10. ENVIRONMENTAL IMPACT ASSESSMENT - OTHER ENVIRONMENTAL FACTORS - MINE SITE DEVELOPMENT ENVELOPE

Other relevant environmental factors for the Mine Site Development Envelope comprise the following:

- Landforms.
- Subterranean Fauna.
- Terrestrial Environmental Quality.
- Air Quality and Atmospheric Gases.
- Human Health.

Potential impacts for each factor are detailed in Sections 10.1 to 10.5.

10.1 LANDFORMS

The EPA's objective for landforms is "*to maintain the variety, integrity, ecological functions and environmental values of landforms*".

10.1.1 Key Statutory Requirements, Environmental Policy and Guidance

The key legislation relating to managing impacts on landforms in Western Australia includes:

- *Environmental Protection Act 1986* (WA).

In addition to State legislation, the following policy and guidance statements were considered in the impact assessment for landforms:

- Environmental Assessment Guideline 8, Environmental Assessment Guideline for Environmental Principles, Factors and Objectives (EPA 2015c).
- Environmental Protection Bulletin No. 23, Guidance on the EPA Landforms Factor (EPA 2015g).

10.1.2 Assessment of Potential Impact

The EPA defines landform as a 'distinctive, recognisable physical feature on the earth's surface having a characteristic shape produced by natural processes' (EPA 2015g).

From a review of regional contours surrounding the Mine Site Development Envelope (up to 30 km away), it is clear that the most distinctive landforms in relation to the Mine Site are a northwest to southeast trending band of low hills parallel to the Mine Site Development Envelope associated with the Reeves Land System. The distinctive landform features within the band are Reeves Hill, Dampier Hill, Mt Jowlaenga and several unnamed smaller hills to the east and north of the Mine Site Development Envelope (Figure 21). None of these landforms will be impacted by the project.

The only two constructed landforms remaining at closure of the project will comprise the mineral deposit area and the initial TSF. The mineral deposit area will be progressively backfilled and rehabilitated and will not be significantly distinguishable from the surrounding area. Potential impacts associated with these two constructed landforms include:

- **Post-mining landforms are inconsistent with the surroundings.**
- **Post-mining landforms are unstable.**

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

10.1.2.1 Post-mining Landforms Inconsistent with Surroundings

The mining process will change the detail of the flat, evenly sloping profile of the current site, creating shallow sloping raised areas and depressions. These minor amendments to the relative levels are consistent with rehabilitation practices at other mineral sands mines and are not expected to result in landforms that are inconsistent with their surroundings.

The initial TSF surface at the end of mine life will potentially be elevated in excess of 10 m above the surrounding landscape and hence will be more pronounced. This will be shaped and rehabilitated to match surrounding landforms as outlined in the preliminary MCP (Appendix 4) and as detailed in subsequent revisions of the MCP.

The mining process and initial TSF are 'Unlikely' to result post-mining landforms that are inconsistent with their surroundings. The potential residual impact, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Post-mining landforms are inconsistent with surroundings.	Minor	Unlikely	Low

10.1.2.2 Post-mining Landforms are Unstable

Materials characterisation work has been completed on soils and mine waste, including overburden and process residues (Appendix 6, Appendix 19 and Appendix 20). This work determined that overburden material, including the local Pindan soils, has a low coherence and limited wet strength and is not favourable for rehabilitation of steeply sloping surfaces. However, the material is well suited for rehabilitation of flat or gently sloping surfaces such as expected within the mineral deposit area or the initial TSF surface. The only potential requirement to rehabilitate steeply sloping surfaces is on the embankments of the initial TSF. Pindan soil blended with ferruginous sandstone overburden is expected to provide a suitable cover for these areas that will not excessively erode or result in instability.

Post-mining landforms are considered 'Unlikely' to be unstable with only 'Minor' erosion expected. The potential residual impact, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Post-mining landforms are Unstable.	Minor	Unlikely	Low

10.1.3 Management Measures

Management measures for constructed landforms are detailed in the preliminary MCP (Appendix 4).

10.1.4 Predicted Outcome

Due to the lack of impact on existing landforms from project activities, and the predicted low impact of constructed landforms, Sheffield considers that the environmental objective (Section 10.1) for landforms will be met.

10.2 SUBTERRANEAN FAUNA

The EPA's objective in relation to subterranean fauna is "*to maintain representation, diversity, viability and ecological function at the species, population and assemblage level*".

10.2.1 Key Statutory Requirements, Environmental Policy and Guidance

Subterranean fauna are protected under Commonwealth and State legislation, governed by three Acts:

- *Wildlife Conservation Act 1950* (WA).
- *Environmental Protection Act 1986* (WA).
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

In addition to State legislation, the following policy and guidance statements were considered in undertaking fauna surveys and in the impact assessment for subterranean fauna:

- Environmental Assessment Guideline 12, Consideration of Subterranean Fauna in Environmental Impact Assessment in Western Australia (EPA 2013a).
- EPA Guidance Statement 54a, Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (EPA 2007).

10.2.2 Assessment of Potential Impact

Despite widespread sampling during the pilot survey within the Mine Site Development Envelope, no stygofauna were recorded. This together with the absence of previous records of stygofauna on the Dampier Peninsula indicates that it is unlikely that a significant or diverse stygofaunal assemblage exists within the Mine Site Development Envelope.

The majority of the Mine Site Development Envelope provides little to no habitat for troglofauna and is comprised almost solely of sands above the water table. This is supported by the fact that only a single specimen was recorded from within the Mine Site Development Envelope while a second specimen was recorded in the sandstone ranges to the east of the Mine Site Development Envelope, despite five drill holes containing rock strata being sampled. Given the fact that this taxon was recorded within the sandstone strata, which continues extensively to the east and north of the Mine Site Development Envelope, its distribution is unlikely to be confined to the Mine Site Development Envelope.

10.2.3 Management Measures

No management measures are required for subterranean fauna.

10.2.4 Predicted Outcome

Due to the lack of subterranean fauna being recorded within the Mine Site Development Envelope and immediate surroundings, the project will not result in loss to the representation, diversity, viability or ecological function of subterranean fauna species, population and assemblages. Sheffield considers that the environmental objective for subterranean fauna (Section 10.2) will be met.

10.3 TERRESTRIAL ENVIRONMENTAL QUALITY

The EPA's objective in relation to terrestrial environmental quality is "*to maintain the quality of land and soils so that the environment values, both ecological and social, are protected*".

10.3.1 Key Statutory Requirements, Environmental Policy and Guidance

Terrestrial environmental quality is protected under Commonwealth and State legislation, governed by the following Acts:

- *Dangerous Goods Safety Act 2004* and associated regulations (WA).
- *Contaminated Sites Act 2003* and associated regulations (WA).
- *Environmental Protection (Unauthorised Discharges) Regulations 2004* (WA).
- *Environmental Protection (Rural Landfill) Regulations 2002 (WA)*.
- *Environmental Protection (Controlled Waste) Regulations 2004 (WA)*.
- *Mining Act 1978* and associated regulations (WA).
- *Mines Safety and Inspection Act 1994* and Regulations 1995 (WA).

In addition to State legislation, the following policy and guidance statements were considered in the impact assessment for terrestrial environmental quality:

- Guidelines for Preparing Mine Closure Plans (DMP and EPA 2015).
- Principles of the Strategic Framework for Mine Closure (ANZMEC and MCA 2000).
- Guide to Departmental Requirements for the Management and Closure of Tailings Storage Facilities (DMP 2015).
- Guidance for the Assessment of Environmental Factors 6, Rehabilitation of Terrestrial Ecosystem (EPA 2006a).
- Guideline on Investigation Levels for Soil and Groundwater. Schedule B1. (NEPC 2013)

10.3.2 Assessment of Potential Impact

Potential impacts to terrestrial environmental quality in the Mine Site Development Envelope are:

- **Erosion and sedimentation causing loss of topsoil.**
- **Erosion and sedimentation causing loss of soil material from disturbed areas**.
- **Disposal of mine and processing wastes causing contamination of the environment** – disposal within the initial Tailings Storage Facility (TSF) and as backfill within the mining excavation leading to contamination of the environment.
- **Accidental spills and leaks causing contamination of the environment** – spills or leaks of hydrocarbons and process reagents leading to contamination of the environment.
- **Discharge of inadequately treated sewage effluent causing contamination of the environment**.
- **Poorly designed and operated landfill causing contamination of the environment.**

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

10.3.2.1 Erosion and Sedimentation Causing Loss of Topsoil

Topsoil will initially be stockpiled for use in rehabilitation and revegetation and then direct replaced as part of progressive rehabilitation activities. Inappropriate removal and stockpiling methods can result in a reduction in soil quality and structure, as well as affecting the viability of the seed bank within the topsoil. In order to prevent this from happening, Sheffield will ensure that topsoil is not handled when wet to avoid damaging soil structure and

composition. Topsoil when requiring storage, will be stored in low stockpiles no higher than 2 m to retain the viability of seeds and prevent erosion from affecting the stockpiles. The duration that topsoil is stockpiled will be minimised as far as practicable, and where possible, will be returned directly to mined areas that are ready to be rehabilitated. All topsoil stockpiles will be located away or protected from stormwater flows, minimising potential losses via erosion and sedimentation.

Some minor topsoil loss is 'Likely' to occur over the life of the project; however this is not expected to cause any noticeable impacts on associated environmental values within the Mine Site Development Envelope. The potential residual impact of erosions and sedimentation on topsoil, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Erosion and sedimentation causing loss of topsoil	Incidental	Likely	Low

10.3.2.2 Erosion and Sedimentation Causing Loss of Soil Material from Disturbed Areas

The natural land surface within the Mine Site Development Envelope will be disturbed by construction of infrastructure and progressive mining within the mineral deposit area. This may result in erosion of soil materials and subsequent transfer of sediment downstream.

Drainage in the Mine Site area typically occurs as low energy sheet flow due to the low gradient. Some concentrated streams are expected around infrastructure areas such as the ore processing plant and Initial TSF and these may cause minor and very localised erosion if inappropriately managed. Sheffield proposes to use a series of sediment traps in these locations to reduce flow energy and remove sediment from stormwater.

Rehabilitation is planned for all disturbed surfaces with the initial TSF being the only remaining permanent landform. Soil profiles will be reinstated as the mining excavation is progressively backfilled and rehabilitated with mine wastes, overburden, process residues and topsoil. Revegetation of disturbed surfaces with native species will provide stability to disturbed soils and will minimise erosion and sedimentation processes. Rehabilitation and Closure is discussed further in Section 12.

Some minor, localised soil loss is considered 'Likely' to occur over the life of mine within disturbed areas; however the consequence on associated environmental values within the Mine Site Development Envelope is considered to be 'Incidental'. This impact is therefore assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Erosion and sedimentation causing loss of soil material from disturbed areas	Incidental	Minor	Low

10.3.2.3 Mining and Disposal of Mine and Processing Wastes Causing Contamination of the Environment

Impacts from mining and disposal of mine and processing wastes causing contamination of the terrestrial environment are considered in Section 8.4.2.3 Inland Water Quality. However, impacts to soil are considered to be less than those to water quality as Potentially Acid Forming (PAF) material found at a depth does not form part of the ore body and will not be mined by Sheffield, so should not result in excavation and potential placement of this material at the surface.

Based on the assessment results as presented in Section 8.4.2.3 Inland Water Quality, it is considered 'Unlikely' that mining activities will result in any exceedances of soil quality guidelines at any sensitive receptors within or adjacent to the Mine Site Development Envelope with an impact consequence of 'Minor' for the vast majority of

waste overburden/soil/mixed residues streams. The potential impact from mining and mine and process wastes disposal on the terrestrial soil quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Disposal of mine and processing wastes causing contamination of the environment	Minor	Unlikely	Low

10.3.2.4 Accidental Spills and Leaks Causing Contamination of the Environment

Impacts from accidental spills and leads causing contamination of the terrestrial environment are considered the same as those for Inland Water Quality as discussed in Section 8.4.2.2.

10.3.2.5 Discharge of Inadequately Treated Sewage Effluent Causing Contamination of the Environment

Impacts from discharge of inadequately treated sewage effluent causing contamination of the terrestrial environment are considered the same as those for Inland Water Quality as discussed in Section 8.4.2.3.

10.3.2.6 Poorly Designed and Operated Landfill Causing Contamination of the Environment

Impacts from poorly designed and operated landfill causing contamination of the terrestrial environment are considered the same as those for Inland Water Quality as discussed in Section 8.4.2.3.

10.3.3 Management Measures

A summary of key measures to address potential impacts on Terrestrial Environmental Quality is shown in Table 72. No further specific management measures for terrestrial environmental quality are required as management measures detailed in Section 8.1.2 for flora and vegetation, Section 8.4.3 inland water quality and Section 12 rehabilitation and decommissioning adequately mitigate impacts to terrestrial environmental quality.

Table 72: Proposed Management Measures for Protection of Terrestrial Environmental Quality for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Dust generation or product spillage	• Dust will be managed by watering unsealed roads with a water cart or with fixed sprays as required. • Vehicle traffic will be confined to defined roads and tracks. • During high winds, topsoil and overburden stripping and spreading activities will be restricted if dust cannot be adequately controlled. • Vehicles will be required to travel at safe operating speeds on unsealed roads and will be restricted from accessing rehabilitated surfaces except for management purposes. • Spilt ore and materials outside of the ore processing areas will be regularly cleaned up. • Bulk products will be transported in covered containers.
Radiation exposure affecting terrestrial environment	• Rehabilitated areas will be monitored to ensure radiation levels are within environmental screening criteria (10 µGy/h) or established pre-mining background levels.

10.3.4 Predicted Outcome

There will be no permanent disturbance aside from a small TSF which represents 106 ha of disturbance on completion as the mining excavation will be backfilled and rehabilitated. Mine wastes are expected to be benign apart from sulfidic material measured at extreme depth, with monitoring and management measures to be developed and implemented before this material is disturbed.

Sheffield considers that the potential impacts on terrestrial environmental quality will be able to be adequately managed such that the objective (Section 10.3) will be met, and that the residual impacts are therefore acceptable.

10.4 AIR QUALITY AND ATMOSPHERIC GASES

The EPA's objective in relation to air quality is "*to maintain air quality for the protection of the environment and human health and amenity, and to minimise the emission of greenhouse and other atmospheric gases through the application of best practice*".

10.4.1 Key Statutory Requirements, Environmental Policy and Guidance

The key legislation relating to managing impacts on landforms in Western Australia includes:

- *National Environmental Protection (Ambient Air Quality) Measure 2003* (WA).

In addition to State legislation, the following policy and guidance statements were considered in the impact assessment for air quality and atmospheric gases:

- Air Quality Modelling Guidance Notes. Perth, WA. (DEC 2006).
- A Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and Other Related Activities (DEC 2011).
- EPA Guidance Statement No. 3, Separation Distances Between Industrial and Sensitive Land Uses (EPA 2005).
- Environmental Protection Bulletin Number 24, Greenhouse Gas Emissions and Consideration of Projected Climate Change Impacts in the EIA Process (EPA 2015h).
- *National Environment Protection Measure for Ambient Air Quality 1994* as Amended 2003 (NEPC 2003).

10.4.2 Assessment of Potential Impact

Activities to be conducted at the Mine Site Development Envelope, including mining, processing, handling and transport of mined material, as well as onsite power generation and process heat requirements, have the potential to impact on air quality through emissions of dust and combustion products. The following impacts may occur:

- **Dust emissions affecting air quality** from:
  - Mining activities (e.g. clearing, vehicle movements).
  - Fixed stacks associated with the secondary processing plant.
  - Handling and transport of mined material, process material and final product.
  - Stored mine wastes (Tailings Storage Facility [TSF] and mine excavation backfill).

Combustion emissions from onsite power generation, process heating requirements, and vehicles and equipment can affect air quality.

- **Combustion emissions affecting air quality**:
  - Oxides of nitrogen.
  - Carbon monoxide.
  - Sulfur dioxide.
  - Greenhouse gas emissions.

Other potential impacts were screened out from further assessment (Section 7.4) as they were either assessed as not likely to occur or were unlikely to have any discernible consequence on any factor different to background levels:

Stressor	Justification for Exclusion
Odour emissions affecting air quality	A purpose built landfill facility will be constructed at the Mine Site for disposal of putrescible wastes. These will be covered with at least 200 mm of inert material about once a week. Sewage will be treated to an acceptable standard via package WWTP located in the accommodation village and ore processing are before disposal of effluent and solids. Odour emissions from processing (in particular roasting) are expected to be minor and rapidly dispersed by use of an elevated stack as for other gaseous emissions which were modelled. Odours from these sources will be minimised by correct operation of the facilities. Any odour emissions will be localised and are not expected to affect air quality for employees who are the closest sensitive receptors.

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

10.4.2.1 Dust Emissions Affecting Air Quality

Airborne particulate matter produced from construction and mine activities can potentially reduce air quality, and be inhaled. Particles of size greater than 10 microns aerodynamic diameter (PM_{10}) are considered to represent an amenity issue rather than a health issue as they adhere to and are screened out in the upper respiratory tract. Particles less than PM_{10}, and specifically those less than 2.5 microns ($PM_{2.5}$) are strongly linked to adverse human health effects such as cardiovascular disease and respiratory effects (NEPC 2014).

Dust impacts from the Mine Site Development Envelope were assessed using predictive modelling undertaken by Atmospheric Solutions (Appendix 12), with results compared to National Environmental Protection Measures (NEPM) Ambient Air Quality (AAQ) standards.

Modelling indicates that airborne particulates (TSP, PM_{10} and $PM_{2.5}$) and deposited dust levels are 'likely' to be elevated in localised areas within the immediate vicinity of the sources of emissions, i.e. the Mine Site and Site Access Road. However, these levels quickly fall below the standard within a short distance. It is important to note that the NEPM reference air quality criteria for PM_{10} and $PM_{2.5}$ are intended for application within the ambient air environment of residential areas, not at the lease boundary of industrial point source emissions. Given the lack of such receptors, there is not expected to be any adverse air quality impacts.

The accommodation village is located 4 km from the Mine Site, and is predicted to experience air quality well within the criteria – only $PM_{2.5}$ being increased marginally above ambient background levels.

Impacts of deposited dust on vegetation immediately adjacent to the Site Access Road and mining activity is discussed in Section 8.1.

Standard processes and procedures will be implemented during operation of the project to minimise dust emission, such as; vehicles and mining equipment will keeping to designated roads, progressive clearing kept to a minimum requirement at any one time, progressive rehabilitation and dust suppression. Positional dust monitoring will be undertaken as required for the radiation management plan and environmental management plan at suitable locations around the Mine Site Development Envelope such as a suitable distance from the active void area and boundary locations.

Based on the modelling results, mining activities are predicted to 'Rarely' result in any exceedances of the NEPM AAQ standards at any sensitive receptors within or adjacent to the Mine Site Development Envelope. The residual impact from dust emissions on air quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Dust emissions affecting air quality	Incidental	Rare	Low

10.4.2.2 Combustion Emissions Affecting Air Quality

Combustion emissions produced from activities within the Mine Site Development Envelope that may reduce air quality are oxides of nitrogen, carbon monoxide, sulfur dioxide and greenhouse gas (carbon dioxide) emissions.

Measures to reduce combustion emissions are considered to be universal for all species emitted, such as regular preventative and, where needed, corrective maintenance on vehicles and plant and use of Euro V standard vehicles and equipment (post 2009) or appropriate quality diesel fuel will be used to lower NOx and particulate emissions. Additionally, where appropriate, options for reduction in greenhouse gas emissions and/or carbon offsets will be investigated during the project life.

Oxides of Nitrogen Affecting Air Quality

Oxides of nitrogen (NO_X) include nitric oxide (NO), a colourless gas with a sharp, sweet odour, and nitrogen dioxide (NO_2), a dark brown gas with a pungent, acrid odour. Both NO and NO_2 can reduce visibility, with NO_X contributing significantly to haze as well as to regional air pollution as a precursor to photochemical pollution. NO_X is also a factor in the formation of acid rain. Elevated levels of NO_X, particularly NO_2, can cause a variety of impacts including damage to plant tissues and the increased acidity of rain (i.e. lower pH) which can in turn, lower soil, surface water, and groundwater pH, potentially having harmful secondary effects. In humans, exposure to elevated NO_2 levels can result in a number of health impacts.

NO_X are produced by the combustion of fuel in the presence of nitrogen, however approximately 95% of NO_X present in exhaust gas is NO, with the remaining 5% NO_2 (sometimes called 'thermal NO_2'). On release, NO reacts with available ozone (O_3) to form NO_2, increasing the ratio of NO_2 to NO. Subsequently, NO_2 breaks down in the presence of sunlight to form NO and O_3. It is this (highly simplified) series of reactions that contributes to photochemical smog, a significant problem in populated cities. The ambient air quality limit for environmental health exposure for NO_2 in the NEPM AAQ is 0.12 ppm, or 246 µg/m^3, on an hourly average (NEPC 2003).

In the project location, there will be limited background O_3 levels to allow for significant NO_2 generation. Modelling by Atmospheric Solutions (2016, Appendix 12), indicates that predicted NO_2 levels are highest in the immediate vicinity of the power station and mineral separation plant with maximum hourly average levels of approximately 30 µg/m^3 which is significantly below the NEPM AAQ criteria of 246 µg/m^3. No observable increase in concentration is predicted at the accommodation village. Newer fuel standards including Euro V (DIRD 2016) have lowered NO_X emissions by 17% versus previous 2004 standards in diesel vehicles and will be adopted to lower NO_X as much as practicable.

Based on the modelling results, power generation and processing activities 'Rarely' result in any exceedances of the NEPM AAQ standards for NOx at any sensitive receptors within or adjacent to the Mine Site Development Envelope. The potential residual impact from oxides of nitrogen on air quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Oxides of nitrogen affecting air quality	Incidental	Rare	Low

Carbon Monoxide Affecting Air Quality

Carbon monoxide (CO) is an odourless, colourless gas produced via natural sources such as the oxidation of methane, and from the incomplete combustion of fossil fuels. CO is eventually converted to carbon dioxide in the atmosphere, or through the action of soil micro-organisms and plants. CO prevents the absorption and transport of oxygen in the blood by combining with haemoglobin to produce carboxy-haemoglobin. As such, CO is toxic at high concentrations, and exposure can be fatal. Chronic exposure to mild or moderate (occupational) levels of CO can lead to a number of health disorders (ATSDR 2012).

The ambient air quality limit for environmental health exposure for 8 hourly averaged CO in the NEPM AAQ is 9.0 ppm, or 10,300 µg/m^3 (NEPC 2003). Modelling by Atmospheric Solutions (Appendix 12) has indicated maximum 8 hourly CO levels in the vicinity of the power station and processing plant of approximately 20 µg/m^3 due to relatively low levels of combustion emissions. No observable increase in concentration is predicted at the proposed accommodation village.

Based on the modelling results, power generation and processing activities will 'Rarely' result in any exceedances of the NEPM AAQ standards for CO at any sensitive receptors within or adjacent to the Mine Site Development Envelope. The potential residual impact of carbon monoxide on air quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Carbon monoxide affecting Air quality	Incidental	Rare	Low

Sulphur Dioxide Affecting Air Quality

Sulphur dioxide (SO_2) is the most abundant sulphur-containing compound in the atmosphere generated from man-made sources. The main contributor globally is the burning of coal, with considerable contributions also from petroleum combustion (diesel fuel) and smelting.

SO_2 in the atmosphere is eventually oxidised to sulphur trioxide (SO_3) which combines with water (H_2O) to form sulphuric acid (H_2SO_4). H_2SO_4 is removed from the atmosphere by rainfall (and to a lesser extent by adsorption to particulate matter and particulate deposition) and therefore is the main component of acid rain. Acid rain has a critical effect on human, animal and plant health, with acidic deposits adversely affecting both land and water ecosystems. Human exposure to low concentrations of SO_2 can cause irritation of the eyes, nose and throat, choking and coughing. Repeated or prolonged exposure to moderate concentrations may cause inflammation of the respiratory tract, wheezing and lung damage. It has also been proved to be harmful to the reproductive systems of animals and caused developmental changes in their newborn.

The ambient air quality limit for environmental health exposure for SO_2 as an hourly average in the NEPM AAQ is 0.2 ppm, or 570 µg/m^3 (NEPC 2003). Modelled SO_2 levels were found to be very low with maximum modelled concentrations of 0.25 to 0.3 µg/m^3 (Appendix 12).

Based on the modelling results, mining and processing activities will 'Rarely' result in any exceedances of the NEPM AAQ standards for SO_2 at any sensitive receptors within or adjacent to the Mine Site Development

Envelope. The potential residual impact of sulphur dioxide on air quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Sulfur dioxide affecting air quality	Incidental	Rare	Low

Greenhouse Gas Emissions Affecting Air Quality

Greenhouse gas emissions (mostly as carbon dioxide) will primarily be produced from power generation and transport fuel requirements including transport of product for export. Use of compressed gases (e.g. welding) in workshops etc. and onsite waste management/landfill are considered to be comparatively small in comparison to the above sources and have been excluded from emissions calculations. Land clearing conducted progressively throughout the project will be offset by re-vegetation and is considered carbon neutral overall. Table 73 summarises the estimated projected greenhouse gas emissions from diesel consumption (dozers, excavators, trucks, watercarts, graders and light vehicles) and gas consumption (power generation, roasting and other processing requirements) across the two mining stages (Section 1.2.1) and for the total life of the project.

Table 73: Average Annual and Total Life of Mine Estimated Greenhouse Gas Emissions*

Source	Unit	Quantity	Emissions (t CO_2-e)	Percentage of Total
Stage I				
Total Diesel Fleet	kL/annum	4,431	12,060	9.8
Power Generation	GJ/annum	1,040,996	53,642	43.5
Roaster	GJ/annum	552,672	28,479	23.1
Other Processing	GJ/annum	566,352	29,184	23.7
Stage I Total (5 years)			**123,365**	**100%**
Stage II				
Total Diesel Fleet	kL/annum	7,032	19,139	7.6
Power Generation	GJ/annum	2,278,125	117,392	46.6
Roaster	GJ/annum	1,105,344	56,958	22.6
Other Processing	GJ/annum	1,132,704	58,368	23.2
Stage II Total (42 years)			**251,857**	**100%**
Total Life of Project				
Total Diesel Fleet	kL	331,563	902,410	8.0
Power Generation	GJ	100,886,230	5,198,667	46.3
Roaster	GJ	49,187,808	2,534,648	22.6
Other Processing	GJ	50,405,328	2,597,387	23.1
Grand Total (47 years)			**11,233,112**	**100%**

** Stage I calculated based on 7.5 Mtpa processing rate finishing in year 5, Stage II 15 Mtpa processing years 6 to 47.*

Results provided in Table 73 are considered an upper estimate as they assume maximum energy consumption at all times over the life of the project and are based on 2004 diesel specifications. For comparative purposes, predicted carbon dioxide emissions for the project have been compared to the corporate reporting figures of Iluka Resources for the 2014/15 reporting period (Iluka 2014), as published by National Greenhouse and Energy Reporting:

- Iluka Resources 900,200 t of product for National Greenhouse and Energy Reporting reported 255,006 t CO_2-e (0.28 t CO_2/t product).
- Sheffield Stage II 644,000 t of product for calculated 251,857 t CO_2-e (0.39 t CO_2/t product).

Given the conservative assessment used to derive the project CO_2 emissions, the project emissions are considered comparable to those reported by Iluka Resources for similar production – allowing for a deeper ore resource at the Thunderbird deposit in comparison to generally shallow Iluka deposits.

Additional minor contributions are anticipated from travel of site personnel, waste removal from site, and site deliveries by external contractors. These processes are considered to be under the operational control of contractors and have been excluded from this assessment. Based on projected mining and processing activities, it is considered 'Almost Certain' to result in net CO_2 emissions, however the consequence of these to the state is considered 'Minor'. The potential residual impact of greenhouse gas emissions on air quality, after implementation of management measures, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Greenhouse gas emissions affecting air quality	Minor	Almost Certain	Medium

10.4.3 Management Measures

A summary of key measures to address potential impacts on air quality is shown in Table 74. No further management measures are considered necessary.

Table 74: Proposed Management Measures for Air Quality for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Dust emissions affecting air quality	• During high winds, topsoil stripping and spreading activities will be restricted if dust cannot be adequately controlled. • Vehicles and mining equipment will keep to designated roads. • Vehicles will be required to travel at safe operating speeds on unsealed roads and will be restricted from accessing rehabilitated surfaces except for management purposes. • Clearing will be undertaken progressively and kept to the minimum requirement. • Progressive rehabilitation will be undertaken on disturbed areas as they become available. • Dust suppression will be carried out during construction, operation and closure. • Sheffield will maintain equipment in accordance with manufacturers' specifications to minimise particulate and gaseous emissions.
Combustion emissions affecting air quality	• Vehicles and plant will undergo regular preventative maintenance and, as needed, corrective maintenance. • Euro V standard vehicles and equipment (post 2009) or appropriate quality diesel fuel will be used to minimise NOx and particulate emissions. • Energy efficiency has been considered in the selection and design of equipment and plant. • Sheffield will specify preference for use of low emission producing equipment in equipment supply contracts.

10.4.4 Predicted Outcome

The results of modelling indicate that all pollutants, both dust (TSP, PM_{10}, $PM_{2.5}$ and dust deposition) and combustion products (NO_X, CO, SO_2), will be well within the assessment levels at appropriate distances from the activity and nearby receptors such as the accommodation village. No residential receptors outside the Mine Site Development Envelope will be impacted by pollutants.

Potential air quality impacts from the project may occur as a result of dust generated by the construction, mining, processing, handling and transport of the mined material, as well as low levels of gaseous combustion emissions from onsite power generation and process heat requirements. Dust generation is the primary contributor to potential air quality impacts for the project, however use of dust suppression along the Site Access Road around the Mine Site will adequately control dust emissions.

The air quality impacts of the Mine Site Development Envelope and unsealed access road are not expected to result in any adverse air quality impacts in the region (Appendix 12).

Sheffield considers that the potential impacts to air quality will be able to be adequately managed such that the environmental objective (Section 10.4) for air quality will be met, and that the residual impacts are therefore acceptable.

10.5 HUMAN HEALTH

The EPA's objective in relation to human health is "*to ensure that human health is not adversely affected*".

10.5.1 Key Statutory Requirements, Environmental Policy and Guidance

The key legislation relating to managing human health in Western Australia includes:

- *Radiation Safety Act 1975* (WA).
- *Radiation Safety (Transport of Radioactive Substances) Regulations 2012 (WA)*.
- *Mines Safety and Inspection Regulations 1995* (WA).

10.5.2 Assessment of Potential Impact

This section discusses the radiological environment in relation to the project, in particular the potential impact of the Mine Site operations on potential worker and public exposures. Assessment of potential for human health impacts from respirable dust and combustion emissions is discussed in Section 10.4.

Naturally occurring radioactive materials (NORMs) contain the elements thorium and uranium which are associated with heavy minerals, and in particular with monazite. As demonstrated in the mine residues characterisation (MBS 2016, Appendix 20) the uranium and thorium in monazite is tightly bound and unavailable environmentally, but is still subject to radioactive decay and emissions proportional to the concentration of monazite. Ore, waste and product materials generated by the mining and processing of heavy mineral sands on site has the potential to impact on human health by exposure to radiation. As the Mine Site will generate significant quantities of product and various waste materials for return to the mining void, these materials will be classed and regulated as radioactive substances under the *RS Act*. A Radiation Management Plan (RMP) and Radiation Waste Management Plan (RWMP) will be prepared which will outline the management measures for return of waste materials to the mine void for later rehabilitation and to ensure worker and public radiation exposures are managed in accordance with the legislation.

Potential exposures and exposure routes to radiation included the assessment of:

- **Radiation exposure affecting the health of mine workers** – by inhalation of dust containing radionuclides, inhalation of radon, external gamma irradiation.
- **Radiation exposure affecting the health of process plant workers** – by inhalation of dust containing radionuclides, inhalation of radon, external gamma irradiation from the minerals separation process.
- **Radiation exposure affecting the health of members of the public**

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

10.5.2.1 Radiation Exposure Affecting the Health of Mine Workers

Potential exposures for mine workers were estimated based on:

- Exposure to external gamma irradiation by general proximity to the NORMs.
- Inhalation of dust containing radionuclides (and hence exposure to otherwise short lived alpha particles).
- Inhalation of radon gas and radon decay products.

Radon is a gas which may accumulate in areas with reduced ventilation based on the concentration of uranium and the rate of air exchange. Potential exposures for mine workers by these exposure routes were estimated

(Radiation Professionals 2016, Appendix 21, summarised in Table 75) in comparison to the occupational exposure limit of 20 mSv/year (Regulation 16.18 *Mines Safety and Inspection Regulations 1995*).

Table 75: Summary of Estimated Mine Workers Radiation Exposure

Exposure Pathway	Unit	Calculated Dose	Guideline Value	Percentage Guideline
External Gamma	mSv/year	0.34	20	1.7 %
Dust Inhalation	mSv/year	0.11	20	0.55 %
Radon Inhalation	mSv/year	1.7	20	8.5 %
Total Exposure	**mSv/year**	**2.15**	**20**	**10.75 %**

Radiation exposure to mine workers is considered 'Almost Certain' within the Mine Site Development Envelope, but the total exposure is considered 'Incidental'. The potential residual impact of radiation on the health of mine workers, after implementation of the RMP and RWMP, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Radiation exposure affecting the health of mine workers	Incidental	Almost Certain	Medium

10.5.2.2 Radiation Exposure Affecting the Health of Process Plant Workers

Potential exposures for process plant workers were estimated based on:

- Exposure to external gamma irradiation by general proximity to the NORM materials.
- Inhalation of dust containing radionuclides (and hence exposure to otherwise short lived alpha particles).
- Inhalation of radon gas and radon decay products.

Exposures for process plant workers by these exposure routes were estimated (Radiation Professionals 2016, Appendix 21, summarised in Table 76) in comparison to the occupational exposure limit of 20 mSv/year (Regulation 16.18 *Mines Safety and Inspection Regulations 1995*). The assessment is considered conservative as it does not account for shielding from the equipment itself, a high general dust loading (e.g. 2 mg/m^3 in the crushing area) and that workers will spend 2,000 working hours in close proximity to these materials within the plant.

Table 76: Summary of Estimated Process Plant Workers Radiation Exposure

Exposure Pathway	Unit	Calculated Dose	Guideline Value	Guideline (%)
External Gamma	mSv/year	1.24	20	6.2 %
Dust Inhalation	mSv/year	0.25	20	1.25 %
Radon Inhalation	mSv/year	1.5	20	7.5 %
Total Exposure	mSv/year	**3**	**20**	**15 %**

Although radiation exposure to process plant workers is considered 'Almost Certain' within the Mine Site Development Envelope, the total exposure is considered 'Incidental'. The potential residual impact of radiation on the health of process plant workers, after implementation of the RMP and RWMP, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Radiation exposure affecting the health of process plant workers	Incidental	Almost Certain	Medium

10.5.2.3 Radiation Exposure Affecting the Health of Members of the Public

Potential exposures for members of the public may occur by means of external gamma irradiation (if in sufficiently close proximity to the products or waste material) or by inhalation of radionuclides within the dust.

Radon inhalation is not considered significant due to its rapid decay. As the only potential residence adjacent to the Mine Site Development Envelope is the Mt Jowlaenga pastoral homestead some 8 km away and the site access road is approximately 30 km from the Great Northern Highway, potential for gamma radiation exposure to the public in the vicinity of the Mine Site was considered extremely low.

Dust emissions from the project are expected to be primarily generated throughout the process of extracting the required mineral sands products during the concentration, heating and separation procedures and the generation of the waste by-products. The majority of the operations will be contained within the process buildings, which will utilise dust suppression and ventilation arrangements to minimise the potential for dust generation, and are very removed from any potential dust inhalation impacts on the public (30 km away) (Radiation Professionals 2016, Appendix 21). Local Aboriginal people will either be engaged as employees and therefore subject to normal personal radiation monitoring for mine/process workers or have only brief exposure to site conditions as visitors during active operations.

The guideline for exposure assessment to the public is 1 mSv/year (as opposed to 20 mSv/year for radiation workers) (ARPANSA 2002). Radiation waste management and rehabilitation post mining will ensure surface and environmental radiation levels are returned are within environmental screening (10 µGy/h) or determined background levels such that radiation exposure is incidental only and less than 1 mSv/year.

Radiation exposure to members of the public above background levels is considered 'Unlikely' within the Mine Site Development Envelope, and the total exposure is considered 'Incidental'. The potential residual impact of radiation on the health of members of the public and Traditional Owners, after implementation of the RMP and RWMP, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Radiation exposure affecting the health of members of the public	Incidental	Unlikely	Low

10.5.3 Management Measures

A summary of key measures to address potential impacts on human health from radiation is shown in Table 77. No further management measures are considered necessary.

Table 77: Proposed Management Measures for Radiation on Human Health for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Radiation affecting the health of employees and contractors	• The mine will be registered under the RSA with the Radiological Council and DMP and Sheffield will appoint a Radiation Safety Officer (RSO) to implement a Radiation Management Plan (RMP) and the Radiation Waste Management Plan (RWMP) on behalf of Sheffield. • Provision and maintenance of equipment and facilities for controlling radiation sources, including housekeeping, dust suppression and surface contamination control to maintain a duty of care to employees and the public. • A radiation monitoring program will be developed and implemented in consultation with Radiological Council and DMP. This will include monitoring of personal exposure for mine and process plant workers, hand held gamma monitoring and monitoring of airborne dust scintillation counting (Bq/m3) and radon.
Radiation affecting the health of members of the public	• Processing and mining wastes will be blended prior to final disposal as backfill within the mining excavation in accordance with a prepared RWMP. • Rehabilitated areas will be monitored to ensure radiation levels are within environmental screening criteria (10 µGy/h) or established pre-mining background levels.

Further detail regarding the assessment and management measures for the protection of human health are detailed in Appendix 21 (Radiation Professionals, 2016).

10.5.4 Predicted Outcome

The predicted dose to mine workers and process plant workers was conservatively estimated to be 2.15 mSv/year and 3 mSv/year respectively, which is well below the dose rate limit for radiation workers of 20 mSv/year. The predicted dose to a member of the public was considered to be negligible and below assessable levels.

All activities at the Mine Site associated with the project will be undertaken in accordance with the *Radiation Safety Act.* Sheffield will engage a Radiation Safety Officer (RSO) upon the implementation of a Radiation Management Plan (RMP) and a Radiation Waste Management Plan (RWMP), to implement periodic personal and environmental monitoring of radiation levels for formal reporting to the Radiological Council and the DMP.

Implementation of these arrangements will ensure that any potential radiation doses to workers, the public and the environment will be monitored, controlled and minimised to ensure that all legal requirements are met and that radiation doses are below regulatory limits.

Sheffield considers that the potential impacts of radiation to human health will be able to be adequately managed such that the objective (Section 10.5) will be met, and that the residual impacts are therefore acceptable.