum 24-hour PM_{10} Zone 6 Construction	Maximum 24-hour PM_{10} Operation	Maximum 24-hr $PM_{2.5}$ Zone 1 Construction	Maximum 24-hr $PM_{2.5}$ Zone 6 Construction	Maximum 24-hr $PM_{2.5}$ Operation
R1	0.45	0.31	0.27	0.24	0.22	0.21
R2	0.46	0.39	0.34	0.31	0.30	0.29

Receptor Number	Maximum 24-hr PM_{10} Zone 1 Construction	Maximum 24-hour PM_{10} Zone 6 Construction	Maximum 24-hour PM_{10} Operation	Maximum 24-hr $PM_{2.5}$ Zone 1 Construction	Maximum 24-hr $PM_{2.5}$ Zone 6 Construction	Maximum 24-hr $PM_{2.5}$ Operation
R3	0.43	0.29	0.25	0.25	0.24	0.22
R4	0.39	0.25	0.15	0.12	0.11	0.11
R5	0.42	0.28	0.17	0.13	0.13	0.13
R6	0.40	0.28	0.24	0.13	0.12	0.12
R7	0.76	0.49	0.24	0.19	0.15	0.11
R8	0.52	0.49	0.26	0.15	0.14	0.10
R9	0.42	0.42	0.15	0.12	0.12	0.10
R10	0.29	0.39	0.17	0.13	0.12	0.12
R11	0.26	0.30	0.19	0.12	0.12	0.11
R12	0.26	0.25	0.21	0.12	0.12	0.12
R13	0.29	0.25	0.22	0.12	0.12	0.11
R14	0.66	0.64	0.58	0.55	0.54	0.53
R15	0.67	0.66	0.62	0.49	0.48	0.48
R16	0.68	0.67	0.65	0.49	0.48	0.48
R17	0.92	0.93	0.89	0.71	0.71	0.70
R18	1.07	1.07	1.04	0.81	0.81	0.81
R19	1.63	1.63	1.63	0.80	0.80	0.80
R20	2.36	2.36	2.35	0.68	0.68	0.67
R21	1.87	1.87	1.86	0.79	0.79	0.79
R22	2.07	2.07	2.05	0.82	0.82	0.81
R23	1.47	1.47	1.45	0.65	0.65	0.65
R24	0.44	0.44	0.42	0.18	0.17	0.17
R25	0.77	0.76	0.75	0.27	0.27	0.26
R26	0.90	0.90	0.90	0.30	0.30	0.30
R27	1.24	1.24	1.24	0.34	0.34	0.34
R28	2.07	2.07	2.07	0.55	0.55	0.55
R29	1.92	1.92	1.91	0.58	0.58	0.58
R30	1.31	1.31	1.30	0.46	0.46	0.46
R31	1.02	1.02	1.01	0.50	0.50	0.50
R32	1.08	1.07	1.06	0.47	0.47	0.47
R33	0.92	0.92	0.92	0.77	0.77	0.76
R34	1.40	1.40	1.40	1.22	1.22	1.22
R35	1.14	1.12	1.02	0.97	0.96	0.93
R36	1.31	1.30	1.29	1.12	1.12	1.12
R37	0.80	0.89	0.77	0.74	0.74	0.73
R38	1.04	1.08	0.79	0.80	0.81	0.73
R39	0.84	0.83	0.46	0.41	0.40	0.36

Receptor Number	Maximum 24-hr PM_{10} Zone 1 Construction	Maximum 24-hour PM_{10} Zone 6 Construction	Maximum 24-hour PM_{10} Operation	Maximum 24-hr $PM_{2.5}$ Zone 1 Construction	Maximum 24-hr $PM_{2.5}$ Zone 6 Construction	Maximum 24-hr $PM_{2.5}$ Operation
R40	1.18	1.66	0.71	0.70	0.75	0.64
R41	1.74	1.69	0.92	1.11	1.04	0.86
R42	1.54	1.57	0.83	0.95	0.92	0.79
R43	1.57	1.49	0.50	0.70	0.62	0.34
R44	1.48	1.05	0.35	0.40	0.30	0.18
R45	0.48	0.46	0.22	0.20	0.18	0.12
R46	0.33	0.22	0.18	0.18	0.17	0.16
R47	0.32	0.22	0.12	0.11	0.08	0.07
R48	0.32	0.22	0.17	0.10	0.10	0.10
R49	0.27	0.20	0.20	0.09	0.09	0.09
R50	0.35	0.23	0.21	0.10	0.10	0.10
R51	0.29	0.21	0.21	0.09	0.08	0.08
R52	0.27	0.22	0.22	0.11	0.10	0.09
R53	0.52	0.32	0.19	0.12	0.10	0.07
R54	0.55	0.38	0.15	0.13	0.11	0.07
R55	0.50	0.33	0.14	0.11	0.09	0.08
R56	0.30	0.38	0.17	0.11	0.11	0.09
R57	0.22	0.29	0.18	0.10	0.10	0.10
R58	0.25	0.24	0.21	0.11	0.10	0.10
R59	0.41	0.39	0.35	0.33	0.33	0.32
R60	0.51	0.51	0.51	0.26	0.26	0.25
R61	0.73	0.73	0.72	0.42	0.41	0.40
R62	1.01	1.01	1.01	0.67	0.67	0.67
R63	0.99	0.99	0.97	0.52	0.52	0.52
R64	0.66	0.66	0.66	0.21	0.21	0.20
R65	0.76	0.76	0.76	0.23	0.23	0.23
R66	1.07	1.07	1.06	0.31	0.31	0.31
R67	1.33	1.33	1.33	0.40	0.40	0.40
R68	0.85	0.85	0.85	0.38	0.38	0.38
R69	0.93	0.93	0.93	0.29	0.29	0.29
R70	0.60	0.59	0.58	0.39	0.39	0.39
R71	0.51	0.51	0.51	0.31	0.31	0.31
R72	0.64	0.64	0.64	0.22	0.22	0.22
R73	0.51	0.51	0.50	0.33	0.33	0.33
R74	0.52	0.52	0.52	0.40	0.40	0.40
R75	0.45	0.45	0.45	0.30	0.30	0.30
R76	1.04	1.04	1.03	0.92	0.92	0.92

Receptor Number	Maximum 24-hr PM_{10} Zone 1 Construction	Maximum 24-hour PM_{10} Zone 6 Construction	Maximum 24-hour PM_{10} Operation	Maximum 24-hr $PM_{2.5}$ Zone 1 Construction	Maximum 24-hr $PM_{2.5}$ Zone 6 Construction	Maximum 24-hr $PM_{2.5}$ Operation
R77	0.81	0.80	0.70	0.67	0.67	0.64
R78	0.30	0.30	0.29	0.17	0.16	0.15
R79	0.49	0.50	0.48	0.32	0.32	0.31
R80	1.35	1.34	1.33	1.24	1.24	1.24
R81	0.42	0.42	0.41	0.31	0.31	0.30
R82	0.99	0.99	0.97	0.93	0.93	0.93
R83	0.58	0.58	0.57	0.48	0.48	0.48
R84	1.11	1.05	0.63	0.73	0.71	0.59
R85	1.26	1.29	0.65	0.79	0.79	0.61
R86	1.16	1.05	0.62	0.71	0.65	0.56
R87	0.54	0.53	0.51	0.44	0.44	0.44
R88	1.16	1.07	0.55	0.68	0.62	0.51
R89	0.97	0.86	0.32	0.48	0.41	0.29
R90	1.66	1.49	0.77	1.00	0.91	0.73
R91	0.82	0.77	0.28	0.38	0.33	0.25
R92	1.93	1.03	0.54	0.62	0.64	0.51
R93	1.31	0.73	0.35	0.42	0.37	0.32
R94	0.89	0.48	0.20	0.25	0.21	0.14
R95	1.37	1.21	0.67	0.79	0.71	0.61
R96	0.46	0.41	0.35	0.33	0.32	0.30
R97	0.60	0.50	0.38	0.37	0.36	0.35
R98	0.35	0.34	0.29	0.26	0.26	0.24
R99	0.80	0.51	0.33	0.33	0.35	0.31
R100	0.33	0.25	0.25	0.23	0.23	0.23
R101	0.32	0.23	0.22	0.10	0.10	0.10
R102	0.16	0.13	0.08	0.05	0.04	0.03
R103	0.35	0.46	0.30	0.16	0.17	0.14
R104	0.83	0.47	0.24	0.18	0.14	0.13
R105	0.59	0.37	0.28	0.27	0.27	0.26
R106	0.53	0.34	0.23	0.20	0.20	0.20
R107	0.24	0.22	0.17	0.15	0.15	0.15
R108	0.24	0.19	0.19	0.08	0.07	0.07
R109	0.35	0.40	0.33	0.19	0.18	0.17
R110	0.64	0.41	0.36	0.33	0.32	0.30
R111	0.63	0.39	0.35	0.32	0.32	0.32
R112	0.50	0.32	0.23	0.15	0.15	0.14
R113	0.18	0.18	0.18	0.10	0.10	0.10

Receptor Number	Maximum 24-hr PM_{10} Zone 1 Construction	Maximum 24-hour PM_{10} Zone 6 Construction	Maximum 24-hour PM_{10} Operation	Maximum 24-hr $PM_{2.5}$ Zone 1 Construction	Maximum 24-hr $PM_{2.5}$ Zone 6 Construction	Maximum 24-hr $PM_{2.5}$ Operation
R114	0.36	0.36	0.36	0.14	0.14	0.14
R115	0.68	0.46	0.31	0.26	0.25	0.25
R116	0.20	0.18	0.17	0.16	0.16	0.16
R117	0.21	0.15	0.10	0.07	0.06	0.05
R118	0.21	0.19	0.19	0.07	0.07	0.07

Table 8.3: Annual Average PM_{10} and $PM_{2.5}$ at Sensitive Receptors for each scenario

Receptor Number	Annual Average PM_{10} Zone 1 Construction	Annual Average PM_{10} Zone 6 Construction	Annual Average PM_{10} Operation	Annual Average $PM_{2.5}$ Zone 1 Construction	Annual Average $PM_{2.5}$ Zone 6 Construction	Annual Average $PM_{2.5}$ Operation
R1	0.05	0.04	0.02	0.02	0.02	0.01
R2	0.05	0.04	0.02	0.03	0.02	0.02
R3	0.05	0.04	0.02	0.02	0.02	0.02
R4	0.04	0.03	0.02	0.02	0.02	0.02
R5	0.05	0.04	0.03	0.02	0.02	0.02
R6	0.05	0.04	0.03	0.03	0.02	0.02
R7	0.05	0.04	0.03	0.03	0.03	0.02
R8	0.05	0.04	0.03	0.03	0.03	0.03
R9	0.04	0.04	0.03	0.03	0.02	0.02
R10	0.04	0.04	0.03	0.03	0.03	0.03
R11	0.05	0.04	0.04	0.03	0.03	0.03
R12	0.05	0.04	0.04	0.03	0.03	0.03
R13	0.05	0.05	0.04	0.03	0.03	0.03
R14	0.14	0.14	0.13	0.11	0.11	0.11
R15	0.18	0.18	0.17	0.14	0.14	0.13
R16	0.19	0.19	0.18	0.14	0.14	0.14
R17	0.21	0.21	0.20	0.14	0.14	0.14
R18	0.22	0.22	0.21	0.14	0.13	0.13
R19	0.22	0.22	0.21	0.11	0.11	0.11
R20	0.23	0.23	0.22	0.10	0.10	0.10
R21	0.28	0.27	0.27	0.10	0.10	0.10
R22	0.20	0.20	0.19	0.08	0.08	0.07
R23	0.15	0.15	0.14	0.06	0.06	0.06
R24	0.09	0.09	0.08	0.04	0.04	0.03
R25	0.14	0.14	0.14	0.05	0.05	0.05
R26	0.18	0.18	0.17	0.07	0.07	0.06
R27	0.20	0.20	0.19	0.08	0.07	0.07

Receptor Number	Annual Average PM_{10} Zone 1 Construction	Annual Average PM_{10} Zone 6 Construction	Annual Average PM_{10} Operation	Annual Average $PM_{2.5}$ Zone 1 Construction	Annual Average $PM_{2.5}$ Zone 6 Construction	Annual Average $PM_{2.5}$ Operation
R28	0.26	0.25	0.25	0.09	0.09	0.09
R29	0.33	0.33	0.32	0.14	0.14	0.13
R30	0.26	0.26	0.25	0.13	0.13	0.13
R31	0.23	0.23	0.22	0.13	0.13	0.13
R32	0.23	0.22	0.21	0.13	0.13	0.13
R33	0.15	0.14	0.13	0.08	0.08	0.08
R34	0.13	0.13	0.11	0.08	0.08	0.07
R35	0.13	0.12	0.10	0.07	0.07	0.06
R36	0.13	0.12	0.09	0.07	0.07	0.06
R37	0.13	0.13	0.08	0.07	0.07	0.05
R38	0.13	0.14	0.07	0.06	0.07	0.05
R39	0.12	0.15	0.06	0.05	0.06	0.04
R40	0.14	0.20	0.05	0.06	0.07	0.03
R41	0.16	0.24	0.05	0.06	0.08	0.03
R42	0.17	0.21	0.04	0.06	0.07	0.03
R43	0.18	0.22	0.04	0.06	0.07	0.03
R44	0.13	0.16	0.03	0.05	0.05	0.02
R45	0.09	0.09	0.03	0.03	0.03	0.02
R46	0.04	0.03	0.02	0.02	0.02	0.01
R47	0.04	0.03	0.02	0.02	0.02	0.01
R48	0.04	0.03	0.02	0.02	0.02	0.01
R49	0.03	0.03	0.02	0.02	0.02	0.01
R50	0.04	0.03	0.02	0.02	0.02	0.02
R51	0.03	0.03	0.02	0.02	0.02	0.01
R52	0.04	0.03	0.02	0.02	0.02	0.02
R53	0.04	0.03	0.02	0.02	0.02	0.02
R54	0.04	0.03	0.03	0.02	0.02	0.02
R55	0.03	0.03	0.02	0.02	0.02	0.02
R56	0.04	0.04	0.03	0.02	0.02	0.02
R57	0.04	0.03	0.03	0.02	0.02	0.02
R58	0.04	0.04	0.04	0.03	0.03	0.03
R59	0.09	0.08	0.08	0.06	0.06	0.06
R60	0.12	0.12	0.11	0.08	0.08	0.08
R61	0.17	0.17	0.16	0.12	0.12	0.12
R62	0.19	0.19	0.18	0.11	0.10	0.10
R63	0.16	0.16	0.15	0.08	0.08	0.07
R64	0.13	0.13	0.13	0.05	0.05	0.05

Receptor Number	Annual Average PM_{10} Zone 1 Construction	Annual Average PM_{10} Zone 6 Construction	Annual Average PM_{10} Operation	Annual Average $PM_{2.5}$ Zone 1 Construction	Annual Average $PM_{2.5}$ Zone 6 Construction	Annual Average $PM_{2.5}$ Operation
R65	0.15	0.15	0.14	0.06	0.06	0.06
R66	0.15	0.15	0.14	0.07	0.07	0.06
R67	0.22	0.22	0.21	0.10	0.10	0.10
R68	0.20	0.20	0.19	0.10	0.10	0.10
R69	0.14	0.14	0.13	0.07	0.07	0.07
R70	0.19	0.19	0.18	0.11	0.11	0.10
R71	0.16	0.16	0.15	0.09	0.09	0.09
R72	0.12	0.12	0.11	0.06	0.06	0.06
R73	0.14	0.14	0.13	0.08	0.08	0.07
R74	0.13	0.13	0.11	0.07	0.07	0.07
R75	0.10	0.10	0.08	0.05	0.05	0.05
R76	0.11	0.11	0.09	0.06	0.06	0.06
R77	0.11	0.11	0.08	0.06	0.06	0.05
R78	0.09	0.09	0.07	0.05	0.05	0.04
R79	0.11	0.11	0.08	0.06	0.06	0.05
R80	0.11	0.12	0.08	0.06	0.06	0.05
R81	0.08	0.09	0.05	0.04	0.04	0.03
R82	0.11	0.11	0.06	0.05	0.06	0.04
R83	0.08	0.09	0.05	0.04	0.04	0.03
R84	0.11	0.13	0.06	0.05	0.05	0.04
R85	0.11	0.13	0.05	0.05	0.06	0.03
R86	0.10	0.11	0.05	0.05	0.05	0.03
R87	0.08	0.08	0.04	0.04	0.04	0.03
R88	0.12	0.14	0.05	0.05	0.06	0.03
R89	0.13	0.16	0.05	0.05	0.06	0.03
R90	0.14	0.15	0.04	0.05	0.05	0.02
R91	0.10	0.09	0.03	0.04	0.04	0.02
R92	0.12	0.13	0.04	0.05	0.05	0.02
R93	0.09	0.08	0.03	0.04	0.03	0.02
R94	0.08	0.09	0.03	0.03	0.03	0.02
R95	0.14	0.17	0.04	0.06	0.06	0.03
R96	0.07	0.07	0.03	0.03	0.03	0.02
R97	0.05	0.05	0.02	0.02	0.02	0.01
R98	0.05	0.05	0.02	0.02	0.02	0.01
R99	0.07	0.07	0.03	0.03	0.03	0.02
R100	0.04	0.03	0.02	0.02	0.02	0.01
R101	0.04	0.03	0.02	0.02	0.02	0.02

Receptor Number	Annual Average PM_{10} Zone 1 Construction	Annual Average PM_{10} Zone 6 Construction	Annual Average PM_{10} Operation	Annual Average $PM_{2.5}$ Zone 1 Construction	Annual Average $PM_{2.5}$ Zone 6 Construction	Annual Average $PM_{2.5}$ Operation
R102	0.02	0.02	0.01	0.01	0.01	0.01
R103	0.06	0.06	0.05	0.04	0.04	0.04
R104	0.06	0.05	0.03	0.03	0.03	0.02
R105	0.06	0.05	0.02	0.03	0.02	0.02
R106	0.06	0.04	0.02	0.03	0.02	0.01
R107	0.03	0.03	0.02	0.01	0.01	0.01
R108	0.03	0.02	0.01	0.01	0.01	0.01
R109	0.07	0.07	0.06	0.05	0.05	0.05
R110	0.06	0.05	0.03	0.03	0.02	0.02
R111	0.07	0.05	0.02	0.03	0.02	0.02
R112	0.06	0.04	0.02	0.02	0.02	0.01
R113	0.05	0.05	0.04	0.03	0.03	0.02
R114	0.06	0.06	0.05	0.03	0.03	0.03
R115	0.09	0.07	0.03	0.04	0.03	0.02
R116	0.02	0.02	0.01	0.01	0.01	0.01
R117	0.03	0.02	0.01	0.01	0.01	0.01
R118	0.03	0.02	0.02	0.01	0.01	0.01

The data shown in **Table 8.2** and **Table 8.3** has been used in the risk characterization.

8.3 Risk characterization

The health risk calculations have been undertaken to assess the potential increases in mortality, hospital admissions and emergency department visits. Local population data was used to calculate the number of attributable health outcomes due to the incremental increase in PM_{10} and $PM_{2.5}$ for each scenario.

As described in Section 8.1, epidemiological studies have shown that a wide range of health effects are associated with exposure to PM. Australian studies (NEPC, 2012; EPHC 2006) have found associations between $PM_{2.5}$ and PM_{10} levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality;
- increases in hospital admissions for respiratory disease and cardiovascular disease; and
- increases in emergency room attendances for asthma.

These health outcomes have been assessed in this health risk assessment for the relevant age groups.

Although no studies specifically investigating the long term effects of exposure to PM on health have been conducted in Australia, there have been several international studies that have shown strong associations between long-term exposure to PM_{10} and $PM_{2.5}$ and increases in mortality. On the basis of the findings of these studies, long-term mortality has also been assessed.

There are several groups within the general population that have been identified as being more vulnerable to the effects of air pollution. These include:

- the elderly;
- people with existing cardiovascular and respiratory disease;
- people with asthma;
- low socio-economic groups; and
- children.

Compared to healthy adults, children are generally more sensitive to air pollutants as their exposure is generally higher. The reasons for this are that children inhale more air per minute and have a larger contact lung surface area relative to their size compared to adults. Other factors that increase the potential for exposure in children are that children generally spend more time outdoors and more time exercising.

Studies have shown that people who have a low socioeconomic status (SES) also form a group within the population that is particularly vulnerable to the effects of air pollution.

To calculate the number of people that might be affected by air pollution, exposure-response functions for each outcome being assessed are required. These functions are a measure of the change in the health outcome within the population for a given change in PM_{10} or $PM_{2.5}$ concentration for example a 1% increase per 10 µg/m^3 increase in pollutant concentration.

The exposure-response functions in **Table 8.4** and **Table 8.5** have been taken from Australian studies and in particular two multicity meta-analyses (Simpson et al., 2005; EPHC, 2011). The use of Australian meta-analyses is consistent with the NHMRC (2006) and NEPC (2011) recommendations for selecting exposure-response functions.

The exposure-response functions for long-term exposure to PM_{10} and $PM_{2.5}$ have been taken from the American Cancer Society study (HEI, 2009). This study is considered by the WHO as the most reliable study to assess long-term effects of air pollution. The use of these values is also consistent with the recommendations made by NHMRC (2006) and NEPC (2011).

Table 8.4: Exposure response functions for PM_{10} for selected health outcomes

Outcome	Averaging Period	Exposure Response Function per 1 µg/m^3 increase in PM_{10}
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.004
Daily all-cause mortality(non-accidental) all ages	24 hours	0.002
Daily mortality cardiovascular disease all ages	24 hours	0.002
Hospital Admissions respiratory disease 65+ years	24 hours	0.003
Hospital Admissions cardiac disease 65+ years	24 hours	0.002
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.0013
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits asthma 1-14 years	24 hours	0.015

Source: EPHC (2011) and HEI (2009)

Table 8.5 shows the exposure response functions used for $PM_{2.5}$.

Table 8.5: Exposure response functions for $PM_{2.5}$ for selected health outcomes

Outcome	Averaging Period	Exposure Response Function per 1 µg/m^3 increase in $PM_{2.5}$
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.006
Annual cardiopulmonary mortality 30+	Annual average	0.014
Annual mortality ischemic heart disease 30+ years	Annual average	0.024
Annual mortality lung cancer 30+ years	Annual average	0.014
Daily all-cause mortality (non-accidental) all ages	24 hours	0.0023
Daily mortality cardiovascular disease - all ages	24 hours	0.0013
Hospital Admissions respiratory disease 65+ years	24 hours	0.004
Hospital Admissions cardiac disease 65+ years	24 hours	0.005
Hospital Admissions cardiovascular disease 65+ years	24 hours	0.003
Hospital Admissions ischemic heart disease 65+ years	24 hours	0.004
Hospital Admissions COPD 65+ years	24 hours	0.004
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.005
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits asthma 1-14 years	24 hours	0.0015

Source: EPHC (2011) and HEI (2009)

Using the predicted annual average and 24-hour average PM_{10} and $PM_{2.5}$ concentrations for the most affected receptors, the population in each of these locations for the each of the suburban areas assessed (Mount Pleasant- Canadian, Mount Clear – Mount Helen, Sebastopol-Redan) and the exposure response function in **Table 8.4** and **Table 8.5**, the health effects attributable to PM_{10} and $PM_{2.5}$ been calculated using the following equation:

Number of attributable cases = exposure response function (Change in health outcome) per 1µg/m^3 increase in PM x PM concentration x baseline health incidence rate/ 100,000 population x actual population

The annual average concentrations have been used to calculate the long-term health risks. The daily concentrations predicted for each day of the year have been used to calculate the short-term health risks.

In this assessment it is assumed that the data for the maximum impacted receptor point is representative of the whole population of each of the suburbs that have been assessed. This is a conservative assumption that will provide an overestimate of the risk to the whole population as the PM levels decrease with distance from the mine site.

For each scenario the number of attributable cases is shown **Table 8.6**(PM_{10}) and **Table 8.7** ($PM_{2.5}$). The number of attributable cases is the increase in the number, for example hospital admissions for respiratory disease that may arise from exposure to PM specifically from the construction and operation of the TSF4.

Table 8.6: Attributable Health Outcomes (additional cases per year) due to PM_{10} from the Construction and Operation of TSF4

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian			
All-cause mortality 30+years (long-term)	0.06	0.06	0.06
Daily mortality all causes all ages	0.03	0.03	0.03
Daily mortality cardiovascular disease all ages	0.009	0.009	0.009
Hospital admissions respiratory disease 65+ years	0.07	0.07	0.07
Hospital admissions cardiac disease 65+ years	0.06	0.06	0.06
Hospital admissions respiratory disease 15-64 years	0.05	0.05	0.05
Emergency Department visits asthma 1-14 years	0.007	0.007	0.007
Mount Clear – Mount Helen			
All-cause mortality 30+years (long-term)	0.03	0.03	0.02
Daily mortality all causes all ages	0.01	0.02	0.009
Daily mortality cardiovascular disease all ages	0.004	0.005	0.003
Hospital admissions respiratory disease 65+ years	0.03	0.04	0.02
Hospital admissions cardiac disease 65+ years	0.03	0.03	0.02
Hospital admissions respiratory disease 15-64 years	0.02	0.03	0.01
Emergency Department visits asthma 1-14 years	0.004	0.005	0.003
Sebastopol - Redan			
All-cause mortality 30+years (long-term)	0.02	0.01	0.01
Daily mortality all causes all ages	0.008	0.007	0.006
Daily mortality cardiovascular disease all ages	0.002	0.002	0.002
Hospital admissions respiratory disease 65+ years	0.02	0.02	0.02
Hospital admissions cardiac disease 65+ years	0.02	0.02	0.01
Hospital admissions respiratory disease 15-64 years	0.01	0.01	0.009

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Emergency Department visits asthma 1-14 years	0.002	0.001	0.001

As can be seen in **Table 8.6**, the predicted number of attributable cases due to PM_{10} from construction and operation of the TSF4 for all areas assessed is low. The highest risk would be for hospital admissions for respiratory disease in people over 65 years of age in the Mount-Pleasant-Canadian area, with 6 additional admissions per 100 years attributable to PM_{10} from the construction and operation of the TSF4. The risks in all other areas and for all other health outcomes are lower than that predicted for hospital admissions for respiratory disease in people 65 years and older.

The highest risk predicted for emergency department attendances for children with asthma is low for all areas with an additional 2-7 attendances per 1000 years predicted across all areas.

It should be noted that the construction of each Zone of the TSF4 will be undertaken over a period of 10 to 12 months and the life of the TSF4 is 10 years. These timelines are shorter than those over which adverse health effects would be observed and as indicated by the results presented in **Table 8.6** the risks to the local population from PM_{10} from the proposed construction and operation of the TSF4 are very low and would not be detected in the population.

As can be seen from **Table 8.7**, similar to PM_{10}, the predicted number of attributable cases due to $PM_{2.5}$ from the construction and operation of the TSF4 are low for all areas assessed. The highest risk would be for hospital admissions for pneumonia and bronchitis in people over 65 years of age with 7 additional admissions per 100 years attributable to $PM_{2.5}$ from the construction and operation of the TSF4. The risks for all other health outcomes for all areas assessed are lower than that predicted for hospital admissions for pneumonia and bronchitis in people 65 years and older.

As shown in **Table 8.7,** the risks to the local populations from $PM_{2.5}$ from the proposed construction and operation of the TSF4 are very low and would not be detected in the population.

Table 8.7: Attributable Health Outcomes (additional cases per year) due to $PM_{2.5}$ from the Construction and Operation of TSF4

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian			
All-cause mortality 30+years (long-term)	0.04	0.04	0.04
Cardiopulmonary mortality 30+years (long-term)	0.04	0.04	0.04
Ischemic Heart Disease 30+ years (long-term)	0.03	0.03	0.03
Lung cancer mortality 30+ years (long-term)	0.006	0.006	0.006
Daily mortality all causes all ages	0.02	0.02	0.02
Daily mortality cardiovascular disease all ages	0.003	0.003	0.003
Hospital admissions respiratory disease 65+ years	0.04	0.04	0.04
Hospital admissions cardiac disease 65+ years	0.06	0.06	0.06
Hospital admissions pneumonia and bronchitis 65+ years	0.07	0.07	0.07
Hospital admissions cardiovascular disease 65+ years	0.01	0.01	0.01
Hospital admissions respiratory disease 15-64 years	0.02	0.02	0.02
Emergency Department visits asthma 1-14 years	0.003	0.003	0.003
Mount Clear – Mount Helen			
All-cause mortality 30+years (long-term)	0.02	0.02	0.02
Cardiopulmonary mortality 30+years (long-term)	0.02	0.02	0.02
Ischemic Heart Disease 30+ years (long-term)	0.01	0.01	0.01
Lung cancer mortality 30+ years (long-term)	0.003	0.003	0.002
Daily mortality all causes all ages	0.007	0.007	0.007
Daily mortality cardiovascular disease all ages	0.001	0.001	0.001
Hospital admissions respiratory disease 65+ years	0.01	0.01	0.01
Hospital admissions cardiac disease 65+ years	0.03	0.03	0.02
Hospital admissions pneumonia and bronchitis 65+ years	0.03	0.03	0.03
Hospital admissions cardiovascular disease 65+ years	0.005	0.005	0.005

Health Outcome	Construction Zone 1	Construction Zone 6	Operation
Hospital admissions respiratory disease 15-64 years	0.008	0.008	0.008
Emergency Department visits asthma 1-14 years	0.002	0.002	0.002
Sebastopol - Redan			
All-cause mortality 30+years (long-term)	0.01	0.01	0.01
Cardiopulmonary mortality 30+years (long-term)	0.01	0.01	0.01
Ischemic Heart Disease 30+ years (long-term)	0.009	0.009	0.008
Lung cancer mortality 30+ years (long-term)	0.002	0.002	0.002
Daily mortality all causes all ages	0.005	0.005	0.005
Daily mortality cardiovascular disease all ages	0.001	0.001	0.001
Hospital admissions respiratory disease 65+ years	0.01	0.01	0.01
Hospital admissions cardiac disease 65+ years	0.02	0.02	0.02
Hospital admissions pneumonia and bronchitis 65+ years	0.03	0.03	0.03
Hospital admissions cardiovascular disease 65+ years	0.005	0.004	0.004
Hospital admissions respiratory disease 15-64 years	0.006	0.006	0.006
Emergency Department visits asthma 1-14 years	0.001	0.001	0.001

9 Metals

9.1 Hazard assessment

Beyond the impacts of the dust itself, particles can also carry potentially toxic elements including metals, which convey additional health risks (e.g., Csavina et al., 2012). Once solubilised, these contaminants can be transferred directly into the blood stream where a range of toxic effects have been documented, including carcinogenicity (for arsenic, cadmium, chromium and nickel), neurological effects (lead and mercury) and renal damage (chromium, cadmium and mercury) (Dreary et al., 2021).

The transition metals (cobalt, copper, nickel and zinc) are also of concern due to their ability to generate reactive oxygen species within the body, and iron bearing minerals and oxides are known to cause lung inflammation (Entwistle et al., 2019). The mining and processing of ore in semi-arid regions tends to generate metalloid-containing dust, where arid conditions increase risks of dust generation and distribution (Ettler et al., 2019).

There is not a clear correlation between metal(loid) loads and particle size, which can be influenced by mineralogical composition and the source of contamination (Ettler et al., 2019), and the pathway of metal contaminants from mining activities into the indoor residential environment remains poorly understood (Entwistle et al., 2019). The community health impact of metals present in house dust on residents near mine sites has been studied by Zota et al., (2011; 2016). These studies have looked at the metal concentrations in indoor dust and biomarkers in children less than 2 years of age.

Children in this age group are more vulnerable to the impact of contaminants in house dust as they spend more time on the floor and have significant hand to mouth behaviours. The study showed that there was a correlation in blood lead in children with dust from the mine site known to contain lead. Other metals, such as manganese, arsenic and cadmium were at lower levels and did not differ significantly from levels in homes away from the mine site.

Studies conducted in the goldfield areas of Victoria have shown elevated levels of arsenic in the toenails of children (Martin et al., 2013; Pearce et al., 2007). In the study by Martin et al., (2013), arsenic uptake from soil by children living in goldfield areas in Victoria was demonstrated using toenail arsenic concentration as a biomarker, with evidence of some systemic absorption associated with periodic exposures. Residential soil samples (N = 14) and toenail clippings (N = 24) were analyzed for total arsenic using instrumental neutron activation analysis, including 19 toenail clippings samples that were obtained from the same study cohort in 2006. Toenail arsenic concentrations in 2011 (geometric mean, 0.171 lg/g; range, 0.030–0.540 lg/g) were significantly lower than those in a previous study (Pearce et al., 2007) (geometric mean, 0.464 lg/g; range, 0.150–2.10 lg/g; p < 0.001). Although the levels were lower than in the previous study, toenail arsenic concentrations were correlated with soil arsenic levels. Spending time outdoors more often and for longer periods correlates with increased arsenic uptake. In this study there was no identification of adverse health effects associated with arsenic levels in toenails.

A number of metals have been identified as being present in the tailings and soil associated with the with the construction and operation of the TSF4 as well as the current mine operations. These are summarised in **Table 9.1**.

Table 9.1: Metals Assessed for Construction and Operation of Proposed TSF4

Metal	
Antimony	Vanadium
Arsenic	Cadmium
Lead	Chromium VI and VIII
Barium	Zinc
Manganese	Cobalt
Nickel	Strontium

These metals have a range of health effects from non-cancer respiratory effects (e.g., shortness of breath, coughing, and wheezing), effects on the cardiovascular and central nervous systems, gastrointestinal effects, through to cancer.

9.2 Exposure Assessment

Calculated emission rates for total suspended particles (TSP) and particulate matter (PM_{10} and $PM_{2.5}$) were used as input to the dispersion model to predict the deposition rate and ambient air concentration of heavy metals at sensitive receptors described in Section 6 of this report. The model results were scaled by the proportion of heavy metals from laboratory analysis of solid samples of waste rock, mine tailings, surface and subsoil within the TSF4 area and applying the proportion to the modelled results of TSP, PM_{10} and $PM_{2.5}$. For concrete batching activities heavy metal concentrations were not available, with emission factors for metals from the United States Environmental Protection Agency (US EPA) used instead.

To assess the potential health risk from metals, the metals concentrations in the PM_{10} fraction have been used. The analytical data for the metal content in the tailings is shown in Appendix 2. **Table 9.2** summarises the maximum PM_{10} metal concentrations – both 24 hour and annual average – for the most affected receptors in each of the areas assessed in this HRA. These values have been used in the risk characterization for both cancer and non-cancer risks. For the operation scenario, the tailings are wet and therefore there are no emissions from metals. The metals shown in **Table 9.2** and subsequent tables for the operation scenario arise from the dust from the haul roads and other earth moving activities. For all metals marked '-', this means that they are not present in the dust on the site.

Table 9.2: Maximum PM_{10} Metal Concentrations (µg/m^3)

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
Mount Pleasant - Canadian				
Antimony	Annual	0.000000036	0.000000027	-
	24 hours	0.0000011	0.00000036	-
Arsenic	Annual	0.0000030	0.0000017	0.000031
	24 hours	0.000047	0.000020	0.00018
Barium	Annual	0.00000043	0.00000029	-
	24 hours	0.000012	0.0000038	-
Cadmium	Annual	0.000000017	0.0000000055	-
	24 hours	0.00000030	0.000000073	-
Chromium	Annual	0.00000021	0.00000016	-
	24 hours	0.0000061	0.0000022	-
Cobalt	Annual	0.00000015	0.00000014	0.0000019
	24 hours	0.0000040	0.0000017	0.000011
Lead	Annual	0.00000025	0.00000018	-
	24 hours	0.0000074	0.0000024	-
Manganese	Annual	0.0000022	0.0000035	0.000078
	24 hours	0.000036	0.000043	0.00046
Nickel	Annual	0.00000021	0.00000014	-
	24 hours	0.0000050	0.0000018	-
Strontium	Annual	0.00000052	0.00000040	-
	24 hours	0.000017	0.0000053	-
Vanadium	Annual	0.00000018	0.00000011	-
	24 hours	0.0000050	0.0000015	-

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
Zinc	Annual	0.00000046	0.00000064	0.000013
	24 hours	0.000010	0.0000079	0.000078
Mount Clear – Mount Helen				
Antimony	Annual	0.00000032	0.00000044	-
	24 hours	0.0000044	0.0000040	-
Arsenic	Annual	0.000012	0.000014	0.000016
	24 hours	0.00014	0.00011	0.00027
Barium	Annual	0.0000035	0.0000047	-
	24 hours	0.000047	0.000043	-
Cadmium	Annual	0.000000070	0.000000088	-
	24 hours	0.00000093	0.00000081	-
Chromium	Annual	0.0000017	0.0000023	-
	24 hours	0.000023	0.000021	-
Cobalt	Annual	0.0000012	0.0000015	0.0000010
	24 hours	0.000016	0.000014	0.000017
Lead	Annual	0.0000020	0.0000028	-
	24 hours	0.000028	0.000025	-
Manganese	Annual	0.000012	0.000014	0.000042
	24 hours	0.00014	0.00012	0.00069
Nickel	Annual	0.0000012	0.0000017	-
	24 hours	0.000017	0.000015	-
Strontium	Annual	0.0000048	0.0000066	-
	24 hours	0.000066	0.000060	-
Vanadium	Annual	0.0000014	0.0000018	-
	24 hours	0.000019	0.000017	-
Zinc	Annual	0.0000033	0.0000040	0.0000070
	24 hours	0.000039	0.000032	0.00012
Sebastopol - Redan				
Antimony	Annual	0.000000068	0.000000035	-
	24 hours	0.0000013	0.00000073	-

Metal	Averaging Period	Construction Zone 1	Construction Zone 6	Operation
Arsenic	Annual	0.0000027	0.0000016	0.0000060
	24 hours	0.000071	0.000036	0.000069
Barium	Annual	0.00000074	0.00000037	-
	24 hours	0.000014	0.0000078	-
Cadmium	Annual	0.000000015	0.0000000069	-
	24 hours	0.00000035	0.00000015	-
Chromium	Annual	0.00000036	0.00000018	-
	24 hours	0.0000068	0.0000039	-
Cobalt	Annual	0.00000026	0.00000016	0.00000037
	24 hours	0.0000055	0.0000034	0.0000043
Lead	Annual	0.00000043	0.00000022	-
	24 hours	0.0000083	0.0000046	-
Manganese	Annual	0.0000028	0.0000023	0.000015
	24 hours	0.000082	0.000060	0.00018
Nickel	Annual	0.00000027	0.00000014	-
	24 hours	0.0000053	0.0000029	-
Strontium	Annual	0.0000010	0.00000052	-
	24 hours	0.000019	0.000011	-
Vanadium	Annual	0.00000029	0.00000015	-
	24 hours	0.0000056	0.0000031	-
Zinc	Annual	0.00000074	0.00000053	0.0000026
	24 hours	0.000018	0.000013	0.000029

9.3 Risk characterization

The purpose of the risk characterization is to estimate potential risks associated with exposure to the metals in the dust from the proposed construction and operation of the TSF4. For the assessment of health effects where there is a known threshold for effect, the predicted short-term or annual average metal concentration is compared to the health-based guideline values. The ratio of the predicted level to the guideline is termed the hazard quotient (HQ) (enHealth, 2012):

HQ = predicted metal concentration / health-based guideline

The hazard quotients associated with predicted metal concentrations have been estimated for all sensitive receptors considered in this HRA.

The risks presented in the following sections have been calculated using data from the air quality modelling that has been conducted assuming adoption of the mitigation measures outlined in the Section 8.2. Both non-carcinogenic and carcinogenic risks have been assessed as applicable. For non-carcinogenic risks, both short-term and long-term, the air quality guidelines shown in **Table 9.3** have been used to calculate the hazard quotients. For the carcinogenic metals – arsenic, cadmium, chromium VI, lead and nickel – the Californian EPA Office Environmental Health Hazard Assessment (OEHHA) unit risk factors have been used to calculate the incremental lifetime cancer risk from the construction and operation of the TSF4. A unit risk factor is the increase in cancer per 1 µg/m^3 increase in carcinogenic substance in air. The enHealth acceptable risk level of 1x10^{-5} has been used to assess the incremental lifetime cancer risk from these activities. This acceptable risk level is also used by WHO and the USEPA. A cancer risk of 1x10^{-6} (1 case in 1 million population) is considered negligible by all these agencies.

9.3.1 Non-carcinogenic risks

Table 9.3 shows the air quality guidelines used in the risk assessment for the metals.

Table 9.3: Non-carcinogenic risks

Metals	Health Based Air Quality Guidelines (µg/m^3)	Health Based Air Quality Guidelines Sources
Arsenic	1-hour – 0.2 Annual average – 0.015	OEHHA chronic reference exposure level REL (2015)
Antimony	24-hours – 1 Annual average – 0.3	ATSDR inhalation minimal risk level (MRL) (2022)
Barium	1-hour – 5 Annual average – 0.5	TCEQ ESL
Cadmium	Annual average – 0.02	OEHHA chronic reference exposure level
Chromium VI	Annual average – 0.2	OEHHA chronic reference exposure level
Chromium III	8-hour – 0.12 Annual average – 0.06	OEHHA Acute reference exposure level OEHHA chronic reference exposure level
Cobalt	24-hours – 0.095 Annual average – 0.0017	TCEQ 24 hours AMCV health (2017) TCEQ long-term AMCV health (2017)
Lead	Annual average – 0.5	EPA Victoria ERS 26 May 2021
Manganese	24-hours average – 0.17 Annual average – 0.09	OEHHA 8-hour reference exposure level REL (2015) OEHHA chronic reference exposure level REL (2015)
Nickel	8-hours – 0.06 Annual average – 0.014	OEHHA acute reference exposure level REL (2015) OEHHA chronic reference exposure level
Strontium	24-hours – 20 Annual average – 2	TCEQ short-term ESL (2003) TCEQ long-term ESL (2003)
Vanadium	24-hours – 0.31 Annual average – 0.066	TCEQ 24-hour health (2021) TCEQ long-term AMCV health (2021)
Zinc	1 hour – 20	TCEQ short-term ESL (2010)

Metals	Health Based Air Quality Guidelines (µg/m³)	Health Based Air Quality Guidelines Sources
	Annual average – 2	TCEQ long-term ESL (2010)

The hazard quotients for non-carcinogenic risks for the metals for the most affected receptors are shown in **Table 9.4** for the construction scenarios and operation of the TSF4**.**

Table 9.4: Acute and Chronic Hazard Quotients for Metals – Construction and Operation TSF4

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Mount Pleasant – Canadian						
Antimony	0.00000023	0.000000071		0.000000072	0.000000053	
Arsenic	0.00024	0.00010	0.000182	0.00020	0.00011	0.00204
Barium	0.0000025	0.00000076		0.00000086	0.00000057	
Cadmium				0.00000085	0.00000027	
Chromium III	0.000013	0.0000046		0.0000035	0.0000027	
Chromium VI				0.0000010	0.00000080	
Cobalt	0.000020	0.0000084	0.00018	0.0000073	0.0000068	0.0000068
Lead				0.00000051	0.00000035	
Manganese				0.000025	0.000038	0.000038
Nickel	0.000025	0.0000091		0.000015	0.000010	
Strontium	0.00000084	0.00000027		0.00000026	0.00000020	
Vanadium	0.00000025	0.000000075		0.000000088	0.000000056	
Zinc	0.00000051	0.00000039	0.000078	0.00000023	0.00000032	0.00000032
Mount Clear – Mount Helen						
Antimony	0.00000088	0.00000081		0.00000064		
Arsenic	0.00071	0.00057	0.00027	0.00079		0.00109

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Barium	0.0000095	0.0000086		0.0000069	0.0000094	
Cadmium				0.0000035	0.0000044	
Chromium III	0.000048	0.000044		0.000028	0.000038	
Chromium VI				0.0000084	0.000011	
Cobalt	0.000078	0.000068	0.00027	0.000060	0.000077	0.000077
Lead				0.0000041	0.0000055	
Manganese				0.000133	0.00015	0.00015
Nickel	0.000084	0.000077		0.000089	0.000119	
Strontium	0.0000033	0.0000030		0.0000024	0.0000033	
Vanadium	0.00000093	0.00000085		0.00000068	0.00000092	
Zinc	0.0000020	0.0000016	0.00012	0.0000016	0.0000020	0.000002
Sebastopol – Redan						
Antimony	0.00000026	0.00000015		0.00000014	0.000000069	
Arsenic	0.00035	0.00018	0.000069	0.00018	0.00011	0.00040
Barium	0.0000028	0.0000016		0.0000015	0.00000074	
Cadmium				0.00000076	0.00000035	
Chromium III	0.000014	0.0000081		0.0000060	0.0000031	
Chromium VI				0.0000018	0.00000092	
Cobalt	0.000028	0.000017	0.000069	0.000013	0.0000078	0.0000078

Metal	Construction Zone 1 Acute HQ	Construction Zone 6 Acute HQ	Operations Acute HQ	Construction Zone 1 Chronic HQ	Construction Zone 6 Chronic HQ	Operations Chronic HQ
Lead				0.00000087	0.00000044	
Manganese				0.000031	0.000026	0.000026
Nickel	0.000027	0.000014		0.000019	0.0000097	
Strontium	0.00000095	0.00000055		0.00000051	0.00000026	
Vanadium	0.00000028	0.00000015		0.00000015	0.000000073	
Zinc	0.00000092	0.00000063	0.000029	0.00000037	0.00000027	0.00000027

As shown in **Table 9.4**, all hazard quotients for all scenarios are well below the acceptable limit of 1. A hazard quotient of 0.1 is considered negligible by enHealth, WHO and US EPA. All HQs in **Table 9.4** are well below 0.1 indicating that all potential risk from exposure to metals from the construction and operation of the TSF4 are negligible.

The hazard quotients for the individual metals have not been summed. It is only possible to sum the hazard quotients if the health effects associated with exposure to the metals are the same. Given that all the HQs in **Table 9.4** are orders of magnitude below the acceptable and negligible risk levels, even if they were summed the risk would still be negligible.

9.3.2 Cancer risks

The carcinogenic risks for arsenic, cadmium, chromium VI, lead and nickel are shown in **Table 9.5**. The annual average PM_{10} concentrations modelled as part of the air dispersion modelling undertaken for this HRA have been used to calculate the annual average metal concentrations.

As can be seen from **Table 9.5** all carcinogenic risk levels are several orders of magnitude below $1x10^{-5}$ even at the most impacted receptors. enHealth, consistent with WHO guidance, considers that risks below $1x10^{-6}$ are negligible. All carcinogenic risks calculated for the metals associated with the construction and operation of the TSF4 are well below this level. The risk is therefore considered to be negligible. The cancer risk estimate for arsenic is an overestimate of the risk as it has assumed that all the arsenic is bioavailable. Even with this conservative assumption the risk is still considered to be negligible.

Table 9.5: Cancer risks from the Construction and Operation of TSF4 – Most Affected Receptors

Scenario	Cancer Risk				
	As	Pb	Cd	Ni	Cr VI
Mount Pleasant – Canadian					
Construction Zone 1	$9.8x10^{-9}$	$3.1x10^{-12}$	$7.2x10^{-11}$	$4.6x10^{-11}$	$3.1x10^{-8}$
Construction Zone 6	$4.9x10^{-9}$	$2.1x10^{-12}$	$2.3x10^{-11}$	$2.9x10^{-11}$	$2.4x10^{-8}$
Operations	$1x10^{-7}$				
Mount Clear - Mount Helen					
Construction Zone 1	$3.9x10^{-8}$	$2.4x10^{-11}$	$2.9x10^{-10}$	$2.9x10^{-10}$	$2.5x10^{-7}$
Construction Zone 6	$4.5x10^{-8}$	$3.3x10^{-11}$	$3.7x10^{-10}$	$3.8x10^{-10}$	$3.4x10^{-7}$
Operations	$5.4x10^{-8}$				
Sebastopol - Redan					
Construction Zone 1	$8.8x10^{-9}$	$5.2x10^{-12}$	$6.4x10^{-11}$	$6.2x10^{-11}$	$5.4x10^{-8}$
Construction Zone 6	$5.3x10^{-9}$	$2.6x10^{-12}$	$2.9x10^{-11}$	$3.1x10^{-11}$	$2.8x10^{-8}$
Operations	$2x10^{-8}$				

OEHHA (2015) recommends that in conducting a cancer risk assessment a 10-fold factor be added to the risk estimates for children. This is to account for a greater vulnerability due to the developmental stages during childhood. Even with a 10-fold in risk to account for this, the cancer risk for all the metals and all areas assessed are below negligible risk levels.

10 Respirable Crystalline Silica

10.1 Hazard assessment

Respirable crystalline silica (RCS) can bioaccumulate in the lungs and cause respiratory disease. Large bioaccumulated loads of RCS in the lung can cause a build-up of connective tissue, termed silicosis, a specific form of pneumoconiosis. Silicosis is an irreversible and progressive condition. The majority of the epidemiological evidence of adverse health effects associated with exposure to RCS comes from occupational studies. There are limited studies of communities exposed to RCS.

Exposure to RCS at levels that appear not to cause silicosis can cause chronic bronchitis and chronic obstructive airways disease. An increased susceptibility to tuberculosis occurs in workers with silicosis. Epidemiological studies have also revealed an excess prevalence of autoimmune diseases like scleroderma, rheumatoid arthritis and systemic lupus erythematosus associated with exposure to RCS.

There are several epidemiological studies that have been conducted in communities close to gold mines in Johannesburg, South Africa. The findings of these studies have shown mixed results. A study by Kootbodien et al. (2019) found no association between non-occupational exposures and tuberculosis but did find an association with occupational exposures. A further study by Iyaloo et al. (2020) found that people living within 500 m of a gold mine had increases in adverse respiratory health effects such as upper respiratory symptoms, wheeze and chronic obstructive airways disease, associated with exposure to crystalline silica compared to communities living further away (>1.5 km). Chronic bronchitis and tuberculosis risks did not differ significantly among groups.

RCS has been classified by the International Agency for Research into Cancer (IARC) as a category 1 carcinogen as it has been shown to cause cancer in humans. It is accepted that RCS does not directly cause DNA damage. It is believed that inflammatory processes in the lung are the driving force for carcinogenicity rather than direct DNA damage. It is generally accepted that an inflammation-based mechanism as described in IARC (1997) is a likely mechanism responsible for the induction of lung cancer associated with exposure to RCS. It is accepted that inflammation and development of silicosis occurs before the development of lung cancer and that there is a threshold, or safe level, below which silicosis does not develop.

10.1.1 Exposure assessment

The modelling undertaken for this HRA has used the conservative assumption that the predicted $PM_{2.5}$ concentrations were 100% RCS. This will lead to an overestimate of risk posed by the increase in RCS due to the proposed construction and operation of the TSF4.

Table 10.1: Maximum Annual Average RCS concentrations

Receptor	Scenario	Annual Average RCS (µg/m^3)
Mount Pleasant - Canadian	Construction Zone 1	0.14
	Construction Zone 6	0.14
	Operation	0.14
Mount Clear – Mount Helen	Construction Zone 1	0.08
	Construction Zone 6	0.08
	Operation	0.08
Sebastopol - Redan	Construction Zone 1	0.03
	Construction Zone 6	0.03
	Operation	0.03

10.1.2 Risk characterization

The purpose of the risk characterization is to estimate potential residual risks associated with exposure to RCS from the proposed Project. For the assessment of health effects where there is a known threshold for effect, the predicted annual average RCS concentration is compared to the health based guideline values. The ratio of the predicted level to the guideline is termed the hazard quotient (HQ) (enHealth, 2012):

HQ = predicted RCS concentration / health based guideline

The hazard quotients associated with predicted RCS concentrations have been estimated for the most impacted receptors for each of the areas assessed. Using the most impacted receptors is indicative of the highest risk posed to the potentially exposed population. All other risks from exposure to RCS will be lower. The hazard quotients shown in **Table 10.1** have been calculated for both the increment from the construction and operation of the TSF4.

In calculating the hazard quotients, the health based guideline has been adopted from the Californian EPA Office of Health Hazard Assessment (OEHHA). The OEHHA guideline is 3 µg/m^3 as an annual average. This guideline has been established to protect against silicosis. This guideline has also been adopted by EPA as an Air Quality Assessment Criteria.

Table 10.2: Hazard quotients for Respirable Crystalline Silica

Year	Hazard Quotient Project Increment alone
Mount Pleasant - Canadian	
Construction Zone 1	0.05
Construction Zone 6	0.05
Operation	0.05

Year	Hazard Quotient Project Increment alone
Mount Clear – Mount Helen	
Construction Zone 1	0.03
Construction Zone 6	0.03
Operation	0.03
Sebastopol - Redan	
Construction Zone 1	0.01
Construction Zone 6	0.01
Operation	0.01

As can be seen from **Table 10.2** all hazard quotients for all receptors for all areas are well below 1 and within acceptable risk levels adopted by enHealth (2012). The hazard quotients are also below the negligible risk level of 0.1.

11 Impacts on groundwater

The potential for groundwater to be contaminated by leachate from the TSF4 and impacts on recreational users of the Yarrowee River was raised by the community during the consultation on the Planning Permit Application. This section reviews the groundwater monitoring conducted by Balmaine Gold and the potential exposure pathways for exposure to recreational users of the river. If there is no complete exposure pathway, then there is no potential risk to human health.

11.1 Hydrogeological setting

The AECOM groundwater impacts report[1] set out the hydrogeological setting of the proposed TSF4, which is summarised as follows:

- The proposed TSF4 is located in Whitehorse Gully, an ephemeral drainage line east of the Yarrowee River, with a surface elevation of 465 m AHD in the east to 400 m AHD in the west.
- The proposed TSF4 site is underlain by Castlemaine Group (marine turbiditic sandstone, siltstone, mudstone, black shale and minor granule conglomerate), with Whitehorse Gully Deep Leads originally present as thin alluvial deposits in the gullies, but heavily modified during historic mining activities and now present as hummocky deposits throughout the gullies.
- There are two hydrogeological units underlying the proposed TSF4:
  - Calivil Formation, located within the Whitehorse Gully Deep Leads (i.e., localised to gullies within the proposed TSF4 area). This unit has limited connection with the underlying Basement aquifer and is considered to be a perched groundwater system.

[1] AECOM, March 2020. *Groundwater impact assessment – TSF4*. Prepared for Castlemaine Goldfields Pty Limited. AECOM reference: 60593424.

  – Basement aquifer within the Castlemaine Group (undifferentiated sedimentary basement rocks). Low-yielding weathered siltstones and sandstones with largely north-south fracture orientations.
- Hydraulic conductivity within the Basement aquifer was reported by AECOM to be highly variable at a local scale, and dependent on faulting or fracturing of the bedrock. Site-specific conductivity results reported by AECOM were 0.005 m/day for the Basement aquifer.
- Groundwater flows from east to west, with the groundwater table present as a subdued reflection of the surface topography.
- Recharge of the Basement and Cavil Formation aquifers occurs largely via infiltration of rainfall.
- Local flow systems may discharge to the Yarrowee River, while intermediate and regional flow systems likely discharge further down the catchment.
- Leachate in the landfill located adjacent to the southern boundary of the proposed TSF4 is lower than the groundwater at the proposed TSF4 site.

11.2 Conceptual site model for groundwater

The source of potential impacts to groundwater that could impact on human health is water contaminated by the leachate from the tailings. This could occur either leachate from the TSF or the post-closure infiltration of rainwater into the TSF re-saturating the tailings and subsequent leakage of leachate.

As described in the AECOM report, a leachate collection system will be installed as part of the construction of TSF4. The system is designed to collect leachate from the floor of the TSF, which would be pumped out of the facility via an above-ground pipe which would not penetrate the walls of the embankment. The design includes a toe drain located at the bottom of the embankment to catch any seepage of rainfall infiltration through the downgradient wall of the TSF.

According to the AECOM report, post-closure, the TSF will be de-saturated. In this context, it is unlikely that the volume of water from rainfall that infiltrates the cap and saturate the tailings would be sufficient to cause leaching through the clay liner resulting in an impact on groundwater.

As shown in the CSM for the site (Section 5 of this report), the main pathway for groundwater impacts is the subsurface migration of impacted water from TSF4 into groundwater.

The low site-specific hydraulic conductivity presented in the AECOM report suggests a reduced risk of groundwater impact from contaminated water infiltration.

There is also the possibility that any contaminated groundwater may be discharged to surface waters such as the Yarrowee River.

11.2.1 Groundwater bores

A search of the Victorian groundwater bore database was carried out by T+T in May 2023. A total of 16 groundwater bores are recorded as being located within 1 km of the proposed TSF4. Of these bores:

- 10 bores have a reported use of ‘groundwater investigation’ or ‘observation’.
- Three bores have a reported use of ‘domestic and stock’, however these bores are all located within the boundaries of either the mine or the adjacent water treatment plant, and it is considered likely that the bores have been miscategorised.

- One bore has a reported use of 'commercial' and is located adjacent to the water treatment plant.
- One bore has a reported use of 'irrigation' and is located adjacent to an area of mine stockpiling.
- One bore does not have a recorded use and is located approximately 500 m east (up gradient) of the proposed TSF4 site.

None of the identified bores have a reported use for potable water. The bores identified for domestic or stock uses are located on industrial land and are unlikely to be used for drinking water.

There are no known users of the Cavil Formation aquifer, and as this aquifer is highly localised (limited to the gullies in the proposed TSF4 footprint) and perched and it is unlikely that people will be in contact with the water from this aquifer. As detailed in the AECOM report, the Cavil Formation will be removed during construction of TSF4 removing this as a potential groundwater source.

11.3 Groundwater quality

The results of groundwater monitoring conducted by Balmaine Gold between 2020 and 2023 from groundwater wells in the vicinity of existing TSF3 and proposed TSF4 were provided to T+T. These results were assessed against the following health-based criteria to assess whether impacts from the existing TSF3 have impacted groundwater quality and may pose a risk to human health:

- To assess water quality for use as drinking water: ADWG 2022[2] health criteria.
- To assess water quality for use as irrigation water: ANZECC 2000[3] Irrigation Long Term trigger levels.
- To assess water quality for use for water-based recreation: ADWG 2022 health criteria with a factor of 10 applied (as specified in the Assessment of Site Contamination NEPM, ASC NEPM amended 2013).

The most stringent criteria are the drinking water criteria and therefore, provided these criteria are met, the criteria for irrigation water and water-based recreation will also be met.

The locations of all wells were not able to be determined from the information provided, however it is known that three wells (BEB9, VMB4 and VMB5) are located east (upgradient) of TSF3 and are therefore considered to be representative of background groundwater quality. As a conservative approach, all other groundwater wells have been assumed to be downgradient of TSF3.

Table 11.1 shows the analytes that exceeded each of the health-based assessment criteria for both the background (upgradient) and other groundwater wells.

Table 11.1: Analytes exceeding the adopted health-based assessment criteria

Assessment criteria	Background wells	Other wells
Drinking water	Cadmium Nickel	Nickel

[2] NHMRC, NRMMC, 2011 (updated September 2022). *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

[3] ANZECC & ARMCANZ, 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Assessment criteria	Background wells	Other wells
Irrigation	pH Nitrogen Cobalt Iron Nickel Manganese	pH Nitrogen Cobalt Iron Nickel Manganese
Water-based recreation	Chloride pH Total dissolved solids Iron Manganese Zinc	pH Total dissolved solids Ammonia Chloride Iron Zinc Manganese

Table 11.1 shows that all analytes that exceed the assessment criteria in downgradient wells also exceed the assessment criteria in the background wells, suggesting that the exceedances are representative of background water quality and are unlikely to be indicative of impacts from TSF3.

Figure 11.1 shows the data from arsenic concentrations from both the upgradient and downgradient wells. From **Figure 11.1** it can be seen that the upgradient concentrations of arsenic are higher or similar to the downgradient wells indicating that the operation of the current TSF3 is not impacting groundwater quality on the site.

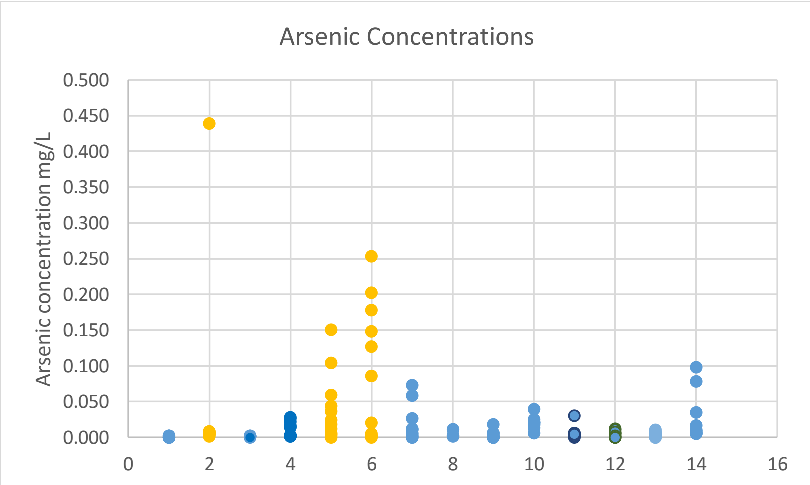

Figure 11.1: Arsenic concentrations in upgradient (in yellow) and downgradient groundwater wells at Balmaine Gold site

The AECOM assessment states that tailings in TSF3 are enriched with arsenic and sulfate. The groundwater quality data indicates that there were no exceedances of the adopted health-based criteria for arsenic or sulfate in either the upgradient or downgradient wells. It is noted that the ADWG do not provide a health-based guideline for sulfate as there is insufficient data to set a health guideline. For this assessment the aesthetic criterion for sulfate (with a factor of 10 applied) was adopted to assess water quality for water-based recreation.

The range of concentrations of sulfate and arsenic in the groundwater results between 2020 and 2023 are show in **Table 11.2**. Higher concentrations of both sulfate and arsenic were reported in the upgradient wells.

Table 11.2: Range of concentrations of indicator analytes at upgradient and downgradient wells

Analyte	Upgradient wells (mg/L)	Downgradient wells (mg/L)
Sulfate (as SO_4)	28 – 435	2 – 299
Arsenic	0.001 – 0.253	0.001 – 0.098

The results shown in **Table 11.2**. The ADWG for arsenic is 0.01 mg/L. This is exceeded for both upgradient and downgradient wells. The resulting recreational water quality guideline would be 0.1 mg/L (10x ADWG) which is exceeded in the upgradient wells. The results shown in **Table 11.2** indicate that the operation of the TSF3 does not lead to contamination of the groundwater at the site. If the downgradient groundwater data was to discharge to the Yarrowee River, or other surface water bodies in the area, contact with the groundwater would not pose a risk to human health through recreational contact as the concentration of arsenic meet the recreational water quality guidelines.

11.4 Summary

Based on the analysis conducted above, the risk of health impacts from exposure to groundwater from the site and potential impacts on users of the Yarrowee River from the construction and operation of the TSF4 is considered to be low. The proposed leachate management system would reduce the risk of leachate building to the point where seepage through the clay liner would occur. It is also unlikely that a sufficient volume of rainwater would infiltrate through the cap post-closure to re-saturate the tailings and leach into groundwater. Overall, the risk of contaminated water impacting groundwater is considered low.

In addition, the hydraulic conductivity of the Basement aquifer is very low, suggesting that in the event that there is leakage to groundwater, groundwater flow is likely to be an ineffective pathway for contaminant transport.

There are no clear exposure pathways for people to be exposed to groundwater in either the Cavil Formation or Basement aquifers. There are no groundwater bores downgradient of the site that are not on industrial land. The existing bores can't be accessed by the public therefore there are no direct exposure pathways.

Groundwater quality results suggest that the existing TSF3 is not impacting groundwater quality downgradient of the mine. Based on the results of the ground water monitoring, the downgradient water quality is similar, if not better, than the upgradient quality. This indicates that the current mine operations including the TSF3 is not impacting on groundwater in the area. As the proposed TSF4 is based on the same construction principles as TSF3 it is reasonable to assume that the potential impacts to groundwater would be similar for both operations. In addition, the ore being mined will be the same or similar to that currently being processed meaning that any impact on groundwater quality would be similar to that currently observed. If groundwater was to enter the Yarrowee River, there would be no impact from the mine and the TSF4 above that from background groundwater. The groundwater from the downgradient wells meets the recreational water guidelines for arsenic which means that if it did discharge to surface waters it would not pose a risk to human health through recreational use.

12 Conclusions

A human health risk assessment has been undertaken to assess the potential impacts of emissions from the construction and operation of the TSF4 at the Ballarat Gold Mine on the local community. The HRA has been conducted to address issues raised by the local community and to inform Ballarat City Council's decision on the Planning Permit for the TSF4.

The HRA assesses the potential risk from PM_{10} and $PM_{2.5}$, metals in the dust and RCS. All risks are very low and below acceptable risk levels. In many cases, such as the metals and RCS, the potential risks are below negligible risk levels established by enHealth, WHO and the US EPA.

The HRA shows that if the mitigation measures that have been adopted in the air dispersion modelling and described in Section 8.2 are implemented at the site, the TSF4 can be constructed and operated without posing an unacceptable risk to the health of the local community.

In addition, Balmaine Gold has installed two real-time monitors for a dust management program for the site. Both PM_{10} and $PM_{2.5}$ plus meteorological data with results reported at the quarterly ERC meetings. The dust management plan has a tiered response process that is based on trigger concentrations that are set well below the PM standards. This approach requires additional use of water on roads and dust sources if windy/dry conditions are forecast. If the interim triggers are exceeded, additional water will be applied, traffic is slowed and if that does not reduce the dust levels, activities are stopped until weather conditions improve. This reactive dust management approach will further minimise any off-site impacts and any associated health risks.

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14 Applicability

This report has been prepared for the exclusive use of our client Balmaine Gold Pty Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of a Planning Permit Application for the construction and operation of the TSF4 and that Ballarat City Council as the responsible authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Pty Ltd
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Pty Ltd by:

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Technical Lead Environmental Project Director

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Appendix A Air dispersion modelling

REPORT

Tonkin+Taylor

Atmospheric Dispersion Modelling

Inputs to Human Health Risk Assessment

Prepared for

Balmaine Gold Pty Ltd (in administration)

Prepared by

Tonkin & Taylor Pty Ltd

Date

June 2023

Job Number

1090275 v1

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Document control

Title:	**Atmospheric Dispersion Modelling**				
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
June 2023	0	Draft for client comments	[redacted]	[redacted]	[redacted]
June 2023	1	Final	[redacted]	[redacted]	[redacted]

Distribution:

Balmaine Gold Pty Ltd (in administration) 1 PDF copy

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1 Introduction

Balmaine Gold Pty Ltd (in administration), has engaged Tonkin & Taylor Pty Limited (T+T) to complete a Human Health Risk Assessment (HHRA) of the construction and operation of the Tailings Storage Facility (TSF4) (the Project) at the Ballarat Gold Mine located at 10 Woolshed Gully Dr, Mount Clear VIC 3350 (the Site).

The HHRA focusses on the potential impacts to the health of the surrounding community through the construction and operation of the TSF4 through emissions to air. The pollutants considered include particulate air pollution, PM_{10} and $PM_{2.5}$, as well as metals such as arsenic that may be associated with the dust.

The HHRA requires data on the anticipated ambient air contaminant concentrations and deposition rates at specific sensitive receptor locations identified by the HHRA as being representative of exposure of the surrounding population. To provide this information, atmospheric dispersion modelling has been used to predict likely concentrations and deposition rates to provide an understanding of the spatial nature of impact.

This work has been carried out in accordance with our proposal dated 21 April 2023.

1.1 Project description

The process of extracting gold from the ore mined underground requires the crushing of the ore through a primary, secondary and tertiary crusher. Gravity separation and a float circuit is used to recover gold nuggets. To recover smaller gold, a ‘leach circuit’ is used whereby a chemical process dissolves gold from the ore, with the gold then recovered through a second chemical process. The processing of gold through the leach circuit results in a waste which is known as tailings. These tailings are in the form of a wet slurry, allowing them to be pumped to the tailings dam.

The Site currently has three authorised tailings facilities TSF1, TSF2 and TSF3. TSF1 and TSF2 are full and TSF3 is nearing capacity. To enable the mine to continue operation, a new tailings facility is required to take the tailings from the continued gold production.

The Site has permission from Earth Resources for TSF4, however permission is also required from the City of Ballarat Council (the Council) for planning permission. In accordance with the requirements under the Planning Scheme, the Council has requested a HHRA to demonstrate that the construction and operation of TSF4 does not pose a risk to the surrounding land use which is predominantly used for residential purposes.

The Project is located to the south of the TSF3 and other mining infrastructure; it is to the north of Whitehorse Road with the Mount Clear residential area to the east and the Sebastopol residential area located to the west. The Project site currently consists of bushland with softwood plantations, as presented in Figure 1-1. The area has been heavily disrupted by historical mining activities, including surface prospecting and shallow alluvial works. Following the completion of TSF4, tailings will no longer be pumped onto TSF3 which is nearly at capacity.

The Project comprises the construction of the proposed TSF4, which will include land clearance, areas of earthworks, excavations and the construction of an embankment. A new access road to TSF4 will be constructed from Whitehorse Road to the south. Construction is currently proposed to be progressively undertaken in six zones, with the commencement of the embankment construction to start in Zone 1 and then (proceeding eastwards) increased in height until Zone 6 (which is nearest to the Mount Clear residential area). Further details on the staging of construction are presented in Section 2.1. Mining operations will continue on-site during the construction of TSF4.

1.2 Project locality

The Project area, the surrounding area and nearby sensitive receptors (as selected for the HHRA) are identified in Figure 1-1.

CITY OF BALLARAT

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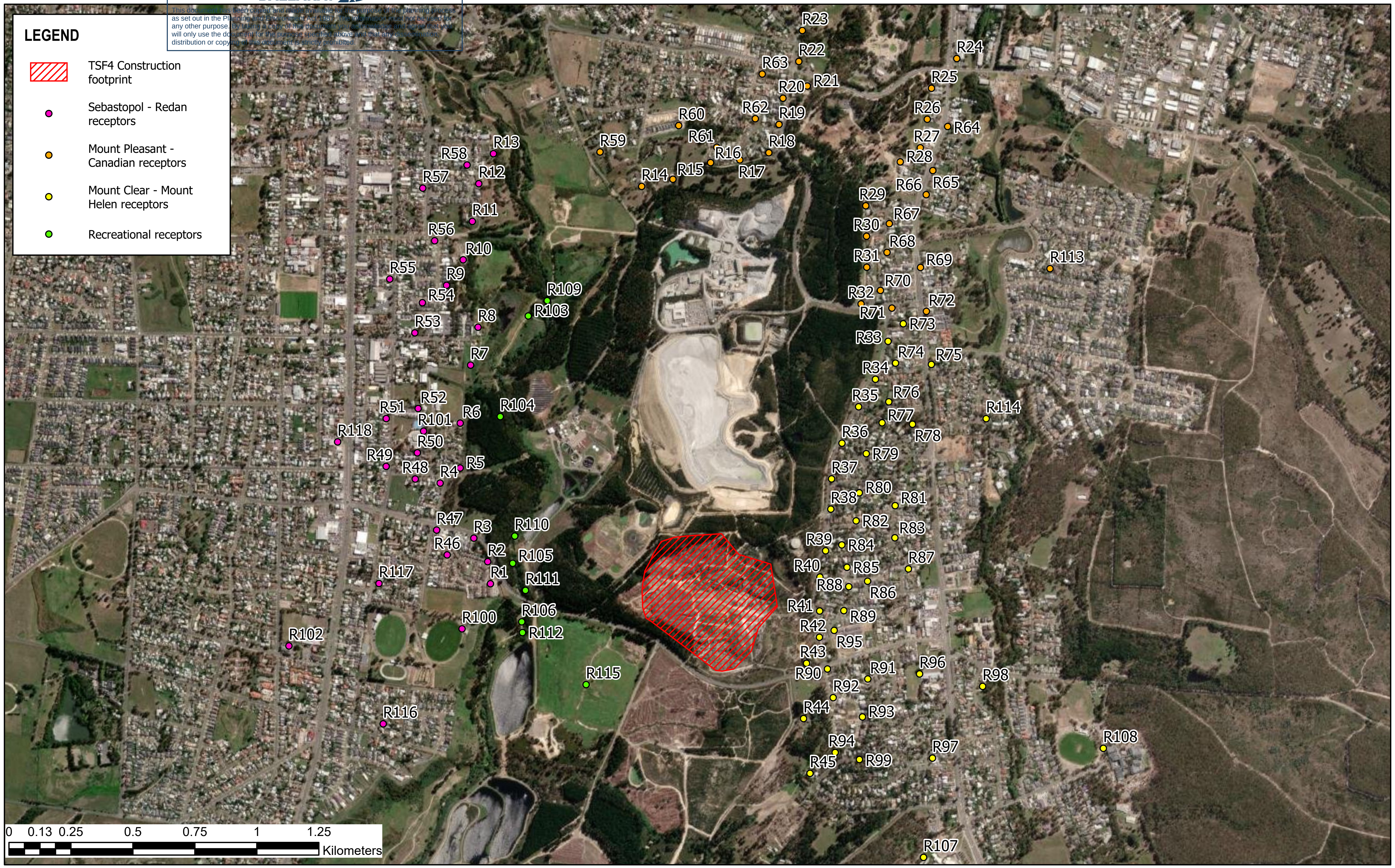

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REV	DESCRIPTION	GIS	CHK	DATE
0	First version	SAOL	SYLO	31/5/23

LOCATION PLAN: Ballarat

PROJECT No.	1090275.1000	
DESIGNED	SAOL	MAY.23
DRAWN	SAOL	MAY.23
CHECKED		
APPROVED		DATE

CLIENT: BALMAINE GOLD PTY LTD (IN ADMINISTRATION)
PROJECT: BALMAINE GOLD - TSF4 HRA
TITLE: PROJECT LOCATION AND SENSITIVE RECEPTORS MODELLED
SCALE (A3) FIG No. FIGURE 1- 1 REV 0

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1.3 Purpose and scope of report

The purpose of the atmospheric dispersion modelling is to assess the incremental contribution and cumulative impact of air emissions from the Project construction and operation at receptor locations specified by the HHRA specialist. To achieve this, the following scope of work has been completed:

- Review of available Project and third-party data and information as considered relevant to the atmospheric dispersion modelling.
- Identification of significant dust generating activities that will be undertaken as part of the Project and development of emissions inventories for each assessment scenario.
- Identification of mitigation measures to eliminate (where possible), or reduce and otherwise manage significant emissions (where not possible to eliminate) and therefore impacts to sensitive receptors. In the context of air quality, these measures are designed to reduce Project emissions and minimise human health impacts to as low as reasonably practicable.
- Development of a project-specific meteorological dataset for input to the dispersion model.
- Development of a dispersion model to predict Project construction and operational air quality (ambient concentrations and deposition rates). Dispersion modelling was carried out for the anticipated residual emissions following the implementation of mitigation measures for each of the assessment scenarios. The results of the dispersion modelling were provided to the HHRA specialist as input to the HHRA.

This report does not consider the results of the modelling in comparison to published air quality standards in Victoria, rather the results are used within the HHRA to assess the impact to the surrounding population.

1.4 Structure of report

This dispersion modelling report is structured as follows:

- **Section 2** – Project description: a summary description of the Project as relevant to the atmospheric dispersion modelling completed for the HHRA.
- **Section 3** – Statutory context: an overview of the statutory context and information regarding relevant Acts, regulations, policies, protocols and guidelines related to atmospheric dispersion modelling.
- **Section 4** – Existing conditions: a summary of the local meteorological conditions and surrounding land use.
- **Section 5** – Dispersion modelling methodology: explanation of the emissions estimation techniques, explanation of the methodology used to build the meteorological and dispersion models, and site-specific data used in the modelling.
- **Section 6 –** summary of the results produced for the HHRA.
- **Section 7** – summary of the study.
- **Section 8** – Statement of limitations.

2 Project description

2.1 Overview

The Project comprises the construction and operation of a new tailings dam and associated infrastructure in Whitehorse Gully, which will be known as TSF4. A new access road to TSF4 will be constructed from Whitehorse Road to the south of the Project in advance of the construction of TSF4. It is considered that the construction of this road will generate less particulate emissions than construction of the TSF4, and this phase of the project has therefore not been assessed.

Construction of TSF4 will be split into six zones, with the breakdown of material volumes handled and construction timeframes presented in Table 2.1.

During the construction of Zone 1, the embankment will be raised to a crest level of EL 435 m, with an approximate embankment height of 25 m. Over the construction of the subsequent five zones, the embankment will be raised a further 9 m to a final crest level of EL 444m.

Table 2.1: Materials handled for each zone and construction timeframes

Zones	Construction timeframe (months)	Materials handled (m^3)			
		Select earthfill	Shoulder earthfill	Waste rock	Waste material
1	8 – 10	81,250	195,000	32,500	50,000
2	6 – 8	48,750	117,000	19,500	30,000
3	6 – 8	48,750	117,000	19,500	30,000
4	6 – 8	48,750	117,000	19,500	30,000
5	6 – 8	48,750	117,000	19,500	30,000
6	6 – 8	48,750	117,000	19,500	30,000
Total materials handled (all zones)		325,000	780,000	130,000	200,000

Construction activities will comprise the following:

- Movement of waste rock from current approved rehabilitation areas to TSF4 footprint for use as base in TSF4 construction within construction of Zone 1.
- Movement of waste rock from underground to the TS4 embankment area for construction of Zones 2 to 6.
- Excavation and removal of material within TSF4 that is unsuitable for use.
- Excavation of material and movement within TSF4 to construct required embankments.
- Construction of embankments.
- Onsite concrete batching.
- Haulage of materials using on-site unsealed haul roads.

Mining operations will continue during the construction of TSF4. Ore will be removed from the mine shaft to stockpiles. However, control of the volume of waste rock extraction means that only the required amount of waste rock that is needed for the construction works of TSF4 will be removed directly from underground to the embankment (during construction of zones 2 to 6 only) of the TSF4 being built. In other words, waste rock stockpiles are not created above ground, rather any additional waste rock will remain underground. There will also be crushing and processing associated with the extraction of gold from ore.

During construction of TSF4, processing of the ore will continue, with the tailings pumped into TSF3 until such time as construction of Zone 1 of TSF4 is complete and ready to receive tailings. However, TSF3 is nearing capacity. To generate capacity within TSF3 for the fresh tailings a process known as dry stacking will be undertaken. This process excavates older drier tailings from the TSF3 and places it onto a dry stack, which is an elevated stockpile of tailings. The tailings within the stockpile naturally form a crust over time which prevents wind erosion.

2.2 Modelled scenarios

The modelling was completed for the following three scenarios:

- Construction of Zone 1 of TSF4 – this is the period of the largest earth movement activity.
- Construction of Zone 6 of TSF4 – this is the period when earth moving activities are closest to residential receptors.
- Operation of TSF4 – this is a period of minimal emissions from TSF4, but indicates ongoing operations of the site.

The construction scenarios incorporate both the construction activities of TSF4 and operational activities because day-to-day operations of the mine will continue during the construction phase. As such, both construction scenarios include all construction emission sources and emission sources from the current mine operation processes.

Table 2.2 summarises the processes considered within each scenario.

Table 2.2: Processes considered for each model scenario

Processes	Zone 1 Construction	Zone 6 Construction	TSF4 Operation
North Prince Ventilation Shaft	✓	✓	✓
Diesel generators 1 - may be used at the commencement of TSF4 operations	✗	✓	✓
Ore handling and processing	✓	✓	✓
Dry stacking of TSF3 whilst Zone 1 of TSF4 is constructed to allow ongoing operations	✓	✗	✗
Extraction, movement and placement of waste rock from current rehab area to embankment	✓	✗	✗
Movement and placement of waste rock from underground to embankment	✗	✓	✗
Extraction, movement and placement of soils from TSF4 excavation area to embankment	✓	✓	✗
Extraction and movement of soils from TSF4 to off-site which cannot be reused within the embankment	✓	✓	✗
Concrete batching plant activities	✓	✓	✓

3 Statutory context

The atmospheric dispersion modelling documented in this report has been completed to inform an HHRA. However, there are overarching requirements within the *Environment Protection Act 2017* (the EP Act) [1] which govern how activities are undertaken to reduce the risk to the surrounding land use.

3.1 Policy and legislation

The EP Act came into effect on 1 July 2021. The Act endeavours to ensure that individual industries take responsibility for the risks they pose to the environment. At the centre of the Act is the General Environmental Duty (GED), which requires emissions to the environment be abated/managed so that risks of harm to the environment and to human health are effectively minimised.

With specific regard to air emissions, the new *EPA Publication 1961 - Guideline for assessing and minimising air pollution in Victoria* (the Guideline) provides technical guidance and a framework for assessing and controlling risks associated with air pollution[2].

3.1.1 General Environmental Duty

Complying with the GED means taking proactive steps as well as employing good work practices to minimise risk to human health and the environment, so far as reasonably practicable. Reasonably practicable means putting controls in place that are proportionate to the risk of harm. The EPA has released a number of publications outlining how a duty holder can assess the various risks and determine what is reasonably practicable for their individual project and circumstances:

- *EPA Publication 1741.1 – Industry guidance: supporting you to comply with the general environmental duty*[3]*, 26 October 2020*; and
- *EPA Publication 1856 – Reasonably practicable*[4]*, 22 September 2020*.

3.1.2 Guideline for assessing and minimising air pollution in Victoria

The Guideline outlines a range of ways to identify, assess, minimise and monitor risks and is divided into four steps for the assessment and control of risk, as shown in Figure 3-1.

[1] As amended by the Environment Protection Amendment Act 2018
[2] The Guideline also presents Air Quality Assessment Criteria (AQAC) for the assessment and management of emissions to air. These criteria supersede those in the State Environment Protection Policy (Air Quality Management) 2001 (SEPP AQM) and the Protocol for Environmental Management: Mining and Extractive Industries (the Mining PEM) 2007. These criteria are intended to be used within the broader management framework, effective from 1 July 2021, the central pillar of which is GED and minimising risk as far as reasonably practicable.
[3] Available at https://www.epa.vic.gov.au/about-epa/publications/1741-1.
[4] Available at https://www.epa.vic.gov.au/about-epa/publications/1856.

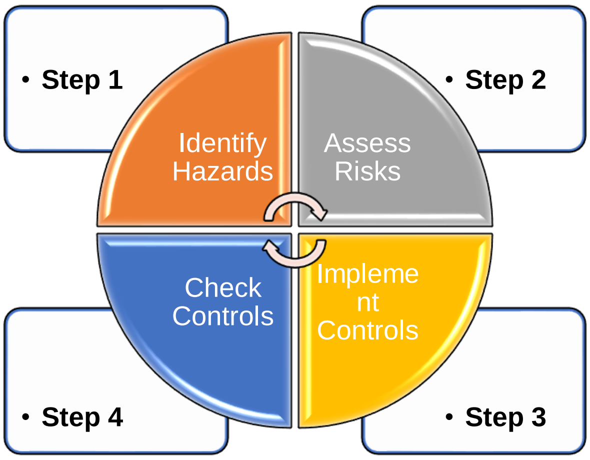

Figure 3-1: Steps in controlling hazards and risks

As noted above, the objective of the Guideline is to help those responsible for emissions of pollutants to identify, understand and manage these so that risks of harm to human health and the environment can be effectively minimised. In the case of the Project, emissions are predominantly dust. The term dust is used here as a generic term to include the following:

- Total Suspended Particulate (TSP);
- Particulate matter of less than 10 micrometres in aerodynamic diameter (PM_{10});
- Particulate matter of less than 2.5 micrometres in aerodynamic diameter ($PM_{2.5}$); and
- Their RCS and heavy metal components.

The minimisation of dust emissions is the proponent's GED and they have a responsibility to enact proportionate controls to eliminate or minimise risks. According to Section 2 of the Guideline:

"Being proportionate and preventative requires the duty holder to:

- *Understand their risks*
- *Actively seek out ways to eliminate or minimise these risks, so far as reasonably practicable*
- *Ensure any risks remaining after the implementation of all controls are within acceptable limits."*

The Guideline notes two specific types of risk, namely 'inherent risk' and 'residual risk'. These are defined as follows:

Inherent risk: The pre-control risk which represents the risks that would be present if no controls were in place.

Residual risk: The post-control risk which represents the risk that remains following the implementation of controls.

Based on these definitions of risk and noting the management objectives in the Guideline, the following sections discuss the approach to risk management for the Project, which can be described broadly as shown below in Figure 3-2.

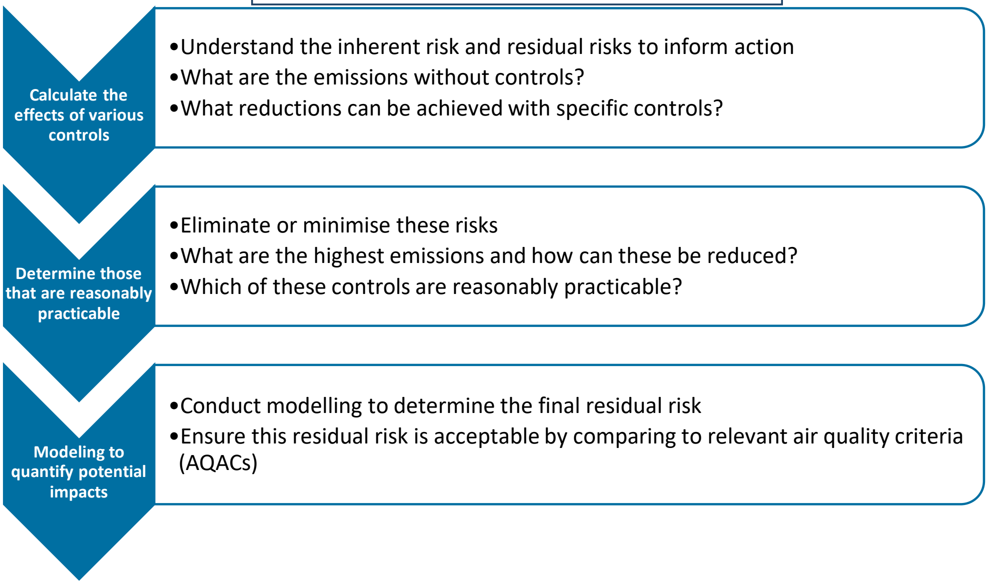

Figure 3-2: Approach to risk management

The four steps described in the Guideline (and shown in Figure 3-1) required to follow this approach are mentioned below. Section 5.2 describes the outcome of this approach for this Project.

1. **Identify hazards** – Define the hazards that might cause harm
2. **Assess risks** – Estimate the level of severity of risk, based on the likelihood and consequence
3. **Implement controls** – Investigate the measures that are suitable and available to eliminate or reduce each risk
4. **Check controls** – Review these controls to ensure they are effective

3.1.2.1 Step 1: Identifying hazards

The hazards are the emissions to atmosphere that have the potential to cause harm to ambient air quality. In the case of the development and operation of TSF4, this includes the emissions of particulates from dust-generating activities such as extracting and unloading of material, wheel-generated dust from haulage and windblown dust from exposed areas in addition to any heavy metals which may be associated with the materials moved, driven upon or from windblown emissions of those sources.

3.1.2.2 Step 2: Assessing risks

The methodology to minimise, so far as reasonably practicable, risks of harm to human health and the environment has been taken from *EPA Publication 1695.1 - Assessing and controlling risk: A guide for business*[5]. Understanding the risks of the operation allows more effective decisions to be made around controlling dust generating activities and reducing the overall residual risk of the Project.

[5] Available at https://www.epa.vic.gov.au/-/media/epa/files/publications/1695-1.pdf.

Rather than immediately assessing the risk of a predicted concentration at a receptor, the approach here is to first look at the risk of dust emissions leaving the site and reaching sensitive receptors. Increasing the controls that can be put in place at the source results in lower risk off-site.

3.1.2.3 Step 3: Implementing controls

Risk controls can be used to prevent or mitigate. Preventative controls eliminate the risk while mitigating controls reduce the impact. The GED requires that the proponent take actions to reduce the potential harm caused by the release of pollutants, as far as reasonably practicable. *EPA Publication 1856 – Reasonably practicable* discusses what is meant by the term reasonably practicable, and this is outlined in the following.

To do what is reasonably practicable, the proponent must put into place controls to mitigate or minimise the risk of harm that are proportionate to that risk. The types of controls required will depend on the type of pollutant sources, but the principles are generally the same.

These principles follow a basic hierarchy giving preference to prevention and avoidance, then to reduction and minimisation. Usually a combination of the two is used. Measures that eliminate a hazard are the most effective as that source of risk is no longer present.

In many cases, it is unlikely that all sources can be eliminated and so measures need to be employed to reduce emissions at the source through engineering or management practices.

The risk of generating emissions from individual activities are assessed (as described above) and controls can then be quantified to enable decisions to be made regarding whether or not they are reasonably practicable.

Figure 3-3 shows a simple outline of the steps involved in this process.

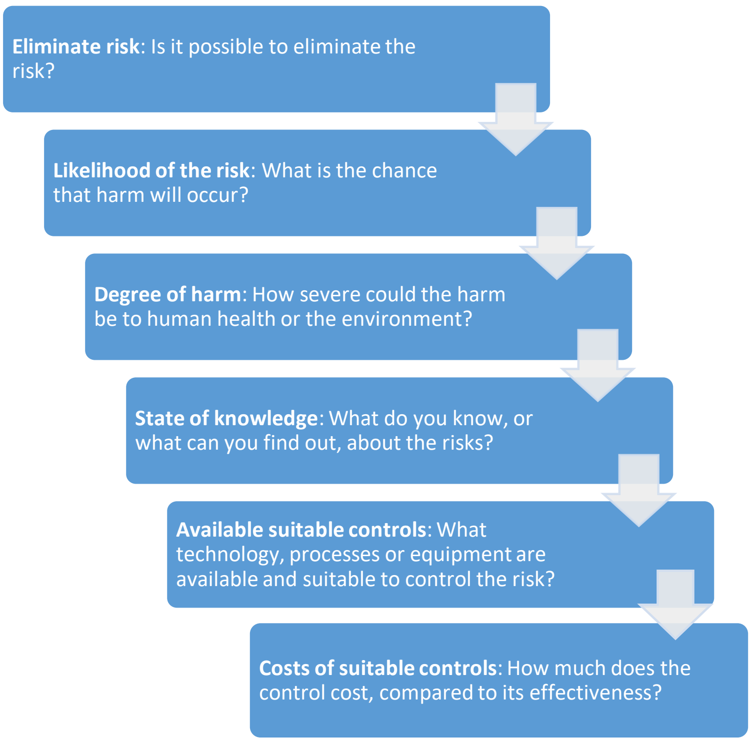

Figure 3-3: Steps to determine what controls are reasonably practicable

Section 5.2 details the considered mitigation measures, why these measures are considered to represent approaches that will reduce emissions to as low as reasonably practicable and the percentage reduction that the mitigation measures represent.

3.1.2.4 Step 4: Checking controls

As the results from the dispersion modelling, which incorporate mitigation measures, documented in this report are being used for a HHRA, the 'checking of controls' is driven by the determination as to whether the level of human health risk from the project is considered to be acceptable.

The controls that are proposed to mitigate risks must be monitored to confirm they are effective. Ongoing performance evaluation through monitoring and continuous improvement is required by the proponent to ensure ongoing compliance. This is generally done with an Air Quality Management Plan (AQMP) as described in the Guideline. A good AQMP will include proactive measures as well as adaptive management and will apply to the whole project. The AQMP should be incorporated into the Construction Environment Management Plan (CEMP) for the construction phase and the Environmental Management System (EMS) for the operational phase to minimise the risk of dust emissions, as far as reasonably practicable, from the Project area. The AQMP should be reviewed and updated at an appropriate frequency as established in the overarching EMS with consideration to the level of risk, statutory requirements, monitoring results, community complaints and in response to audit findings.

4 Existing Conditions

4.1 Overview

This section presents the existing site and surrounding area conditions with relation to sensitive receptors, meteorological conditions and the existing background air quality.

4.2 Surrounding land use

Figure 4-1 provides the planning zones for the area surrounding the Site.

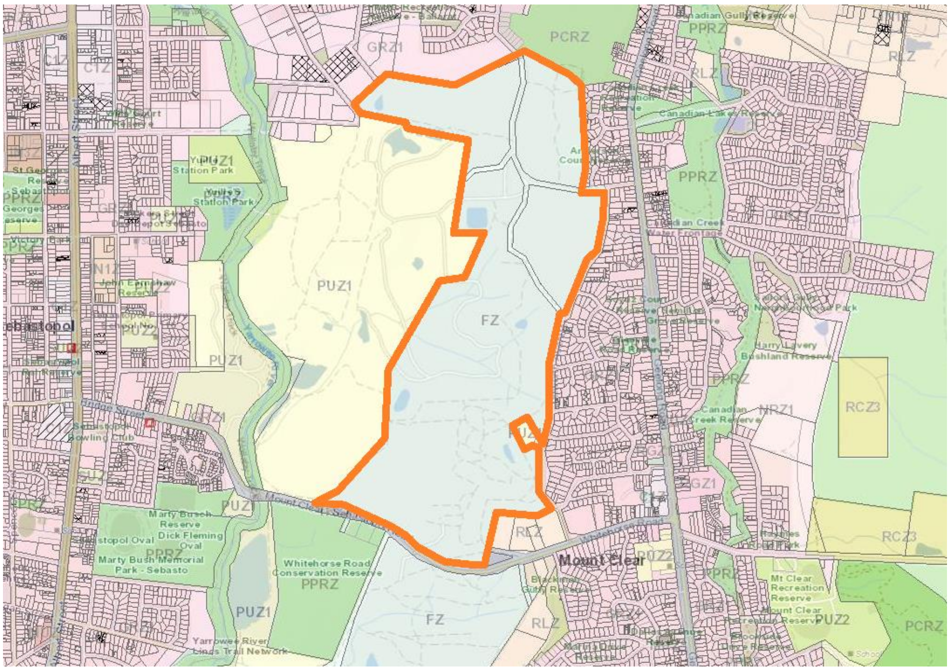

Figure 4-1: Planning zones surrounding the Site. Site boundary outlined in orange.

From our analysis of the planning zone map in Figure 4-1, we note the following regarding the surrounding land use:

- North of the Site is a residential area and a public conservation and resource zone (PCRZ).
- East of the Site the land is zoned for residential use (GRZ1).
- The land at the south-east corner of the site is zoned as a rural living zone which is also used for residential use but which has larger blocks than the residential use to the east of the Site (RLZ).
- To the south of the Site the land is a farming zone (FZ), however farming zones can be used for a variety of uses which may or may not include farming in the common understanding of the word. The exact use of this land is unclear, however from aerial photography there appear to be no dwellings within this area.
- To the south-west of the site the land is zone PPRZ, this is a public recreation zone and is used as a park.

- To the west of the Site, the land is zoned for public use (PUZ1). Within this area is a wastewater treatment plant (WWTP) and the associated buffer with undeveloped land. The public use zone containing the WWTP is bounded by other public use zones to the west which from aerial photography are parks. These parks give way to residential (GRZ1) use further west.

4.3 Climate

The climate in Ballarat is characterised by:

- Warm summers with average daytime temperatures in January at around 25°C and cold winters with average daytime temperatures in July at around 10°C;
- Approximately 30 % overcast or mostly cloudy skies in summer and 57 % in winter;
- Annual Rainfall ranging from 551 mm in 2019 to 839 mm in 2022;
- Low humidity through the year; and
- Frequent winds from the north and south with moderate frequency of winds from the west and limited winds from the east. Wind speeds are typically moderate to strong with calm conditions (< 1.1 kph) occurring 2.3 % of the time.

4.3.1 Temperature

Figure 4-2 provides the average daytime and night time temperatures through the year together with the 25th to 75th and 10th to 90th percentile bands for Ballarat. This data indicates that Ballarat has warm summers and cool to cold winters.

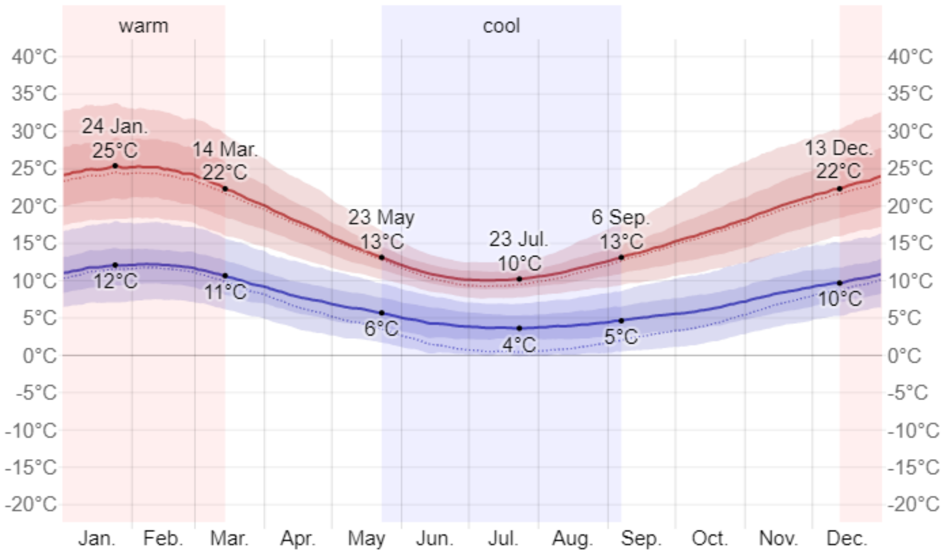

Figure 4-2: Average temperatures in Ballarat with 25th to 75th and 10th to 90th percentile bands (Source: © WeatherSpark.com)

4.3.2 Cloud cover

Figure 4-3 provides the percentage of time that cloudy conditions (overcast or mostly cloudy) occur in comparison to conditions where insolation may heat the ground directly (clear to partly cloudy). In summer clear to partly cloudy conditions occur between 60% and 70% of the time, in winter clear to partly cloudy conditions only occur 45 % to 50 % of the time. This means that thermal buoyancy which aids dispersion is likely to more readily occur in summer than in winter.

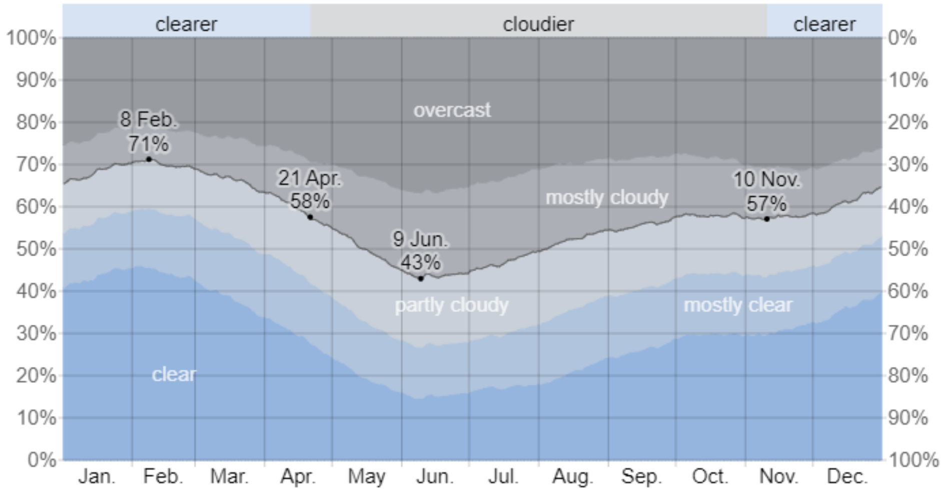

Figure 4-3: Average cloud cover in Ballarat (Source: © WeatherSpark.com)

4.3.3 Precipitation

Figure 4-4 provides the average precipitation in Ballarat for each month of the year with the 25th to 75th and 10th to 90th percentile bands. The data indicates that the driest month is typically March with the wettest months from September to October.

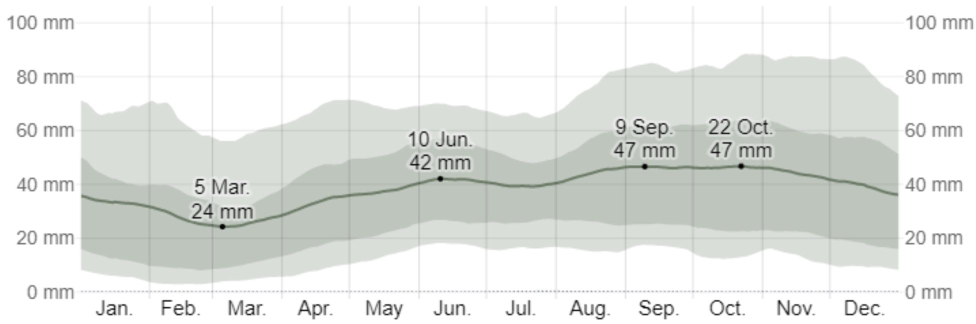

Figure 4-4: Average precipitation in Ballarat with 25th to 75th and 10th to 90th percentile bands (Source: © WeatherSpark.com)

Total precipitation rates for the last ten years are shown in *Figure 4-5*. The data indicates that the amount of rainfall is typically dependant on whether the year is has been impacted by larger climate drivers El Niño and La Niña or neutral. El Niño and La Niña are driven by whether the surface waters in the pacific are warmer near the western (El Niño) or eastern (La Niña) side of the Pacific Ocean. In Australia the warmer waters near to Australia during La Niña result in greater amounts of moisture in the atmosphere which results in greater rainfall on the east coast of Australia. For example, 2018 and 2019 were both El Niño years whilst 2020 tipped from El Niño to La Niña and 2021 and 2022 were strong La Niña years.

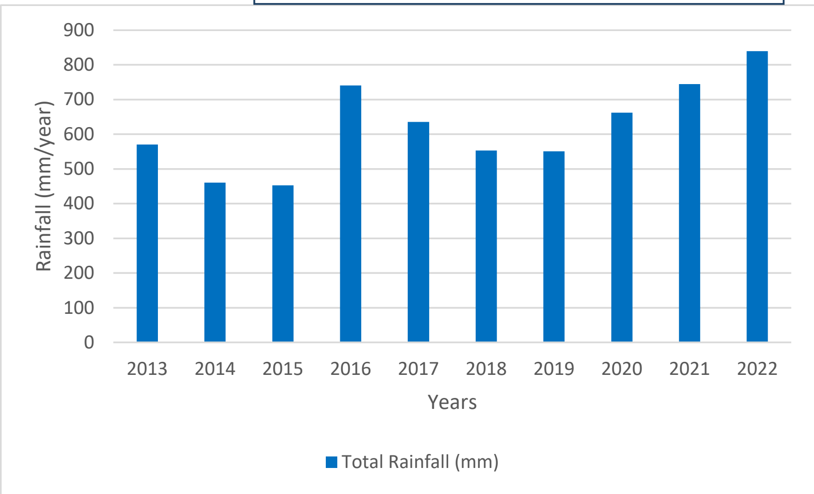

Figure 4-5: Total precipitation per year for 2013 to 2022 (Source: willyweather.com)

4.3.4 Observed wind conditions

The nearest publicly available meteorological data is from the Bureau of Meteorology Station at Ballarat Airport (located approximately 10 km from the Site). Figure 4-6 shows a wind rose of the last five years of data. This indicates that the winds occur approximately:

- 33 % of the time from the north or south (these are the dominant directions);
- 24 % of the time between the south-south-west and west;
- 20 % of the time between the east-south-east to south-south-east;
- 12 % of the time between the north-north-east and east;
- 9 % of the time between the west-north-west and north-north-west; and
- 2 % of the time conditions are calm (<1.1 kph).

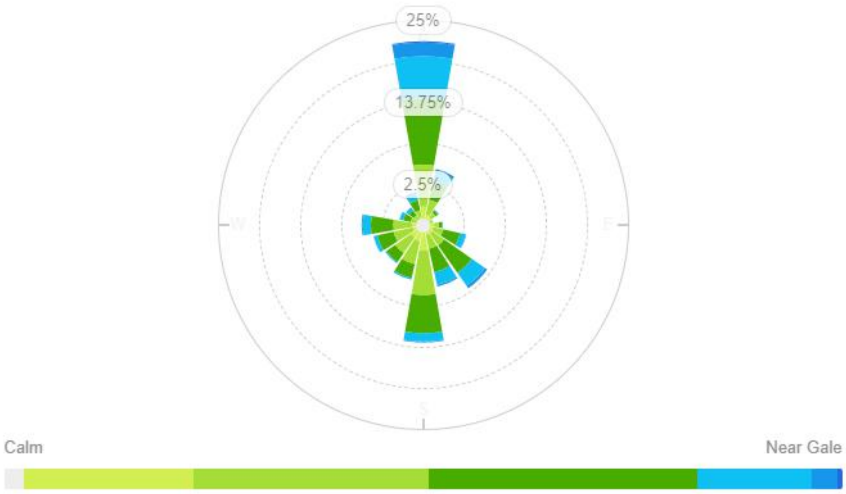

Figure 4-6: Wind rose for the last five years for Ballarat Airport (Source: https://wind.willyweather.com.au/vic/central-highlands/ballarat-airport.html)

5 Dispersion modelling methodology

5.1 Meteorological modelling

5.1.1 Selection of representative meteorological year

The selection of one representative meteorological year for modelling was driven by the requirement of the HHRA which assessed concentrations based on one year of meteorological data. It was important to determine which year should be used as a representative year. Dust generation and dispersion occurs more readily in low rainfall years than during high rainfall years. The past five years were examined and 2018 and 2019 were found to have similar levels of rainfall. Although rainfall levels in 2019 were slightly lower (552.8 mm in 2018 compared to 551 mm in 2019 - Figure 4-5), it was recognised that there were a number of bushfires in the Blue Mountains region in November and December 2019 which caused elevated background particulate levels at that time in Victoria. Consequently, 2018 was selected as the representative year.

5.1.2 Prognostic data generation

EPA Publication 1550 - Construction of input meteorological data files for EPA Victoria's regulatory air pollution model (AERMOD)[6] suggests the use of TAPM or MM5 as the prognostic model. It should be noted that EPA Victoria's guidance is now 10 years old, and the TAPM model is no longer being developed by CSIRO and the MM5 model was replaced by the Weather Research and Forecasting Model (WRF). Accordingly, to provide a meteorological file developed using the latest understanding of the science, prognostic modelling was completed using WRF Version 4.1.

WRF Version 4.1 is a widely used three-dimensional numerical meteorological model which contains non-hydrostatic dynamics, and a variety of physics options for parameterizing cumulus clouds, microphysics, the planetary boundary layer, and atmospheric radiation. WRF is also used to generate three-dimensional gridded meteorological data (such as hourly wind and temperature fields) in the modelling domain through the treatment and assimilation of available surface/upper air/precipitation observations. WRF provides surface level and vertical profiles of parameters that can be used within air dispersion modelling, when passed through the CALWRF or MMIF processing programs to generate suitable meteorological files for CALMET or AERMOD respectively.

To provide data for the HHRA, WRF modelling was completed for the period 1 January 2018 to 31 December 2018 (inclusive) for the Site. The process of developing the WRF datasets involved a nested approach centred on the Project site. The resolution and extent of each grid is outlined in Table 5.1. The WRF prognostic model was modelled to a resolution of 1 km (as required by EPA *Publication 1550*) for locations with non-complex terrain). The output from the prognostic modelling was processed through MMIF to translate the output into a format compatible with AERMOD.

Table 5.1: WRF modelling parameters

Grid	Resolution	Extent
1	9 km	882 km × 972 km
2	3 km	342 km × 342 km
3	1 km	30 km × 30 km

[6] Available at https://www.epa.vic.gov.au/about-epa/publications/1550

5.1.2.1 WRF setup

5.1.2.1.1 Initialisation datasets

WRF meteorological datasets were developed for the period 1 January 2018 – 31 December 2018 inclusive using data from the European Centre for Medium Weather Forecasts (ECMWF) global reanalysis dataset, known as ERA5. Data from the ERA5 dataset is available globally every 3 hours on a 27 km grid.

The ERA5 dataset provides information both for the surface conditions and 137 mandatory vertical levels. There are over 25 different variables including geopotential height, temperature, relative humidity and u- and v- wind components.

The ERA5 dataset assimilates a great deal of observational data, including surface pressure, sea level pressure, geopotential height, temperature, sea surface temperature, soil values, ice cover, relative humidity, u- and v- wind components, vertical motion, vorticity, winds and in-situ data such as moisture from radiosondes and pressure from surface observations. Also included in these datasets are additional precipitation data, profiler data, dropsondes, pilot balloons, aircraft temperatures and winds, land surface and moisture data and cloud drift winds from geostationary satellites. To assist in improving the performance of the WRF simulation, the ERA5 dataset was provided to the WRF Pre-processing System (WPS) stage to provide WRF with more initial-guess data both spatially and temporally at the start of the simulation.

5.1.2.1.2 Geospatial WRF inputs for the 9 km grids

WRF geospatial inputs are available from the US National Center for Atmospheric Research (NCAR) with default sets of static data for terrain, vegetation/land use and soil type. NCAR distributes various resolutions of global terrain and land-use data bases to support WRF simulations. The data bases are:

- 5-minute (approximately 9.25 km in mid-latitudes)
- 2-minute (approximately 4.00 km in mid-latitudes)
- 30-sec (approximately 0.900 km in mid-latitudes)
- 15-sec (approximately 0.450 km in mid-latitudes), which is only available for MODIS land use category.

The data was assigned to the WRF simulations based on the resolution of the simulation domain.

In addition to the above inputs, finer resolution inputs were derived for land use and terrain using local datasets to provide better representation of land use to the model.

5.1.2.1.3 Geospatial WRF inputs for finer grids

The conventional approach among the air quality modelling community is that WRF's highest resolution simulations are performed at 1 km gridded resolution with terrain and land use datasets at 30 arc seconds (approx. 900 m) resolution. WRF simulations are not conventionally performed at less than 1 km gridded resolution because of the difficulty in utilizing higher resolution datasets in WRF. Executing WRF at resolutions less than 1 km with the default datasets will not result in an analysis that is inherently more refined, since the input terrain and land use data resolution is coarser than the resolution being output by WRF. Therefore, there is no benefit in performing the simulation at finer resolutions without providing higher-resolution geospatial datasets.

<u>Land use</u>

For this study, locally sourced land-use data at 300 m resolution for grids 2 and 3 (3km and 1km) was used. Land use inputs to the WRF model were obtained from two sources:

- Catchment scale land use of Australia (CLUM); and
- National vegetation information system (NVIS).

The two datasets were used as:

- The CLUM does not provide significant detail on levels of vegetation on barren land within more remote regions of Australia; and
- CLUM does not differentiate between forest types or even between desert land or tropical / temperate rainforest in areas labelled for conservation.

Thus, the NVIS was used to substitute in these areas.

Once these databases were combined, they were then translated into the MODIS 21 category as required by WRF.

Terrain

For terrain, the AW3D30 dataset, recognised as one of the most accurate global digital terrain models, was used.

5.1.2.1.4 WRF options

In addition to the domain-wide characteristics noted above, the following discussion describes the physical schemes available within the WRF system and how they were adapted for use in the modelling analysis. The WRF model user has the choice of numerous options for running the model and its pre-processors. Table 5.2 provides a listing of the primary options and describes the reasoning behind the selection of each.

Table 5.2: WRF options selected

WRF Treatment	Option Selected	Reason & Notes
Microphysics	Thompson	A new bulk microphysical parameterization (BMP) has been developed for use with WRF. Compared to earlier single-moment BMPs, the new scheme incorporates a large number of improvements to both physical processes and employs numerous techniques found in far more sophisticated spectral/bin schemes using look-up tables. This scheme is a new scheme with ice, snow and graupel processes suitable for high-resolution simulations.
Shortwave and Longwave Radiation	Rapid Radiation Transfer Model (RRTMG)	This a recent version of the rapid radiation transfer model (RRTM) with random cloud overlap (RRTMG). RRTMG provides more sophisticated cloud treatment and better suited for climate applications than RRTM (option 1). RRTMG also handles cloud fraction whereas RRTM is binary in terms of yes or no for whether cloud cover exists. Based on available guidance, this scheme is considered to be a highly accurate and efficient method. This scheme also incorporates the effects of the comprehensive absorption spectrum taking water vapour, carbon dioxide and ozone into account. This scheme handles better cloud interactions with the Thompson MP scheme.

WRF Treatment	Option Selected	Reason & Notes
Land Surface Model	NOAH	To incorporate the air-soil interaction in the WRF simulation, the Noah Land-Surface Model (LSM) was chosen. Seasonally varying vegetation and soil type are used in the model to handle evapotranspiration. The LSM model also has the effects such as soil conductivity and gravitational flux of moisture. The land-surface model is capable of predicting soil moisture and temperature in four layers (10, 30, 60 and 100 cm thick), as well as canopy moisture and water-equivalent snow depth.
Planetary Boundary Layer (PBL)	Yonsei University (YSU)	This scheme has the enhanced stable boundary layer diffusion algorithm is also devised that allows deeper mixing in windier conditions. It has the ability to predict & simulates vertical mixing. This scheme also seems to show better performance during stable conditions. This scheme was used for WRF analyses with resolutions less than 1.33 km grid resolution.
Cumulus Parameterization	Kain-Fritsch in 36 km, 12 km, 4km	This scheme generally focuses on column moisture, temperature tendencies and surface convective rainfall. It is recommended that cumulus parameterization should not be used at grid sizes < 5-10 km, as the smaller grid size is sufficient to resolve updrafts and downdrafts. Therefore, this scheme was used for WRF analyses with resolutions less than 4 km grid resolution.
Four-dimensional data assimilation (FDDA)	Analysis nudging was applied to winds, temperature & moisture in the 36 & 12 km domains; Temp & moisture nudging was turned off within the PBL; Obs-nudging was used for the 4-km resolution WRF analysis.	FDDA is a method of performing WRF simulations with the full-physics model while blending local observations. By doing so, model equations maintain dynamic consistency while at the same time restraining the model's solutions from deviating too strongly from observations or from a gridded analysis and make up for errors and gaps in the initial analysis and deficiencies in model physics. There are two types of nudging in WRF: Analysis nudging – gently forces the model solution toward gridded fields and also make use of three-dimensional analyses and surface analyses. Observation nudging ("obs nudging") - gently forces the model solution toward individual observations, with the influence of the observations spread in space and time.

5.1.2.2 WRF post processing

The MMIF version 4 program published by the USEPA for the purpose of processing output from WRF to AERMOD.

The default output from MMIF as an input file for AERMOD creates a version that does not account for the latest abilities of the AERMOD model to account for low wind speeds and assumes coarse level (1 km resolution) land use information. To overcome these issues, the AERMET output option in MMIF was therefore selected. This generates a series of files containing meteorological information which can be processed AERMET using an updated landuse profile surrounding the Site and use the latest version of the model to take advantage of the most up to date model developments.

5.1.3 AERMET

The outputs from WRF were processed through AERMET using updated land use information for the Site surrounding the location of the TSF4. EPA Publication 1550 recommends that the surface roughness should be calculated based on the percentage of land use within sectors within 1 km of the site and vary by season. Meanwhile the Albedo and Bowen Ratio should be calculated based on the average land use within 10 km and applied to every wind direction equally. EPA Publication 1550 provides the appropriate values for the surface roughness, albedo and Bowen ratio.

Table 5.3 shows the land cover percentages and the surface roughness for each sector along with the surface roughness values for the seasons.

Table 5.3: Land cover percentages and surface roughness

Sector	Degrees Start	Degrees End	Land Cover	Summer	Autumn	Winter	Spring	Annual
1	20	45	20% mine, 80% forest	1.1	1.1	0.78	0.94	0.98
2	45	140	70% high intensity residential, 30% forest	1.09	1.09	0.97	1.03	1.045
3	140	290	Forest	1.3	1.3	0.9	1.1	1.15
4	290	310	60% forest, 40% mine	0.9	0.9	0.66	0.78	0.81
5	310	330	Industrial	0.7	0.7	0.7	0.7	0.7
6	330	20	Mine	0.3	0.3	0.3	0.3	0.3

Table 5.4 shows the estimated percentages of land cover within 10 km of the Site and the calculated Bowen ratios.

Table 5.4: Land cover and calculated Bowen ratios

10x10km Land use	Land cover	Summer	Autumn	Winter	Spring
High intensity residential	30%	1.5	1.5	1.5	1.5
Industrial/commercial	10%	1.5	1.5	1.5	1.5
Mixed forest	15%	0.3	0.9	0.9	0.7
Grassland	20%	0.8	1	1	0.4
Open water	5%	0.1	0.1	0.1	0.1
Shrub land (non-arid region)	15%	1	1.5	1.5	1
Quarries/strip mines/gravel	5%	1.5	1.5	1.5	1.5
Average	-	0.957	1.143	1.143	0.957

10x10km Land use	Land cover	Summer	Autumn	Winter	Spring
Land cover weighted average	-	1.035	1.24	1.24	1.015

Table 5.5 shows the estimated percentages of land cover within 10 km of the Site and the calculated albedo.

Table 5.5: Land cover and calculated albedo

10x10km Land use	Land cover	Summer	Autumn	Winter	Spring
High intensity residential	30%	0.18	0.18	0.18	0.18
Industrial/commercial	10%	0.18	0.18	0.18	0.18
Mixed forest	15%	0.14	0.14	0.14	0.14
Grassland	20%	0.18	0.18	0.2	0.18
Open water	5%	0.1	0.1	0.1	0.1
Shrub land (non-arid region)	15%	0.18	0.18	0.18	0.18
Quarries/strip mines/gravel	5%	0.2	0.2	0.2	0.2
Average	-	0.166	0.166	0.169	0.166
Land cover weighted average	-	0.171	0.171	0.175	0.171

5.2 Selection of mitigation options

Selection of mitigation options[7] for the processes occurring during construction and operation (Table 2.2) was subjected to consideration of 'as low as reasonably practicable'. The mitigation options considered were based on those recommended in the following documents:

- National Pollutant Inventory (NPI)'s Emission Estimation Technique Manual for Mining (Version 3.1, January 2012)[8];
- NPI's Emission Estimation Technique Manual for Gold Ore Processing (Version 2.0, 2006)[9]; and
- Relevant Sections (Chapter 11.9 Western Surface Coal Mining[10], Chapter 13.2.4 Aggregate Handling and Storage Piles[11], Chapter 13.2.2 Unpaved Roads[12] and Chapter 11.12 Concrete Batching[13]) from AP-42 emission factors (the emission factor compendium by the United States Environmental Protection Agency (USEPA)).

[7] The terms mitigation options, controls and mitigation measures are used interchangeably within this report.
[8] Available at https://www.dcceew.gov.au/sites/default/files/documents/mining.pdf
[9] Available at https://www.dcceew.gov.au/sites/default/files/documents/gold.pdf
[10] Available at https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s09.pdf
[11] Available at https://www.epa.gov/sites/default/files/2020-10/documents/13.2.4_aggregate_handling_and_storage_piles.pdf
[12] Available at https://www.epa.gov/sites/default/files/2020-10/documents/13.2.2_unpaved_roads.pdf
[13] Available at https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s12.pdf

The potential mitigation options considered and the final selected choices are summarised in Table 5.6. Given the proposed operations, it is considered that the use of these measures will result in emissions that are as low as reasonably practicable. As the emissions are linearly linked with concentration, reduction in emissions is directly linked to reduction in risk.

5.3 Emission estimation

5.3.1 Overview

Emission estimates have been developed for particulate emissions including the size fractions for TSP, PM_{10} and $PM_{2.5}$.

TSP emissions are modelled to determine dust deposition rates at specific sensitive receptors. Heavy metal concentrations are estimated using source groupings of specific lithologies of the PM_{10} modelling results and RCS concentrations are estimated using the $PM_{2.5}$ model outputs assuming all $PM_{2.5}$ is RCS.

Regarding combustion emissions, it has been identified that there is potential that small mobile diesel generators may be used at the commencement of operations to pump the tailings from the processing facility to the new tailings facility prior to the installation of electric pumps.

In addition, due to the underground operations there is a ventilation shaft through which the underground vehicular emissions and particulate emissions from mining are ventilated.

The Act requires that the Site understand, abate and manage their emissions so that risks of harm to the environment and human health are effectively minimised. Section 3.1.2 follows the Guideline and details the steps in controlling hazards and risks.

5.3.2 NPI / AP-42

The emission factors used in this assessment are sourced from emission factors published by the NPI and by the USEPA (AP-42). Table 5.7 presents the emission factors for TSP, PM_{10} and $PM_{2.5}$ that have been used in this assessment. References for each equation are provided in the table. The emission factors for machinery operation were developed through the measurement of dust concentrations upwind and downwind. Emissions of particulate from exhaust and braking are therefore inherently contained within the emission factor used in addition to any particulate generation from the movement of soils.

The site specific values for silt and moisture content of the various types of soils and handled material and these have been used as inputs for the emission factor equations where required based on information provided in a variety of documentation detailed in Section 5.3.3. These values are, as expected, different for individual soil types.

Table 5.6: Selection of mitigation options

Processes	Mitigation options considered	Selected options and justification
North Prince Ventilation Shaft	• No reasonable mitigation options available as the shaft ventilates emissions from blasting and background testing taking place underground which cannot be avoided/mitigated. Only the necessary number of blasting/testing occurrences will take place. Blasting and testing being underground mitigates the ambient release of dust to a large degree.	-
Diesel Generators (x 2) - may be used at the commencement of TSF4 operations	• Diesel generators are for temporary usage (at the commencement of TSF4 operations), until such time that electric pumps are installed.	-
Ore handling and processing	• Watering during material handling (unloading/unloading) and of stockpiles. • Good maintenance and wetting of road surfaces.	All recommended as low as reasonably practicable mitigation options for this activity will be implemented: • Watering of all areas/activities where ore material is handled. • All crushers (primary/secondary/ tertiary) fully enclosed. • Sprinklers are to be used within ore conveying system. • Chemical sealants on haul roads with additional watering to increase the damping effect. • Covered loads when being transported to reduce fugitive emissions. The following are noted: • Once crusted on the surface, stockpiles do not tend to be subject to wind erosion (aside from the working face). • The lower height of the underground pit (in relation to ground level) is also an inherent mitigation as the majority of dust emissions (applicable to TSP and PM_{10}) will be retained within the pit. • The material has some inherent moisture (in general, moisture reduces dust emissions) and the dust mitigation will be further enhanced with the damping effect from watering.

Processes	Mitigation options considered	Selected options and justification
Dry stacking of TSF3 whilst Zone 1 of TSF4 is constructed to allow ongoing operations	• Watering during material handling (unloading/unloading) and of stockpiles. • Good maintenance and wetting of road surfaces.	All recommended as low as reasonably practicable mitigation options for this activity will be implemented: • Watering of all areas/activities where material is handled. • Chemical sealants on haul roads with additional watering to increase the damping effect. • Covered loads when being transported to reduce fugitive emissions. The following are noted: • Once crusted on the surface, stockpiles do not tend to be subject to wind erosion (aside from the working face). • The lower height of the underground pit (in relation to ground level) is also an inherent mitigation as the majority of dust emissions (applicable to TSP and PM_{10}) will be retained within the pit. • The material has some inherent moisture (in general, moisture reduces dust emissions) and the dust mitigation will be further enhanced with the damping effect from watering.
Extraction, movement and placement of waste rock from current rehab area to embankment Movement and placement of waste rock from underground to embankment	• Watering during material handling (unloading/unloading). • Good maintenance and wetting of road surfaces.	All recommended as low as reasonably practicable mitigation options for this activity will be implemented: • Watering of all areas/activities where material is handled. • Chemical sealants on haul roads with additional watering to increase the damping effect. • Covered loads when being transported to reduce fugitive emissions. • Inventory control of waste rock extraction such that only the required amount of waste rock for the embankment construction is moved (i.e., no stockpiles formed). The following are noted: • The lower height of the underground pit (in relation to ground level) is also an inherent mitigation as the majority of dust emissions (applicable to TSP and PM_{10}) will be retained within the pit. • The material has some inherent moisture (in general, moisture reduces dust emissions) and the dust mitigation will be further enhanced with the damping effect from watering.

<table>
<tr><th>Processes</th><th>Mitigation options considered</th><th>Selected options and justification</th></tr>
<tr><td>Extraction, movement and placement of soils from TSF4 excavation area to embankment</td><td rowspan="2">• Watering during material handling (unloading/unloading) and of stockpiles.
• Good maintenance and wetting of road surfaces.</td><td rowspan="2">All recommended as low as reasonably practicable mitigation options for this activity will be implemented:
• Watering of all areas/activities where material is handled.
• Chemical sealants on haul roads with additional watering to increase the damping effect.
• Covered loads when being transported to reduce fugitive emissions.
The following are noted:
• Once crusted on the surface, stockpiles do not tend to be subject to wind erosion (aside from the working face).
• The lower height of the underground pit (in relation to ground level) is also an inherent mitigation as the majority of dust emissions (applicable to TSP and PM_{10}) will be retained within the pit.
• The material has some inherent moisture (in general, moisture reduces dust emissions) and the dust mitigation will be further enhanced with the damping effect from watering.</td></tr>
<tr><td>Extraction and movement of soils from TSF4 to off-site which cannot be reused within the embankment</td></tr>
<tr><td>Concrete batching plant activities</td><td>• Baghouse or fabric filter (for material transfer to silo).
• Water sprays, enclosures, hoods, curtains, shrouds, movable and telescoping chutes, central dust collection systems and the like for control of fugitive emissions (such as from transfer of sand and aggregate).
• Good maintenance and wetting of road surfaces.</td><td>All recommended as low as reasonably practicable mitigation options for this activity will be implemented:
• Baghouse used at silo.
• Sprinklers used when receiving material for concrete batching.
• Regular checks/maintenance of dusty surfaces in and around the concrete batching plant area.
• Chemical sealants on haul roads with additional watering.</td></tr>
</table>

Table 5.7: Emission factors for TSP, PM_{10} and $PM_{2.5}$

Inventory Activity	Units	TSP Emission Factor	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Source	Mitigation adopted (% reduction)
Unusable soils excavation						
Loading trucks using FEL	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 NPI Table 2	Water sprays when using a FEL - loading (50%)
Embankment soils						
Scrapers loading	kg/t	0.029	0.0073	0.003 (TSP x 0.105)	AP-42 11.9 Table 11.9-4 and NPI Table 2	Material naturally or artificially moist (50%)
Scrapers unloading	kg/t	0.02	0.005	0.0021 (TSP x 0.105)	AP-42 11.9 Table 11.9-4	Material naturally or artificially moist (50%)
Scrapers (travel mode) (unsealed roads equation – as noted in AP-42)	kg/VKT	$\left(\frac{0.4536}{1.6093}\right) \times 4.9 * \left(\frac{S}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 1.5 * \left(\frac{S}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 0.15 * \left(\frac{S}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	AP-42 13.2.2	Chemical sealants and watering (96 %)
FEL loader loading moxie with earth fill for embankment and moxie unloading across embankment	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 NPI Table 2	Water sprays when using a FEL – loading (50%)

Inventory Activity	Units	TSP Emission Factor	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Source	Mitigation adopted (% reduction)
Waste Rock						
Loading waste rock to moxie by FEL	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL - loading (50%)
Unloading on embankment and repositioning using FEL	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL – unloading (70%)
TSF3 dry stacking						
Loading truck with TSF3 material by FEL	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL - loading (50%)
Unloading to drystack and repositioning using FEL.	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL – unloading (70%)
Ore Processing						
Pickup of ore from stockpile by FEL Shaping of stockpile using FEL	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL - loading and shaping (50%)

Inventory Activity	Units	TSP Emission Factor	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Source	Mitigation adopted (% reduction)
Unloading ore to stockpile. Unloading from FEL to crusher	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP-42 13.2.4 and NPI Table 2	Water sprays when using a FEL – unloading (70%)
Primary Crusher	kg/t	0.01	0.004	0.004 (same as PM_{10} as worst-case assumption)	NPI for Gold Mining table 4	Enclosed (100%)
Secondary Crusher	kg/t	0.03	0.012	0.012 (same as PM_{10} as worst-case assumption)	NPI for Gold Mining table 4	Enclosed (100%)
Tertiary Crusher	kg/t	0.03	0.01	0.01 (same as PM_{10} as worst-case assumption)	NPI for Gold Mining table 4	Enclosed (100%)
Transfer from crushers to conveyor or conveyor transfer points	kg/t	0.005	0.002	0.002 (same as PM_{10} as worst-case assumption)	NPI for Gold Mining table 4	Sprinklers (50%)
Concrete batching						
Weigh hopper/mixer loading	kg/t	0.0026	0.0013	0.0004 (PM_{10} x 0.32)	AP42 Table 11.12-1	Negative pressure extraction to baghouse (94%)
Central mix operations	kg/t	$k \times 0.0032 \times \left(\frac{(U)^a}{(M)^b}\right) + c$ k = 0.19 a = 0.95 b = 0.9 c = 0.0010	$k \times 0.0032 \times \left(\frac{(U)^a}{(M)^b}\right) + c$ k = 0.13 a = 0.45 b = 0.9 c = 0.0010	$k \times 0.0032 \times \left(\frac{(U)^a}{(M)^b}\right) + c$ k = 0.03 a = 0.45 b = 0.9 c = 0.0002	AP42 Table 11.12-1	Controls have been incorporated in the emission factors

Inventory Activity	Units	TSP Emission Factor	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Source	Mitigation adopted (% reduction)
Aggregate/sand transfer	kg/t	0.0046 (summation of aggregate and sand transfer emissions factors)	0.0022 (summation of aggregate and sand transfer emissions factors)	0.001 (PM_{10} x 0.32)	AP42 Table 11.12-1	Water sprays – unloading (70%)
Pneumatic transfer of cement	kg/t	0.0005	0.000170	0.0001 (PM_{10} x 0.32)	AP42 Table 11.12-1	Controls have been incorporated in the emission factors
Transfer of product	kg/t	0.049	0.013	0.0042 (PM_{10} x 0.32)	AP42 Table 11.12-1	Controls have been incorporated in the emission factors
Hauling						
Hauling on unsealed roads	kg/VKT	$\left(\frac{0.4536}{1.6093}\right) \times 4.9 * \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 1.5 * \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 0.15 * \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	AP-42 13.2.2 and NPI Table 2	Chemical sealants and watering (96 %)
Diesel Generators						
Diesel Generators	kg/hr	0.001	0.001	0.001	Based on NPI for Combustion Engines Table 50	Not applicable
Vent shaft						

Inventory Activity	Units	TSP Emission Factor	PM_{10} Emission Factor	$PM_{2.5}$ Emission Factor	Source	Mitigation adopted (% reduction)
Vent shaft	kg/hr	1.3	1.3	0.12	Based on worst case measurements	Not applicable

Notes:

1. M = material moisture content (%), s = material silt content (or surface silt content in unpaved roads) (%), U = wind speed (m/s), W = mean vehicle weight (tonnes), S = mean vehicle speed (km/h), VKT = vehicle kilometre travelled
2. Mitigation option (% reduction) is applied to the emission rates calculated by the emission factors listed.
3. Where emissions occur within the excavation area there is a further reduction of 50 % applied for TSP emissions and 5 % for PM_{10} emissions as a pit retention factor.

5.3.3 Site-specific data

Where data is available, site-specific data for moisture and silt content has been used for inputs into emission estimation:

- Moisture content of various materials is summarised in Table 5.8.
- Silt content of various materials is summarised in Table 5.9.

Table 5.8: Moisture content

Parameter	Moisture content (%)	Source
Moisture content of ore	4	Taken from AECOM Air Quality Assessment (AQA). Appendix J of Planning Permit Application TSF4 dated 16 March 2020
Moisture content of waste rock	5.8	Taken from test data.
Moisture content of embankment material	15	Material excavated is put into embankment. Sourced from AECOM AQA which referenced bore hole samples from a geotechnical report.
Moisture content of TSF4 excavation area	14.1	Taken from AECOM AQA which referenced bore hole samples from a geotechnical report.
Moisture content of tailings	9	Taken from email from mining engineer (21/02/2023), stated 9-11%, taken lower value as more conservative.
Moisture content of concrete batching materials	9	Assumed from similar assessment (Avonbank Mineral Sands Project). [Appendix H https://www.avonbankproject.com.au/]
Moisture content of material to be excavated	15	Taken from AECOM AQA which referenced bore hole samples from a geotechnical report.

Table 5.9: Silt content

Parameter	Moisture content (%)	Source
Silt Content of Tails	15	Email from mine engineer stated 30-40%, however this is outside the range of the emissions equation which is to 15%. Default to 15%.
Silt Content of Ore	6	No data provided on ore, taken to be similar to waste rock as this is adjacent to the ore body.
Silt Content of Waste Rock	6	Taken from 'Mine Waste Stockpile - PSD - B211416issue1.pdf'
Silt Content of Embankment material	12.5	Taken from AECOM AQA which referenced bore hole samples from a geotechnical report.
Silt Content of TSF4 Excavation Area	12.5	Taken from AECOM AQA which referenced bore hole samples from a geotechnical report.
Silt Content of Tailings	15	Percentage of particles that are less than 53 microns in size from the 'GPG- Gravity-Final Tails - Grade by Size Results.xls' document is 35 % but this is measured in a lab and not by sieve analysis which tends to result in higher silt content and is a value outside of the max of the equation bounds. So max of equation bounds used and no mitigation
Silt Content of Haul Roads	6.00	Assumed same as waste rock as waste rock used for haul roads.

5.3.4 Hours of operations

The emission estimation takes into account the hours of operation (Table 5.10) of different activities. In practical terms, for each particular activity group, emissions are 'turned off' for the hours where the activity is not taking place.

Table 5.10: Hours of operation

Activity group	Hours of operations
Construction	7am - 6pm
Mine operations	24 hours a day
Concrete batching	7am - 6pm

5.3.5 Final modelled emission rates

The emission rates for all three modelled scenarios (as described in Section 2.2) are summarised in Appendix A.

5.3.6 Particle size distribution

Modelling of dust deposition within AERMOD requires the input of the particle size distribution (PSD) and the particle density. The values of the particle size distribution (PSD) and particle densities used in the dispersion modelling for dust (TSP) deposition are summarised in Table 5.11.

5.3.7 Heavy metals content

To predict the deposition rate and ambient air concentration of heavy metals at receptors, the model results were scaled by the proportion of heavy metals from laboratory analysis of solid samples of ore, waste rock, mine tailings and subsoil within the TSF4 area and applying the proportion to the modelled results of deposited TSP, PM_{10} and $PM_{2.5}$. For concrete batching activities heavy metal proportions were not available, with emission factors from AP-42 used instead. The heavy metals composition is summarised in

Table **5.12**.

5.3.8 Conservatism in emission estimation

Whilst site-specific factors (Section 5.3.3) are used as far as possible with generic emission factors provided in the AP-42 and NPI (Table 5.7) for assessing dust emissions from gold mining, there is evidence to suggest that these factors are likely to overestimate emissions for certain activities in an operation such as the Project.

The largest emission rates for this Project were associated with the scrapers and the haul road emissions. Appendix H of the Avonbank Mineral Sands Project[14] details a site-specific monitoring campaign in February 2021 to better characterise emissions for that project (where the original emission inventory calculations showed that wheel generated dust, the movement of scrapers and materials handling were the main sources) and to test the appropriateness of these generic emission factors. The study focussed on wheel-generated dust, scrapers picking up and dumping material and wind erosion. A comparison against the NPI and AP-42 emission factors showed that the site-specific emission factors for PM_{10} obtained from that monitoring study were:

- 1.5 % of the default AP-42 / NPI emission factor for scrapers picking up material;
- 0.4 % of the default AP-42 emission factor for scrapers unloading material; and
- Between 10 % and 33 % of the values from the emission equation from AP-42 / NPI for haul road emissions.

It was noted in the Avonbank study, that these results were similar to the results for haul roads found in studies in the Hunter Valley. It is considered likely that this conservatism would also occur within this Project.

[14] Available at https://www.avonbankproject.com.au/

Table 5.11: Particle size distribution

Parameter	Particle size (μm)					Density (g/cm^3)	Source
	1	2.5	5	10	30		
Haul roads (not within the pit)	0.11	0.15	0.19	0.23	0.32	2.3	From PSD provided for the site
Haul roads (within the pit)	0.12	0.17	0.20	0.23	0.28	1.9	From PSD provided for the site
Fresh waste rock	0.11	0.15	0.18	0.23	0.32	2.3	From PSD provided for the site
Aged waste rock	0.14	0.17	0.19	0.22	0.29	2.3	From PSD provided for the site
Tailings	0.022	0.057	0.11	0.22	0.59	2.5	Estimated based on https://iopscience.iop.org/article/10.1088/1757-899X/652/1/012045/pdf#:~:text=Relative%20density%20and%20pH%20of,have%20a%20relative%20high%20density.
Top soil	0.07	0.16	0.16	0.21	0.4	1.6	From PSD provided for the site
Embankment (TSF extracted soil)	0.12	0.17	0.20	0.23	0.28	1.9	From PSD provided for the site
Ventilation shaft	0.092	0.157	0.20	0.24	0.31	1.1	AP-42 Generalised PSD mixed combustion & https://www.sae.org/publications/technical-papers/content/2002-01-0056/#:~:text=The%20results%20show%20that%2C%20the,to%201.2%20g%2Fcm3
Diesel generator	0.18	0.20	0.20	0.21	0.22	1.1	AP-42 Generalised PSD Diesel Fume & https://www.sae.org/publications/technical-papers/content/2002-01-0056/#:~:text=The%20results%20show%20that%2C%20the,to%201.2%20g%2Fcm3
ROM	0.11	0.15	0.18	0.23	0.32	1.8	No PSD for ROM, but waste rock is similar geology so assumed to be the same
Crushing	-	0.03	-	0.27	0.7	1.8	https://www.epd.gov.hk/eia/register/report/eiareport/eia_2232014/html/Appendix%205.2.3.pdf
Concrete	-	0.07	-	0.4	0.53	2.4	https://www.epd.gov.hk/eia/register/report/eiareport/eia_2232014/html/Appendix%205.2.3.pdf

Table 5.12: Heavy metals content

Heavy metals	Ratio						
	Concrete	Diesel	ROM	Subsoil	Tailings	Topsoil	Waste rock
Arsenic (As)	5.50E-05	-	2.06E-04	6.37E-05	9.97E-04	7.02E-06	2.06E-04
Lead (Pb)	6.06E-05	-	-	1.57E-05	1.65E-05	2.28E-05	-
Cadmium (Cd)	8.54E-07	-	-	5.00E-07	5.55E-06	3.73E-07	-
Barium (Ba)	-	-	-	2.67E-05	3.35E-05	1.83E-04	-
Cobalt (Co)	-	-	1.28E-05	8.00E-06	1.05E-05	2.91E-05	1.28E-05
Nickel (Ni)	2.12E-04	-	-	9.40E-06	2.28E-05	3.99E-05	-
Antimony (Sb)	-	-	-	2.50E-06	7.22E-07	3.92E-06	-
Manganese (Mn)	-	-	5.23E-04	3.72E-05	5.74E-04	7.91E-04	5.23E-04
Strontium (Sr)	-	-	-	3.73E-05	-	3.73E-05	-
Zinc (Zn)	-	-	8.78E-05	1.66E-05	6.12E-05	2.68E-05	8.78E-05
Vanadium (V)	-	-	-	1.05E-05	1.73E-05	1.33E-04	-
Chromium (Cr)	1.58E-04	-	-	1.30E-05	5.03E-06	1.40E-04	-

5.4 Modelled receptors

Section 4.2 describes the surrounding land use. It is impractical to model at every residential address within the modelled area. Consequently, the HHRA identified representative locations at which are data is required to determine the risk to human health for the surrounding sensitive receptors. The list of receptors included representative locations for residential use and locations such as schools and aged care facilities. Figure 1-1 provides a map of the receptors specifically modelled for the HHRA.

6 Results

The results at each receptor have been processed to provide the HHRA with:

- PM_{10}, $PM_{2.5}$ and heavy metal ground level concentrations as:
  - 24-hour time series providing a modelled concentration for each day of the year at each receptor; and
  - Annual average.
- Metal deposition as:
  - Annual average.

7 Summary

A dispersion modelling study has been undertaken to predict ambient air contaminant concentrations and deposition rates at representative sensitive receptor locations associated with the emissions of particulate matter from the construction and operation of TSF4. The purpose of the modelling is to provide necessary data for input to a HHRA.

Emission estimates were completed by considering the potential sources of emissions to atmosphere and determining the approach which would result in the reduction of the emissions so far as reasonably practicable. The emissions were then estimated using standard emission factors from the NPI Emission Estimation Technique Manuals and the equivalent from the USEPA known as AP-42. The use of these emission factors is generally considered to be state of knowledge for assessments of this kind; however, recent measurement studies have found that these factors are likely to be very conservative and actual emissions of the most significant sources may be between 66 % and 99 % lower than used in this study.

The modelling was undertaken using AERMOD for the year 2018, with meteorological inputs prepared using WRF and AERMET.

The results from the dispersion modelling assessment in terms of ambient air concentrations of PM_{10} and $PM_{2.5}$, as well as concentrations and deposition rates for heavy metals have been prepared for input to the HHRA.

8 Applicability

This report has been prepared for the exclusive use of our client Balmaine Gold Pty Ltd (in administration), with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by City of Ballarat Council in undertaking its regulatory functions in connection with the Project.

Tonkin & Taylor Pty Ltd
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Pty Ltd by:

[redacted]

Technical Lead Environmental Project Director

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Appendix A Emission rates used for the modelling

Table Appendix A.1: Emission rates for construction of Zone 1 and Zone 6 of TSF4 and operation of TSF4

ID	Activity	Scenario 1 – Construction of Zone 1					Scenario 2 – Construction of Zone 6					Scenario 3 – Operation of TSF4				
		Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
1	North Prince Ventilation Shaft	1	24 hours	0.18	0.14	0.034	1	24 hours	0.17737	0.14190	0.03406	1	24 hours	0.18	0.14	0.034
2	Diesel generator 2	0	24 hours	-	-	-	1	24 hours	0.00028	0.00028	0.00028	1	24 hours	0.00028	0.00028	0.00028
3	Diesel Generator 1	0	24 hours	-	-	-	1	24 hours	0.00028	0.00028	0.00028	1	24 hours	0.00028	0.00028	0.00028
4	ROM Stockpile - Unloading, wind erosion	1	24 hours	0.0059	0.0028	0.00042	1	24 hours	0.00587	0.00277	0.00042	1	24 hours	0.0059	0.0028	0.00042
4	ROM Stockpile - FEL Loading	1	24 hours	0.0057	0.0027	0.00041	1	24 hours	0.00572	0.00270	0.00041	1	24 hours	0.0057	0.0027	0.00041
5	ROM Stockpile - shaping using FEL	1	7am to 6pm	0.021	0.010	0.0015	1	7am to 6pm	0.02133	0.01009	0.00153	1	7am to 6pm	0.021	0.010	0.0015
6	Primary Crusher	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)
7	Primary Crusher to conveyor	1	24 hours	0.052	0.021	0.021	1	24 hours	0.05208	0.02083	0.02083	1	24 hours	0.052	0.021	0.021
8	Conveyor unload to secondary crusher	1	24 hours	0.052	0.021	0.021	1	24 hours	0.05208	0.02083	0.02083	1	24 hours	0.052	0.021	0.021
9	Secondary Crusher	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)
10	Secondary crusher unload to conveyor	1	24 hours	0.052	0.021	0.021	1	24 hours	0.05208	0.02083	0.02083	1	24 hours	0.052	0.021	0.021
11	Conveyor unload to tertiary crusher	1	24 hours	0.052	0.021	0.021	1	24 hours	0.05208	0.02083	0.02083	1	24 hours	0.052	0.021	0.021
12	Tertiary Crusher	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)	1	24 hours	- (enclosed)	- (enclosed)	- (enclosed)
13	Front end loader unloading to Primary Crusher	1	24 hours	0.0059	0.0028	0.00042	1	24 hours	0.00587	0.00277	0.00042	1	24 hours	0.0059	0.0028	0.00042
14	TSF3 FEL Loading	1	7am to 6pm	0.0031	0.0015	0.00022	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
15	TSF3 Unloading, wind erosion	1	7am to 6pm	0.0019	0.00089	0.0001	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
15	TSF3 Shaping using FEL	1	7am to 6pm	0.0031	0.0015	0.00022	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
16	Zone 1 - Scrapers loading earthfill pit for embankment	1	7am to 6pm	0.37	0.092	0.039	1	7am to 6pm	0.22	0.05502	0.023	0	7am to 6pm	-	-	-
16	Zone 1 - FEL loading waste soil	1	7am to 6pm	0.00038	0.00018	0.00003	1	7am to 6pm	0.00023	0.00011	0.00002	0	7am to 6pm	-	-	-
17	Zone 1 - Scraper unloading earthfill	1	7am to 6pm	0.51	0.13	0.053	1	7am to 6pm	0.30	0.076	0.032	0	7am to 6pm	-	-	-
17	Zone 1 - FEL loading moxie with earthfill	1	7am to 6pm	0.0037	0.0018	0.00027	1	7am to 6pm	0.0022	0.0011	0.00016	0	7am to 6pm	-	-	-
17	Zone 1 - Moxie dumping earthfill	1	7am to 6pm	0.0022	0.0011	0.00016	1	7am to 6pm	0.0013	0.00064	0.00010	0	7am to 6pm	-	-	-

ID	Activity	Scenario 1 – Construction of Zone 1					Scenario 2 – Construction of Zone 6					Scenario 3 – Operation of TSF4				
		Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
18	Zone 1 – Waste rock pickup using FEL and put in moxie	1	7am to 6pm	0.0018	0.00083	0.00013	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
19	Zone 1 – Waste rock moxie dumping	1	7am to 6pm	0.0018	0.00083	0.00013	1	7am to 6pm	0.0011	0.00050	0.00008	0	7am to 6pm	-	-	-
19	Zone 1 - FEL repositioning	1	7am to 6pm	0.0018	0.00083	0.00013	1	7am to 6pm	0.0011	0.00050	0.00008	0	7am to 6pm	-	-	-
20	Concrete Batching - Weigh hopper, mixer loading	1	7am to 6pm	0.00001	0.00000	0.00000	1	7am to 6pm	0.00001	0.00000	0.00000	1	7am to 6pm	0.00001	0.000005	0.000002
20	Concrete Batching - central mix operations	1	7am to 6pm	0.00033	0.00004	0.00004	1	7am to 6pm	0.00033	0.00004	0.00004	1	7am to 6pm	0.00033	0.00004	0.00004
21	Concrete Batching - Aggregate and sand transfer	1	7am to 6pm	0.00009	0.00004	0.00001	1	7am to 6pm	0.00009	0.00004	0.00001	1	7am to 6pm	0.00009	0.00004	0.00001
21	Concrete Batching - Pneumatic transfer of cement	1	7am to 6pm	0.00003	0.00001	0.000003	1	7am to 6pm	0.00003	0.00001	0.00000	1	7am to 6pm	0.00003	0.00001	0.00000
22	Concrete Batching - Transfer of product	1	7am to 6pm	0.0031	0.00084	0.00027	1	7am to 6pm	0.0031	0.00084	0.00027	1	7am to 6pm	0.0031	0.00084	0.00027
23	Zone 1 - Scraper travel mode Pit to embankment in pit (RLINE2)	1	7am to 6pm	0.090	0.053	0.0055	1	7am to 6pm	0.085	0.050	0.0053	0	7am to 6pm	-	-	-
23	Zone 1 - Waste rock Pit to embankment in pit (RLINE2)	1	7am to 6pm	0.0066	0.00387	0.00041	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
24	Zone 1 Scrapers (RLINE2A)	1	7am to 6pm	0.018	0.011	0.0011	1	7am to 6pm	0.013	0.0078	0.00082	0	7am to 6pm	-	-	-
25	Zone 1 Waste Rock Moxies (RLINE2B)	1	7am to 6pm	0.0021	0.00120	0.00013	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
26	Zone 1 - Scraper travel mode Pit to embankment outside pit (RLINE2C)	1	7am to 6pm	0.047	0.012	0.0012	1	7am to 6pm	0.040	0.011	0.0011	0	7am to 6pm	-	-	-
27	Zone 1 - Waste Rock Moxies deliver to embankment outside pit (RLINE2D)	1	7am to 6pm	0.0050	0.0013	0.00013	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
28	Mine Shaft to ROM Stockpile (RLINE3)	1	24 hours	0.073	0.020	0.0020	1	24 hours	0.073	0.020	0.0020	1	24 hours	0.073	0.020	0.0020
29	MS - WR to TSF4 (RLINE4)	0	7am to 6pm	-	-	-	1	7am to 6pm	0.013	0.0034	0.00034	0	7am to 6pm	-	-	-
30	CB - TSF4 (RLINE5)	1	7am to 6pm	0.00025	0.00007	0.00001	1	7am to 6pm	0.00025	0.00007	0.00001	0	7am to 6pm	-	-	-
31	CB - TSF4 (RLINE6)	1	7am to 6pm	0.00097	0.00026	0.00003	1	7am to 6pm	0.0010	0.00028	0.00003	0	7am to 6pm	-	-	-
31	WR - TSF4 (RLINE6)	0	7am to 6pm	-	-	-	1	7am to 6pm	0.043	0.012	0.0012	0	7am to 6pm	-	-	-

ID	Activity	Scenario 1 – Construction of Zone 1					Scenario 2 – Construction of Zone 6					Scenario 3 – Operation of TSF4				
		Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Operational? (1 = Yes, 0 = No)	Operation hours	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
32	Brittain Street - CB (RLINE7)	1	7am to 6pm	0.00013	0.00003	0.00000	1	7am to 6pm	0.00013	0.00003	0.00000	1	7am to 6pm	0.00013	0.00003	0.000003
33	TSF3 Material Movement (RLINE8)	1	7am to 6pm	0.028	0.0073	0.00073	0	7am to 6pm	-	-	-	0	7am to 6pm	-	-	-
34	Waste Soil Haul Road for non-reuse in pit (RLINE9)	1	7am to 6pm	0.0096	0.0030	0.00030	1	7am to 6pm	0.0051	0.0016	0.00016	0	7am to 6pm	-	-	-
35	Waste Soil Haul Road for non-reuse outside pit (RLINE9A)	1	7am to 6pm	0.021	0.0056	0.00056	1	7am to 6pm	0.019	0.0051	0.00051	0	7am to 6pm	-	-	-

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Appendix B Tailings analysis Ballarat Gold Mine

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM2101779**	Page	: 1 of 8
Amendment	: **2**		
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Contact	: [redacted]
Address	: 2 SALAMANCA SQUARE HOBART TAS, AUSTRALIA 7000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021 11:05
Order number	: 12537535	Date Analysis Commenced	: 08-Feb-2021
C-O-C number	: ----	Issue Date	: 25-Feb-2021 15:28
Sampler	: GHD		
Site	:		
Quote number	: EN/005		
No. of samples received	: 10		
No. of samples analysed	: 10		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
[redacted]	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
[redacted]	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC

Page	:	2 of 8
Work Order	:	EM2101779 Amendment 2
Client	:	GHD PTY LTD
Project	:	12537535

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T : EM2101779 #1 Poor duplicate precision for total metal due to sample matrix. Confirmed by re-digestion and re-analysis.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- Amendment (11/02/2021): This report has been amended and re-released to allow the reporting of additional analytical data, specifically NAPP and NAG (EA011, EA009, EA013, ED042T) for 001, 003, 005, 006, 008 and 009.
- Amendment (23/02/2021): This report has been amended and re-released to allow the reporting of additional analytical data, specifically Chromium Suite (EA033), metals (EG020T, EG005, EG035T) and Sulphate (ED040T) for 001, 005, 006, 008 and 009.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Page : 3 of 8
Work Order : EM2101779 Amendment 2
Client : GHD PTY LTD
Project : 12537535

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	A-4 (10cm)	A-6 (50cm)	B-4 (10cm)	B-6 (50cm)	C-4 (10cm)
Sampling date / time				21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
				EM2101779-001	EM2101779-002	EM2101779-003	EM2101779-004	EM2101779-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	8.5	8.8	8.9	8.5
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-43.6	----	-35.3	----	-64.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	556	298	226	133	100
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	10.0	----	9.3	----	9.5
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	----	<0.1	----	<0.1
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	----	<0.1	----	<0.1
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	54.0	----	57.0	----	70.7
ANC as CaCO3	----	0.1	% CaCO3	5.5	----	5.8	----	7.2
Fizz Rating	----	0	Fizz Unit	2	----	2	----	2
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.1	----	9.2	----	9.2
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	<2	----	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	<0.02	----	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.188	----	0.412	----	0.195
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	117	----	257	----	121
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	6.29	----	6.40	----	7.58
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1260	----	1280	----	1510
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.01	----	2.05	----	2.43
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	----	1.5	----	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	<0.02	----	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	<10	----	<10
Liming Rate	----	1	kg CaCO3/t	<1	----	<1	----	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.19	----	0.41	----	0.19

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	A-4 (10cm)	A-6 (50cm)	B-4 (10cm)	B-6 (50cm)	C-4 (10cm)
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
Compound	CAS Number	LOR	Unit	EM2101779-001	EM2101779-002	EM2101779-003	EM2101779-004	EM2101779-005
				Result	Result	Result	Result	Result
EA033-E: Acid Base Accounting - Continued								
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	117	----	257	----	121
Liming Rate excluding ANC	----	1	kg CaCO3/t	9	----	19	----	9
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	8.0	----	5.7	----	3.0
ED040: Sulfur as SO4 2-								
Sulfate as SO4 2-	14808-79-8	100	mg/kg	1000	----	540	----	180
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.34	----	0.71	----	0.20
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	920	----	1110	----	1060
Boron	7440-42-8	50	mg/kg	<50	----	<50	----	<50
Iron	7439-89-6	50	mg/kg	31000	----	37200	----	40200
Silver	7440-22-4	2	mg/kg	<2	----	<2	----	<2
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	1180	----	2530	----	726
Selenium	7782-49-2	1	mg/kg	<1	----	<1	----	<1
Barium	7440-39-3	0.1	mg/kg	15.1	----	14.3	----	14.8
Thallium	7440-28-0	0.1	mg/kg	<0.1	----	<0.1	----	<0.1
Beryllium	7440-41-7	0.1	mg/kg	0.2	----	0.2	----	0.1
Cadmium	7440-43-9	0.1	mg/kg	0.3	----	0.1	----	0.2
Bismuth	7440-69-9	0.1	mg/kg	4.0	----	1.5	----	0.8
Cobalt	7440-48-4	0.1	mg/kg	12.4	----	18.0	----	11.4
Chromium	7440-47-3	0.1	mg/kg	7.2	----	4.8	----	5.6
Copper	7440-50-8	0.1	mg/kg	19.4	----	46.5	----	38.4
Thorium	7440-29-1	0.1	mg/kg	5.6	----	5.4	----	6.3
Manganese	7439-96-5	0.1	mg/kg	444	----	613	----	808
Strontium	7440-24-6	0.1	mg/kg	71.6	----	94.5	----	125
Molybdenum	7439-98-7	0.1	mg/kg	0.1	----	0.2	----	0.1
Nickel	7440-02-0	0.1	mg/kg	37.2	----	48.1	----	35.1
Lead	7439-92-1	0.1	mg/kg	55.8	----	81.7	----	33.2
Antimony	7440-36-0	0.1	mg/kg	3.8	----	5.6	----	3.1
Uranium	7440-61-1	0.1	mg/kg	0.9	----	0.9	----	0.9
Zinc	7440-66-6	0.5	mg/kg	54.4	----	54.5	----	69.2
Lithium	7439-93-2	0.1	mg/kg	1.6	----	1.2	----	1.2

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	A-4 (10cm)	A-6 (50cm)	B-4 (10cm)	B-6 (50cm)	C-4 (10cm)
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
				EM2101779-001	**EM2101779-002**	**EM2101779-003**	**EM2101779-004**	**EM2101779-005**
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	1	mg/kg	**5**	----	**4**	----	**5**
Tin	7440-31-5	0.1	mg/kg	**0.1**	----	<0.1	----	<0.1
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	<0.1	----	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	C-6 (50cm)	D-4 (10cm)	D-6 (50cm)	E-4 (10cm)	E-6 (50cm)
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
Compound	CAS Number	LOR	Unit	EM2101779-006	EM2101779-007	EM2101779-008	EM2101779-009	EM2101779-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.1	9.2	9.0	9.1	9.2
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-57.4	----	-45.4	-32.5	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	460	438	373	297	218
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	9.3	----	9.3	8.6	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	----	<0.1	<0.1	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	----	<0.1	<0.1	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	69.9	----	58.6	88.5	----
ANC as CaCO3	----	0.1	% CaCO3	7.1	----	6.0	9.0	----
Fizz Rating	----	0	Fizz Unit	2	----	2	2	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.2	----	9.1	9.1	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	----	<2	<2	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	<0.02	<0.02	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.265	----	0.264	1.09	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	165	----	164	680	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	7.55	----	6.78	12.8	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1510	----	1360	2550	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.42	----	2.17	4.09	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	----	1.5	1.5	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	----	<0.02	<0.02	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	----	<10	<10	----
Liming Rate	----	1	kg CaCO3/t	<1	----	<1	<1	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.26	----	0.26	1.09	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	C-6 (50cm)	D-4 (10cm)	D-6 (50cm)	E-4 (10cm)	E-6 (50cm)
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
Compound	CAS Number	LOR	Unit	EM2101779-006	EM2101779-007	EM2101779-008	EM2101779-009	EM2101779-010
				Result	Result	Result	Result	Result
EA033-E: Acid Base Accounting - Continued								
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	165	----	164	680	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	12	----	12	51	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	13.0	----	12.0	2.3	----
ED040: Sulfur as SO4 2-								
Sulfate as SO4 2-	14808-79-8	100	mg/kg	990	----	610	480	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.41	----	0.43	1.83	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	920	----	1000	1240	----
Boron	7440-42-8	50	mg/kg	<50	----	<50	<50	----
Iron	7439-89-6	50	mg/kg	46800	----	39200	63200	----
Silver	7440-22-4	2	mg/kg	<2	----	<2	<2	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	1470	----	1180	4370	----
Selenium	7782-49-2	1	mg/kg	<1	----	<1	1	----
Barium	7440-39-3	0.1	mg/kg	11.8	----	15.0	15.9	----
Thallium	7440-28-0	0.1	mg/kg	<0.1	----	<0.1	0.5	----
Beryllium	7440-41-7	0.1	mg/kg	0.1	----	0.2	0.2	----
Cadmium	7440-43-9	0.1	mg/kg	1.4	----	0.2	0.2	----
Bismuth	7440-69-9	0.1	mg/kg	0.8	----	1.0	1.9	----
Cobalt	7440-48-4	0.1	mg/kg	12.4	----	11.8	21.0	----
Chromium	7440-47-3	0.1	mg/kg	6.0	----	7.5	8.0	----
Copper	7440-50-8	0.1	mg/kg	57.7	----	38.2	70.4	----
Thorium	7440-29-1	0.1	mg/kg	5.5	----	6.0	6.6	----
Manganese	7439-96-5	0.1	mg/kg	970	----	676	1240	----
Strontium	7440-24-6	0.1	mg/kg	116	----	92.5	160	----
Molybdenum	7439-98-7	0.1	mg/kg	0.2	----	0.4	0.5	----
Nickel	7440-02-0	0.1	mg/kg	35.7	----	45.3	76.1	----
Lead	7439-92-1	0.1	mg/kg	32.6	----	39.6	63.7	----
Antimony	7440-36-0	0.1	mg/kg	7.7	----	2.4	7.0	----
Uranium	7440-61-1	0.1	mg/kg	1.0	----	1.0	1.3	----
Zinc	7440-66-6	0.5	mg/kg	140	----	128	66.8	----
Lithium	7439-93-2	0.1	mg/kg	1.0	----	1.4	1.6	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	C-6 (50cm)	D-4 (10cm)	D-6 (50cm)	E-4 (10cm)	E-6 (50cm)
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00
Compound	CAS Number	LOR	Unit	EM2101779-006	EM2101779-007	EM2101779-008	EM2101779-009	EM2101779-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	1	mg/kg	**4**	----	**6**	**6**	----
Tin	7440-31-5	0.1	mg/kg	<0.1	----	**0.1**	<0.1	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	<0.1	<0.1	----

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EA033-E: Acid Base Accounting

(SOIL) EA033-B: Potential Acidity

(SOIL) EA009: Net Acid Production Potential

(SOIL) ED042T: Total Sulfur by LECO

(SOIL) EA013: Acid Neutralising Capacity

(SOIL) EA011: Net Acid Generation

(SOIL) EA033-C: Acid Neutralising Capacity

(SOIL) EA033-D: Retained Acidity

(SOIL) EA033-A: Actual Acidity

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM2101779**	Page	: 1 of 7
Amendment	: **2**		
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Contact	: [redacted]
Address	: 2 SALAMANCA SQUARE HOBART TAS, AUSTRALIA 7000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021
Order number	: 12537535	Date Analysis Commenced	: 08-Feb-2021
C-O-C number	: ----	Issue Date	: 25-Feb-2021
Sampler	: GHD		
Site	:		
Quote number	: EN/005		
No. of samples received	: 10		
No. of samples analysed	: 10		

ilac-MRA NATA Accreditation No. 825 Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
[redacted]	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
[redacted]	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC

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Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD
Project	: 12537535

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG005(ED093)T: Total Metals by ICP-AES (QC Lot: 3526541)									
EM2101779-001	A-4 (10cm)	EG005T: Silver	7440-22-4	2	mg/kg	<2	<2	0.00	No Limit
		EG005T: Aluminium	7429-90-5	50	mg/kg	920	880	4.12	0% - 50%
		EG005T: Boron	7440-42-8	50	mg/kg	<50	<50	0.00	No Limit
		EG005T: Iron	7439-89-6	50	mg/kg	31000	31600	1.64	0% - 20%
EA002: pH 1:5 (Soils) (QC Lot: 3499778)									
EM2101779-001	A-4 (10cm)	EA002: pH Value	----	0.1	pH Unit	8.1	8.0	1.24	0% - 20%
EA010: Conductivity (1:5) (QC Lot: 3499779)									
EM2101779-010	E-6 (50cm)	EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	218	215	1.62	0% - 20%
EM2101779-001	A-4 (10cm)	EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	556	575	3.41	0% - 20%
EA011: Net Acid Generation (QC Lot: 3511454)									
EB2103736-001	Anonymous	EA011: NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	0.00	No Limit
		EA011: NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	0.00	No Limit
		EA011: pH (OX)	----	0.1	pH Unit	8.0	8.0	0.00	0% - 20%
EB2103736-011	Anonymous	EA011: NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	0.00	No Limit
		EA011: NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	0.00	No Limit
		EA011: pH (OX)	----	0.1	pH Unit	7.4	7.4	0.00	0% - 20%
EA013: Acid Neutralising Capacity (QC Lot: 3511453)									
EB2103736-001	Anonymous	EA013: ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	12.9	11.1	14.9	0% - 20%
EB2103736-011	Anonymous	EA013: ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	3.8	4.1	7.90	No Limit
EA033-A: Actual Acidity (QC Lot: 3526662)									
EB2104851-002	Anonymous	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	0.26	0.26	0.00	0% - 50%
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	164	165	0.00	0% - 20%

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EA033-A: Actual Acidity (QC Lot: 3526662) - continued									
EB2104851-002	Anonymous	EA033: pH KCl (23A)	----	0.1	pH Unit	4.1	4.1	0.00	0% - 20%
EB2104851-012	Anonymous	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	0.11	0.11	0.00	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	70	69	0.00	0% - 20%
		EA033: pH KCl (23A)	----	0.1	pH Unit	4.3	4.4	2.30	0% - 20%
EA033-A: Actual Acidity (QC Lot: 3526663)									
EM2101779-006	C-6 (50cm)	EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	0.00	No Limit
		EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	0.00	No Limit
		EA033: pH KCl (23A)	----	0.1	pH Unit	9.2	9.2	0.00	0% - 20%
EA033-B: Potential Acidity (QC Lot: 3526662)									
EB2104851-002	Anonymous	EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	0.013	0.012	0.00	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.00	No Limit
EB2104851-012	Anonymous	EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	0.012	0.012	0.00	No Limit
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	0.00	No Limit
EA033-B: Potential Acidity (QC Lot: 3526663)									
EM2101779-006	C-6 (50cm)	EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	0.265	0.263	0.606	0% - 20%
		EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	165	164	0.00	0% - 50%
EA033-C: Acid Neutralising Capacity (QC Lot: 3526663)									
EM2101779-006	C-6 (50cm)	EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	7.55	7.53	0.276	0% - 20%
		EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	2.42	2.41	0.00	0% - 20%
		EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	1510	1500	0.276	0% - 20%
EA055: Moisture Content (Dried @ 105-110°C) (QC Lot: 3527219)									
EM2101779-001	A-4 (10cm)	EA055: Moisture Content	----	0.1	%	8.0	8.0	0.00	0% - 20%
ED040T : Total Sulfate by ICPAES (QC Lot: 3527208)									
EM2101779-001	A-4 (10cm)	ED040T: Sulfate as SO4 2-	14808-79-8	100	mg/kg	1000	1020	1.83	0% - 50%
ED042T: Total Sulfur by LECO (QC Lot: 3515582)									
EB2104002-001	Anonymous	ED042T: Sulfur - Total as S (LECO)	----	0.01	%	1.25	1.49	17.1	0% - 20%
EB2104112-007	Anonymous	ED042T: Sulfur - Total as S (LECO)	----	0.01	%	10.4	10.4	0.498	0% - 20%
EG020T: Total Metals by ICP-MS (QC Lot: 3526542)									
EM2101779-001	A-4 (10cm)	EG020Y-T: Thallium	7440-28-0	0.1	mg/kg	<0.1	<0.1	0.00	No Limit
		EG020Y-T: Cadmium	7440-43-9	0.1	mg/kg	0.3	0.2	0.00	No Limit
		EG020Y-T: Bismuth	7440-69-9	0.1	mg/kg	4.0	4.4	11.5	0% - 20%
		EG020Y-T: Thorium	7440-29-1	0.1	mg/kg	5.6	4.8	15.8	0% - 20%
		EG020Y-T: Strontium	7440-24-6	0.1	mg/kg	71.6	61.3	15.6	0% - 20%
		EG020Y-T: Selenium	7782-49-2	1	mg/kg	<1	<1	0.00	No Limit

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Client : GHD PTY LTD
Project : 12537535

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG020T: Total Metals by ICP-MS (QC Lot: 3526543)									
EM2101779-001	A-4 (10cm)	EG020X-T: Arsenic	7440-38-2	0.1	mg/kg	1180	# 784	40.2	0% - 20%
		EG020X-T: Barium	7440-39-3	0.1	mg/kg	15.1	14.7	3.08	0% - 20%
		EG020X-T: Beryllium	7440-41-7	0.1	mg/kg	0.2	0.1	0.00	No Limit
		EG020X-T: Cobalt	7440-48-4	0.1	mg/kg	12.4	# 9.1	31.2	0% - 20%
		EG020X-T: Chromium	7440-47-3	0.1	mg/kg	7.2	6.2	14.2	0% - 20%
		EG020X-T: Copper	7440-50-8	0.1	mg/kg	19.4	# 49.5	87.3	0% - 20%
		EG020X-T: Manganese	7439-96-5	0.1	mg/kg	444	425	4.29	0% - 20%
		EG020X-T: Molybdenum	7439-98-7	0.1	mg/kg	0.1	0.2	0.00	No Limit
		EG020X-T: Nickel	7440-02-0	0.1	mg/kg	37.2	31.4	16.7	0% - 20%
		EG020X-T: Lead	7439-92-1	0.1	mg/kg	55.8	# 18.2	102	0% - 20%
		EG020X-T: Antimony	7440-36-0	0.1	mg/kg	3.8	# 1.9	66.0	0% - 20%
		EG020X-T: Uranium	7440-61-1	0.1	mg/kg	0.9	0.9	0.00	No Limit
		EG020X-T: Lithium	7439-93-2	0.1	mg/kg	1.6	1.3	26.7	0% - 50%
		EG020X-T: Tin	7440-31-5	0.1	mg/kg	0.1	<0.1	0.00	No Limit
		EG020X-T: Zinc	7440-66-6	0.5	mg/kg	54.4	# 84.8	43.6	0% - 20%
		EG020X-T: Vanadium	7440-62-2	1	mg/kg	5	4	0.00	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 3526544)									
EM2101779-001	A-4 (10cm)	EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	0.00	No Limit

Laboratory Duplicate (DUP) Report

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Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD
Project	: 12537535

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG005(ED093)T: Total Metals by ICP-AES (QCLot: 3526541)								
EG005T: Aluminium	7429-90-5	50	mg/kg	<50	15910 mg/kg	97.3	70.0	130
EG005T: Boron	7440-42-8	50	mg/kg	<50	----	----	----	----
EG005T: Iron	7439-89-6	50	mg/kg	<50	33227 mg/kg	106	70.0	130
EG005T: Silver	7440-22-4	2	mg/kg	<2	2.9 mg/kg	84.0	70.0	130
EA010: Conductivity (1:5) (QCLot: 3499779)								
EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1413 µS/cm	99.5	94.5	105
EA011: Net Acid Generation (QCLot: 3511454)								
EA011: NAG (pH 7.0)	----	----	kg H2SO4/t	----	26.74 kg H2SO4/t	80.2	70.0	130
EA013: Acid Neutralising Capacity (QCLot: 3511453)								
EA013: ANC as H2SO4	----	----	kg H2SO4 equiv./t	----	49 kg H2SO4 equiv./t	96.0	82.0	120
EA033-A: Actual Acidity (QCLot: 3526662)								
EA033: pH KCl (23A)	----	----	pH Unit	----	4.4 pH Unit	97.7	91.0	107
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	15 mole H+ / t	114	70.0	124
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-A: Actual Acidity (QCLot: 3526663)								
EA033: pH KCl (23A)	----	----	pH Unit	----	4.4 pH Unit	97.7	91.0	107
EA033: Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	15 mole H+ / t	95.1	70.0	124
EA033: sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	----	----	----	----
EA033-B: Potential Acidity (QCLot: 3526662)								
EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	0.155 % S	106	77.0	121
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-B: Potential Acidity (QCLot: 3526663)								
EA033: Chromium Reducible Sulfur (22B)	----	0.005	% S	<0.005	0.155 % S	107	77.0	121
EA033: acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 3526662)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	10 % CaCO3	100	91.0	112
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
EA033-C: Acid Neutralising Capacity (QCLot: 3526663)								
EA033: Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	<0.01	10 % CaCO3	100	91.0	112
EA033: acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	<10	----	----	----	----
EA033: sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	<0.01	----	----	----	----
ED040T : Total Sulfate by ICPAES (QCLot: 3527208)								

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Client	: GHD PTY LTD
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Sub-Matrix: **SOIL**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
ED040T : Total Sulfate by ICPAES (QCLot: 3527208) - continued								
ED040T: Sulfate as SO4 2-	14808-79-8	100	mg/kg	<100	15000 mg/kg	105	84.7	117
ED042T: Total Sulfur by LECO (QCLot: 3515582)								
ED042T: Sulfur - Total as S (LECO)	----	0.01	%	<0.01	10.92 %	99.9	70.0	130
EG020T: Total Metals by ICP-MS (QCLot: 3526542)								
EG020Y-T: Selenium	7782-49-2	1	mg/kg	<1	----	----	----	----
EG020Y-T: Thallium	7440-28-0	0.1	mg/kg	<0.1	0.16 mg/kg	91.1	80.0	120
EG020Y-T: Cadmium	7440-43-9	0.1	mg/kg	<0.1	1.23 mg/kg	87.2	80.0	120
EG020Y-T: Bismuth	7440-69-9	0.1	mg/kg	<0.1	1.75 mg/kg	120	80.0	120
EG020Y-T: Thorium	7440-29-1	0.1	mg/kg	<0.1	3.51 mg/kg	94.0	80.0	120
EG020Y-T: Strontium	7440-24-6	0.1	mg/kg	<0.1	73.8 mg/kg	93.5	80.0	120
EG020T: Total Metals by ICP-MS (QCLot: 3526543)								
EG020X-T: Arsenic	7440-38-2	0.1	mg/kg	<0.1	111 mg/kg	103	80.0	120
EG020X-T: Barium	7440-39-3	0.1	mg/kg	<0.1	96.1 mg/kg	93.3	80.0	120
EG020X-T: Beryllium	7440-41-7	0.1	mg/kg	<0.1	0.67 mg/kg	105	80.0	120
EG020X-T: Cobalt	7440-48-4	0.1	mg/kg	<0.1	10.6 mg/kg	106	80.0	120
EG020X-T: Chromium	7440-47-3	0.1	mg/kg	<0.1	19 mg/kg	83.4	80.0	120
EG020X-T: Copper	7440-50-8	0.1	mg/kg	<0.1	54 mg/kg	91.9	80.0	120
EG020X-T: Manganese	7439-96-5	0.1	mg/kg	<0.1	556 mg/kg	85.2	80.0	120
EG020X-T: Molybdenum	7439-98-7	0.1	mg/kg	<0.1	2.15 mg/kg	103	80.0	120
EG020X-T: Nickel	7440-02-0	0.1	mg/kg	<0.1	14.4 mg/kg	109	80.0	120
EG020X-T: Lead	7439-92-1	0.1	mg/kg	<0.1	72.1 mg/kg	84.0	80.0	120
EG020X-T: Antimony	7440-36-0	0.1	mg/kg	<0.1	2.57 mg/kg	104	80.0	120
EG020X-T: Uranium	7440-61-1	0.1	mg/kg	<0.1	0.58 mg/kg	104	80.0	120
EG020X-T: Zinc	7440-66-6	0.5	mg/kg	<0.5	168 mg/kg	86.6	80.0	120
EG020X-T: Lithium	7439-93-2	0.1	mg/kg	<0.1	14.83 mg/kg	81.0	80.0	120
EG020X-T: Vanadium	7440-62-2	1	mg/kg	<1	62.7 mg/kg	94.2	80.0	120
EG020X-T: Tin	7440-31-5	0.1	mg/kg	<0.1	5.18 mg/kg	94.5	80.0	120
EG035T: Total Recoverable Mercury by FIMS (QCLot: 3526544)								
EG035T: Mercury	7439-97-6	0.1	mg/kg	<0.1	0.64 mg/kg	102	70.0	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
				Concentration	MS	Low	High
EG020T: Total Metals by ICP-MS (QCLot: 3526542)							

Sub-Matrix: **SOIL**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report: Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG020T: Total Metals by ICP-MS (QCLot: 3526542) - continued							
EM2101779-003	B-4 (10cm)	EG020Y-T: Cadmium	7440-43-9	50 mg/kg	95.4	78.8	130
EG020T: Total Metals by ICP-MS (QCLot: 3526543)							
EM2101779-003	B-4 (10cm)	EG020X-T: Arsenic	7440-38-2	50 mg/kg	# Not Determined	71.2	121
		EG020X-T: Chromium	7440-47-3	50 mg/kg	86.5	70.0	130
		EG020X-T: Copper	7440-50-8	250 mg/kg	93.4	73.1	120
		EG020X-T: Nickel	7440-02-0	50 mg/kg	90.2	72.8	126
		EG020X-T: Lead	7439-92-1	250 mg/kg	98.2	70.9	122
		EG020X-T: Zinc	7440-66-6	250 mg/kg	98.8	70.0	128
EG035T: Total Recoverable Mercury by FIMS (QCLot: 3526544)							
EM2101779-003	B-4 (10cm)	EG035T: Mercury	7439-97-6	0.5 mg/kg	116	76.0	116

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM2101779**	Page	: 1 of 10
Amendment	: **2**		
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021
Site	:	Issue Date	: 25-Feb-2021
Sampler	: GHD	No. of samples received	: 10
Order number	: 12537535	No. of samples analysed	: 10

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Duplicate outliers exist - please see following pages for full details.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **SOIL**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Duplicate (DUP) RPDs							
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Arsenic**	7440-38-2	40.2 %	0% - 20%	**RPD exceeds LOR based limits**
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Cobalt**	7440-48-4	31.2 %	0% - 20%	**RPD exceeds LOR based limits**
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Copper**	7440-50-8	87.3 %	0% - 20%	**RPD exceeds LOR based limits**
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Lead**	7439-92-1	102 %	0% - 20%	**RPD exceeds LOR based limits**
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Antimony**	7440-36-0	66.0 %	0% - 20%	**RPD exceeds LOR based limits**
EG020T: Total Metals by ICP-MS	EM2101779--001	A-4 (10cm)	**Zinc**	7440-66-6	43.6 %	0% - 20%	**RPD exceeds LOR based limits**
Matrix Spike (MS) Recoveries							
EG020T: Total Metals by ICP-MS	EM2101779--003	B-4 (10cm)	**Arsenic**	7440-38-2	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

Outliers : Analysis Holding Time Compliance

Matrix: **SOIL**

Method		*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA002: pH 1:5 (Soils)							
Snap Lock Bag							
A-4 (10cm), B-4 (10cm), C-4 (10cm), D-4 (10cm), E-4 (10cm),	A-6 (50cm), B-6 (50cm), C-6 (50cm), D-6 (50cm), E-6 (50cm)	08-Feb-2021	28-Jan-2021	**11**	----	----	----
EA010: Conductivity (1:5)							
Snap Lock Bag							
A-4 (10cm), B-4 (10cm), C-4 (10cm), D-4 (10cm), E-4 (10cm),	A-6 (50cm), B-6 (50cm), C-6 (50cm), D-6 (50cm), E-6 (50cm)	08-Feb-2021	28-Jan-2021	**11**	----	----	----
EA033-A: Actual Acidity							
Snap Lock Bag							
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	24-Feb-2021	22-Jan-2021	**33**	----	----	----
EA033-B: Potential Acidity							

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Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD
Project	: 12537535

Matrix: **SOIL**

Method		Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		Date extracted	Due for extraction	Days overdue	Date analysed	Due for analysis	Days overdue
EA033-B: Potential Acidity - Analysis Holding Time Compliance							
Snap Lock Bag							
A-4 (10cm),	B-4 (10cm),	24-Feb-2021	22-Jan-2021	**33**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
EA033-C: Acid Neutralising Capacity							
Snap Lock Bag							
A-4 (10cm),	B-4 (10cm),	24-Feb-2021	22-Jan-2021	**33**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
EA033-D: Retained Acidity							
Snap Lock Bag							
A-4 (10cm),	B-4 (10cm),	24-Feb-2021	22-Jan-2021	**33**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
EA033-E: Acid Base Accounting							
Snap Lock Bag							
A-4 (10cm),	B-4 (10cm),	24-Feb-2021	22-Jan-2021	**33**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
EA055: Moisture Content (Dried @ 105-110°C)							
Soil Glass Jar - Unpreserved							
A-4 (10cm),	B-4 (10cm),	----	----	----	23-Feb-2021	04-Feb-2021	**19**
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
ED040: Sulfur as SO4 2-							
Soil Glass Jar - Unpreserved							
A-4 (10cm),	B-4 (10cm),	23-Feb-2021	28-Jan-2021	**26**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
ED042T: Total Sulfur by LECO							
Snap Lock Bag							
A-4 (10cm),	B-4 (10cm),	17-Feb-2021	28-Jan-2021	**20**	----	----	----
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						
EG035T: Total Recoverable Mercury by FIMS							
Soil Glass Jar - Unpreserved							
A-4 (10cm),	B-4 (10cm),	23-Feb-2021	18-Feb-2021	**5**	24-Feb-2021	18-Feb-2021	**6**
C-4 (10cm),	C-6 (50cm),						
D-6 (50cm),	E-4 (10cm)						

Outliers : Frequency of Quality Control Samples

Matrix: **SOIL**

Quality Control Sample Type / Method	Count QC	Count Regular	Rate (%) Actual	Rate (%) Expected	Quality Control Specification
Matrix Spikes (MS)					
Total Metals by ICP-AES	0	7	0.00	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EA002: pH 1:5 (Soils)								
Snap Lock Bag (EA002)								
A-4 (10cm),	A-6 (50cm),	**21-Jan-2021**	**08-Feb-2021**	28-Jan-2021	×	**08-Feb-2021**	08-Feb-2021	✓
B-4 (10cm),	B-6 (50cm),							
C-4 (10cm),	C-6 (50cm),							
D-4 (10cm),	D-6 (50cm),							
E-4 (10cm),	E-6 (50cm)							
EA010: Conductivity (1:5)								
Snap Lock Bag (EA010)								
A-4 (10cm),	A-6 (50cm),	**21-Jan-2021**	**08-Feb-2021**	28-Jan-2021	×	**08-Feb-2021**	08-Mar-2021	✓
B-4 (10cm),	B-6 (50cm),							
C-4 (10cm),	C-6 (50cm),							
D-4 (10cm),	D-6 (50cm),							
E-4 (10cm),	E-6 (50cm)							
EA011: Net Acid Generation								
Snap Lock Bag (EA011)								
A-4 (10cm),	B-4 (10cm),	**21-Jan-2021**	**16-Feb-2021**	21-Jan-2022	✓	**16-Feb-2021**	15-Aug-2021	✓
C-4 (10cm),	C-6 (50cm),							
D-6 (50cm),	E-4 (10cm)							
EA013: Acid Neutralising Capacity								
Snap Lock Bag (EA013)								
A-4 (10cm),	B-4 (10cm),	**21-Jan-2021**	**16-Feb-2021**	21-Jan-2022	✓	**16-Feb-2021**	15-Aug-2021	✓
C-4 (10cm),	C-6 (50cm),							
D-6 (50cm),	E-4 (10cm)							

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Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA033-A: Actual Acidity								
Snap Lock Bag (EA033)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**24-Feb-2021**	22-Jan-2021	×	**24-Feb-2021**	25-May-2021	✓
EA033-B: Potential Acidity								
Snap Lock Bag (EA033)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**24-Feb-2021**	22-Jan-2021	×	**24-Feb-2021**	25-May-2021	✓
EA033-C: Acid Neutralising Capacity								
Snap Lock Bag (EA033)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**24-Feb-2021**	22-Jan-2021	×	**24-Feb-2021**	25-May-2021	✓
EA033-D: Retained Acidity								
Snap Lock Bag (EA033)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**24-Feb-2021**	22-Jan-2021	×	**24-Feb-2021**	25-May-2021	✓
EA033-E: Acid Base Accounting								
Snap Lock Bag (EA033)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**24-Feb-2021**	22-Jan-2021	×	**24-Feb-2021**	25-May-2021	✓
EA055: Moisture Content (Dried @ 105-110°C)								
Soil Glass Jar - Unpreserved (EA055)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**----**	----	----	**23-Feb-2021**	04-Feb-2021	×
ED040: Sulfur as SO4 2-								
Soil Glass Jar - Unpreserved (ED040T)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**23-Feb-2021**	28-Jan-2021	×	**24-Feb-2021**	23-Mar-2021	✓
ED042T: Total Sulfur by LECO								
Snap Lock Bag (ED042T)								
A-4 (10cm), C-4 (10cm), D-6 (50cm),	B-4 (10cm), C-6 (50cm), E-4 (10cm)	**21-Jan-2021**	**17-Feb-2021**	28-Jan-2021	×	**17-Feb-2021**	16-Aug-2021	✓

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Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD
Project	: 12537535

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*		*Sample Date*	*Extraction / Preparation*			*Analysis*		
			Date extracted	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EG005(ED093)T: Total Metals by ICP-AES								
Soil Glass Jar - Unpreserved (EG005T)								
A-4 (10cm),	B-4 (10cm),	**21-Jan-2021**	**23-Feb-2021**	20-Jul-2021	✓	**23-Feb-2021**	20-Jul-2021	✓
C-4 (10cm),	C-6 (50cm),							
D-6 (50cm),	E-4 (10cm)							
EG020T: Total Metals by ICP-MS								
Soil Glass Jar - Unpreserved (EG020Y-T)								
A-4 (10cm),	B-4 (10cm),	**21-Jan-2021**	**23-Feb-2021**	20-Jul-2021	✓	**23-Feb-2021**	20-Jul-2021	✓
C-4 (10cm),	C-6 (50cm),							
D-6 (50cm),	E-4 (10cm)							
EG035T: Total Recoverable Mercury by FIMS								
Soil Glass Jar - Unpreserved (EG035T)								
A-4 (10cm),	B-4 (10cm),	**21-Jan-2021**	**23-Feb-2021**	18-Feb-2021	×	**24-Feb-2021**	18-Feb-2021	×
C-4 (10cm),	C-6 (50cm),							
D-6 (50cm),	E-4 (10cm)							

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Acid Neutralising Capacity (ANC)	EA013	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chromium Suite for Acid Sulphate Soils	EA033	3	23	**13.04**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (1:5)	EA010	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Moisture Content	EA055	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Net Acid Generation	EA011	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH (1:5)	EA002	1	10	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate as SO4 2- Total	ED040T	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfur - Total as S (LECO)	ED042T	2	17	**11.76**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	7	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-AES	EG005T	1	7	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite X	EG020X-T	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite Y	EG020Y-T	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Acid Neutralising Capacity (ANC)	EA013	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chromium Suite for Acid Sulphate Soils	EA033	2	23	**8.70**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (1:5)	EA010	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Net Acid Generation	EA011	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate as SO4 2- Total	ED040T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfur - Total as S (LECO)	ED042T	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-AES	EG005T	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite X	EG020X-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite Y	EG020Y-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chromium Suite for Acid Sulphate Soils	EA033	2	23	**8.70**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (1:5)	EA010	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate as SO4 2- Total	ED040T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfur - Total as S (LECO)	ED042T	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-AES	EG005T	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite X	EG020X-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite Y	EG020Y-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Total Mercury by FIMS	EG035T	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-AES	EG005T	0	7	**0.00**	**5.00**	×	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite X	EG020X-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Work Order : EM2101779 Amendment 2
Client : GHD PTY LTD
Project : 12537535

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Matrix Spikes (MS) - Continued							
Total Metals by ICP-MS - Suite Y	EG020Y-T	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH (1:5)	EA002	SOIL	In house: Referenced to Rayment and Lyons 4A1 and APHA 4500H+. pH is determined on soil samples after a 1:5 soil/water leach. This method is compliant with NEPM Schedule B(3).
Net Acid Production Potential	EA009	SOIL	In house: Referenced to Coastech Research (Canada)(Mod.). NAPP = Acid Production Potential (APP or MAP- Maximum Acid Potential) minus Neutralising Capacity (ANC). NAPP may be +ve, zero or -ve.
Electrical Conductivity (1:5)	EA010	SOIL	In house: Referenced to Rayment and Lyons 3A1 and APHA 2510. Conductivity is determined on soil samples using a 1:5 soil/water leach. This method is compliant with NEPM Schedule B(3).
Net Acid Generation	EA011	SOIL	In house: Referenced to Miller (1998) Titremetric procedure determines net acidity in a soil following peroxide oxidation. Titrations to both pH 4.5 and pH 7 are reported.
Acid Neutralising Capacity (ANC)	EA013	SOIL	In house: Referenced to USEPA 600/2-78-054, I. Miller (2000). A fizz test is done to semiquanititatively estimate the likely reactivity. The soil is then reacted with an known excess quantity of an appropriate acid. Titration determines the acid remaining, and the ANC can be calculated from comparison with a blank titration.
Chromium Suite for Acid Sulphate Soils	EA033	SOIL	In house: Referenced to Ahern et al 2004. This method covers the determination of Chromium Reducible Sulfur (SCR); pHKCl; titratable actual acidity (TAA); acid neutralising capacity by back titration (ANC); and net acid soluble sulfur (SNAS) which incorporates peroxide sulfur. It applies to soils and sediments (including sands) derived from coastal regions. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
Moisture Content	EA055	SOIL	In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 105-110 degrees C. This method is compliant with NEPM Schedule B(3).
Sulfate as SO4 2- Total	ED040T	SOIL	In house: Total Sulfate is determined off a HCl digestion by ICPAES as S , and reported as SO4
Sulfur - Total as S (LECO)	ED042T	SOIL	In house: Dried and pulverised sample is combusted in a high temperature furnace in the presence of strong oxidants / catalysts. The evolved S (as SO2) is measured by infra-red detector
Total Metals by ICP-AES	EG005T	SOIL	In house: Referenced to APHA 3120; USEPA SW 846 - 6010. Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM Schedule B(3)
Total Metals by ICP-MS - Suite X	EG020X-T	SOIL	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite Y	EG020Y-T	SOIL	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Analytical Methods	Method	Matrix	Method Descriptions
Total Mercury by FIMS	EG035T	SOIL	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2) (Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Drying at 85 degrees, bagging and labelling (ASS)	EN020PR	SOIL	In house
HCl Digest	EN24	SOIL	1g of soil is digested in 30 ml of 30% HCl and the resultant digest bulked and filtered for analysis by ICP.
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of reagent grade water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM Schedule B(3).
Dry and Pulverise (up to 100g)	GEO30	SOIL	#

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **EM2101779**		
Amendment	: **2**		
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Contact	: [redacted]
Address	: 2 SALAMANCA SQUARE HOBART TAS, AUSTRALIA 7000	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: [redacted]	E-mail	: [redacted]
Telephone	: ----	Telephone	: [redacted]
Facsimile	: ----	Facsimile	: [redacted]
Project	: 12537535	Page	: 1 of 4
Order number	: 12537535	Quote number	: EB2020GHDSER0038 (EN/005)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	:		
Sampler	: GHD		

Dates

Date Samples Received	: 08-Feb-2021 11:05	Issue Date	: 23-Feb-2021
Client Requested Due Date	: 02-Mar-2021	Scheduled Reporting Date	: **02-Mar-2021**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 19.9°C
Receipt Detail	:	No. of samples received / analysed	: 10 / 10

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please direct any queries related to sample condition / numbering / breakages to Client Services.**
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- **Analytical work for this work order will be conducted at ALS Springvale and ALS Brisbane.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Issue Date	: 23-Feb-2021
Page	: 2 of 4
Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

Method *Sample ID*	Sample Container Received	Preferred Sample Container for Analysis
Chromium Suite for Acid Sulphate Soils : EA033		
A-4 (10cm)	- Snap Lock Bag	- Snap Lock Bag - frozen
B-4 (10cm)	- Snap Lock Bag	- Snap Lock Bag - frozen
C-4 (10cm)	- Snap Lock Bag	- Snap Lock Bag - frozen
C-6 (50cm)	- Snap Lock Bag	- Snap Lock Bag - frozen
D-6 (50cm)	- Snap Lock Bag	- Snap Lock Bag - frozen
E-4 (10cm)	- Snap Lock Bag	- Snap Lock Bag - frozen

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **SOIL**

Laboratory sample ID	*Sampling date / time*	*Sample ID*	SOIL - ASS1 NAPP	SOIL - EA011 Net Acid Generation (NAG)	SOIL - EA033 Chromium Suite for Acid Sulphate Soils	SOIL - EG005T (solids) Total Metals by ICP-AES	SOIL - EG020X-T Total Metals by ICPMS - Suite X	SOIL - EG020Y-T Total Metals by ICPMS - Suite Y	SOIL - IN-4S pH plus EC (1:5)
EM2101779-001	21-Jan-2021 00:00	A-4 (10cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-002	21-Jan-2021 00:00	A-6 (50cm)							✓
EM2101779-003	21-Jan-2021 00:00	B-4 (10cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-004	21-Jan-2021 00:00	B-6 (50cm)							✓
EM2101779-005	21-Jan-2021 00:00	C-4 (10cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-006	21-Jan-2021 00:00	C-6 (50cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-007	21-Jan-2021 00:00	D-4 (10cm)							✓
EM2101779-008	21-Jan-2021 00:00	D-6 (50cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-009	21-Jan-2021 00:00	E-4 (10cm)	✓	✓	✓	✓	✓	✓	✓
EM2101779-010	21-Jan-2021 00:00	E-6 (50cm)							✓

Matrix: **SOIL**

Laboratory sample ID	*Sampling date / time*	*Sample ID*	SOIL - EA055-103 Moisture Content	SOIL - ED040T Sulfate Total	SOIL - EG035T (solids) Total Mercury by FIMS
EM2101779-001	21-Jan-2021 00:00	A-4 (10cm)	✓	✓	✓
EM2101779-003	21-Jan-2021 00:00	B-4 (10cm)	✓	✓	✓
EM2101779-005	21-Jan-2021 00:00	C-4 (10cm)	✓	✓	✓
EM2101779-006	21-Jan-2021 00:00	C-6 (50cm)	✓	✓	✓
EM2101779-008	21-Jan-2021 00:00	D-6 (50cm)	✓	✓	✓
EM2101779-009	21-Jan-2021 00:00	E-4 (10cm)	✓	✓	✓

Proactive Holding Time Report

Issue Date	: 23-Feb-2021
Page	: 3 of 4
Work Order	: EM2101779 Amendment 2
Client	: GHD PTY LTD

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received Date	Samples Received Evaluation	Instructions Received Date	Instructions Received Evaluation
EA002: pH (1:5)							
A-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
A-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
B-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
D-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
E-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Feb-2021	08-Feb-2021	×	----	----
EA010: Electrical Conductivity (1:5)							
A-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
A-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
B-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
D-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
E-6 (50cm)	Snap Lock Bag	28-Jan-2021	08-Mar-2021	08-Feb-2021	×	----	----
EA033: Chromium Suite for Acid Sulphate Soils							
A-4 (10cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Snap Lock Bag	22-Jan-2021	22-Apr-2021	08-Feb-2021	×	----	----
EA055: Moisture Content							
A-4 (10cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Soil Glass Jar - Unpreserved	----	04-Feb-2021	08-Feb-2021	×	----	----
ED040T: Sulfate as SO4 2- Total							
A-4 (10cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Soil Glass Jar - Unpreserved	28-Jan-2021	25-Feb-2021	08-Feb-2021	×	----	----
ED042T: Sulfur - Total as S (LECO)							
A-4 (10cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----
B-4 (10cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----
C-4 (10cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----
C-6 (50cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----
D-6 (50cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----
E-4 (10cm)	Snap Lock Bag	28-Jan-2021	16-Aug-2021	08-Feb-2021	×	----	----

Issue Date	:	23-Feb-2021
Page	:	4 of 4
Work Order	:	EM2101779 Amendment 2
Client	:	GHD PTY LTD

Requested Deliverables

[redacted]

ACCOUNTS PAYABLE

- A4 - AU Tax Invoice (INV) Email

GHD LAB REPORTS

- *AU Certificate of Analysis - NATA (COA) Email
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) Email
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) Email
- A4 - AU Sample Receipt Notification - Environmental HT (SRN) Email
- EDI Format - ESDAT (ESDAT) Email
- Electronic SRN for ESdat (ESRN_ESDAT) Email

[redacted]

- *AU Certificate of Analysis - NATA (COA) Email
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) Email
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) Email
- A4 - AU Sample Receipt Notification - Environmental HT (SRN) Email
- A4 - AU Tax Invoice (INV) Email
- Chain of Custody (CoC) (COC) Email
- EDI Format - ESDAT (ESDAT) Email
- EDI Format - XTab (XTAB) Email
- Electronic SRN for ESdat (ESRN_ESDAT) Email

[redacted]

- *AU Certificate of Analysis - NATA (COA) Email
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) Email
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) Email
- A4 - AU Sample Receipt Notification - Environmental HT (SRN) Email
- Chain of Custody (CoC) (COC) Email
- EDI Format - ESDAT (ESDAT) Email
- EDI Format - XTab (XTAB) Email
- Electronic SRN for ESdat (ESRN_ESDAT) Email

[redacted]

- *AU Certificate of Analysis - NATA (COA) Email
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) Email
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) Email
- A4 - AU Sample Receipt Notification - Environmental HT (SRN) Email
- Chain of Custody (CoC) (COC) Email
- EDI Format - ESDAT (ESDAT) Email
- EDI Format - XTab (XTAB) Email
- Electronic SRN for ESdat (ESRN_ESDAT) Email

CHAIN OF CUSTODY RECORD

GHD

GHD Hobart
2 Salamanca Square, Hobart 7000
Telephone: 61 3 6210 0600 Facsimile: 61 3 6210 0601
Email: hbamail@ghd.com.au

GHD Launceston
102 Cameron Street, Launceston 7250
Telephone: 61 3 6332 5500 Facsimile: 61 3 6332 5555
Email: lstmail@ghd.com.au

GHD Burnie
10 Columnar Court, Burnie 7320
Telephone: 61 3 6432 7900 Facsimile: 61 3 6432 7901
Email: bwtmail@ghd.com.au

URGENT

Environmental Division
Melbourne
Work Order Reference
EM2101779

Telephone : + 61-3-8549 9600

Job Number: 12537535
GHD Office: Hobart
Project: Ballarat Gold Mine Tailings Material Testing Proposal
[redacted]
Requested Completion Date: Standard TAT
Purchase Order Number:

Laboratory: [redacted]
Address:
Laboratory Contact:

Page 1 of 1

PLEASE NOTE:
Sign white copy on r... samples. Samples ar... Laboratory address.
On receipt of sample... should sign the whit... Contact.
On completion of ar... copy with results.
Pink copy is returned to the sampler once the courier has signed for the samples.
Email results to the email address of the relevant GHD Office and cc GHD Project Manager and GHD Contact with the GHD Job Number in the email subject line.
Provide results in ESDAT compatible format.

Container type: J: soil jar B: bag; V: vial G: glass bottle; P: plastic bottle
Sample Matrix: S: Soil SL: Sludge; W: Water A: Air; GW: Groundwater

Analyses Required: NAPP (ASS-1); 1:5 water leach, pH, EC (EN34, IN4-; (CRS) (EA026); NAG (EA011); ICPMS Metals (ME-02S); Hg (EG035T); SO4 (ED040T); ASLP (EN60); ASLP pH (EA005); ASLP EC plus TDS (In-1); ASLP major cations (NT-1); ASLP total hardness (ED093F); ASLP major anions (NT-2A); ASLP ICPMS metals (ME-02); ASLP Hg (EG035F); Kinetic NAG K-NAG (EA011K)

Sample ID	Date	Time	Composite Sample	Sample Matrix	Preservative	Type	Number of items	Volume (mL)	Remarks
A-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location A – North side on batter of discharge cone. Slightly damp at surface due to sprinklers operating but fairly dry at depth
A-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
A-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
A-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
A-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
A-6 (50cm)	21/01/2021			Tailings	NA	B	1	2	
B-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location B – NE corner on breached crater. Dry at surface and at depth
B-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
B-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
B-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
B-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
B-6 (50cm)	21/01/2021			Tailings	NA	B	1	2	
C-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location C – Eastern side between two 'volcanos'. Leachate discharge pipe and pond quite close, with sample hole filling with seeping water at 0.5m (roughly RL of the leachate pond)
C-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
C-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
C-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
C-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
C-6 (50cm)	21/01/2021			Tailings	NA	B	1	2	
D-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location D – on batter of recently decommissioned spigot mound. Still quite wet through sample depth
D-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
D-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
D-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
D-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
D-6 (50cm)	21/01/2021			Tailings	NA	B	1	2	
E-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location E – sampled from existing crater breach. Reasonably dry right through
E-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
E-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
E-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
E-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
E-6 (50cm)	21/01/2021			Tailings	NA	B	1	2	

Sampled by:			
Received by:	Date/Time:	Relinquished by:	Date/Time:
Received by Courier:	Date/Time:	Relinquished by:	Date/Time:
Received by Lab: Aamc	Date/Time:	Relinquished by:	Date/Time:
	Date/Time:	Relinquished by:	Date/Time:

Received: 8/2 16:05 Carrier: TNT
C/note: ATA 30025?? 209
Temp: 9.0 °C Seal: Y N
Ice / Icebricks / NA

ALS

19694

CHAIN OF CUSTODY RECORD

12537535_Chain of Custody Record.xlsx

GHD Hobart
2 Salamanca Square, Hobart 7000
Telephone: 61 3 6210 0600 Facsimile: 61 3 6210 0601
Email: hbamail@ghd.com.au

GHD Launceston
102 Cameron Street, Launceston 7250
Telephone: 61 3 6332 5500 Facsimile: 61 3 6332 5555
Email: lstmail@ghd.com.au

GHD Burnie
10 Columnar Court, Burnie 7320
Telephone: 61 3 6432 7900 Facsimile: 61 3 6432 7901
Email: bwtmail@ghd.com.au

Job Number: 12537535
GHD Office: Hobart
Project: Ballarat Gold Mine Tailings Material Testing Proposal
[redacted]
Completion Date: Standard TAT
Purchase Order Number: 12537535

Laboratory:
Address: [redacted]
Laboratory Contact:

Page 1 of 1

PLEASE NOTE:
Sign white copy on receipt and release of samples. Samples are to be delivered to the Laboratory address.
On receipt of samples, the laboratory contact should sign the white copy and fax to GHD Contact.
On completion of analyses please return white copy with results.
Pink copy is returned to the sampler once the courier has signed for the samples.
Email results to the email address of the relevant GHD Office and cc GHD Project Manager and GHD Contact with the GHD Job Number in the email subject line.
Provide results in ESDAT compatible format.

Sample Matrix — S: Soil, SL: Sludge, W: Water, A: Air, GW: Groundwater
Container Type — J: soil jar, B: bag, V: vial, G: glass bottle, P: plastic bottle

Analyses Required: PP (ASS, pH, ES) | (EAG | (EA | metals | (EG03 | (ED04 | P (EN | pH (EA | plus T | or cati | hardness | anio | S met | Hg (EG | K-NA

Sample ID	Date	Time	Composite Sample	Sample Matrix	Preservative	Container Type	Number of	Volume (mL)	Remarks
A-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location A – North side on batter of discharge cone. Slightly damp at surface due to sprinklers operating but fairly dry at depth
A-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
A-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
A-4 (10cm)	21/01/2021	1		Tailings	NA	B	1	2	
A-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
A-6 (50cm)	21/01/2021	2		Tailings	NA	B	1	2	
B-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location B – NE corner on breached crater. Dry at surface and at depth
B-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
B-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
B-4 (10cm)	21/01/2021	3		Tailings	NA	B	1	2	
B-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
B-6 (50cm)	21/01/2021	4		Tailings	NA	B	1	2	
C-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location C – Eastern side between two 'volcanos'. Leachate discharge pipe and pond quite close, with sample hole filling with seeping water at 0.5m (roughly RL of the leachate pond)
C-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
C-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
C-4 (10cm)	21/01/2021			Tailings	NA	B	1	2	
C-5 (30cm)	21/01/2021	5		Tailings	NA	B	1	2	
C-6 (50cm)	21/01/2021	6		Tailings	NA	B	1	2	
D-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location D – on batter of recently decommissioned spigot mound. Still quite wet through sample depth
D-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
D-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
D-4 (10cm)	21/01/2021	7		Tailings	NA	B	1	2	
D-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
D-6 (50cm)	21/01/2021	8		Tailings	NA	B	1	2	
E-1 (10cm)	21/01/2021			Tailings	NA	B	1	10	Location E – sampled from existing crater breach. Reasonably dry right through
E-2 (30cm)	21/01/2021			Tailings	NA	B	1	10	
E-3 (50cm)	21/01/2021			Tailings	NA	B	1	10	
E-4 (10cm)	21/01/2021	9		Tailings	NA	B	1	2	
E-5 (30cm)	21/01/2021			Tailings	NA	B	1	2	
E-6 (50cm)	21/01/2021	10		Tailings	NA	B	1	2	

Please refer to emailed
6C sent by Sarah
Gilmour
Regards
Dan Brooke

Sampled by:	GHD				
Received by:		Date/Time:	Relinquished by:	DBrooke	Date/Time: 5/2/21
Received by Courier:		Date/Time:	Relinquished by:		Date/Time:
Received by Lab:	Morri	Date/Time:	Relinquished by:		Date/Time:
		Date/Time:	Relinquished by:		Date/Time:

Received: 8/2 1105 Carrier: TNT
C/note: ATA 30015 2709
Temp: 19.9 Seal: Y N
Ice / Icebricks / NA

https://oos.ghd.com/x/_layouts/xlprintview.aspx?NoAuth=1&sessionId=32.59d30024627e4ec8b4b100b6bba678461.A88.1.V24.458077yg3RbtjPG%2fTvdWah5l14.5.en-US5.en-AU32.a36b577f5e6...

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM2102784**	Page	: 1 of 6
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Contact	: [redacted]
Address	: LEVEL 8, 180 LONSDALE ST MELBOURNE VIC, AUSTRALIA 3001	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021 11:05
Order number	: 12537535	Date Analysis Commenced	: 23-Feb-2021
C-O-C number	: ----	Issue Date	: 25-Feb-2021 15:55
Sampler	: ----		
Site	:		
Quote number	: EN/005		
No. of samples received	: 3		
No. of samples analysed	: 3		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
[redacted]	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EA010-P: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- This is a rebatch of EM2101779.
- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.
- EN60: Where leachable PFAS analysis is requested, centrifugation rather than pressure filtration is used as the default approach for removal of particulates, in line with AS 4439.3.

Analytical Results

Sub-Matrix: **ASLP LEACHATE**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	E-4	A-4	C-4	----	----
Sampling date / time				21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	----	----
				EM2102784-001	EM2102784-002	EM2102784-003	--------	--------
				Result	Result	Result	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	4190	3920	3120	----	----
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	----	1	mg/L	2720	2550	2030	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	453	158	213	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	1440	1160	1240	----	----
Total Alkalinity as CaCO3	----	1	mg/L	1440	1160	1240	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	25	40	10	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	8	13	6	----	----
ED093C: Leachable Major Cations								
Calcium	7440-70-2	1	mg/L	83	43	61	----	----
Magnesium	7439-95-4	1	mg/L	31	18	20	----	----
Potassium	7440-09-7	1	mg/L	5	5	3	----	----
EG020C: Leachable Metals by ICPMS								
Aluminium	7429-90-5	0.1	mg/L	<0.1	0.2	0.2	----	----
Arsenic	7440-38-2	0.005	mg/L	0.030	0.187	0.069	----	----
Boron	7440-42-8	0.1	mg/L	<0.1	0.2	<0.1	----	----
Barium	7440-39-3	0.1	mg/L	<0.1	<0.1	<0.1	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.001	mg/L	<0.001	0.003	<0.001	----	----
Cobalt	7440-48-4	0.01	mg/L	0.04	0.05	0.06	----	----
Chromium	7440-47-3	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Cerium	7440-45-1	0.001	mg/L	0.002	<0.001	0.001	----	----
Copper	7440-50-8	0.01	mg/L	0.06	0.03	0.08	----	----
Caesium	7440-46-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Lithium	7439-93-2	0.001	mg/L	0.004	0.004	0.002	----	----
Manganese	7439-96-5	0.01	mg/L	3.39	1.88	2.35	----	----
Molybdenum	7439-98-7	0.01	mg/L	<0.01	<0.01	<0.01	----	----

Analytical Results

Sub-Matrix: ASLP LEACHATE (Matrix: WATER)			Sample ID	E-4	A-4	C-4	----	----
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	EM2102784-001	EM2102784-002	EM2102784-003	--------	--------
				Result	Result	Result	----	----
EG020C: Leachable Metals by ICPMS - Continued								
Nickel	7440-02-0	0.01	mg/L	**0.18**	**0.10**	**0.12**	----	----
Dysprosium	7429-91-6	0.001	mg/L	**0.001**	<0.001	<0.001	----	----
Lead	7439-92-1	0.01	mg/L	**0.07**	**0.02**	**0.03**	----	----
Antimony	7440-36-0	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Tin	7440-31-5	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thallium	7440-28-0	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Hafnium	7440-58-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Holmium	7440-60-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Zinc	7440-66-6	0.1	mg/L	**0.3**	**0.4**	**0.4**	----	----
Indium	7440-74-6	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Iron	7439-89-6	0.05	mg/L	**12.5**	**9.91**	**14.0**	----	----
Lanthanum	7439-91-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Lutetium	7439-94-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Neodymium	7440-00-8	0.001	mg/L	**0.001**	<0.001	<0.001	----	----
Praseodymium	7440-10-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Rubidium	7440-17-7	0.001	mg/L	**0.004**	**0.005**	**0.002**	----	----
Samarium	7440-19-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Silver	7440-22-4	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Strontium	7440-24-6	0.01	mg/L	**0.68**	**0.37**	**0.45**	----	----
Tellurium	22541-49-7	0.005	mg/L	<0.005	<0.005	<0.005	----	----
Terbium	7440-27-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thulium	7440-30-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Uranium	7440-61-1	0.001	mg/L	**0.003**	**0.002**	**0.002**	----	----
Ytterbium	7440-64-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Yttrium	7440-65-5	0.001	mg/L	**0.005**	**0.003**	**0.004**	----	----
Zirconium	7440-67-7	0.005	mg/L	<0.005	<0.005	<0.005	----	----
EG035C: Leachable Mercury by FIMS								

Analytical Results

Sub-Matrix: **ASLP LEACHATE** (Matrix: **WATER**)			Sample ID	**E-4**	**A-4**	**C-4**	**----**	**----**
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EM2102784-001**	**EM2102784-002**	**EM2102784-003**	**--------**	**--------**
				Result	Result	Result	----	----
EG035C: Leachable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0010	mg/L	<0.0010	<0.0010	<0.0010	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	<0.1	----	----

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

			Sample ID	E-4	A-4	C-4	----	----
			Sampling date / time	21-Jan-2021 00:00	21-Jan-2021 00:00	21-Jan-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	EM2102784-001	EM2102784-002	EM2102784-003	--------	--------
				Result	Result	Result	----	----
EN60: ASLP Leaching Procedure - Inorganics/PFAS (Plastic Vessel)								
Initial pH	----	0.1	pH Unit	**7.6**	**6.6**	**6.2**	----	----
After HCl pH	----	0.1	pH Unit	**1.7**	**1.7**	**1.7**	----	----
Extraction Fluid pH	----	0.1	pH Unit	**5.0**	**5.0**	**5.0**	----	----
Final pH	----	0.1	pH Unit	**5.2**	**5.1**	**5.1**	----	----

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM2102784**	Page	: 1 of 7
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Contact	: [redacted]
Address	: LEVEL 8, 180 LONSDALE ST MELBOURNE VIC, AUSTRALIA 3001	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021
Order number	: 12537535	Date Analysis Commenced	: 23-Feb-2021
C-O-C number	: ----	Issue Date	: 25-Feb-2021
Sampler	: ----		
Site	:		
Quote number	: EN/005		
No. of samples received	: 3		
No. of samples analysed	: 3		

NATA Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
[redacted]	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
[redacted]	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA010P: Conductivity by PC Titrator (QC Lot: 3528527)									
EM2102433-015	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	274	275	0.364	0% - 20%
EM2102796-005	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	11100	11500	3.19	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3528529)									
EM2102805-001	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	397	401	0.928	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	397	401	0.928	0% - 20%
EM2102796-005	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	746	753	0.925	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	746	753	0.925	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3528139)									
EM2102805-002	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	276	279	1.09	0% - 20%
EM2102625-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	16	18	15.7	0% - 50%
ED045G: Chloride by Discrete Analyser (QC Lot: 3528140)									
EM2102729-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	5	5	0.00	No Limit
EM2102729-014	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	6	6	0.00	No Limit
ED093C: Leachable Major Cations (QC Lot: 3528766)									
EM2102784-001	E-4	ED093C: Calcium	7440-70-2	1	mg/L	83	83	0.00	0% - 20%
		ED093C: Magnesium	7439-95-4	1	mg/L	31	32	0.00	0% - 20%
		ED093C: Potassium	7440-09-7	1	mg/L	5	4	0.00	No Limit
EG020C: Leachable Metals by ICPMS (QC Lot: 3528767)									
EM2102784-001	E-4	EG020A-C: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-C: Cadmium	7440-43-9	0.001	mg/L	<0.001	<0.001	0.00	No Limit

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EG020C: Leachable Metals by ICPMS (QC Lot: 3528767) - continued									
EM2102784-001	E-4	EG020A-C: Lithium	7439-93-2	0.001	mg/L	0.004	0.004	0.00	No Limit
		EG020A-C: Arsenic	7440-38-2	0.005	mg/L	0.030	0.031	3.95	No Limit
		EG020A-C: Cobalt	7440-48-4	0.01	mg/L	0.04	0.05	0.00	No Limit
		EG020A-C: Chromium	7440-47-3	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Copper	7440-50-8	0.01	mg/L	0.06	0.06	0.00	No Limit
		EG020A-C: Manganese	7439-96-5	0.01	mg/L	3.39	3.63	6.92	0% - 20%
		EG020A-C: Molybdenum	7439-98-7	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Nickel	7440-02-0	0.01	mg/L	0.18	0.20	6.33	0% - 50%
		EG020A-C: Lead	7439-92-1	0.01	mg/L	0.07	0.07	0.00	No Limit
		EG020A-C: Antimony	7440-36-0	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Tin	7440-31-5	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Thallium	7440-28-0	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-C: Iron	7439-89-6	0.05	mg/L	12.5	12.0	3.89	0% - 20%
		EG020A-C: Aluminium	7429-90-5	0.1	mg/L	<0.1	<0.1	0.00	No Limit
		EG020A-C: Boron	7440-42-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
		EG020A-C: Barium	7440-39-3	0.1	mg/L	<0.1	<0.1	0.00	No Limit
		EG020A-C: Zinc	7440-66-6	0.1	mg/L	0.3	0.3	0.00	No Limit
EG020C: Leachable Metals by ICPMS (QC Lot: 3528768)									
EM2102784-001	E-4	EG020B-C: Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-C: Cerium	7440-45-1	0.001	mg/L	0.002	0.002	0.00	No Limit
		EG020B-C: Caesium	7440-46-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-C: Rubidium	7440-17-7	0.001	mg/L	0.004	0.004	0.00	No Limit
		EG020B-C: Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-C: Uranium	7440-61-1	0.001	mg/L	0.003	0.003	0.00	No Limit
		EG020B-C: Tellurium	22541-49-7	0.005	mg/L	<0.005	<0.005	0.00	No Limit
		EG020B-C: Silver	7440-22-4	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020B-C: Strontium	7440-24-6	0.01	mg/L	0.68	0.74	9.08	0% - 20%
		EG020B-C: Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	0.00	No Limit
EG020C: Leachable Metals by ICPMS (QC Lot: 3528769)									
EM2102784-001	E-4	EG020D-C: Dysprosium	7429-91-6	0.001	mg/L	0.001	<0.001	0.00	No Limit
		EG020D-C: Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Holmium	7440-60-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Indium	7440-74-6	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Lanthanum	7439-91-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Lutetium	7439-94-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit

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Work Order : EM2102784
Client : GHD PTY LTD
Project : 12537535

Sub-Matrix: **WATER**

Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Laboratory Duplicate (DUP) Report					
				LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG020C: Leachable Metals by ICPMS (QC Lot: 3528769) - continued									
EM2102784-001	E-4	EG020D-C: Neodymium	7440-00-8	0.001	mg/L	0.001	<0.001	0.00	No Limit
		EG020D-C: Praseodymium	7440-10-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Samarium	7440-19-9	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Terbium	7440-27-9	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Thulium	7440-30-4	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Ytterbium	7440-64-4	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020D-C: Yttrium	7440-65-5	0.001	mg/L	0.005	0.005	0.00	No Limit
		EG020D-C: Zirconium	7440-67-7	0.005	mg/L	<0.005	<0.005	0.00	No Limit
		EG020D-C: Hafnium	7440-58-6	0.01	mg/L	<0.01	<0.01	0.00	No Limit
EG035C: Leachable Mercury by FIMS (QC Lot: 3528547)									
EM2102784-001	E-4	EG035C: Mercury	7439-97-6	0.0001	mg/L	<0.0010	<0.0010	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 3528525)									
EM2101881-002	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.9	0.9	0.00	No Limit
EM2102796-005	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.5	0.5	0.00	No Limit

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Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA010P: Conductivity by PC Titrator (QCLot: 3528527)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1412 µS/cm	98.4	85.0	119
ED037P: Alkalinity by PC Titrator (QCLot: 3528529)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	110	85.0	116
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3528139)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	107	85.8	117
				<1	500 mg/L	109	80.0	120
ED045G: Chloride by Discrete Analyser (QCLot: 3528140)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	108	85.0	115
				<1	1000 mg/L	105	85.0	122
ED093C: Leachable Major Cations (QCLot: 3528766)								
ED093C: Calcium	7440-70-2	1	mg/L	<1	5 mg/L	104	80.0	120
ED093C: Magnesium	7439-95-4	1	mg/L	<1	5 mg/L	103	80.0	120
ED093C: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	110	80.0	120
EG020C: Leachable Metals by ICPMS (QCLot: 3528767)								
EG020A-C: Aluminium	7429-90-5	0.1	mg/L	<0.1	0.5 mg/L	98.8	80.0	120
EG020A-C: Arsenic	7440-38-2	0.005	mg/L	<0.005	0.1 mg/L	110	80.0	120
EG020A-C: Boron	7440-42-8	0.1	mg/L	<0.1	0.5 mg/L	115	80.0	120
EG020A-C: Barium	7440-39-3	0.1	mg/L	<0.1	0.1 mg/L	105	80.0	120
EG020A-C: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	113	80.0	120
EG020A-C: Cadmium	7440-43-9	0.001	mg/L	<0.001	0.1 mg/L	96.0	80.0	120
EG020A-C: Cobalt	7440-48-4	0.01	mg/L	<0.01	0.1 mg/L	103	80.0	120
EG020A-C: Chromium	7440-47-3	0.01	mg/L	<0.01	0.1 mg/L	98.7	80.0	120
EG020A-C: Copper	7440-50-8	0.01	mg/L	<0.01	0.1 mg/L	100	80.0	120
EG020A-C: Lithium	7439-93-2	0.001	mg/L	<0.001	0.1 mg/L	108	80.0	120
EG020A-C: Manganese	7439-96-5	0.01	mg/L	<0.01	0.1 mg/L	94.8	80.0	120
EG020A-C: Molybdenum	7439-98-7	0.01	mg/L	<0.01	0.1 mg/L	109	80.0	120
EG020A-C: Nickel	7440-02-0	0.01	mg/L	<0.01	0.1 mg/L	101	80.0	120
EG020A-C: Lead	7439-92-1	0.01	mg/L	<0.01	0.1 mg/L	95.7	80.0	120
EG020A-C: Antimony	7440-36-0	0.01	mg/L	<0.01	0.02 mg/L	116	80.0	120
EG020A-C: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	110	80.0	120
EG020A-C: Tin	7440-31-5	0.01	mg/L	<0.01	0.1 mg/L	109	80.0	120
EG020A-C: Thallium	7440-28-0	0.01	mg/L	<0.01	0.1 mg/L	99.5	80.0	120
EG020A-C: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	100	80.0	120
EG020A-C: Zinc	7440-66-6	0.1	mg/L	<0.1	0.1 mg/L	100	80.0	120

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EG020C: Leachable Metals by ICPMS (QCLot: 3528767) - continued								
EG020A-C: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	100	80.0	120
EG020C: Leachable Metals by ICPMS (QCLot: 3528768)								
EG020B-C: Bismuth	7440-69-9	0.001	mg/L	<0.001	0.1 mg/L	98.5	80.0	120
EG020B-C: Cerium	7440-45-1	0.001	mg/L	<0.001	0.1 mg/L	102	80.0	120
EG020B-C: Caesium	7440-46-2	0.001	mg/L	<0.001	0.1 mg/L	102	80.0	120
EG020B-C: Rubidium	7440-17-7	0.001	mg/L	<0.001	0.1 mg/L	103	80.0	120
EG020B-C: Silver	7440-22-4	0.01	mg/L	<0.01	0.02 mg/L	99.4	70.0	130
EG020B-C: Strontium	7440-24-6	0.01	mg/L	<0.01	0.1 mg/L	104	80.0	120
EG020B-C: Tellurium	22541-49-7	0.005	mg/L	<0.005	0.1 mg/L	94.0	80.0	120
EG020B-C: Thorium	7440-29-1	0.001	mg/L	<0.001	0.1 mg/L	103	80.0	120
EG020B-C: Titanium	7440-32-6	0.01	mg/L	<0.01	0.1 mg/L	106	80.0	120
EG020B-C: Uranium	7440-61-1	0.001	mg/L	<0.001	0.1 mg/L	103	80.0	120
EG020C: Leachable Metals by ICPMS (QCLot: 3528769)								
EG020D-C: Dysprosium	7429-91-6	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Erbium	7440-52-0	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Europium	7440-53-1	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Gadolinium	7440-54-2	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Gallium	7440-55-3	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Hafnium	7440-58-6	0.01	mg/L	<0.01	----	----	----	----
EG020D-C: Holmium	7440-60-0	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Indium	7440-74-6	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Lanthanum	7439-91-0	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Lutetium	7439-94-3	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Neodymium	7440-00-8	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Praseodymium	7440-10-0	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Samarium	7440-19-9	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Terbium	7440-27-9	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Thulium	7440-30-4	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Ytterbium	7440-64-4	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Yttrium	7440-65-5	0.001	mg/L	<0.001	----	----	----	----
EG020D-C: Zirconium	7440-67-7	0.005	mg/L	<0.005	----	----	----	----
EG035C: Leachable Mercury by FIMS (QCLot: 3528547)								
EG035C: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.01 mg/L	95.1	72.0	115
EK040P: Fluoride by PC Titrator (QCLot: 3528525)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	105	80.8	118

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3528139)							
EM2102625-005	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	100 mg/L	77.9	70.0	130
ED045G: Chloride by Discrete Analyser (QCLot: 3528140)							
EM2102729-003	Anonymous	ED045G: Chloride	16887-00-6	400 mg/L	131	70.0	142
EG020C: Leachable Metals by ICPMS (QCLot: 3528767)							
EM2102784-001	E-4	EG020A-C: Arsenic	7440-38-2	1 mg/L	110	70.0	130
		EG020A-C: Barium	7440-39-3	1 mg/L	110	70.0	130
		EG020A-C: Beryllium	7440-41-7	1 mg/L	98.2	70.0	130
		EG020A-C: Cadmium	7440-43-9	0.25 mg/L	99.1	70.0	130
		EG020A-C: Cobalt	7440-48-4	1 mg/L	103	70.0	130
		EG020A-C: Chromium	7440-47-3	1 mg/L	101	70.0	130
		EG020A-C: Copper	7440-50-8	1 mg/L	102	70.0	130
		EG020A-C: Manganese	7439-96-5	1 mg/L	119	70.0	130
		EG020A-C: Nickel	7440-02-0	1 mg/L	97.6	70.0	130
		EG020A-C: Lead	7439-92-1	1 mg/L	101	70.0	130
		EG020A-C: Vanadium	7440-62-2	1 mg/L	106	70.0	130
		EG020A-C: Zinc	7440-66-6	1 mg/L	102	70.0	130
EG035C: Leachable Mercury by FIMS (QCLot: 3528547)							
EM2102784-002	A-4	EG035C: Mercury	7439-97-6	0.01 mg/L	95.4	84.0	118
EK040P: Fluoride by PC Titrator (QCLot: 3528525)							
EM2101881-003	Anonymous	EK040P: Fluoride	16984-48-8	5 mg/L	103	70.0	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM2102784**	Page	: 1 of 6
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: [redacted]	Telephone	: [redacted]
Project	: 12537535	Date Samples Received	: 08-Feb-2021
Site	:	Issue Date	: 25-Feb-2021
Sampler	: ----	No. of samples received	: 3
Order number	: 12537535	No. of samples analysed	: 3

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Analysis Holding Time Compliance

Matrix: **SOIL**

Method / Container / Client Sample ID(s)		Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Days overdue	Date analysed	Due for analysis	Days overdue
EN60: ASLP Leaching Procedure - Inorganics/PFAS (Plastic Vessel)							
Non-Volatile Leach: 28 day HT(e.g. Hg, CrVI) E-4, C-4	A-4,	23-Feb-2021	18-Feb-2021	**5**	----	----	----

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EN60: ASLP Leaching Procedure - Inorganics/PFAS (Plastic Vessel)								
Non-Volatile Leach: 28 day HT(e.g. Hg, CrVI) (EN60a-P) E-4, C-4	A-4,	**21-Jan-2021**	**23-Feb-2021**	18-Feb-2021	×	**----**	----	----

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA010P: Conductivity by PC Titrator								
Clear Plastic Bottle - Natural (EA010-P) E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	23-Mar-2021	✓
ED037P: Alkalinity by PC Titrator								
Clear Plastic Bottle - Natural (ED037-P) E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	09-Mar-2021	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Clear Plastic Bottle - Natural (ED041G) E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	23-Mar-2021	✓

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Work Order	: EM2102784
Client	: GHD PTY LTD
Project	: 12537535

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
ED045G: Chloride by Discrete Analyser								
Clear Plastic Bottle - Natural (ED045G)								
E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	23-Mar-2021	✓
ED093C: Leachable Major Cations								
Clear Plastic Bottle - Nitric Acid; Unfiltered (ED093C)								
E-4, C-4	A-4,	**23-Feb-2021**	**24-Feb-2021**	23-Mar-2021	✓	**24-Feb-2021**	23-Mar-2021	✓
EG020C: Leachable Metals by ICPMS								
Clear Plastic Bottle - Nitric Acid; Unfiltered (EG020D-C)								
E-4, C-4	A-4,	**23-Feb-2021**	**24-Feb-2021**	22-Aug-2021	✓	**24-Feb-2021**	22-Aug-2021	✓
EG035C: Leachable Mercury by FIMS								
Clear Plastic Bottle - Nitric Acid; Unfiltered (EG035C)								
E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	23-Mar-2021	✓
EK040P: Fluoride by PC Titrator								
Clear Plastic Bottle - Natural (EK040P)								
E-4, C-4	A-4,	**23-Feb-2021**	**----**	----	----	**24-Feb-2021**	23-Mar-2021	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	2	18	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Major Cations	ED093C	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Mercury by FIMS	EG035C	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite A	EG020A-C	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite B	EG020B-C	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite D	EG020D-C	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Major Cations	ED093C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Mercury by FIMS	EG035C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite A	EG020A-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite B	EG020B-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Major Cations	ED093C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Mercury by FIMS	EG035C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite A	EG020A-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite B	EG020B-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite D	EG020D-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Mercury by FIMS	EG035C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Leachable Metals by ICPMS - Suite A	EG020A-C	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Conductivity by PC Titrator	EA010-P	SOIL	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM Schedule B(3)
Calculated TDS (from Electrical Conductivity)	EA016	SOIL	In house: Calculation from Electrical Conductivity (APHA 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM Schedule B(3)
Hardness as CaCO3	EA065	SOIL	In house: Referenced to APHA 2340 B. This method is compliant with NEPM Schedule B(3)
Alkalinity by PC Titrator	ED037-P	SOIL	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) on a settled supernatant aliquot of the sample using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM Schedule B(3)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	SOIL	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM Schedule B(3)
Chloride by Discrete Analyser	ED045G	SOIL	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA seal method 2 017-1-L
Leachable Major Cations	ED093C	SOIL	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations in leachates are determined by either ICP-AES or ICP-MS techniques.
Leachable Metals by ICPMS - Suite A	EG020A-C	SOIL	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020: The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Leachable Metals by ICPMS - Suite B	EG020B-C	SOIL	In house: referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Leachable Metals by ICPMS - Suite D	EG020D-C	SOIL	In house: referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Leachable Mercury by FIMS	EG035C	SOIL	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the TCLP solution. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM Schedule B(3).

Analytical Methods	Method	Matrix	Method Descriptions
Fluoride by PC Titrator	EK040P	SOIL	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals in TCLP Leachate	EN25C	SOIL	In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM Schedule B(3)
ASLP for Non & Semivolatile Analytes - Plastic Leaching Vessel	EN60a-P	SOIL	In house QWI-EN/60 referenced to AS4439.3 Preparation of Leachates.

Rebatch

Client / Client code: GHD
Project: 12537535
Project Manger: [redacted]
Date /time sample rec: 8/2 @ 11:05am
Date/time Instructions rec: 16/2 @ 3:07pm
Due date: std
Due date surcharge:

CS Contact: Shirley
Additional Information:
please include Sarah to recieve report.

Environmental Division
Melbourne
Work Order Reference
EM2102784

Telephone : + 61-3-8549 9600

	Sample information							Analysis			Leach							
New Lab ID	Client ID	Date Sampled	Previous Work Order Reference	Previous ALS ID	Tray Number(s)	Container	Number of Containers				ASLP - Hg	ASLP - EC & TDS (IN-1)	ASLP - MAJOR CATIONS	ASLP - TOTAL HARDNESS	ASLP - MAJOR ANIONS (NT-2A)	ASLP - MAJOR ANIONS (NT-2A)	ASLP - METASL (ME-02)	
1	E-4	21/01/2021 0:00	EM2101779	9	MS505-6						X	X	X	X	X	X	X	
2	A-4	21/01/2021 0:00	EM2101779	1	MS505-6						X	X	X	X	X	X	X	
3	C-4	21/01/2021 0:00	EM2101779	5	MS505-6						X	X	X	X	X	X	X	

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Good morning [redacted]

After reviewing the results,

Could we complete the ASLP section of my COC on the following three samples:

E-4, A-4 and C-4

Could we no longer do the KNAG testing that was added to the end of the COC as I no longer need it.

Thanks,

Sarah

From [redacted]
Sent: Friday, February 19, 2021 12:16 PM
To: [redacted]
Subject: NAPP& NAG

As promised

Sub-Matrix			SOIL	SOIL	SOIL
Sample Name			A-4 (10cm)	A-6 (50cm)	B-4 (10
Sample Description					
Depth Type					
Depth in metres					
Analyte			21/01/2021 0:00	21/01/2021 0:00	21/01,
	Units	Rep. LOR	EM2101779-001	EM2101779-002	EM210
pH Value	pH Unit	0.1	8.1	8.5	
Net Acid Production Potential	kg H2SO4/t	0.5	-43.6		
Electrical Conductivity @ 25°C	µS/cm	1	556	298	
pH (OX)	pH Unit	0.1	10		
NAG (pH 4.5)	kg H2SO4/t	0.1	<0.1		<0.1
NAG (pH 7.0)	kg H2SO4/t	0.1	<0.1		<0.1
ANC as H2SO4	kg H2SO4 equiv./t	0.5	54		
ANC as CaCO3	% CaCO3	0.1	5.5		
Fizz Rating	Fizz Unit	0	2		
Sulfur - Total as S (LECO)	%	0.01	0.34		

[redacted]

2

Rebatch

Client / Client code: GHD
Project: 12537535
Project Manger: [redacted]
Date /time sample rec: 8/2 @ 11:05am
Date/time Instructions rec: 16/2 @ 3:07pm
Due date: std
Due date surcharge:

CS Contact: [redacted]
Additional Information:
please include [redacted] to recieve report.

Environmental Division
Melbourne
Work Order Reference
EM2102784

Telephone : + 61-3-8549 9600

	Sample information							Analysis										
											Leach							
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1	E-4	21/01/2021 0:00	EM2101779	9	MS505-6						X	X	X	X	X	X	X	
2	A-4	21/01/2021 0:00	EM2101779	1	MS505-6						X	X	X	X	X	X	X	
3	C-4	21/01/2021 0:00	EM2101779	5	MS505-6						X	X	X	X	X	X	X	

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Depth in metres					
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ANC as H2SO4	kg H2SO4 equiv./t	0.5	54		
ANC as CaCO3	% CaCO3	0.1	5.5		
Fizz Rating	Fizz Unit	0	2		
Sulfur - Total as S (LECO)	%	0.01	0.34		

[redacted]

2