ANNEXURE N1:
AIR QUALITY STUDY BY AIRSHED PLANNING PROFESIONALS

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Aurecon

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED EXPANSION PROJECT FOR RÖSSING URANIUM MINE IN NAMIBIA: PHASE 2 OF THE SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT

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REPORT DETAILS

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Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
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EXECUTIVE SUMMARY

Airshed Planning Professionals (Pty) Limited was appointed by Aurecon to undertake an air quality impact assessment for a proposed expansion project for Rio Tinto Rössing Uranium Limited (hereafter referred to as Rössing Uranium). The Social and Environmental Impact Assessment for the expansion project was carried out in two phases.

The current study is undertaken for Phase 2 of the Social and Environmental Impact Assessment. This phase comprises of:

- Extension of the current mining activities in the existing SJ open pit;
- Increased waste rock disposal capacity;
- Erecting an additional crusher plant;
- Increased tailings disposal capacity;
- Establishing an acid heap leaching facility; and
- Ripios disposal facility.

The aim of the investigation was to quantify the possible impacts resulting from operational activities on the surrounding environment and human health. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

The investigation followed the methodology required for a specialist report, comprising the baseline characterisation and the impact assessment study.

Baseline Assessment

The baseline study encompassed the analysis of on-site meteorological data recorded at Rössing Uranium. Hourly average wind field, temperature and pressure data for the period 2000 - 2004 was used to determine the dispersion potential for the region.

Impact Assessment Criteria

Particulates represented the main pollutant of concern given the nature of the operations. Particulate matter is classified as a criteria pollutant, with ambient air quality guidelines and standards having been established by various countries to regulate ambient concentrations of this pollutant. Air quality guidelines and standards for particulates are given for various particle size fractions, including Total Suspended Particulates (TSP) and thoracic particulates or PM10 (i.e. particulate matter with an aerodynamic diameter of < 10 µm).

Emissions Inventory

Emissions inventories provide the source input required for the simulation of ambient air concentrations and dust deposition rates. During current and proposed activities, fugitive emissions from vehicle entrainment, materials handling, wind erosion and drilling and blasting activities were quantified. Emissions from onsite stacks (i.e. roasters, scrubbers and baghouse) were provided for proposed operating conditions.

Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important assumptions and limitations of the air quality impact assessment are summarised as follows:

- Information required to calculate emissions from fugitive dust sources for current and proposed operations were provided by Rössing Uranium personnel. The assumption was made that this information was accurate and correct.

- The impact assessment was limited to airborne particulates (including TSP and PM10). Although the proposed activities will also emit gaseous pollutants from vehicle exhausts, the impact of these compounds are regarded to be low and was omitted from this study.

- The construction, closure and post closure phases were assessed qualitatively.

- Measured upper air data was not available for the study area. Use was therefore made of calculated ETA data obtained from the South African Weather Services.

- Historical meteorological data (2000-2004) was used for the current study as this data was sufficiently comprehensive for dispersion modelling purposes.

- Radiation associated with wind blown dust has not been considered as part of the air quality impact assessment and will be covered by the Radiation Specialist. The predicted PM10 concentrations were however used to determine the potential impacts from radionuclide concentrations within the modelling domain;

Impact Prediction Study

Particulate concentrations and deposition rates due to the operational activities were simulated using the United States Environmental Protection Agency (US-EPA) approved AERMET/AERMOD dispersion modelling suite. Ambient concentrations were simulated to ascertain highest daily and annual averaging levels occurring as a result of the current and proposed operations.

For the current assessment, two cases were evaluated, i.e. Basecase (for the period 2010) and the Expansion Case (for the period 2013). Although the proposed Expansion Case extends to the year 2023, the year 2013 was selected as a conservative approach as the particulate emissions are the highest during this period.

Conclusions

The following conclusions for ***current*** operations at Rössing were reached:

- The prevailing wind direction at the Rössing mine is from the north-northeast (with ~10% frequency of occurrence) and is characterised by the occurrence of high wind speeds (>10m/s). Dominant winds during the period also occur from the north-western, western and south-western sectors.

- A two month monitoring campaign was undertaken to assist in the understanding of baseline and background ambient air quality levels at Rössing. From the measured PM10 daily concentrations at Arandis and Arandis Airport, all measured concentrations were within the current SA Limit of 120 µg/m³, with two exceedances of the proposed SA Limit of 75 µg/m³ occurring at the Arandis sampling site. The measured daily PM10 concentrations at Arandis and Arandis Airport were in exceedance of the EC and WHO guideline of 50 µg/m³ on a number of occasions during the monitoring campaign.

- Monthly measured SO_2 and NO_2 concentrations (undertaken by passive diffusive monitoring) levels for the two month monitoring campaign were generally low and well below the SA annual standard and EC annual limit of 19 ppb and 21 ppb respectively.

- Highest predicted daily ground level concentrations due to routine operations at Rössing were 480 µg/m³ at the mine boundary exceeding all relevant ambient guidelines. The predicted off-site annual average PM10 ground level concentrations at the mine boundary (56 µg/m³) exceeded all relevant ambient guidelines.

- At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing Basecase operations were 73 µg/m³ which is within the US-EPA guideline and SA Limits but exceeds the WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year. The frequency of exceedance of the EC daily limit at the sensitive receptor of Arandis was predicted to be 2. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m³) was well within all relevant ambient guidelines.

- The predicted maximum deposition directly off-site due to current routine operations at Rössing was below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas).

The following conclusions for ***proposed*** operations at Rössing were reached:

- Predicted daily PM10 ground level concentrations due to proposed routine operations at Rössing were predicted to be 440 µg/m³ at the mine boundary exceeding all relevant ambient guidelines. The highest predicted off-site annual average PM10 ground level concentrations at the mine boundary (45 µg/m³) were within the proposed SA annual limit of 50µg/m³ but exceeded the current SA annual limit and EC limit of 40 µg/m³ and the WHO annual PM10 guideline of 20 µg/m³.

- At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing were 80 µg/m³ which is within the US-EPA guideline and current SA Limit but exceeds the proposed SA Limit, WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year and the daily PM10 SA Standards allow for 4 exceedances in a calendar year. The frequency of exceedance of the EC daily limit and proposed SA daily limit at the sensitive receptor of Arandis was predicted to be 2 and 1 respectively. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m³) was well within all relevant ambient guidelines.

- The predicted maximum deposition directly off-site due to proposed routine operations at Rössing was below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas).

It should be noted that no significant increase in ambient PM10 concentrations and dust deposition were predicted from current to proposed operations at Rössing.

Recommendations

- It is recommended that the dust fallout network (as established for the two month monitoring campaign) be continued to monitor increases in dust fallout in the surrounding area due to the proposed expansion activities;

- As exceedances of the PM10 EC daily limit and WHO daily guideline was measured at Arandis, it is recommended that continued PM10 monitoring be undertaken at this sensitive receptor in order to establish emission contributions from Rössing Uranium;

- Although the predicted PM10 concentrations and deposition rates are provided for a high easterly wind episode, a confidence level cannot be attributed to the results. Therefore, depending on the level of detail required for assessment of impacts during high easterly wind episodes, the assessment of this incident should perhaps be repeated with updated meteorological data and deposition measurements in the field.

- As the main source of fugitive particulate emissions (also predicted to contribute to the highest impacts) is from vehicle entrainment on unpaved road surfaces within and around the open pit, it is recommended that dust control products such as Hydro Tac or Hydro Sperse be investigated to further reduce emissions from this fugitive dust source;

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AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED EXPANSION PROJECT FOR RÖSSING URANIUM MINE IN NAMIBIA: PHASE 2 OF THE SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT

1. INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Aurecon to undertake an air quality impact assessment for a proposed expansion project for Rio Tinto Rössing Uranium Limited (hereafter referred to as Rössing Uranium). The Social and Environmental Impact Assessment for the expansion project was carried out in two phases.

Phase 1 comprising of the establishment of an on-site sulphur burning sulphuric acid production plant; the establishment of a radiometric ore sorter plant with associated reject rock disposal facilities and a satellite open pit development (SK4), within the larger area designated as SK has been completed and the Final SEIA Report (Ninham Shand Report No. 4492/402239) was submitted to the Ministry of Environment & Tourism: Directorate of Environmental Affairs (MET:DEA) for a decision. Their approval of the Phase 1 SEIA was issued on 7 April 2008, by means of an Environmental Clearance.

The current study is undertaken for Phase 2 of the SEIA. This phase comprises of:

- Extension of the current mining activities in the existing SJ open pit;
- Increased waste rock disposal capacity;
- Erecting an additional crusher plant;
- Increased tailings disposal capacity;
- Establishing an acid heap leaching facility; and
- Ripios disposal facility.

Specialist investigations conducted as part of an air quality assessment typically comprise two components, viz. a baseline study and an air quality impact and compliance assessment study.

The baseline study includes the review of the site-specific atmospheric dispersion potential, relevant air quality guidelines and limits and existing ambient air quality in the region. In this investigation, use was made of readily available surface meteorological data recorded in the study area in the characterisation of the baseline condition. An air quality impact assessment of the Basecase (2010) operations at Rössing Uranium was also established.

The ambient air quality impact assessment comprised the establishment of an emissions inventory for the proposed development, the simulation of ambient air pollutant concentrations and dustfall rates occurring due to project development and operation, and the evaluation of the resultant potential for impacts and non-compliance. For the current assessment, the Expansion Case (for the period 2013) was selected. Although the proposed

Expansion Case extends to the year 2023, the year 2013 was selected as a conservative approach as the particulate emissions are the highest during this period.

1.1 Terms of Reference

The terms of reference of the *baseline study component* are as follows:

The regional climate and site-specific atmospheric dispersion potential;
Identification of the potential sensitive receptors within the vicinity of the proposed site;
Preparation of hourly average meteorological data for the model input;
Obtain and process topographical data for input into the dispersion model;
Identification of existing sources of emission from current mining operations at Rössing Uranium;
Characterisation of ambient air quality and dustfall levels in the region based on observational data recorded (if available) and available initial baseline monitoring data as per the specified new monitoring programme;
Preparation of background maps; and
The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications informed by the legal review and Namibian requirements.

The terms of reference for the *air quality impact assessment component* include the following:

- Compilation of an emissions inventory, comprising the identification and quantification of potential routine sources of emission for the following scenarios:
- Current Operations*:* Gaseous and particulate emissions due to routine operations from current mining activities at Rössing Uranium;
- Proposed Operations: Gaseous and particulate emissions due to routine operations from proposed mining activities.
- Dispersion simulations of ambient concentrations and dust fallout from the current and proposed routine operations;
- Analysis of dispersion modelling results (*non-radioactive*) from both current and proposed operations, including:
- Assessment of the predicted ground level concentrations. Two episodes will be assessed:
- Dust impact due to the easterly wind episodes;
- Blasting due to worst case meteorological conditions.
- Evaluation of potential for human health and environmental impacts.
- Predicted particulate (radionuclide) and gaseous (radon) concentrations per source group per grid point will be provided to the radiological specialist for the dose response assessment.

1.2 Site Description

The Rössing mine, a large open pit uranium mine, is situated in Namibia, south-western Africa and started operations in 1976. It is located close to the town of Arandis, 70 kilometres inland from the coastal town of Swakopmund in the Namib Desert in the Erongo Region in Namibia (Figure 1-1).

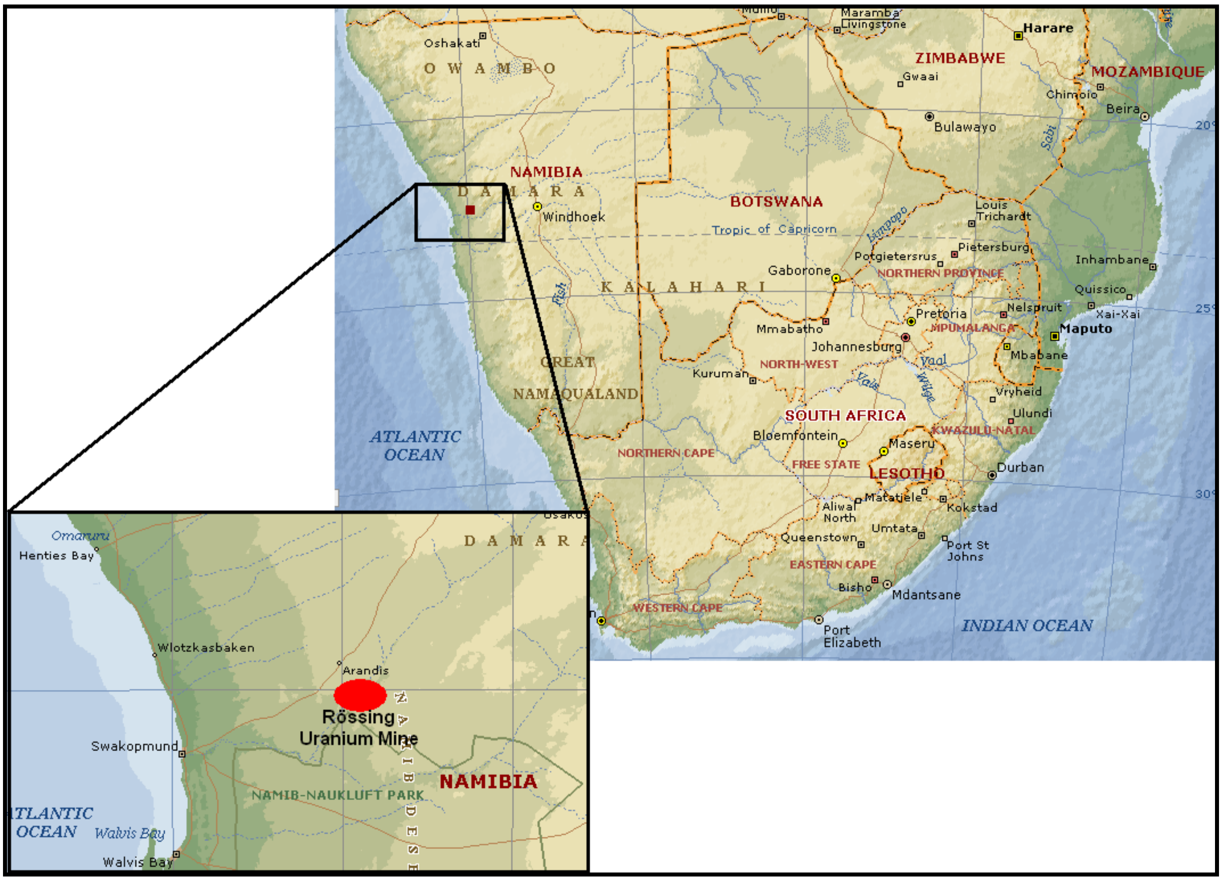

Figure 1-1: Location of the Rössing Uranium Mine in Namibia

1.3 Sensitive Receptors

Given that the project will be associated with low level fugitive emissions (e.g. from mining operations and vehicle entrainment) and elevated emissions (from existing stacks on site), the proposed project has the potential of impacting on receptors in the near and medium fields.

Residential areas in the vicinity of the proposed operations include Arandis located ~2 km northwest of the mine boundary. Larger residential developments within a 50km radius are Swakopmund (west-southwest of the mine).

1.4 Methodological Approach

1.4.1 Atmospheric Dispersion Model Selection

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

It was decided to employ the most recent US Environmental Protection Agency's (US EPA) approved regulatory model. The most widely used US EPA model has been the Industrial Source Complex Short Term model (ISCST3). This model is based on a Gaussian plume model. However, this model has been replaced by the new generation AERMET/AERMOD suite of models. AERMOD is a dispersion model, which was developed under the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of-the-art science in regulatory models (Hanna *et al.,* 1999). The AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature, however retains the single straight line trajectory limitation of ISCST3 (Hanna *et al*, 1999).

AERMET is a meteorological pre-processor for the AERMOD model. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters.

AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for the AERMOD model. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Even if the field instrument accuracy is excellent, there can still be large uncertainties due to unrepresentative placement of the instrument (or taking of a sample for analysis). Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions. It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hourly) and long downwind distances. All of the above factors contribute to the inaccuracies not even associated with the mathematical models themselves.

Similar to the ISC model, a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Although the model has been shown to be an improvement on the ISC model, especially short-term predictions, the range of uncertainty of the model predictions is -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

Input data types required for the AERMOD model include: meteorological data, source data, and information on the nature of the receptor grid. Each of these data types will be described below.

1.4.2 Meteorological Data Requirements

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). On-site surface meteorological data, for the period 2000-2004 was obtained for simulation purposes. An easterly wind episode was simulated to reflect impacts during these conditions. The period 9 June 2004 was selected to simulate this episode. Calculated upper air ETA data was obtained from the South African Weather Services for the point 22°30'S; 15°00'E.

1.4.3 Source Data Requirements

The AERMOD model is able to model point, area, volume and line sources. The materials handling operations were simulated as volume sources. Wind erosion from stockpiles and tailings facilities were modelled as area sources and stacks were modelled as point sources.

1.4.4 Modelling Domain

The dispersion of pollutants was modelled for an area covering ~12 km (north-south) by ~14 km (east-west). This area was divided into a grid with a resolution of ~246 m (north-south) by ~276 m (east-west), and a total of 2 500 receptor points. The AERMOD model simulates ground-level concentrations for each of the receptor grid points.

1.4.5 Topography

The topography in the study area is relatively undulating (Figure 1-2). Digital Elevation Model (DEM) data, provided by Rössing Uranium personnel and obtained from Visual Resource Management Africa cc, for both current (2010) and proposed (for the year 2013) operations were included for dispersion modelling purposes (Figure 1-3 and Figure 1-4 respectively).

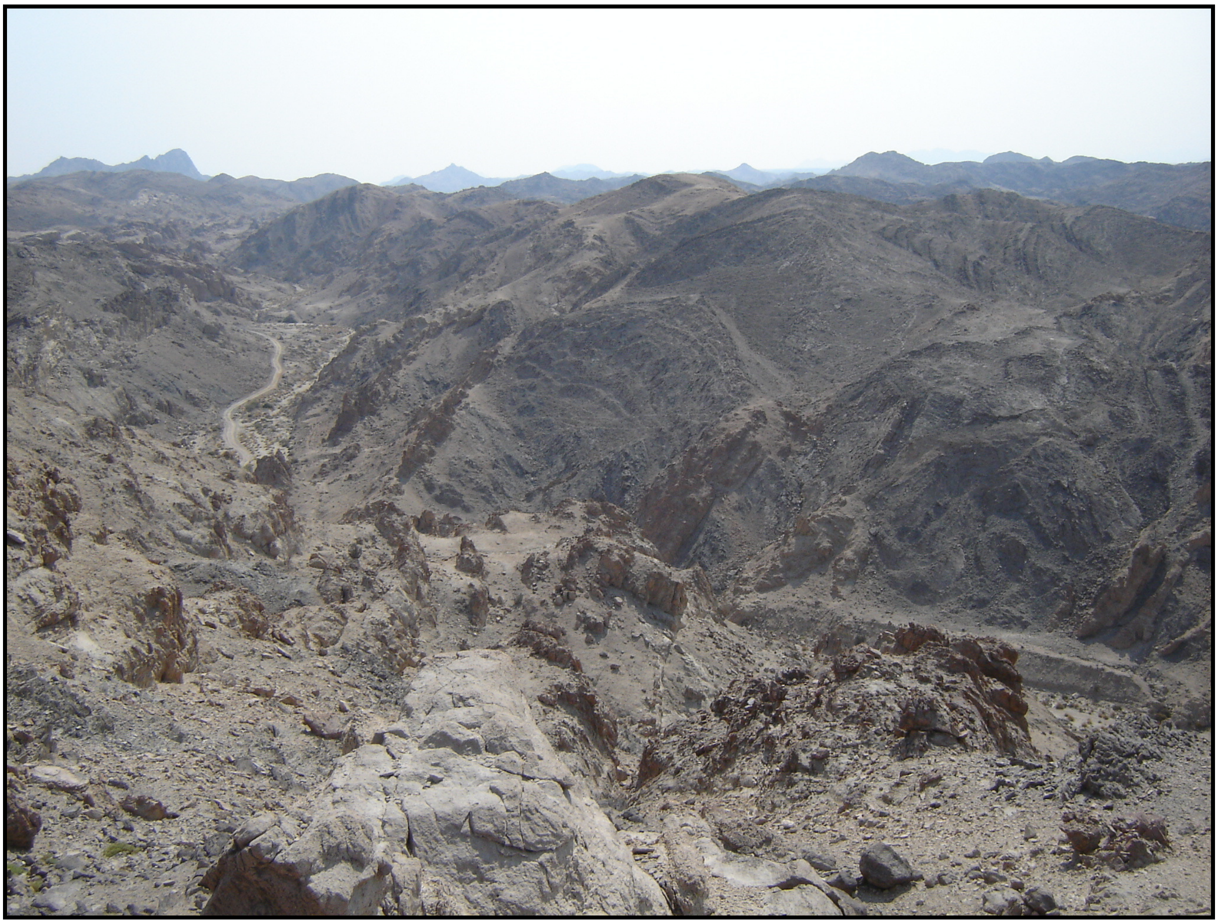

Figure 1-2: Undulating topography at the Rössing Mine site

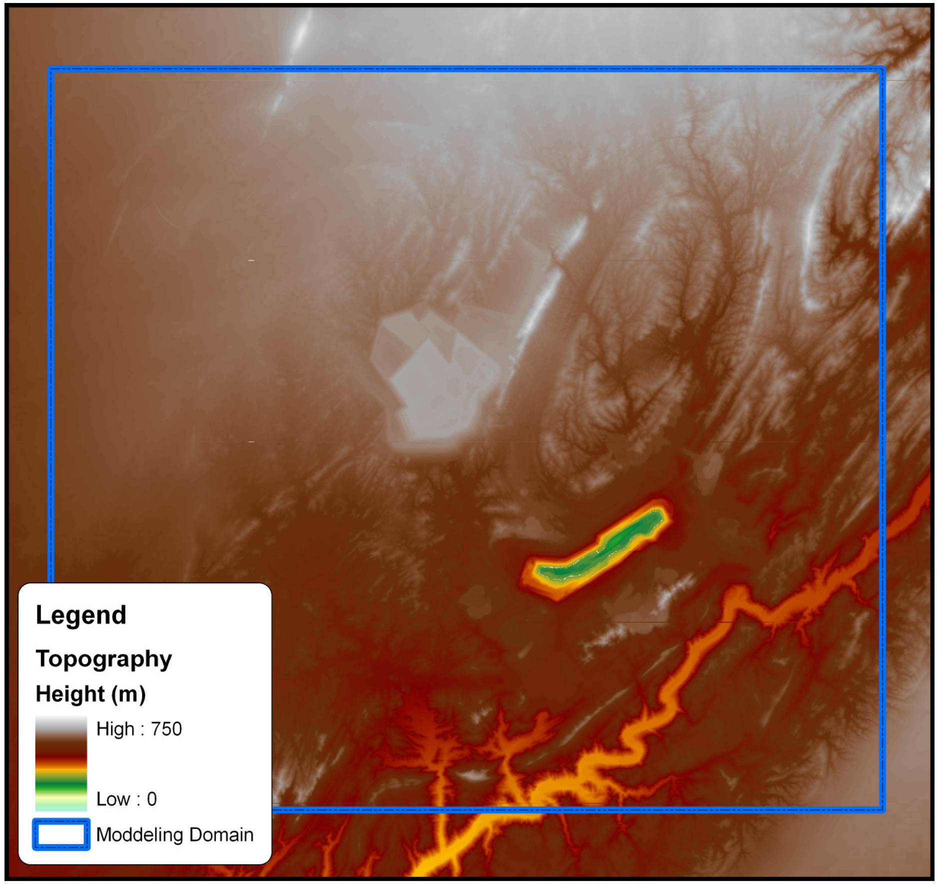

Figure 1-3: Shaded relief profile of the study area for the Basecase (2010).

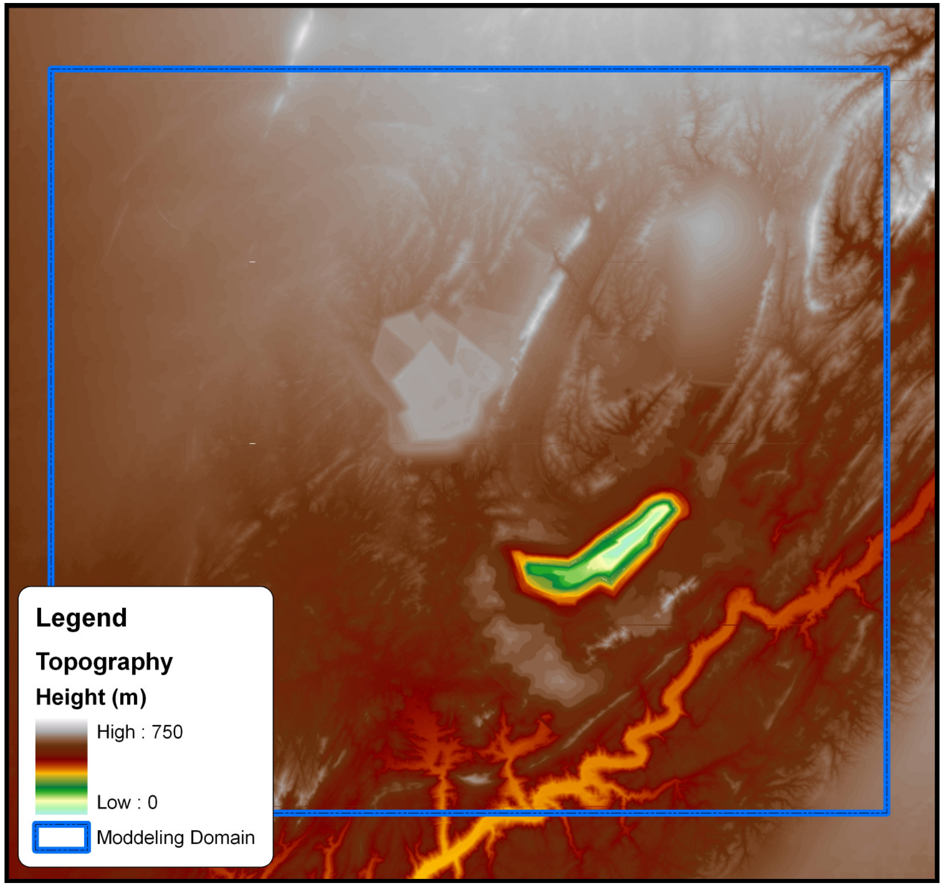

Figure 1-4: Shaded relief profile of the study area for the Expansion Case (year 2013).

1.5 Assumptions and Limitations

In interpreting the study findings it is important to note the limitation and assumptions on which the assessment was based. The most important assumptions and limitations of the air quality impact assessment are summarised as follows:

- Radiation associated with wind blown dust has not been considered as part of the air quality impact assessment and will be covered by the Radiation Specialist. The predicted PM10 concentrations were however used to determine the potential impacts from radionuclide concentrations within the modelling domain.

- Information required to calculate emissions from fugitive dust sources for current and proposed operations were provided by Rössing Uranium personnel. The assumption was made that this information was accurate and correct.

- The impact assessment was limited to airborne particulates (including TSP and PM10). Although the proposed activities will also emit gaseous pollutants from vehicle exhausts, the impact of these compounds are regarded to be low and was omitted from this study.

- The construction, closure and post closure phases were assessed qualitatively.

- Measured upper air data was not available for the study area. Use was therefore made of calculated ETA data obtained from the South African Weather Services.

- Historical meteorological data (2000-2004) was used for the current study as this data was sufficiently comprehensive for dispersion modelling purposes.

1.6 Outline of Report

Legal requirement and human health criteria applicable to the proposed expansion (Phase 2 of the Social and Environmental Impact Assessment) of the Rössing Mine are presented in Section 2. The synoptic climatology and atmospheric dispersion potential of the area are discussed in Section 3 and information on existing sources and baseline air quality given in Section 4. Section 5 presents the emissions inventory for the proposed expansion. Dispersion model results are presented and the main findings of the air quality compliance and impact assessments documented in Section 6. Recommendations and conclusions are presented in Section 7.

2. LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

In addressing the impact of air pollution emanating from proposed operations, some background on the health effects of the various pollutants need to be provided. Since the terms of reference exclude a detailed toxicological study, this discussion is limited to the most important health impact aspects. From the proposed operations, the pollutant of concern is particulate matter. This pollutant thus forms the focus of the current section.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

Reference is made to the ambient air quality guidelines as stipulated internationally (i.e. the World Bank specifications, the European Council (EC), World Health Organisation (WHO) and the United States Environmental Protection Agency (US-EPA)). Since South Africa (a neighbouring country) is also a developing country and has just revised its ambient air quality standards, these were also included as reference.

2.1 Namibia Legislation

As far as could be ascertained, Namibia has adopted the South African air pollution legislation for air quality control in the form of the South African Atmospheric Pollution Prevention Act (Act No 45 of 1965) (APPA). Based on the stipulations of this South African Act, the following parts are applicable:

Part II :	Controls of noxious or offensive gases;
Part III :	Atmospheric pollution by smoke;
Part IV :	Dust control; and
Part V :	Air pollution by fumes emitted by vehicles.

The South African National Environmental Management: Air Quality Act (Act no.39 of 2004) (AQA) commenced with on the 11th of September 2005 as published in the South African Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61. Schedule 2 of the AQA provides ambient air quality standards that were based on the previously adopted Department of Environmental Affairs (DEA) guidelines (the "1st generation ambient air quality standards"). These were revised with the publication of the new ambient air quality standards (*South African Government Gazette No. 32816, 24 December 2009*) ("the 2nd generation ambient air quality standards”). These standards are based on those issued by the South African National Standards (SANS) during 2004.

It is not clear how the legal developments in South Africa have affected the Namibian legislation or whether Namibia has adopted the South African Air Quality Standards. Compliance of the Rössing Uranium operation in the current assessment is therefore measured against the newly promulgated South African AQA standards as well as “best practice” European Community limits and World Health Organisation guidelines.

2.2 World Bank Requirements

As of April 30, 2007, new versions of the World Bank Group Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') are now in use. They replace those documents previously published in Part III of the Pollution Prevention and Abatement Handbook and on the IFC website.

The new EHS Guidelines were developed as part of a two and a half year review process. The EHS Guidelines are intended to be 'living documents', and will be updated on a regular basis going forward.

The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

2.3 Ambient Air Quality Standards and Guidelines

In this section, the guidelines and standards as stipulated by the World Bank Group (WBG) and the Namibian Government are discussed. The newly updated Environmental Health and Safety (EHS) guidelines published by the WB’s International Finance Corporation (IFC) in April 2007 reference the WHO guidelines or other internationally recognised sources (US and EC) in the absence of national legislated standards. Since the Namibian legislation pertaining to air quality management is based on the South African APPA, the guidelines as was stipulated under the APPA will be referenced as well as the new South African ambient air quality standards.

2.3.1 Suspended Particulate Matter

The impact of particles on human health is largely dependent on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.

PM10 limits and standards are documented in Table 2-1.

During the 1990s the World Health Organisation (WHO) stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-2 and 2-3.

Table 2-1: Air quality guidelines and standards for inhalable particulates (PM10)

Authority	Maximum 24-hour concentration (µg/m³)	Annual Average concentration (µg/m³)
Replaced SA Standards[a]	180	60
Current SA Standards [b]	120 [c][e] 75 [d][e]	50 [c] 40 [d]
World Bank Group	[f]	[f]
World Health Organisation	50 [g]	20 [g]
European Community (EC)	50 [h]	40 [i]
United States EPA	150 [j]	-

Notes:

(a) These "1st generation standards" have been replaced by "2nd generation standards" that are more in line with internationally recognised limits.

(b) These "2nd generation standards" were promulgated on the 24 December 2009 (Gazette No. 32816).

(c) Applicable immediately to 31 December 2014.

(d) Applicable from 1 January 2015.

(e) Not to be exceeded more than 4 times per year.

(f) World Bank Group, 2007. EHS Guidelines state that pollutant concentrations do not reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources. (http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines).

(g) WHO (2000) issued linear dose-response relationships for PM10 concentrations and various health endpoints with no specific guideline provided. WHO (2005) made available during early 2006 proposes several interim target levels (see Tables 2-2 and 2-3).

(h) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 35 times per calendar year.

(i) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005.

(j) US National Ambient Air Quality Standards (http://epa.gov/air/criteria.html). Not to be exceeded more than once per year.

Table 2-2: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO Air Quality Guideline (AQG)	**20**	**10**	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
			been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-3: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Daily Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
WHO interim target-2 (IT-2)*	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
WHO interim target-3 (IT-3)**	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO Air Quality Guideline (AQG)	**50**	**25**	Based on relation between 24-hour and annual levels

* 99th percentile (3 days/year)

** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

2.3.2 Dust Deposition

Foreign dust deposition standards issued by various countries are given in Table 2-4. It is important to note that the limits given by Argentina, Australia, Canada, Spain and the USA are based on annual average dustfall. The standards given for Germany are given for maximum monthly dustfall and therefore comparable to the dustfall categories issued locally. Based on a comparison of the annual average dustfall standards it is evident that in many cases a threshold of ~200 mg/m^2/day to ~300 mg/m^2/day is given for residential areas.

Table 2-4: Dust deposition standards issued by various countries

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) ($mg/m^2/day$)	Maximum Monthly Dust Deposition Standards (based on 30 day average) ($mg/m^2/day$)
Argentina	133	
Australia	133 (onset of loss of amenity) 333 (unacceptable in New South Wales)	
Canada Alberta: Manitoba	179 (acceptable) 226 (maximum acceptable) 200 (maximum desirable)	
Germany		350 (maximum permissible in general areas) 650 (maximum permissible in industrial areas)
Spain	200 (acceptable)	
USA:		
Hawaii	200	
Kentucky	175	
New York	200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value)	
Pennsylvania	267	
Washington	183 (residential areas) 366 (industrial areas)	
Wyoming	167 (residential areas) 333 (industrial areas)	

In South Africa dust deposition is evaluated according to the criteria published by the South African Department of Environmental Affairs (DEA). In terms of these criteria dust deposition is classified as follows:

SLIGHT - less than 250 $mg/m^2/day$

MODERATE - 250 to 500 $mg/m^2/day$

HEAVY - 500 to 1200 $mg/m^2/day$

VERY HEAVY - more than 1200 $mg/m^2/day$

The South African Department of Minerals and Energy (DME) use the 1 200 $mg/m^2/day$ threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface, with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 mg/m^2/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

A perceived weakness of the current dustfall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). It has recently been proposed (as part of the SANS air quality standard setting processes) that dustfall rates be evaluated against a four-band scale, as presented in Table 2-5. Proposed target, action and alert thresholds for ambient dust deposition are given in Table 2-6.

Table 2-5: Bands of dustfall rates proposed for adoption

BAND NUMBER	BAND DESCRIPTION LABEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	COMMENT
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2 400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 2-6: Target, action and alert thresholds for ambient dustfall

LEVEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	AVERAGING PERIOD	PERMITTED FREQUENCY OF EXCEEDANCES
TARGET	300	Annual	
ACTION RESIDENTIAL	600	30 days	Three within any year, no two sequential months.
ACTION INDUSTRIAL	1 200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

According to the proposed dustfall limits an enterprise may submit a request to the authorities to operate within the Band 3 ACTION band for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 ALERT.

3. ATMOSPHERIC DISPERSION POTENTIAL

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

3.1 Meso-scale Climatology and Atmospheric Dispersion Potential

The analysis of meteorological data observed for the site provides the basis for the parameterisation of the meso-scale ventilation potential of the site, and to provide the input requirements for the dispersion simulations. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. A comprehensive data set for at least one year of detailed hourly average wind speed, wind direction and temperature data are needed for the dispersion simulations. Meteorological data for the period 2000 - 2004 was obtained from Rössing. The data availability for the meteorological period is given in Table 3-1. Data availability of at least 80% is recommended for dispersion modeling purposes.

Table 3-1: Data availability for the meteorological data provided (2000-2004)

Period	Data Availability (%)
2000	74.6
2001	67.3
2002	96.7
2003	98.1
2004	67.9
2000-2004	*80.9*

3.1.1 Meso-Scale Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds, the grey area, for example, representing winds of 1 m/s to 3 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. For the current wind roses, each dotted circle represents 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

The period, daytime and nighttime wind roses for Rössing Mine are provided in Figure 3-1 with the seasonal wind roses provided in Figure 3-2.

The prevailing wind direction at Rössing for the 5 year period is from the north-northeast (with ~10% frequency of occurrence) and is characterised by the occurrence of high wind speeds (>10m/s) with the maximum recorded at 18.67 m/s. This wind direction also dominates daytime and nighttime wind patterns. Dominant winds during the period also occur from the north-western, western and south-western sectors. Calm conditions (<1m/s) occur for 3.3% of the period. During the day, winds from the southwesterly sector increases. Nocturnal flow reflects increases from the north-westerly sector and associated lower wind speeds. As is typical of nighttime conditions, an increase in calm conditions from 1.7% (during daytime) to 4.9% is noted.

Seasonal average wind roses reflected distinct shifts in the wind field between the summer, autumn, winter and spring months. During the summer months the average wind direction was from the westerly sector, ranging from the southwest to the northwest with a low frequency of winds from the southeast. An increase in frequency of winds from the north-northeast and northeast was evident during the autumn months. Similar wind field patterns are presented for the winter months with more frequent flow from the north-northeast (>15%) and northeast, east-northeast (~14%). Springtime indicate a reduction of northeasterly windflow with frequent winds from the westerly sector. The frequencies of calms are given as 3.3%, 3.3%, 2.1% and 4.7% for summer, autumn, winter and spring, respectively.

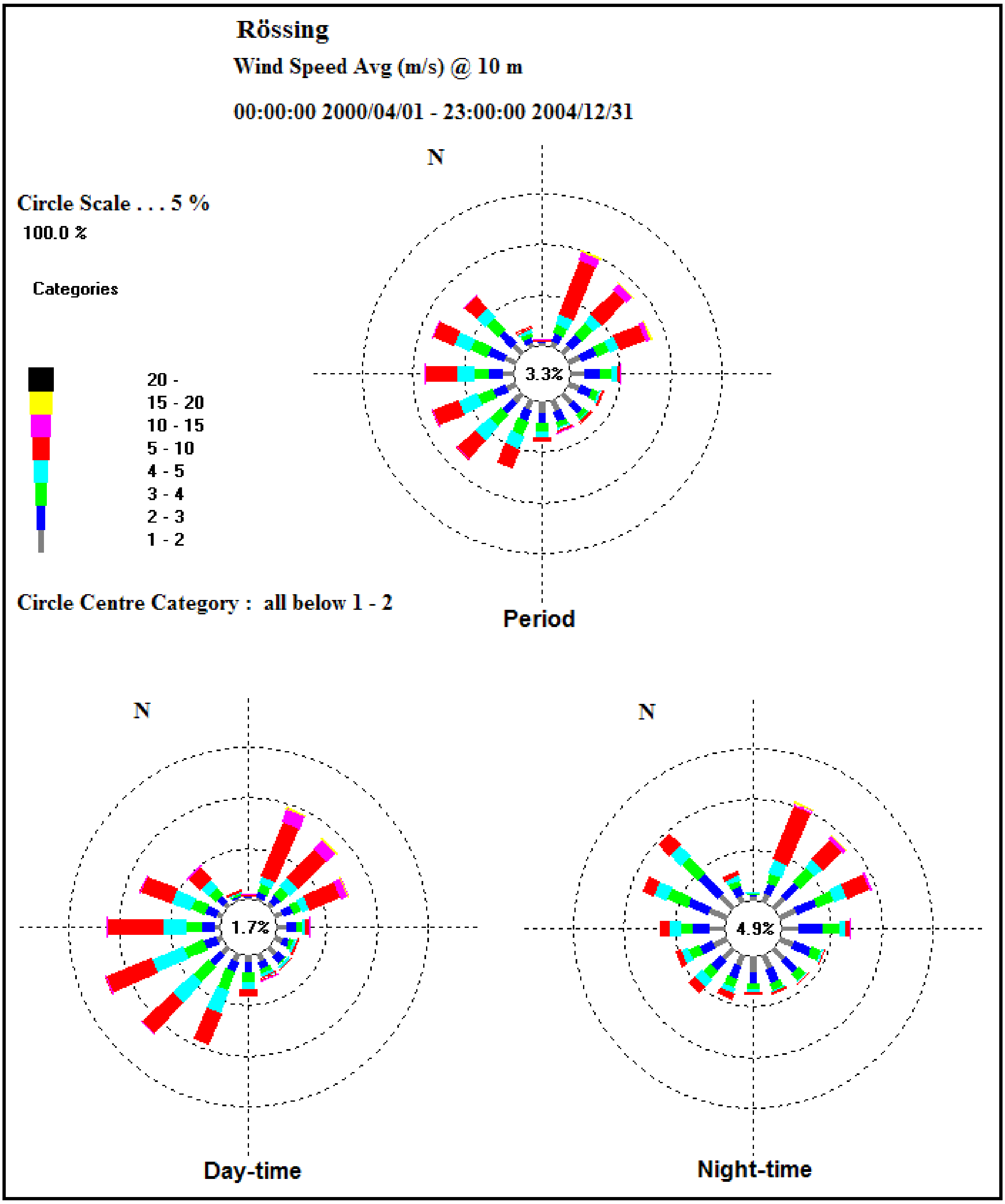

Figure 3-1: **Period, daytime and night-time wind roses for Rössing mine (2000-2004).**

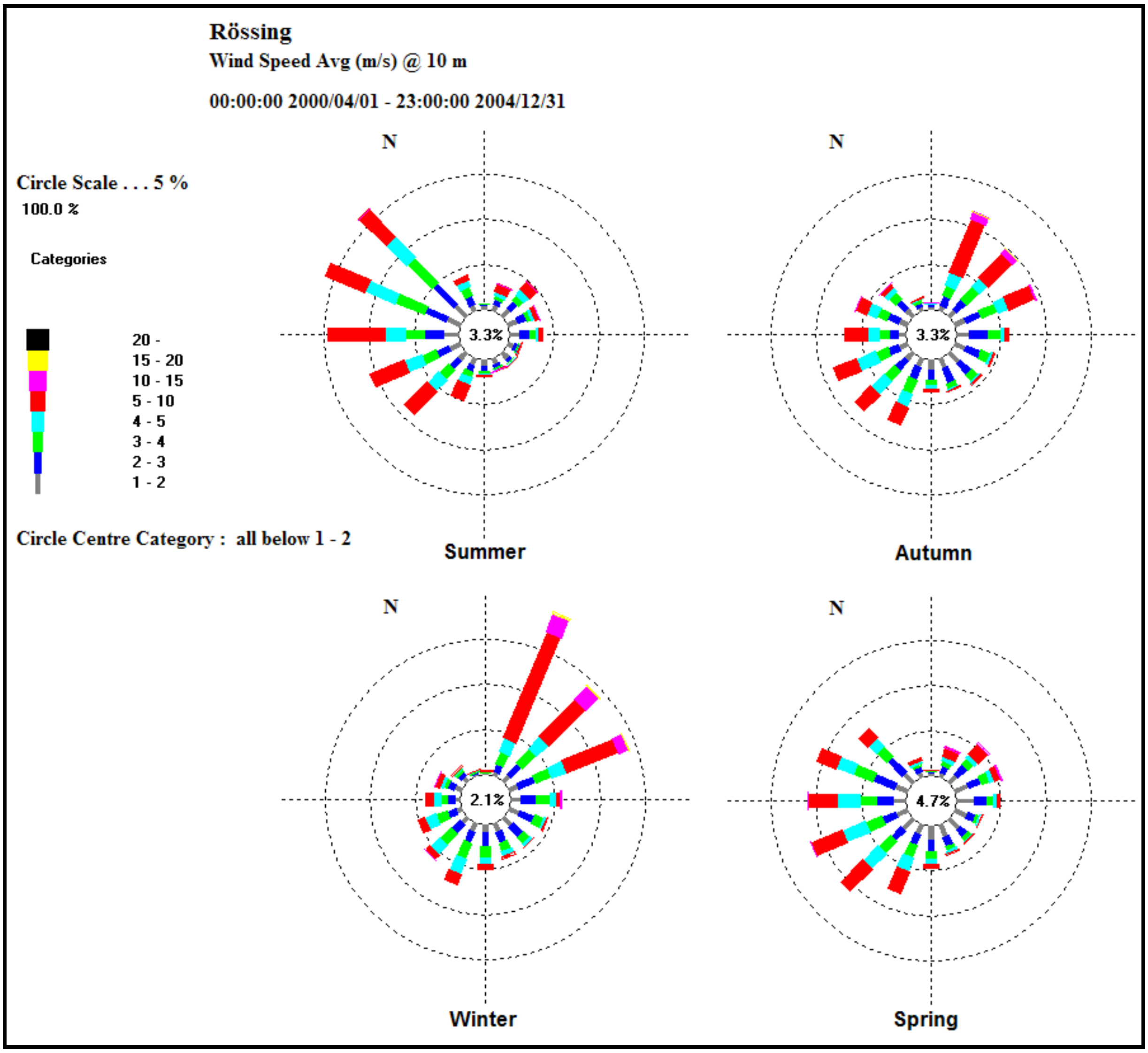

Figure 3-2: Seasonal-average wind roses for Rössing mine (2000-2004).

A particularly strong easterly wind episode (identified through satellite imagery (Figure 3-3)) on the 9 June 2004 was used to model this high wind episode.

The wind parameters for the easterly wind episode are provided in Figure 3-4. It should be noted that winds due to the easterly wind episode are predominantly from the north-northeast and northeast as measured at Rössing mine with the highest measured wind speed for this episode at 18.67 m/s (67.2 km/h).

In assessing the selected easterly wind episode, historical data was referenced in order to determine its severity. From historical data (for the period 1984-2000) obtained from Rössing personnel, the maximum observed wind speeds during the easterly wind episodes ranged from 9.49 m/s (observed in 1999) to 22.9 m/s (observed in 1989). The average wind speeds recorded during these episodes was 10.95%. Wind speeds greater than 18 m/s was only observed twice during this historical period: i.e. in 1989 (occurring for 6.6% of the easterly wind episodes) and in 1994 (occurring for 7.5% of the easterly wind episodes). It can thus be concluded that the wind speeds for the easterly episode selected for analysis (9 June 2004) is above average and in the higher range.

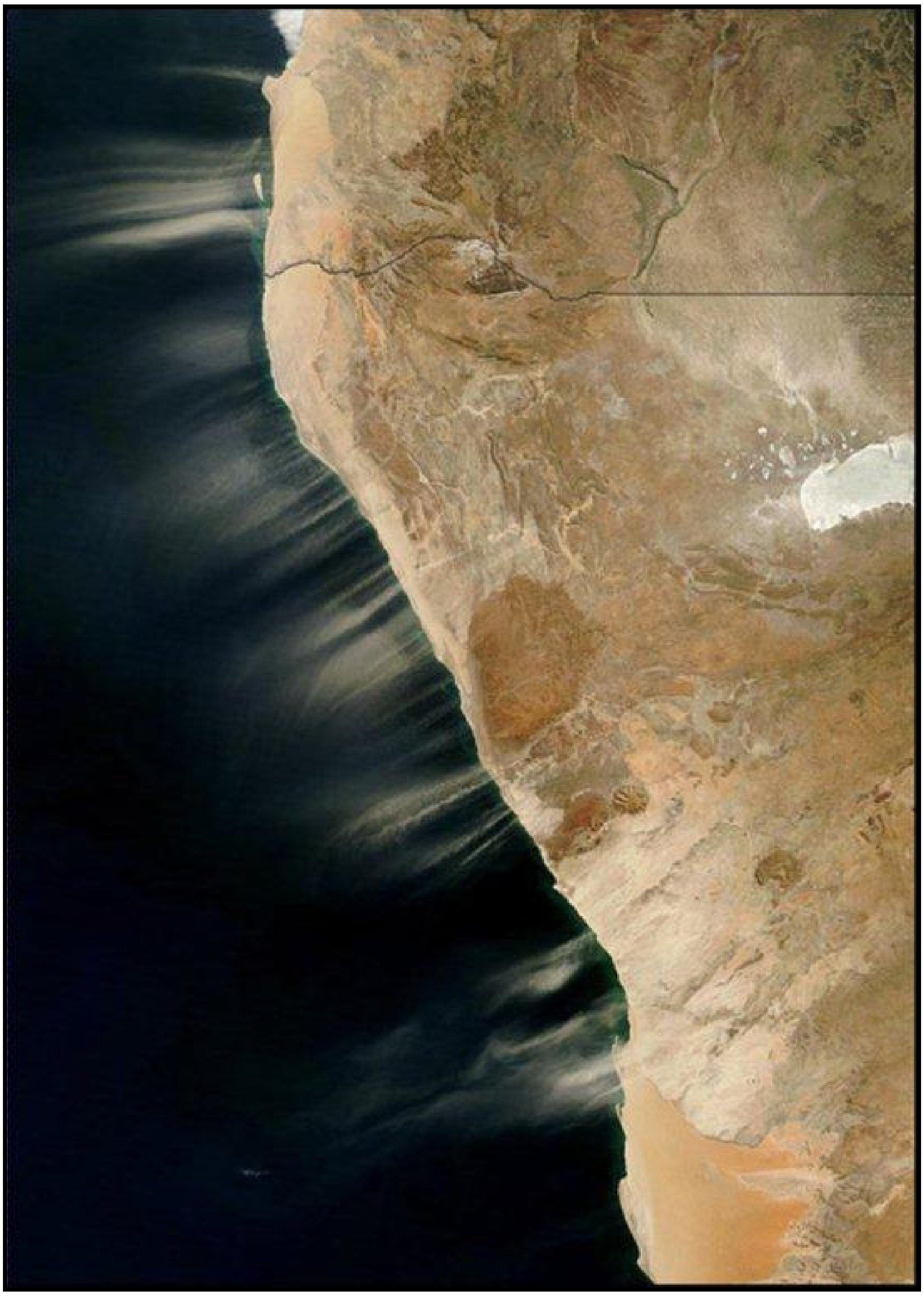

Figure 3-3: Windblown dust from central Namibia as taken from space on June 9, 2004 (Terra MODIS, NASA Goddard Space Flight Center as provided by Annegarn Environmental Research)

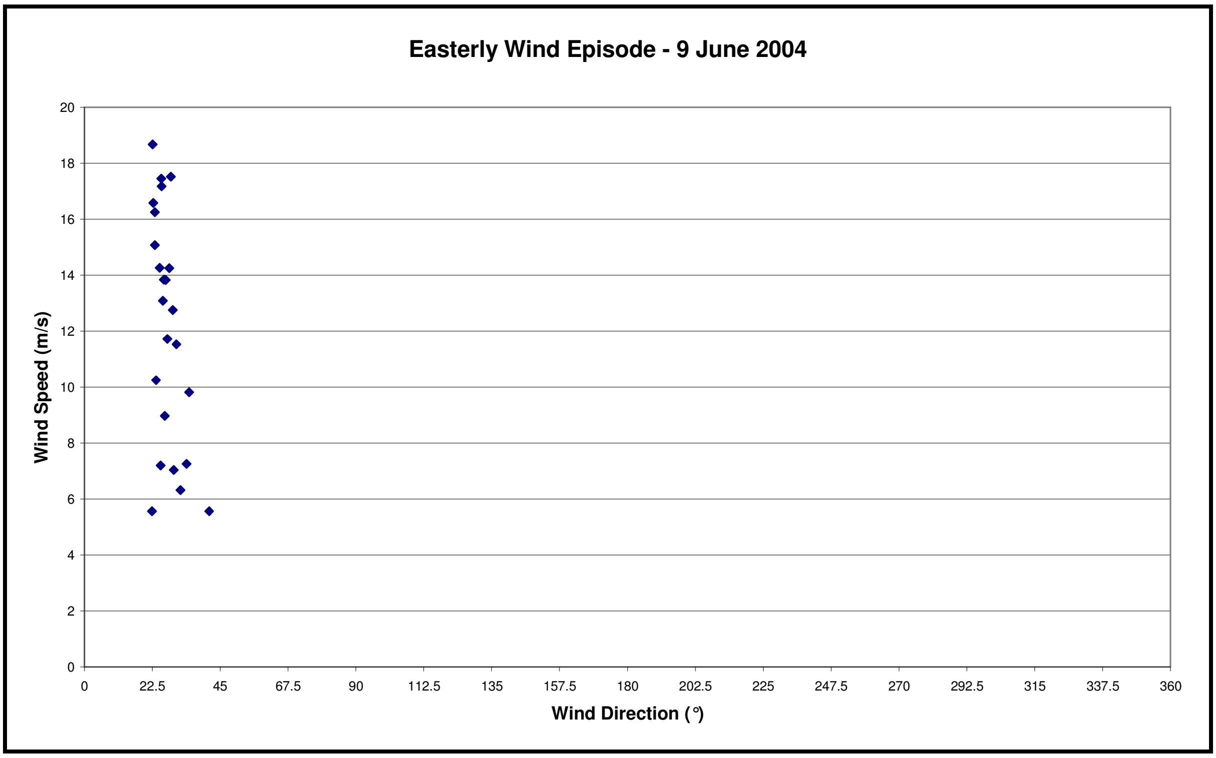

Figure 3-4: Wind speed and wind direction parameters measured on the 9 June 2004

3.1.2 Ambient Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

As the earth cools during night-time the air in direct contact with the earth's surface are forced to cool accordingly. This is clearly evident from Figures 3-5, reflecting the diurnal temperature profiles at Rössing mine. The coldest time of the day appears to be between 04h00 and 07h00, which is just before or after sunrise. After sunrise surface heating occurs and as a consequence the air temperature gradually increases to reach a maximum at approximately 14h00 in the afternoon.

The annual maximum, minimum and mean temperatures are given as 32.7°C, 16.4°C and 23.2°C respectively (Figure 3-6). A maximum temperature of 35.8°C for Rössing mine was recorded during May and a minimum temperature of 12.9°C was recorded in September.

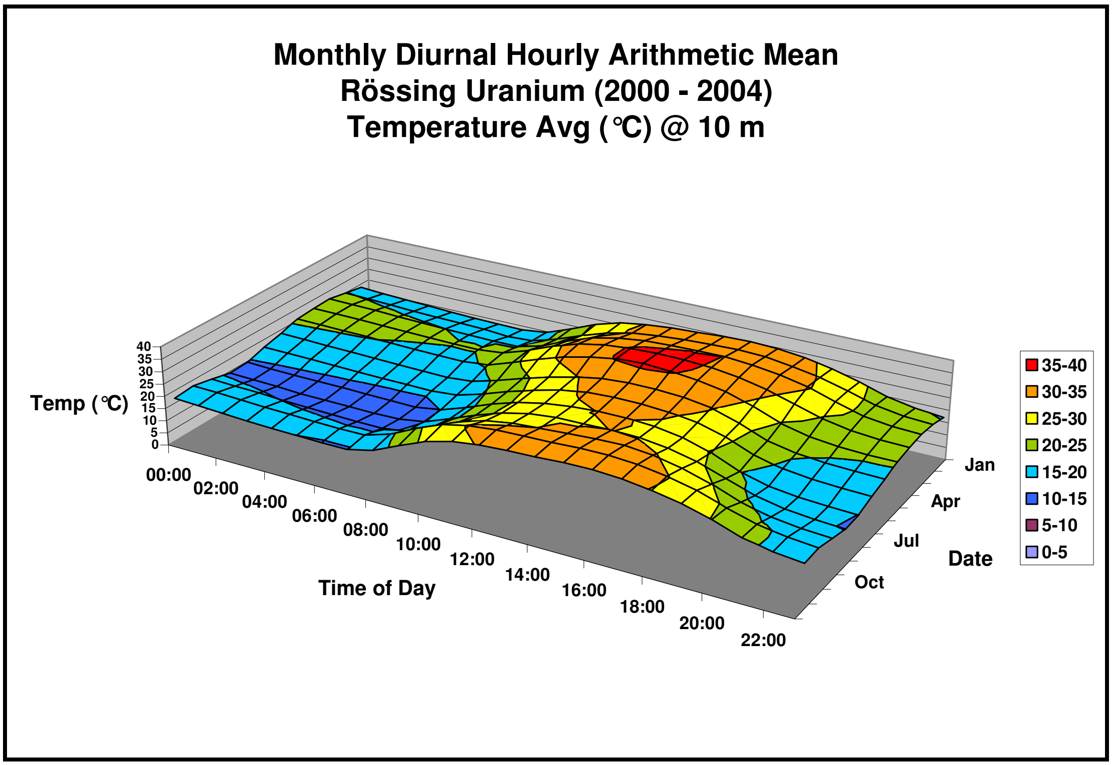

Figure 3-5: Diurnal and monthly variation of ambient air temperatures at Rössing Mine for the period 2000 - 2004.

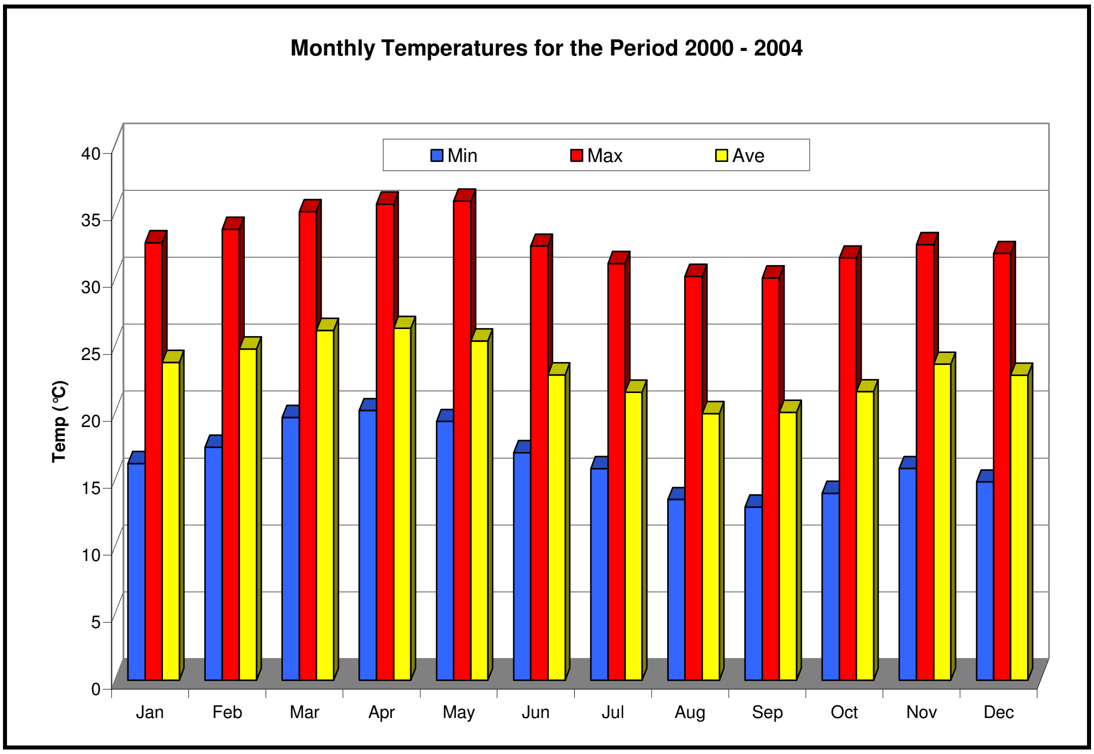

Figure 3-6: Maximum, minimum and mean monthly temperatures at Rössing mine (2000 - 2004).

3.1.3 Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions and the erosion of the mixing layer (Figure 3-7).

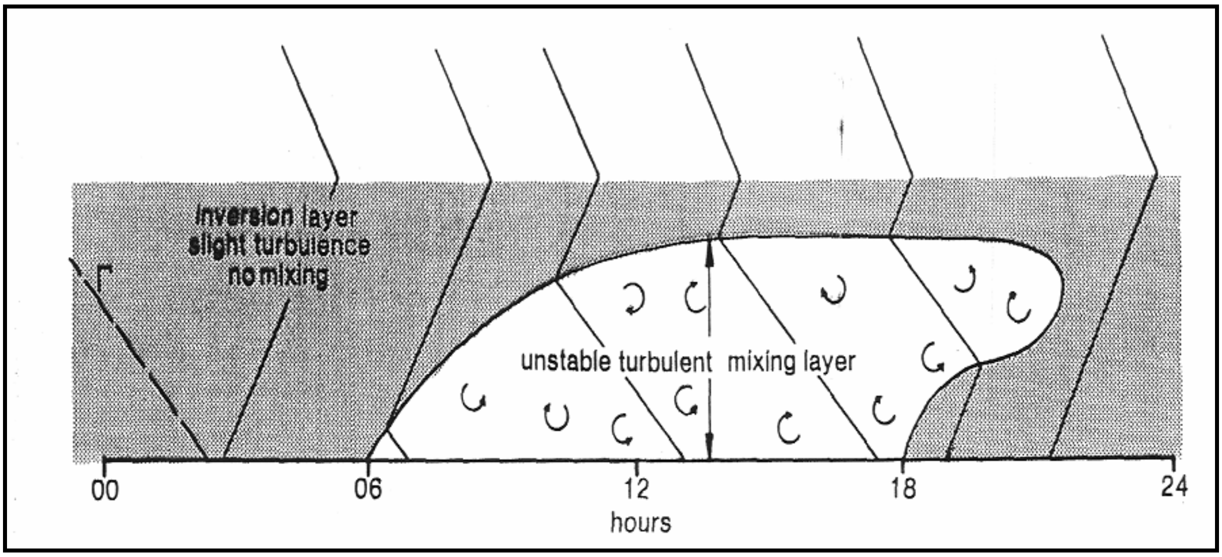

Figure 3-7: Daytime development of a turbulent mixing layer (Preston-Whyte and Tyson, 1988)

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-2. The hourly standard deviation of wind direction, wind speed and predicted solar radiation were used to determine hourly-average stability classes.

Table 3-2: Atmospheric Stability Classes

Designation	Stability Class	Atmospheric Condition
A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions
F	Very stable	low winds, clear skies, cold night-time conditions

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5 to 6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

The variation of stability with wind direction for Rössing mine (for the period 2000 – 2004) is given in Figure 3-8. It is noted that the winds are more frequent from the north-northeast to east-northeast and from the south-southwest to the northwest. A high frequency of neutral conditions occurs from the north-northeast to east-northeast with a high frequency of unstable to neutral conditions occurring from south-southwest to west-northwest.

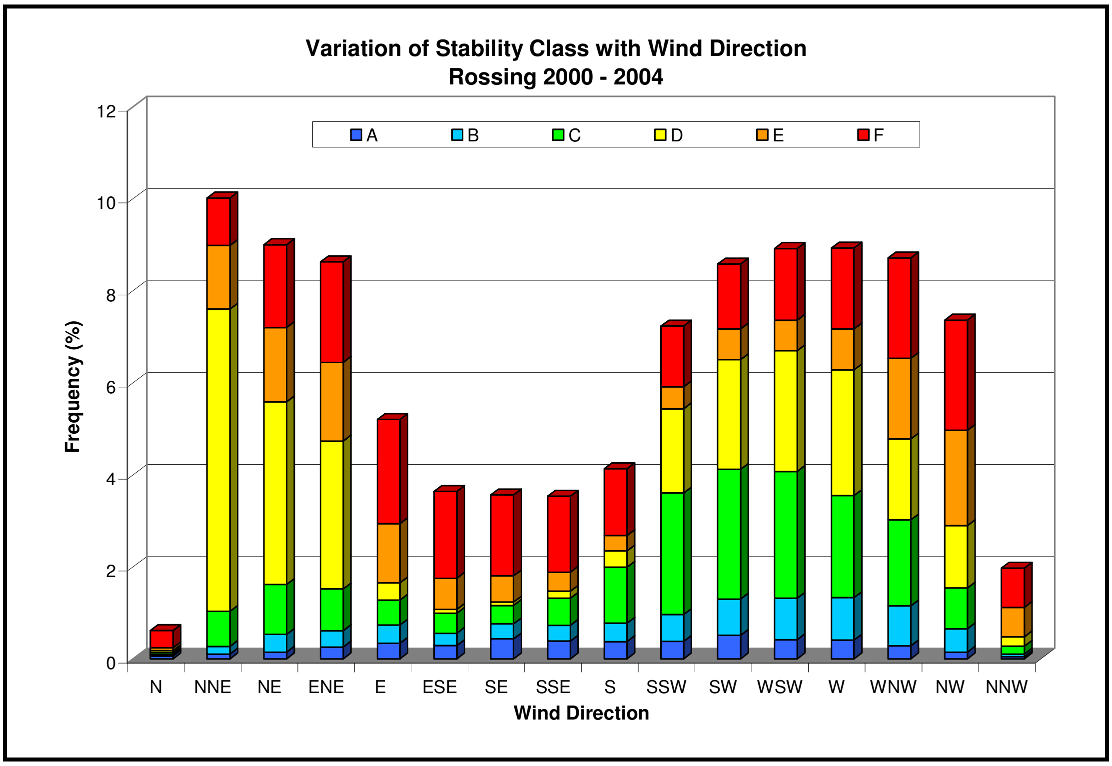

Figure 3-8: Variation of stability with wind direction for Rössing mine (2000 – 2004)

4. BASELINE AIR QUALITY

4.1 Monitored Ambient Air Quality

4.1.1 Dust Fallout

Four dust fallout plates are positioned ~680 m southeast of the tailing dam. The position of these dust fallout plates is given in Table 4-1 and Figure 4-1. The measured dust fallout for the period October 2006 to April 2008 is given in Table 4-2.

The highest measured dust fallout was for the S/EAST 5 monitor (11 670 mg/m^2/day) for the period January 2007 with the lowest measured at NORTH 3 (1 370 mg/m^2/day) for the same period.

Table 4-1: Location of the dust fallout plates

Equipments	Latitude	Longitude
N/East 1	S 22^{0}27.965	E 015^{0}02.523
N/East 2	S 22^{0}27.947	E 015^{0}02.525
North 5	S 22^{0}27.909	E 015^{0}02.506
S/East 5	S 22^{0}28.031	E 015^{0}02.514

Table 4-2: Measured dust fallout for the period October 2006 to October 2007

Date	Fallout Plates Dust Sampling (mg/m^2/day)			
	N/EAST 1	N/EAST 2	NORTH 3	S/EAST 5
Oct-06	4930	3446	2350	6516
Nov-06	4376	3192	3018	6349
Dec-06	4160	3063	2615	6678
Jan-07	9270	6070	1370	11670
Feb-07	8770	4440	1650	13950
Mar-07	5900	4220	2510	9790
Apr-07	4880	2870	2960	7890
May-07	4680	5360	2250	4050
Jun-07	5551	3726	2413	5583
Jul-07	3945	2644	1804	3417
Aug-07	3095	1969	1926	2072
Sep-07	4106	2818	2440	3133
Oct-07	3463	2121	2031	2310
Nov-07	4536	3329	4271	5964
Dec-07	4930	4947	3290	5200
Jan-08	9625	9659	6424	10152
Feb-08	5667	4595	2544	9692
Mar-08	4858	3939	2180	8308

Date	Fallout Plates Dust Sampling (mg/m^2/day)			
	N/EAST 1	N/EAST 2	NORTH 3	S/EAST 5
Apr-08	6297	5105	2826	10769

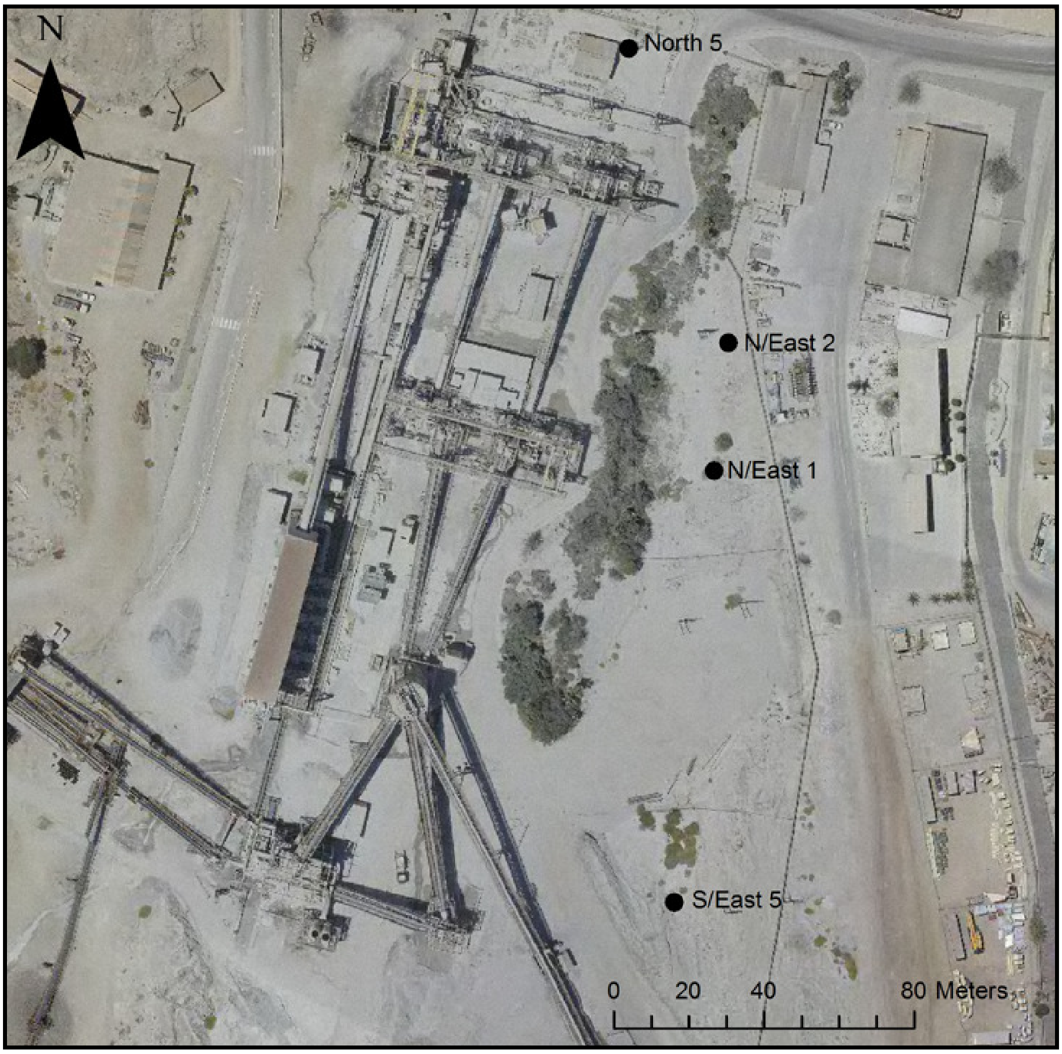

Figure 4-1: Location of dust fallout plates

4.1.2 Personnel Monitors

Use is also made of personnel monitors at Rössing Uranium Mine to monitor inhalable particulate matter. A summary of the average measurements of inhalable particulate concentrations for staff exposed to “outside” air (staff not within buildings) is given in Table 4-3. The location of these areas is given in Figure 4-2.

Table 4-3: Measured inhalable particulate matter at the Rössing mine

Monitoring Area	2005 Average µg/m^3	2006 Average µg/m^3	2007 Average µg/m^3	2008 Average µg/m^3
Pit Field Staff	220	310	710	740
Reduction Staff	350	320	400	1120
Extraction Staff	150	240	150	No samples
Recovery Staff	280	190	100	200
Tailings storage facility Operators	270	130	230	270

The highest measured PM10 concentrations are at the Reduction Staff with 1120 µg/m³ measured for the period 2008. The lowest measured PM10 ground level concentrations occurred at the Extraction Staff (150 µg/m³) for 2005 and 2007, at the Tailings Dam Operators (130 µg/m³) for 2006 and at the Recovery Staff (100 µg/m³) for 2007.

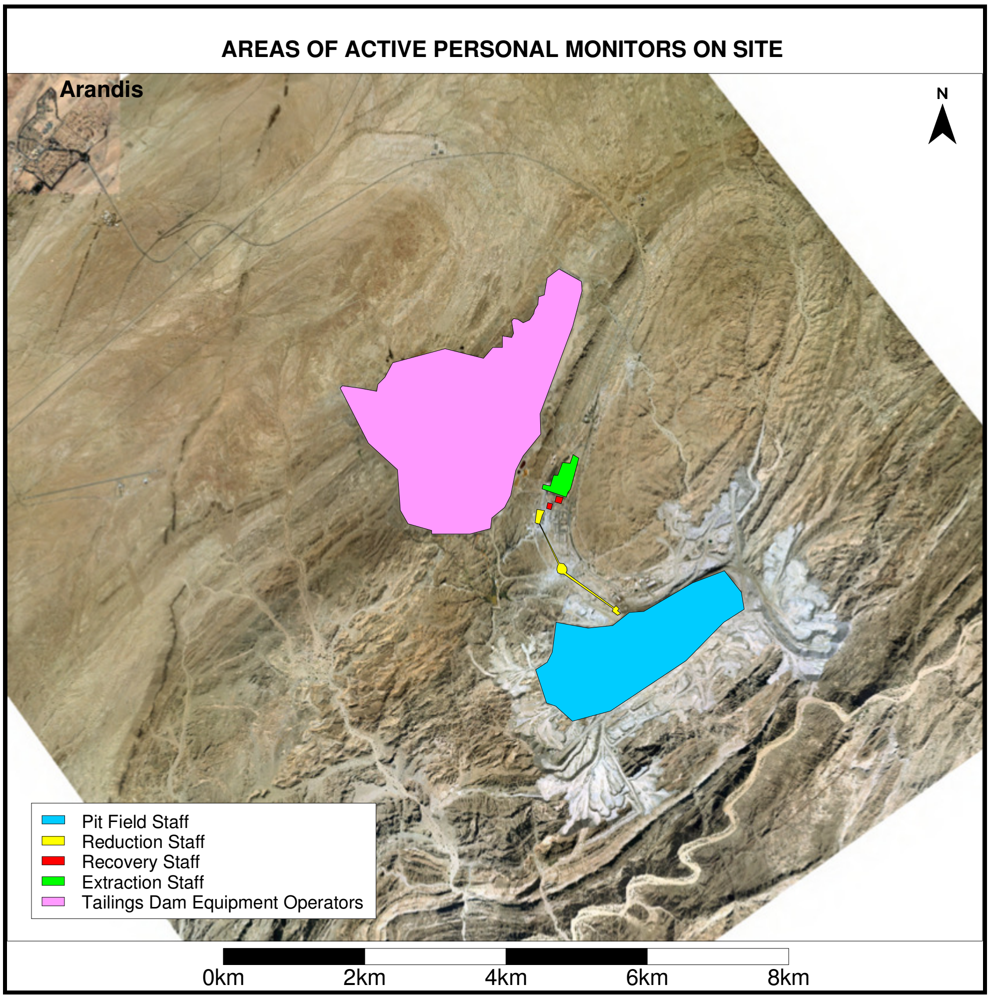

Figure 4-2: Location of areas where personal monitors are in use to measure inhalable particulate matter.

4.1.3 Monitoring Campaign

Ecoserv (now trading as the Environmental Services division of SGS South Africa (Pty) Ltd) were contracted by Aurecon to perform air quality measurements for a period of 2 months at Rössing mine. This monitoring campaign was undertaken to assist in the understanding of baseline (levels of pollutants under the current plant operating conditions before any changes are made to the process) and background (levels of pollutants in the area prior to the establishment of the plant and not influenced by current human pollution generating activity) ambient air quality levels.

Sampling was performed at twelve sites, in and around Rössing mine (Figure 4-3). The measured concentrations obtained from this monitoring campaign is an indicator of ambient air quality levels but data of at least 1 year should be assessed in order to determine average ambient concentrations as this will take into consideration temporal variations.

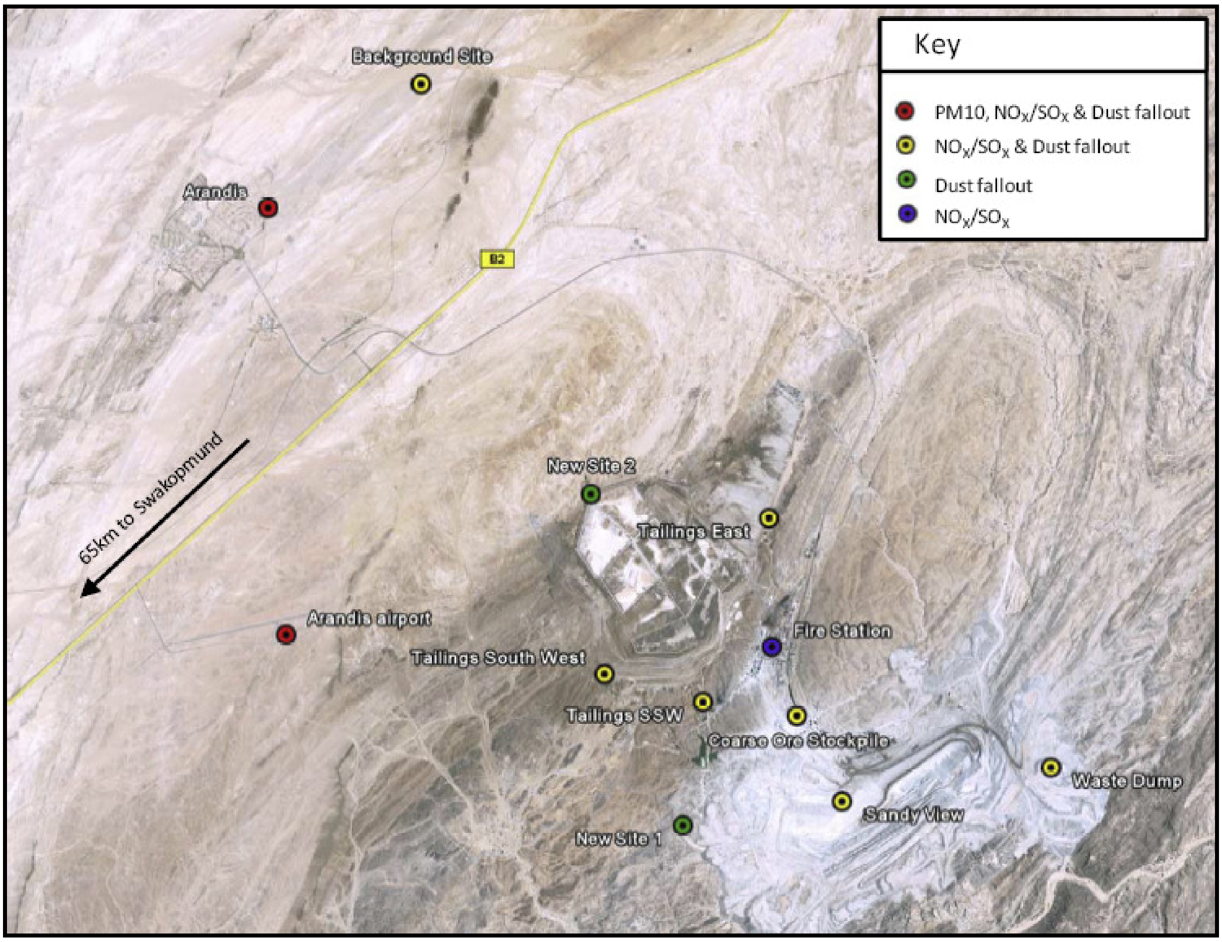

Figure 4-3: Location of the NO_x, SO_x, PM10 and dust fallout sites at Rössing mine (Ecoserv, 2009)

4.1.3.1 Inhalable Particulate Matter (PM10)

The daily PM10 readings for the 2 month monitoring campaign were compared against SA standards (Figure 4-4). At the time the assessment was undertaken, the current SA daily PM10 standards of 180 µg/m^3 were under review. On 24 December 2009, new daily PM10 standards were gazetted: 120 µg/m^3 (effective immediately until 31 December 2014) and 75 µg/m^3 (effective from 1 January 2015). From the measured PM10 daily concentrations at Arandis and Arandis Airport, all measured concentrations are within the current SA Limit of 120 µg/m^2, with two exceedances of the proposed SA Limit of 75 µg/m^3 occurring at the Arandis sampling site, on the 1st and 14th April 2009. The measured daily PM10 concentrations at Arandis and Arandis Airport are in exceedance of the EC and WHO guidelines of 50 µg/m^3 on a number of occasions during the monitoring campaign.

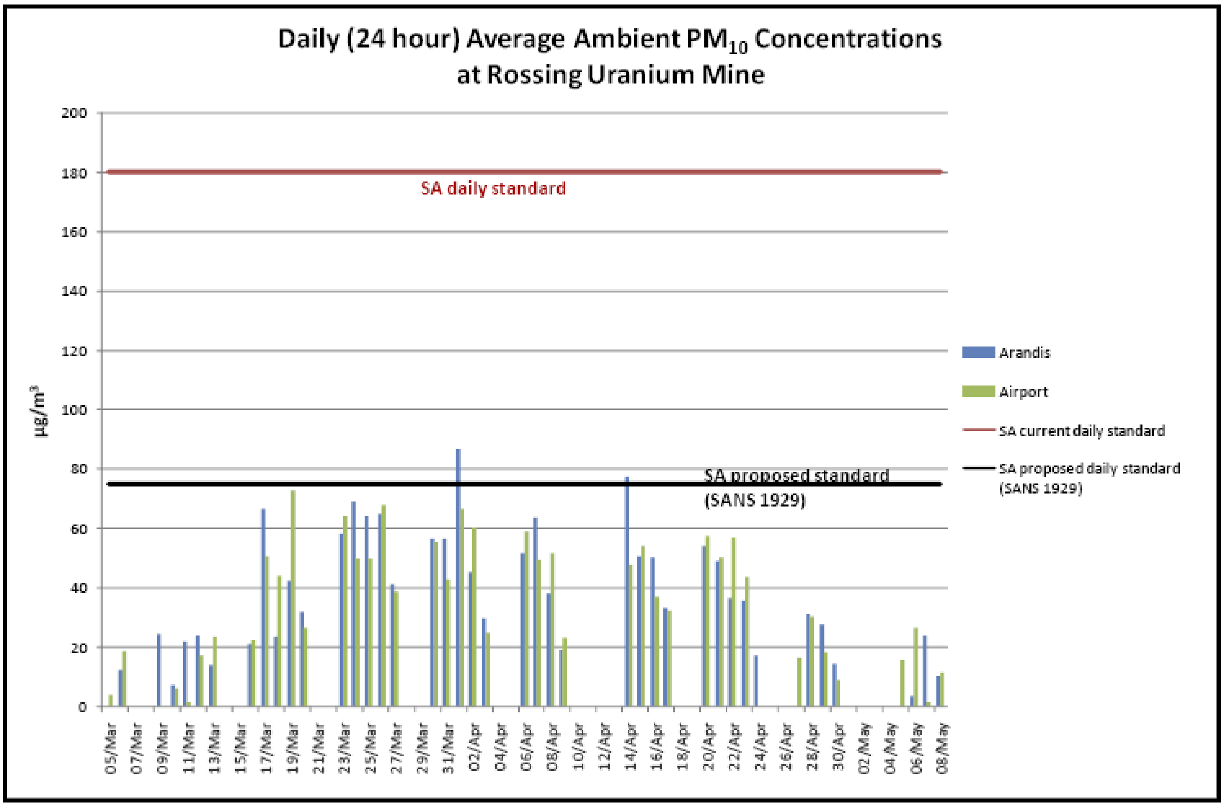

Figure 4-4: Daily PM10 averages at the Arandis and Arandis airport sites during March, April and early May 2009 (Ecoserv, 2009)

The contribution of daily and hourly PM10 readings were classified as background, baseline, Arandis town or mixed using the available wind data that was provided by Rössing. The hourly and daily PM10 results are presented in Table 4-4 and Table 4-5 respectively. Hourly data from the Arandis site could not be used as the light scattering measurements from the sampler were orders of magnitude lower that the gravimetric daily averages for PM10 collected at the site.

Table 4-4: Hourly background, baseline and Arandis town PM10 readings taken from the Arandis Airport monitoring site (Ecoserv, 2009)

Site	Classification	Mean PM10	Std. Dev	No. of samples (days)
Arandis Airport (weather data capture = 53%)	Background	43.87	46.42	595
	Baseline	19.56	19.87	153
	Mixed readings	36.86	29.20	61

Table 4-5: Daily background, baseline, Arandis town and mixed PM10 readings taken from the Arandis and Arandis Airport monitoring sites (Ecoserv, 2009)

Site	Classification	Mean PM10	Std. Dev	No. of samples (days)
Arandis (weather data capture = 53%)	Background	12.87	12.25	3
	Baseline	-	-	-
	Arandis Town	20.82	8.08	8
	Mixed readings	52.94	20.25	12
Arandis Airport (weather data capture = 53%)	Background	32.22	23.35	17
	Baseline	10.97	10.31	2
	Mixed readings	40.15	12.46	4

There was variation between background levels of PM10 calculated using data from the Arandis and Arandis Airport sites. Background levels calculated from Arandis airport data set were significantly higher (more than double) those calculated from the Arandis data set indicating that there is a PM10 source other than the Arandis town and the Rössing mine which lies to the east of the airport. Similarly background levels of PM10 calculated using the hourly PM10 data set from the Arandis airport were more than double that of the baseline level. As the monitor at the Arandis Airport was positioned to the east of the runway, the high background levels (that were measured to come from the west of the monitor) may be directly due to airport traffic (i.e. aircrafts). Thus the background concentrations at the Arandis Airport may not be representative of background levels. It should also be noted that the sample size for background levels at Arandis was very low (3 days of data) owing to the fact that much of this data was classified as “mixed”. These mixed readings come about where there was significant variation in wind direction throughout the day. In addition wind data was only available to classify 53% of the PM10 readings which further reduces the data set. This was due to large amounts of missing weather data from the site (Ecoserv, 2009).

Baseline levels could only be calculated using data from the Arandis airport data set and indicate that the baseline level of PM10 is well below the current and proposed SA Limit of 120 µg/m³ and 75 µg/m³ respectively.

4.1.3.2 Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2)

The results of the monthly passive monitoring SO_2 and NO_2 data are shown in Figure 4-5 and Figure 4-6 respectively.

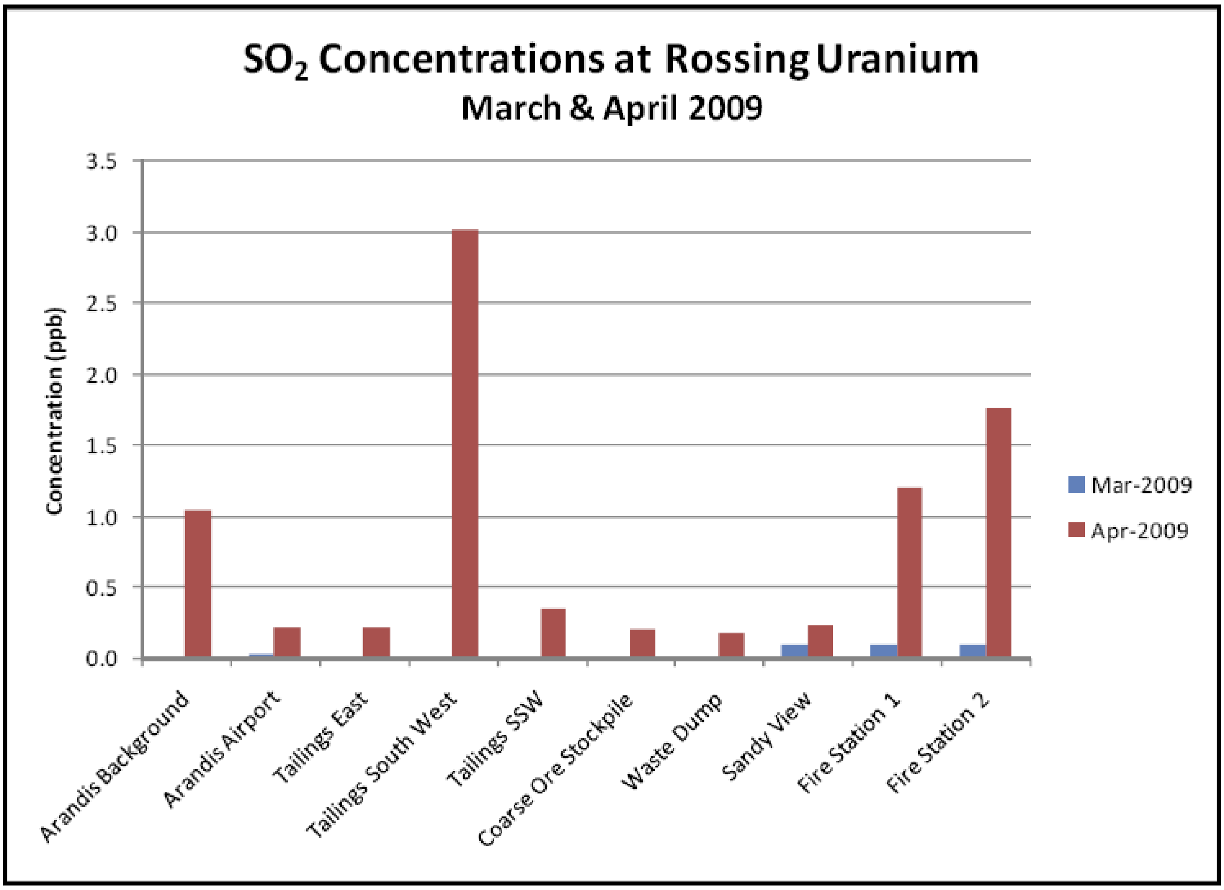

Figure 4-5: Monthly average ambient SO_2 concentrations at Rössing Uranium (Ecoserv, 2009)

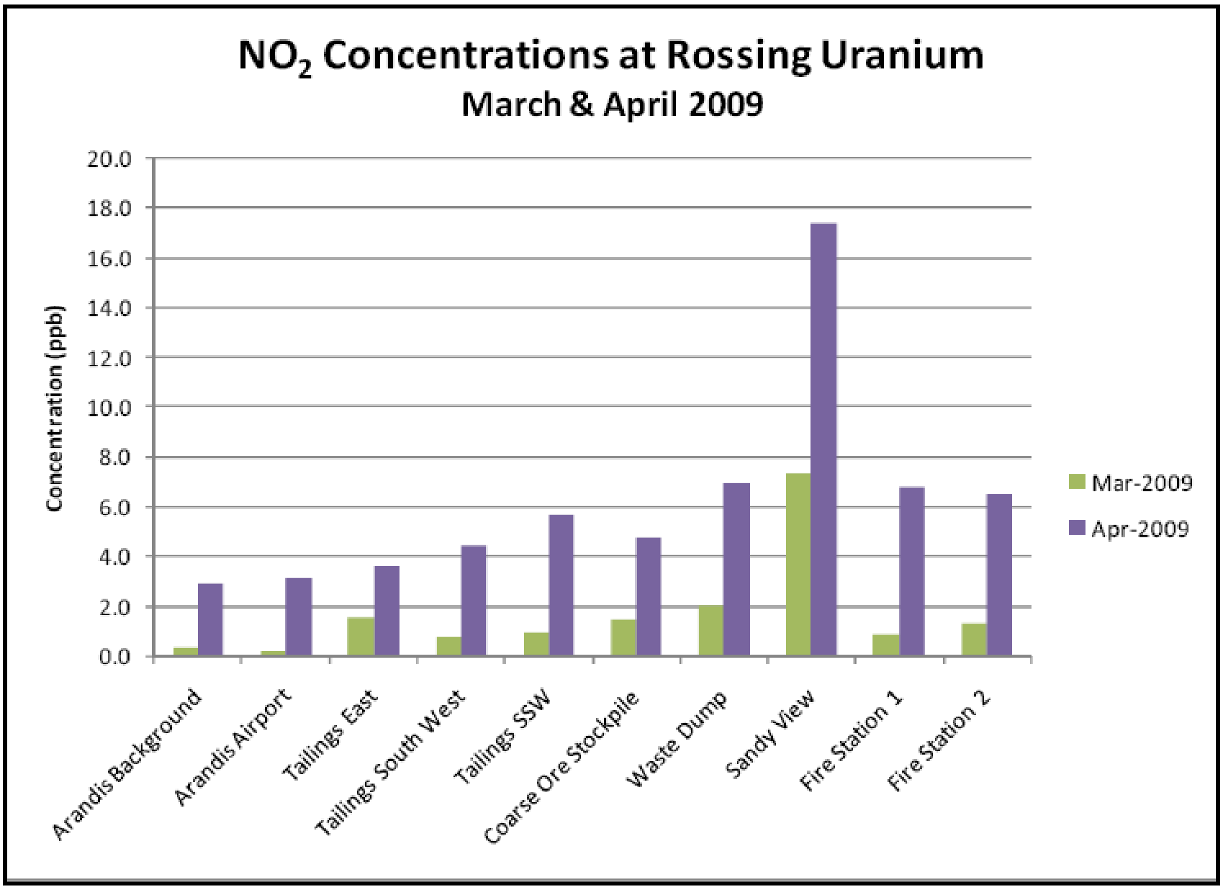

Figure 4-6: Monthly average ambient NO_2 concentrations at Rössing Uranium (Ecoserv, 2009)

As no monthly ambient SO_2 and NO_2 guidelines/standards are available, comparison was made to the annual ambient guidelines/standards. Measured SO_2 levels were generally low and well below the SA standard and EC annual limit of 19 ppb. Since the concentrations were very low (<50% of the annual standard), it is likely that they will also be within the standards for shorter averaging periods. Highest levels of SO_2 were measured at the Tailings South West site during April (3.02 ppb) but average SO2 levels at most sites were below 1ppb during March and April (Ecoserv, 2009).

Similarly NO_2 levels were also low at all sites with the highest levels measured at Sandy's View in April (17.36 ppb). Average NO_2 levels during March and April at most sites were significantly less than 50% of the South African annual guideline for NO_2 (21 ppb) (Ecoserv, 2009). Although the SO_2 and NO_2 concentrations at Sandy's View are well below ambient air quality guidelines, they are higher than any other site at Rössing Uranium and should be further investigated.

4.1.3.3 Dust Fallout

The results of the monthly dust fallout monitoring data are shown in Figure 4-7. Highest dust deposition rates were measured at the Sandy's View site (>800 mg/m²/day) during both March and April. Higher deposition rates were also recorded at the Tailing South westerly site and New Site 2 during April. However these rates fall within the permissible band for heavy commercial and industrial areas as classified in the South African National Standards (SANS). Dust deposition at the Arandis and Arandis airport sites (representing background and baseline levels respectively) were low and fell within the residential band, permissible for residential and light industrial, according to the South African National Standards (SANS) (Ecoserv, 2009).

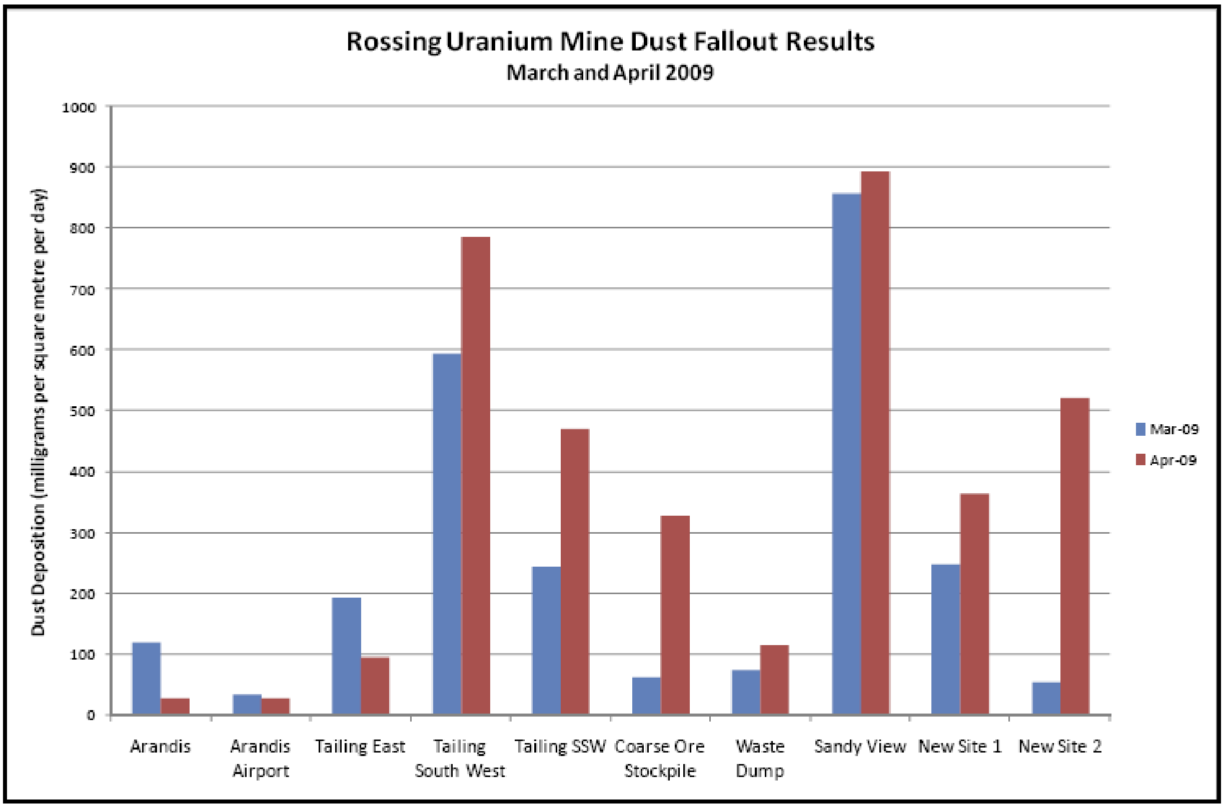

Figure 4-7: Monthly average dust fallout results at Rössing mine during March and April 2009 (Ecoserv, 2009)

4.2 Modelled Ambient Air Quality

The identification of existing sources of emissions at the site is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed operation and its associated emissions. A basic process description of the

Rössing mine is given in the following section with a comprehensive emissions inventory and predicted impact assessment due to current operations at the mine.

4.2.1 Process Description

The Rössing Uranium Mine has a footprint of ~2 165 ha consists of an open pit, uranium extraction plant, tailings dam, waste rock dumps and infrastructure. A basic process description as obtained from the Rössing Uranium Social, Economic and Environmental report to stakeholders (2007) is given in the following section.

4.2.1.1 Drilling and Blasting

Through drilling and blasting, loading and haulage, the uranium ore at Rössing mine is mined. Radiometric scanners are used to measure the radioactivity level of each truckload. This determines whether the material is sent to the primary crushers or to the low-grade stockpile. The waste is transported to a separate storage area. The Rössing mine open pit measures ~3km long, 1.2km wide and ~345m deep.

4.2.1.2 Crushing

Ore is delivered to the primary crushers by haul truck and then via conveyor to the coarse ore stockpile. From the coarse ore stockpile, the ore is conveyed to a further series of crushers and screens until the particles are smaller than 19mm. After weighing, the fine ore is sorted on another stockpile.

4.2.1.3 Grinding

Wet grinding of the crushed ore by means of steel rods reduces the material further to slurry with the consistency of mud. The four rod mills, which are 4.3m in diameter, are utilised as required by production levels and operate in parallel.

4.2.1.4 Leaching

A combined leaching and oxidation process takes place in large mechanically agitated tanks. The uranium content of the pulped ore is oxidised by ferric sulphate and dissolved in a sulphuric acid solution.

4.2.1.5 Slime separation

The product of leaching is a pulp containing suspended sand and slime. Cyclones separate these components and after washing in Rotoscoops to remove traces of uranium-bearing solution, the sand is transported via a sand conveyor to a tailings disposal area.

4.2.1.6 Thickening

Counter-current decantation thickeners wash the slimes derived from the previous stages. A clear uranium-bearing solution (‘pregnant’ solution) over-flows from the thickeners, while the washed slime is mixed with the sands and disposed of at the tailings area.

4.2.1.7 Continuous ion exchange (CIX)

The clear pregnant solution now comes into contact with beads of specially formulated resin. Uranium ions are adsorbed onto the resin and are preferentially extracted from the solution. Beads are removed periodically to elution columns where an acid wash removes the uranium from the beads. The resulting eluate is a purified and more concentrated uranium solution.

4.2.1.8 Solvent extraction (SX)

The acidic eluate from the ion exchange plant is mixed with an organic solvent which takes up the uranium-bearing component. In a second stage, the organic solution is mixed with a neutral aqueous ammonium sulphate solution, which takes up the uranium-rich ‘OK liquor’. The acidic ‘barren aqueous’ solution is then returned to the elution columns.

4.2.1.9 Precipitation

The addition of gaseous ammonia to the ‘OK liquor’ raises the solution PH, resulting in precipitation of ammonium diuranate, which is then thickened to a yellow slurry.

4.2.1.10 Filtration

The ammonium diuranate is recovered on rotating drum filters as yellow paste – ‘yellow cake’.

4.2.1.11 Drying and roasting

Final roasting drives off the ammonia, leaving uranium oxide. The product is then packed into metal drums.

4.2.1.12 Loading and dispatch

The drums of uranium oxide are loaded and exported to overseas converters for further processing. At full capacity, the plant can produce 4 500 tonnes of uranium oxide each year.

4.2.2 Emissions Inventory

The establishment of an emission inventory formed the basis for the assessment of the impacts from of the current operation activities on the receiving environment. An emissions inventory comprises the identification and quantification of sources of emissions.

The nature and significance of air quality impacts associated with current activities at Rössing form the focus of the current section. The approach typically followed includes:

- Identification of sources of emissions;
- Identification of types of pollutants being released;
- Determination of pertinent source parameters; and,
- Quantification of each source's emissions.

The main pollutant of concern due to proposed operations was identified to be particulate matter. Sources of particulate emissions due to current operations are thus assessed in the current section.

In the quantification of fugitive dust emissions use was made of emission factors which associate the quantity of a pollutant to the activity associated with the release of that pollutant. Due to the absence of locally generated emission factors, reference was made to emission factors such as those published by the US Environmental Protection Agency (US-EPA) in its AP-42 document and the Australian National Pollutant Inventory (NPi). The US-EPA AP-42 emission factors are of the most widely used in the field of air pollution.

4.2.2.1 Fugitive Dust Emissions from Materials Handling Operations

Materials handling operations associated with the activities at Rössing mine include the transfer of material by means of tipping of material (i.e. at the coarse ore stockpile (Figure 4-8)), loading (i.e. within the open pit) and off-loading of trucks (i.e. at the primary crusher (Figure 4-9) and waste rock dumps).

Figure 4-8: Tipping operations at the coarse ore stockpile (i.e. materials handling operations)

Figure 4-9: Off-loading operations at the primary crusher (i.e. materials handling operations)

The quantity of dust that will be generated from such operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (i.e. moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles. This control measure has been implemented at the primary crusher where water sprayers have been installed to reduce fugitive emissions (Figure 4-10). According to literature (Holmes Air Sciences (1998)), water sprayers that are used to keep ore wet can reduce fugitive emissions by 50%.

Figure 4-10: Water sprayers at the primary crusher to reduce emissions of fugitive dust due to off-loading operations (i.e. materials handling operations)

The following predictive US-EPA equation was used to estimate emissions from materials handling operations:

$$E_{TSP} = 0.0016 \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}}$$

where,

E_{TSP} = Total Suspended Particulate emission factor (kg dust / t transferred)
U = mean wind speed (m/s)
M = material moisture content (%)
k = particle size multiplier (dimensionless)

The quantity of dust generated from the materials handling operations was based on information provided by Rössing personnel (Table 4-6). The location of the materials handling points is illustrated in Figure 4-11. The PM10 fraction of the TSP was assumed to be 35%. Hourly emission rates, varying according to the wind speed, were used as input in the dispersion simulations.

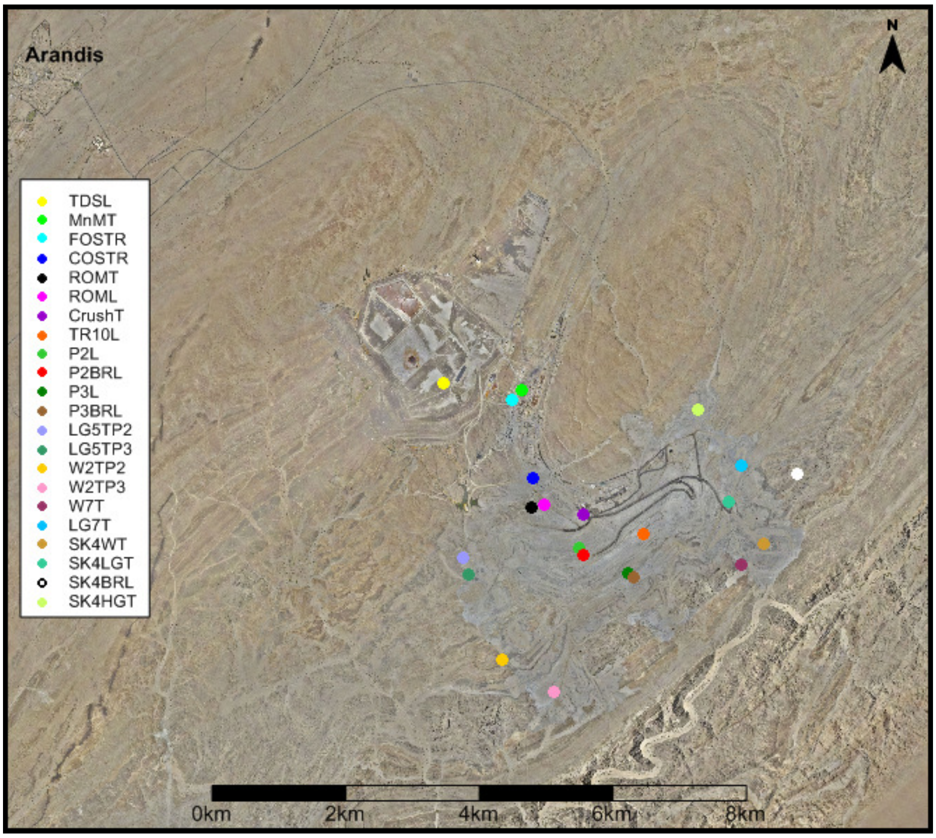

Figure 4-11: Location of materials handling points for Basecase (2010)

Table 4-6: Parameters and calculated particulate matter emissions for material handling sources (for the Basecase 2010)

Description	Name	Annual Tonnage of Ore Material Passing Through Point	Annual Tonnes Tailings to be Distributed at Each Point	% Moisture	Control Efficiency (%)	TSP (tpa)	PM10 (tpa)	X	Y
Material (tailings sand dressing) loaded at the tailings dam for use as dressing for roads, loading and tipping areas	TDSL	841,081		2.05	0	3	1	3331.0	-50878.0
Trolley 10 in Pit	TR10L	13,706,757	87,331	0.67	0	230	80	6320.0	-53134.0
Trolley 10 to Waste 7	W7T	692,069	4,409	0.67	0	12	4	7792.0	-53612.0
Trolley 10 to LG7	LG7T	828,247	5,277	0.67	0	14	5	7793.0	-52122.0
Phase 2 in Pit (RUL)	P2L	7,650,548	48,745	0.67	0	128	45	5352.0	-53347.0
Phase 2 in Pit (Basil Read)	P2BRL	4,500,000	28,671	0.67	0	75	26	5426.0	-53450.0
Phase 2 to Waste	W2TP2	8,800,726	56,073	0.67	0	147	52	4205.0	-55026.0
Phase 2 to LG	LG5TP2	808,468	5,151	0.67	0	14	5	3611.0	-53493.0
Phase 3 in Pit	P3L	28,705,156	182,891	0.67	0	481	168	6088.0	-53737.0
Phase 3 in Pit (Basil Read)	P3BRL	7,500,000	47,785	0.67	0	126	44	6160.0	-53804.0
Phase 3 to Waste	W2TP3	35,445,367	225,836	0.67	0	594	208	4975.0	-55510.0
Phase 3 to LG	LG5TP3	302,155	1,925	0.67	0	5	2	3682.0	-53741.0
SK4 in Pit	SK4BRL	1,073,108	6,837	0.67	0	18	6	8627.0	-52239.0
SK4 to waste	SK4WT	489,341	3,118	0.67	0	8	3	8131.0	-53297.0
SK4 to LG7	SK4LGT	489,341	3,118	0.67	0	8	3	7606.0	-52672.0
SK4 to Ore Stockpile	SK4HGT	94,427	602	0.67	0	2	1	7134.0	-51278.0
Reclaimed from ROM Stockpiles	ROML	1,200,000	7,646	0.67	0	20	7	4825.0	-52723.0
Tipped at ROM "P" Stockpiles	ROMT	3,338,189	21,269	0.67	0	56	20	4661.0	-52755.0
Ore crusher	CrushT	16,385,429	104,398	0.67	50	137	48	5417.0	-52854.0
Manganese Offloading Point	MnMT	19500		0.33	0	1	0	4490.0	-50980.0
Coarse Ore Stockpile	COSTR	13,000,000		0.67	0	216	76	4650.0	-52313.0
Fine Ore Stockpile	FOSTR	13,000,000		0.32	0	607	213	4353.0	-51142.0

4.2.2.2 Wind Erosion

Significant emissions arise due to the mechanical disturbance of granular material from open areas (i.e. open pit (Figure 4-12), area along conveyors where material has been deposited (Figure 4-13), and storage piles (i.e. coarse ore stockpile (Figure 4-8), tailings dam (Figure 4-14), etc.). Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. This aggregation of material is evident on the tailings dam where a crust on some surfaces was observed (Figure 4-15). Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

Figure 4-12: Open pit at Rössing mine

Figure 4-13: Loose material along conveyor belts

Figure 4-14: Tailings dam at Rössing Uranium Mine

Figure 4-15: Crust formation on dry surface of tailings storage facility at Rössing mine

An hourly emissions file was created for the storage piles and open areas. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E(i) = G(i)10^{(0.134(\%clay)-6)}$$

for

$$G(i) = 0.261\left[\frac{P_a}{g}\right]u^{*3}(1+R)(1-R^2)$$

and $$R = \frac{u_*^{\ t}}{u^*}$$

where,

$E_{(i)}$ = emission rate (g/m²/s) for particle size class i
P_a = air density (g/cm³)
g = gravitational acceleration (cm/s³)
u_*^t = threshold friction velocity (m/s) for particle size i
u^* = friction velocity (m/s)

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure 4-16.

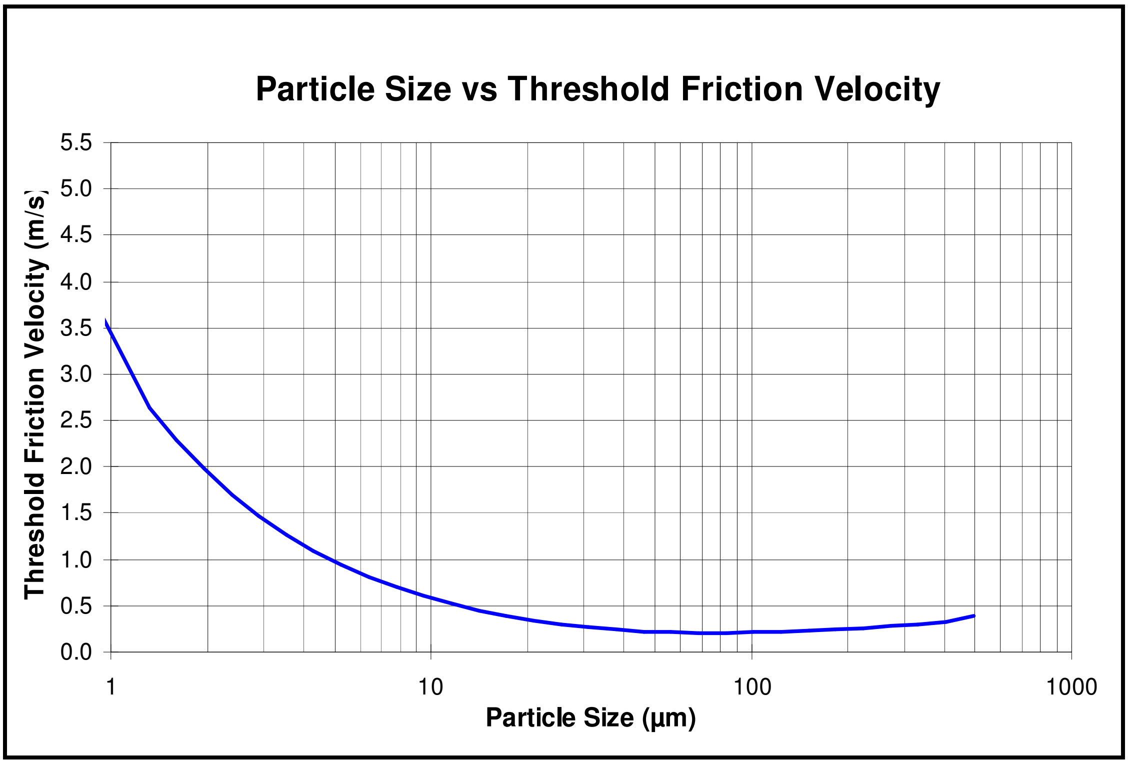

Figure 4-16: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).

The wind speed variation over the storage piles is based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US-EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed (us) to approach wind speed (ur), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure 4-17 (viz. a conical pile, and an oval pile with a flat top and 37° side slope). The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the direction of airflow. (The higher the ratio, the greater the wind exposure potential.) These flow patterns are only applicable with piles that have a height to base ratio of more than 0.25.

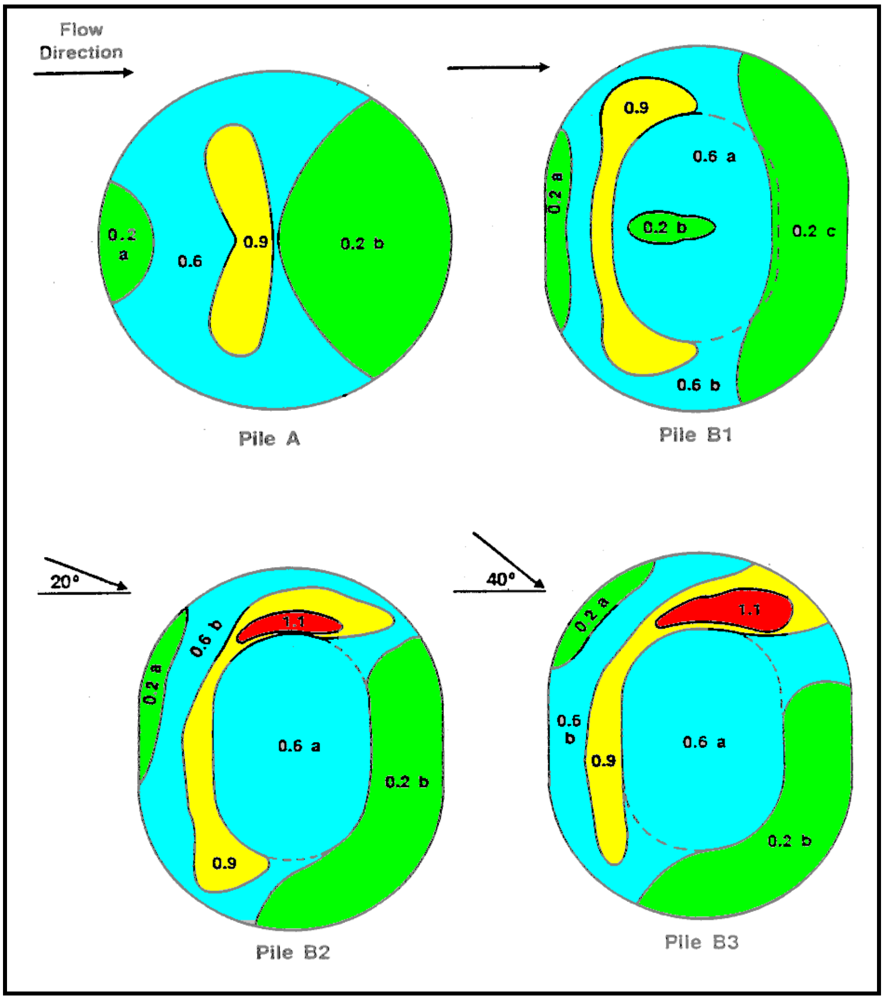

Figure 4-17: Contours of normalised surface wind speeds (i.e. surface wind speed / approach wind speed) (after EPA, 1996).

Numerous samples were taken at Rössing mine in order to assist in the quantification of these fugitive dust sources. The particle size sample analysis as well as moisture content and bulk density are given in Table 4-7. Rössing Uranium also supplied historical particle size distribution to assist in the calculation of the fugitive emissions (Table 4-8). The parameters required to calculate the emissions as provided by Rössing Uranium personnel, are provided in Table 4-9. The wind erosion areas as provided by Rössing are illustrated in Figure 4-18. It should be noted that the wet paddies were not included as a wind erosion source as these areas are wet.

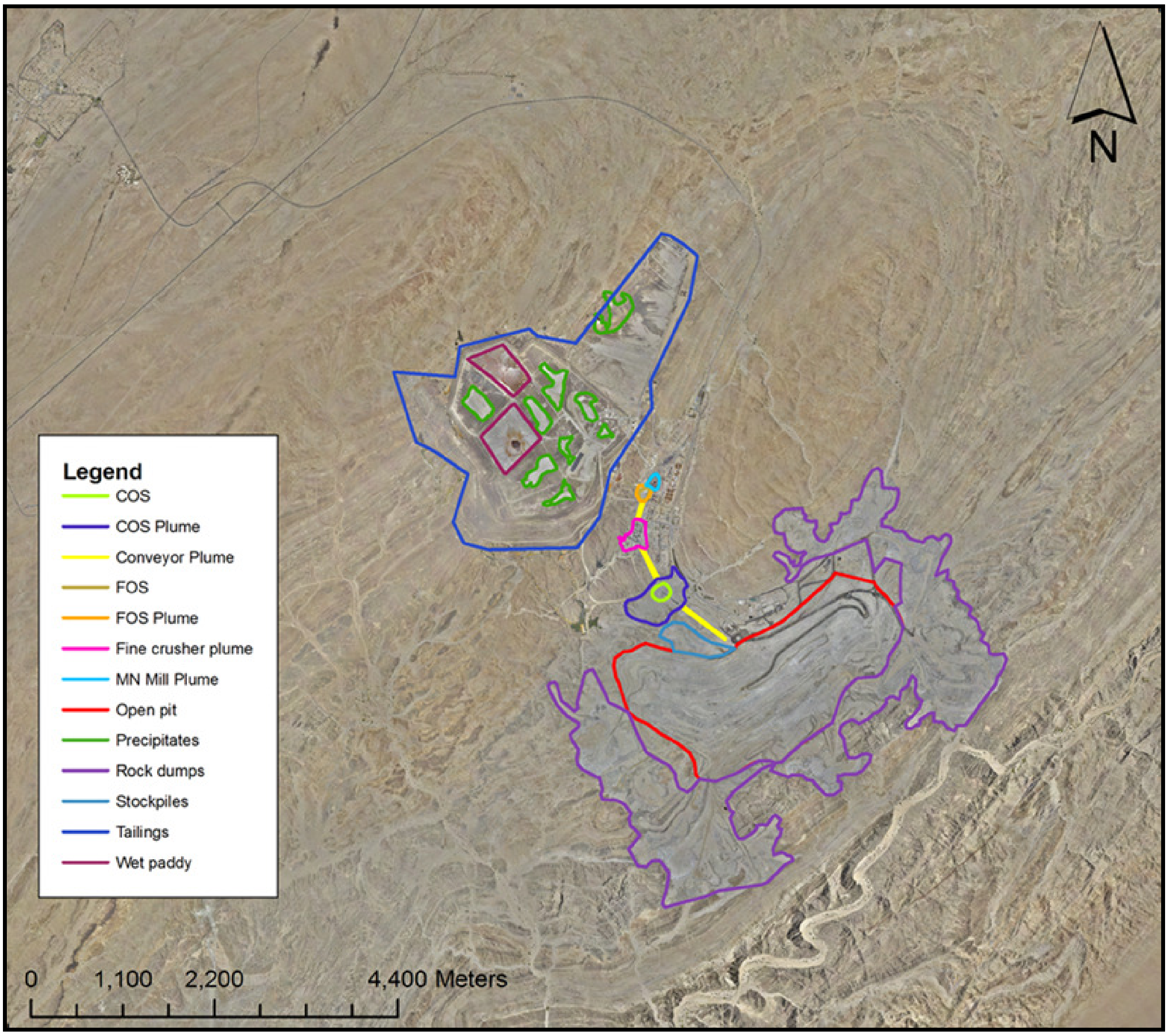

Figure 4-18: Wind erosion sources for the Basecase (2010)

Table 4-7: Particle size distribution, bulk density and moisture content from various samples taken at Rössing Uranium (SGS lab results)

#	Sample Name	Bulk Density (g/cm^3)	Moisture %	Particle size (µm) fraction												
				>1180	1180	850	600	300	150	75	38	25	10	5	2	1
1	Conveyor from primary crusher	2.88	0.01	0.27	0.003	0.011	0.035	0.190	0.205	0.151	0.138	0.095	0.059	0.050	0.041	0.023
2	Conveyor from coarse ore stockpile to fine crusher	2.58	0.33	0.12	0.001	0.008	0.039	0.240	0.263	0.174	0.110	0.046	0.031	0.033	0.035	0.021
3	Conveyor from fine crusher to fine stockpile	2.74	0.32	0.15	0.002	0.002	0.007	0.060	0.221	0.172	0.166	0.080	0.075	0.079	0.082	0.054
4	Open Pit Benches	2.61	0.32	31.61	0.316	0.082	0.073	0.151	0.153	0.081	0.050	0.019	0.020	0.021	0.019	0.015
5	P-Stockpiles	2.39	0.99	28.35	0.283	0.084	0.083	0.165	0.136	0.085	0.042	0.015	0.030	0.031	0.026	0.020
6	Coarse Ore Stockpile	2.08	0.01	6.67	0.067	0.055	0.081	0.291	0.252	0.112	0.050	0.019	0.024	0.021	0.018	0.009
7	Fine Ore Stockpile	2.52	6.89	21.48	0.215	0.089	0.100	0.190	0.140	0.084	0.054	0.022	0.039	0.031	0.025	0.012
8	Proposed Leach Plant Area	2.34	2.30	31.62	0.316	0.120	0.111	0.188	0.134	0.064	0.024	0.007	0.011	0.010	0.009	0.005
9	Tailing Inactive Paddy Wall	2.9	0.01	32.43	0.324	0.117	0.095	0.180	0.156	0.085	0.022	0.010	0.003	0.003	0.003	0.001
10	Tailing Inactive Paddy	2.15	0.93	37.22	0.372	0.118	0.092	0.141	0.117	0.072	0.036	0.012	0.008	0.009	0.012	0.008
11	Tailing Inactive Paddy	2.54	6.93	28.69	0.287	0.126	0.121	0.179	0.135	0.059	0.024	0.030	0.008	0.009	0.013	0.008
12	Tailing Wall Material	2.5	0.33	29.83	0.298	0.113	0.107	0.194	0.143	0.067	0.030	0.010	0.003	0.007	0.014	0.016
13	Seepage Dredged Material	2.36	6.64	33.23	0.332	0.065	0.060	0.116	0.085	0.051	0.040	0.016	0.074	0.064	0.066	0.031
14	Fine Crushing Dust	2.72	0.01	31.53	0.315	0.076	0.072	0.106	0.078	0.045	0.045	0.031	0.084	0.061	0.057	0.030
15	Main Road (Tarred Road)	2.39	0.01	6.91	0.069	0.052	0.083	0.251	0.235	0.155	0.091	0.024	0.008	0.013	0.010	0.009
16	Open Pit Dust-A-Side Road	2.87	0.33	28.21	0.282	0.126	0.127	0.212	0.153	0.061	0.021	0.003	0.003	0.005	0.004	0.002
17	Open Pit Roads Without Dust	2.42	0.33	30.62	0.306	0.101	0.095	0.157	0.131	0.074	0.046	0.014	0.025	0.034	0.018	0.000
18	Tailing Road	2.68	0.67	25.81	0.258	0.127	0.118	0.195	0.135	0.057	0.031	0.011	0.018	0.021	0.018	0.010
19	Coarse Ore Stockpile Conveyor	2.69	0.33	32.95	0.329	0.131	0.119	0.194	0.125	0.055	0.028	0.007	0.003	0.002	0.003	0.003
20	Manganese Mill area road	2.39	0.33	20.51	0.205	0.069	0.067	0.142	0.136	0.082	0.054	0.030	0.191	0.024	0.000	0.000

Table 4-8: Historical particle size distribution supplied by Rössing Uranium (EnviroSolutions, 2001)

Parameter		Mass Median Diameter	Fraction	Size fractions midpoint (µm)				
		MMD (µm)	< 38 µm	2.5	5	10	20	45
Salts		55	0.3	0.14	0.09	0.24	0.24	0.28
Seepage		401	0.17	0.32	0.11	0.21	0.18	0.18
Tailings		300	0.25	0.15	0.15	0.3	0.3	0.1
Waste		550	0.04	0.15	0.15	0.3	0.3	0.1
Coarse deposits	(Coarse ore crusher and Tailings B plume)	50	0.22	0.15	0.15	0.3	0.3	0.1
Fine deposits	(Fine ore crusher plumes)	6	1	0.3	0.23	0.22	0.25	0

Table 4-9: Parameters provided by Rössing to calculate emissions due to wind erosion

Facility	Subdivision	Sub-subdivision	Sample	Area [a]	Percentage >1.18mm	Reference for percentage >1.18mm	Crust-ing (mm)	Name code
Current tailings storage facility	Old benches		#9-12	Total tailings outline	32.04	SGS lab results	4	TAIL
	New benches							
	Paddies x,y,z							
	Operating paddies	Dry proportion						
		Chemical precipitate areas	EnviroSolutions 2001 - "salts"	Precips	0		4	PRECIP
	Benches		#4	Open pit	98.8	ROM particle size distribution [b]	0	PIT
	P Stockpiles		#5	Stockpiles			0	STOCKP
Rock dumps	Waste rock dumps		EnviroSolutions 2001 - "waste"	Waste			0	WASTE
	Low grade and high calc stockpiles							
Plant area	Coarse Ore stockpile		#6	COS	95	Assumption	0	COS
	Coarse ore stockpile plume			COS plume	6.67	SGS lab results	4	COSP
	Fine ore stockpile plume		#7	FOS plume	21.48	SGS lab results	1	FOSP
	Conveyor plume	C1 (along conveyor from primary crusher)	#1	C1	0.27	SGS lab results	0	C1
		C2 (from COS to fine crusher)	#2	C2	0.12	SGS lab results	0	C2
		C3 (from fine crusher to fine stockpile)	#3	C3	0.15	SGS lab results	0	C3
	Manganese mill area road		#20	Mn Mill Plume	20.51	SGS lab results	0	MN
	Fine ore crusher		#14	Fine crushing plume	31.53	SGS lab results	0	FOCP

Notes:

(a) Plot layouts of the wind erosion sources were provided by Rössing personnel

(b) Run Of Mine (ROM) particle size distribution was provided by Rössing personnel

The crusting effect on some of the sources were calculated based on findings by Gillette (1982) whereby individual threshold friction velocities were calculated based on crust thickness. The threshold friction velocity was calculated to be 0.430225 m/s for the tailings and precipitates material, 0.43035 m/s for the coarse ore stockpile plume material and 0.429093 m/s for the fine ore stockpile plume material. Figure 4-19 provides an illustrative comparison of the effect that crusting has on emission rates. Assuming a threshold friction velocity of ~0.43 m/s due to crusting the total emissions are just more than half the emissions when no crusting is assumed.

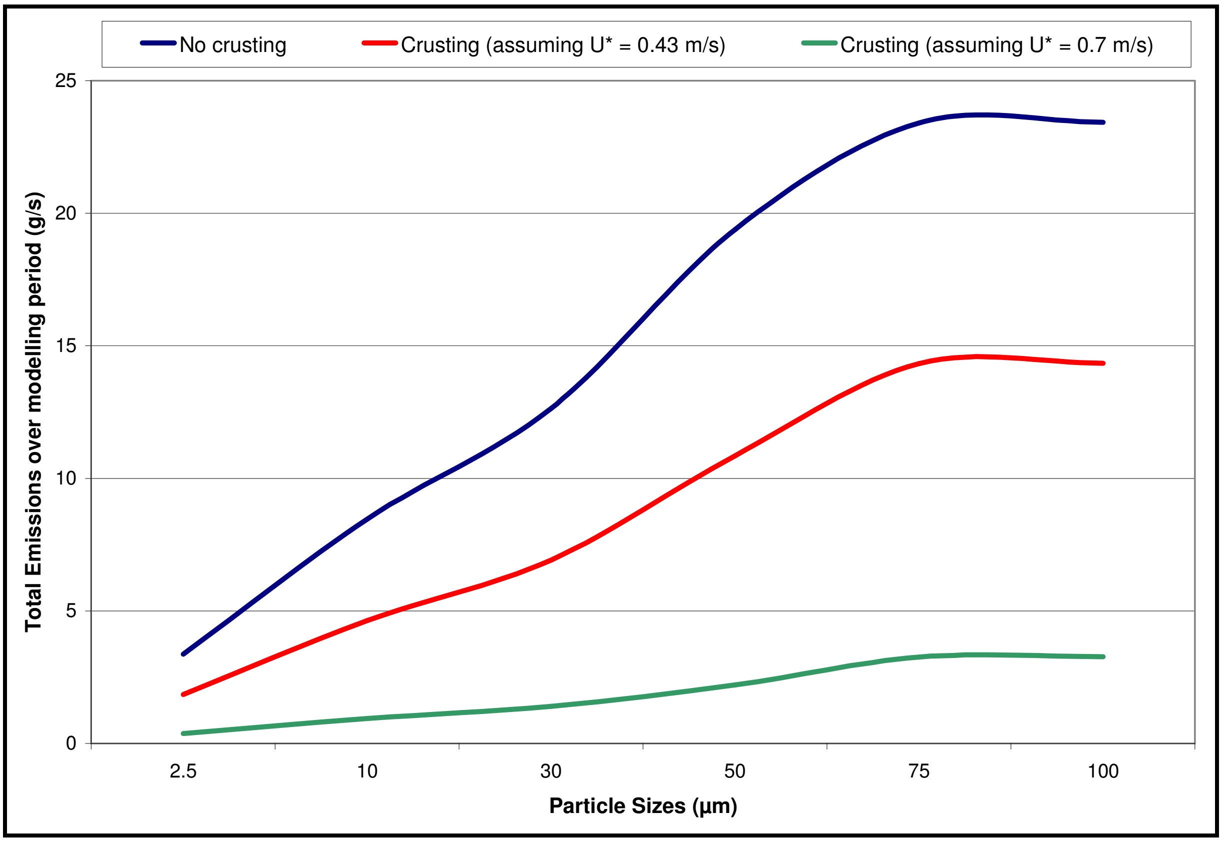

Figure 4-19: Comparison of emissions due to surface crusting of material

4.2.2.3 Vehicle-Entrained Emissions from Unpaved Roads

Vehicle-entrained dust emissions from unpaved haul roads represent a significant source of fugitive dust. The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic, including average vehicle speed, mean vehicle weight, silt content of road material and road surface moisture (EPA, 2006).

A haul truck within the open pit area at Rössing mine is shown in Figure 4-20.

Figure 4-20: Haul truck within the open pit area at Rössing.

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$E = k(\frac{s}{12})^a(\frac{W}{3})^b$$

where,

E = emissions in lb of particulates per vehicle mile travelled (lb/VMT) – 1 lb/VMT = 281.9 g/VKT (vehicle kilometres travelled)

k = particle size multiplier (dimensionless)
s = silt content of road surface material (%)
W = mean vehicle weight (tonnes)

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 1.5 for PM10 and 4.9 for total suspended particulates (TSP). *a* and *b* are given as 0.9 and 0.45 respectively for PM10 and as 0.7 and 0.45 respectively for TSP.

The silt content on the road surfaces was measured (Table 4-10) and was included in the quantification of fugitive emissions from this source.

Table 4-10: Silt content for various unpaved road surfaces at Rössing mine

Sample Name	Silt Content %
Open pit Dust-A-Side roads	2.76
Open pit roads without Dust-A-Side	14.54
Tailing roads	12.36
Coarse Ore Stockpile Conveyor roads	6.77
Manganese Mill area road	30.29

The information on vehicle data used to calculate the emissions of vehicle entrainment on unpaved road surfaces is given in Appendix A.

Rössing has a measure of control efficiency on their pit roads in the form of water sprayers at a rate of 3.66 liters/day/m² for unpaved roads and 0.49 liters/day/m² on Dust-A-Side roads. The US-EPA have control efficiency emission factor for watering:

$$C = 100 - \left(0.8\, pdt/l\right)$$

where,
C = ave control efficiency (%)
p = potential ave daytime evaporation rate (mm/hr)
d = ave hourly daytime traffic rate (hr-1)
t = time between applications
l = application intesity (litres per m²)

These control efficiencies were incorporated into the calculation of the emissions from this fugitive emission source.

4.2.2.4 *Vehicle-Entrained Emissions from Paved Roads*

Particulate emissions will result from the entrainment of loose material from the paved road surface due to vehicle traffic (Cowhert and Engelhart, 1984, 1985; Jones and Tinker, 1984). The extent of particulate emissions from paved roads is a function of the "silt loading" present on the road surface. In return, the silt loading is affected by the mean speed of vehicles on the road, the average daily traffic, the number of lanes and to a lesser extent of the average weight of vehicles travelling on the road (Cowhert and Engelhart, 1985; EPA, 2006). Silt loading (sL) refers to the mass of silt-size material (i.e. equal to or less than 75 microns in diameter) per unit area of the travel surface.

The quantity of dust emitted from vehicle traffic on paved roads was estimated based on the following equation (EPA, 2006):

$$E = k(\frac{sL}{2})^{0.65}(\frac{W}{3})^{1.5} - C$$

where,

E = particulate emission factor in grams per vehicle km travelled (g/VKT)

K = basic emission factor for particle size range and units of interest

sL = road surface silt loadings (g/m^2)

W = average weight (tons) of the vehicles travelling the road

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear (as obtained from the US-EPA emission factors)

The particle size multiplier (k) is given as 4.6 for PM10, and as 24 for TSP. The emission factor (C) is given as 0.1317 g/VKT for PM10 and TSP. The recommended US-EPA silt loading of 8.2 g/m^2 was used to calculate emissions due to vehicle entrainment on the paved road surfaces.

Rössing Uranium currently has a bus service that transports staff members to and from work. Parameters provided by Rössing personnel to calculate emissions from these fugitive dust sources is provided in Table 4-11.

Table 4-11: Parameters provided to calculate emissions from vehicle entrainment on paved road surfaces

Scenario	No of trips per day (K94 Buss)	No of trips per day (K114 Buss)	No of trips per day (Mini Buss)	No of trips per day (Basil Read Buss)	No of trips per day (Basil Read Mini Buss)	K94 Buss weight full (t)	K114 Buss weight full (t)	Mini Buss weight full (t)	Basil Read Buss weight full (t)	Basil Read Mini Buss weight full (t)	Ave Weight (t)
Week day	71	11	6	18	2	21.5	24.5	7.4	13.6	7.4	19.4
Week-end	38	6	2	18	2	21.5	24.5	7.4	13.6	7.4	21.3

4.2.2.5 Dozers and Graders

Emission factors, published by the Australia National Pollutant Inventory (NPi) for the quantification of fugitive dust emissions due to grading and dozing were used in the quantification of these emissions. The emission factors used for graders are as follows:

$$E_{TSP} = 0.0034(S)^{2.5}$$

$$E_{PM10} = 0.0034(S)^{2.0}$$

where,

E = particulate emission factor in kilograms per vehicle km traveled (kg/VKT)
S = mean vehicle speed in km/hr

The average mean vehicle speed for the graders was taken to be 11.4 km/hr as provided by the US-EPA.

The emission factors for the dozers are as follows:

$$E_{TSP} = 2.6 \times s^{1.2} \times M^{-1.3}$$

$$E_{PM10} = 0.34 \times s^{1.5} \times M^{-1.4}$$

where,

E = particulate emission factor in kilograms per hour (kg/hr)
s = silt content (%)
M = moisture content (%)

The parameters required to calculate the emissions from the fugitive dust source were provided by Rössing Uranium personnel (Table 7 and Table 8 in Appendix A).

4.2.2.6 Blasting and Drilling Operations

Drilling (Figure 4-21) and blasting (Figure 4-22) operations represent intermittent sources of fugitive dust emissions.

Single valued emission factors, published by the US-EPA for the quantification of fugitive dust emissions due to drilling operations are as follows:

$$\mathbf{E_{TSP} = 0.59\ kg\ of\ dust\ /\ drill\ hole}$$

It should be noted that the US-EPA equation for blasting does not provide any allowances for the moisture content in the material blasted, the depth of the holes or where the blast is a throw blast or simply a shattering blast. Therefore it must be considered a very rough estimate of the quantity of TSP that will be generated.

There is another equation provided by the Australia NPi for blasting emissions:

$$E_{TSP} = 344\left(\frac{A^{0.8}}{M^{1.9} \times D^{1.8}}\right)$$

where,

E = particulate emission factor in kilograms per blast
A = area blasted in m^2
M = moisture content in %
D = depth of blast holes in meters

This equation takes into account other variables that are likely to be important in the generation of dust. Thus the equation was used to calculate emissions for the study. The PM10 fraction constitutes 52% of the TSP for blasting (EPA, 1998).

As a conservative approach, information pertaining to a blast undertaken on 21 October 2008 was used for the impact assessment in the current study as this activity tended towards larger blasting operations.

The information for the blasting scenario was provided by Rössing Uranium personnel (Table 4-12). Measured PM10 concentrations were undertaken to verify calculated emissions. Use was made of the MiniVol Sampler (manufactured by Airmetrics), which samples ambient air at 5 liters/minute for particulate matter. The MiniVol gives results that closely approximate data from Federal Reference Method samplers.

Figure 4-21: Drilling operations at Rössing Mine

Figure 4-22: Blasting operations at Rössing Uranium Mine.

Table 4-12: Information provided on the blast scenario

BLAST REFERENCE	07/268	05/265 & 05/267	04/243	04/246
BLAST TYPE	Production	Production	Production	Trim
BENCH ELEVATIOM	480m	510m	525m	525m
BLAST HOLE DEPTH	17.8m min & 18.6m max	17.5m min & 19.8m max	11.0m min & 15.2m max	15.6m min & 16.9m max
SUBDRILL	2.0m front & 2.5m rest	2.0m front & 2.5m rest	2.0m front & 2.5m rest	1.5m
BURDEN & SPACING	6.5m x 7.5m	6.5m x 7.5m	6.5m x 7.5m	4.0m x 4.5m (Buffer 3.0 x 4.5)
PATTERN TYPE	Staggered	Staggered	Staggered	Staggered
HOLES	225	199		
CUP DENSITY	1.1	1.1	1.1	1.1
CHARGE DENSITY	100kg/meter	100kg/meter	100kg/meter	28kg/meter
CHARGE HEIGHT	11m	11m	11m	10m
TOTAL AMOUNT OF EXPL. (kg)	270,310	233,230	24,660	15,105
BLASTED TONNAGE (t)	538,590	423,070		
POWDER FACTOR (kg/t)	0.502	0.551		
STEMMING HEIGHT & TYPE	6.0m/19mm Agg.	6.0m/19mm Agg.	6.0m/19mm Agg.	B-row open, C-row 5m, D&E 6.0m
TIE-UP	Closed Chevron	Closed Chevron	Open Chevron	Open Chevron
ACCESSORIES:	350g Trojan Booster	350g Trojan Booster	350g Trojan Booster	350g Trojan Booster
	500ms Down Hole Nonel	500ms Down Hole Nonel	500ms Down Hole Nonel	500ms Down Hole Nonel
	10g/m Deta Cord	10g/m Deta Cord	10g/m Deta Cord	10g/m Deta Cord
	84ms Inter row	84ms Inter row	84ms Inter row	42ms Inter row

The location of the blast platforms as well as the position of the MiniVol sampler is given in Figure 4-23. The moisture content of 0.32% was obtained from soil samples taken in the vicinity of the blasting site.

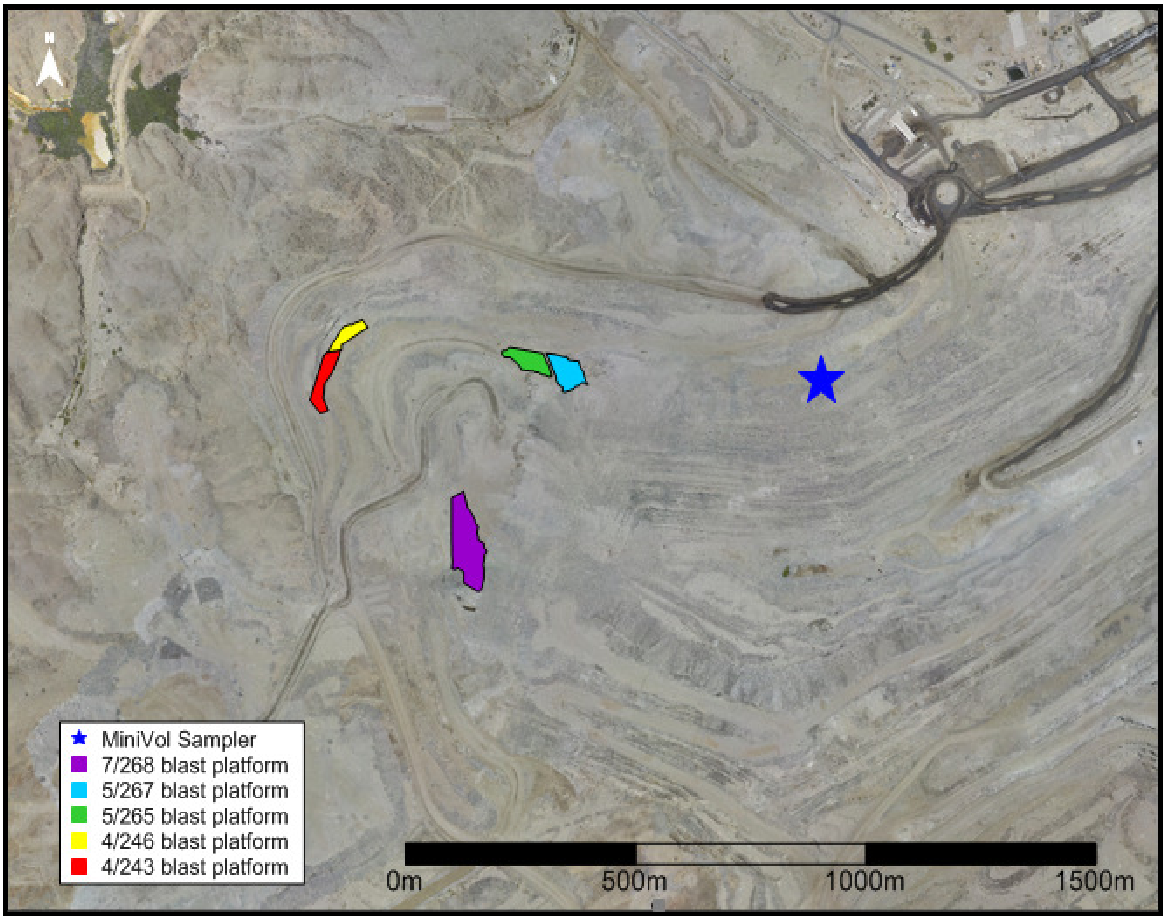

Figure 4-23: Position of the blast platforms and MiniVol sampler on 21 October 2008

The calculated PM10 emissions are provided in Table 4-13. As the blast took place over 8 minutes the peak emissions for this period was calculated. However, the dispersion model is only able to calculate emissions over a 1-hour averaging period (smallest increment of meteorological data available) and thus the emissions were also calculated diluting the levels over a 1 hour time frame.

Table 4-13: Calculated PM10 emissions from the blasting scenario

Blast platform	PM10 Emission Rate (g/s/m^2) based on 8 min release	PM10 Emission Rate (g/s/m^2) based on an hourly exposure average
07/268	2.78	0.37
05/265 & 05/367	2.83	0.38
04/243	6.22	0.83
04/246	4.65	0.62

A summary of the measured PM10 concentrations undertaken on 21 October 2008 is given in Table 4-14.

Table 4-14: Measured PM10 concentrations on 21 October 2008 during a blast operation at Rössing Uranium

Parameter	Value	Unit
Sampling rate	5	Liters/min
Sampling duration	50.94	min
Concentration	0.3	mg
	5.889	µg/min
	1.178	µg/liter
	1177.8563	µg/m³

The calculated emissions were simulated using the European ADMS Gaussian plume model. ADMS 4 is a new generation air dispersion model which differs from the regulatory models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes (the atmospheric boundary layer properties are described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class) and in allowing more realistic asymmetric plume behaviour under unstable atmospheric conditions. Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetric Gaussian expression). ADMS 4 is currently used in many countries worldwide and users of the model include Environmental Agencies in the UK and Wales, the Scottish Environmental Protection Agency (SEPA) and regulatory authorities including the UK Health and Safety Executive (HSE).

Meteorological data was supplied by Rössing personnel for dispersion modelling purposes and the predicted concentrations were compared to measured concentrations that were undertaken.

The verified emissions (that were predicted to provide PM10 ground level concentrations equivalent to that measured by the MiniVol) was a factor of 0.0146 of the calculated emissions (when assessing emissions over an 8 minute period) and 0.1097 (when assuming emissions over 1 hour period) (using the Australia NPi emission factors and the measured moisture content of 0.32%) (Table 4-15 and Table 4-16). As was to be expected, the peak emissions (8-minute) calculated over-predicted the ground level concentrations as the model interpreted the 8-minute emissions as occurring for 1-hour. The average emissions over 1-hour was slightly better when compared to expected emissions based on the ground level concentration measurements but still over-predicted by ~9 times. The limitations are with the model as the incident should be assessed on an incremental short-term basis and the changes to emissions should be input over 1 minute interval. As it was not possible to measure the emissions on these short-term intervals (due to safety issues) it would be difficult to model this episode in more detail.

Table 4-15: Comparison of measured and modelled PM10 concentrations (8 minute) at the MiniVol sampler site

Blast platform	Emission rate (g/s/m²) based on NPi emission factor	Emission rate (g/s/m²) based on measured data	Fraction of verified emission rates (based on measured PM10 concentrations) to calculated emission rates (based on an 8 minute emission release)
07/268	2.78	0.0406	0.0146
05/265 & 05/367	2.83	0.0414	0.0146
04/243	6.22	0.0909	0.0146
04/246	4.65	0.0680	0.0146

Table 4-16: Comparison of measured and modelled PM10 concentrations (1 hour) at the MiniVol sampler site

Blast platform	Emission rate (g/s/m²) based on NPi emission factor	Emission rate (g/s/m²) based on measured data	Fraction of verified emission rates (based on measured PM10 concentrations) to calculated emission rates (assuming an hour exposure)
07/268	0.37	0.0406	0.1097
05/265 & 05/367	0.38	0.0414	0.1097
04/243	0.83	0.0909	0.1097
04/246	0.62	0.0680	0.1097

The modelled PM10 concentrations predicted due to the blast scenario (using emissions calculated with the aid of back-modelling to reflect the measured concentrations) is given in Figure 4-24.

During episodes of low to no wind speeds, the dispersion potential of the site will decrease which will result in higher impacts during blasting episodes. Figure 4-25 provides the predicted impacts from a blasting episode during a hypothetical scenario with a wind speed of 1m/s (from the west-southwest). It can be concluded that for this case scenario the NPi emission factors resulted in an over prediction of the actual ground level concentrations. Given that the blast is an instantaneous event (a few minutes) and that the model simulations were for 1 hour, there are a number of factors that influence the way the plume behaves during that hour. For example the sub-hourly varying wind speed and direction, atmospheric turbulence, geographic location and nature of the blast. Based on the complex nature of blasting and the difficulty to accurately simulate it, this can be a topic for further research.

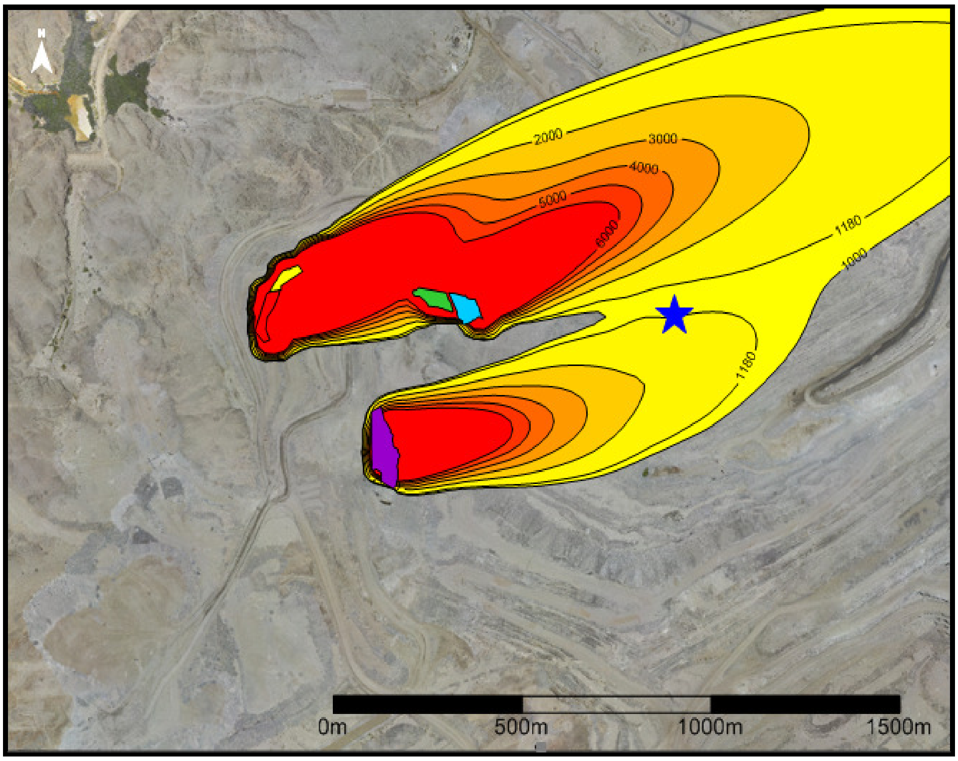

Figure 4-24: Modelled PM10 ground level concentrations (µg/m³) due to the blast scenario on 21 October 2008

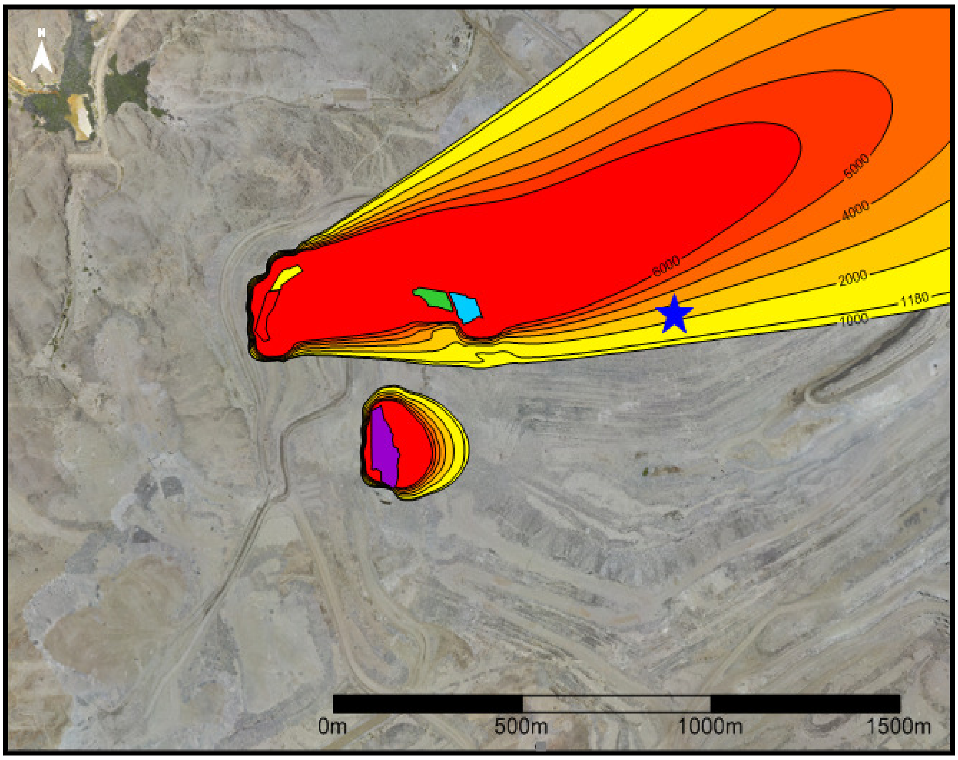

Figure 4-25: Modelled PM10 ground level concentrations (µg/m³) due to the blast scenario on 21 October 2008 (assuming a wind speed of 1 m/s)

4.2.2.7 Fine Crushing Plant

Measurements from three fixed locations (i.e. F1, F3 and Mechanical Workshop) at the fine crusher were provided by Rössing Uranium personnel for the period August 2009 to assess the emissions from this fugitive dust source (Table 4-17). With the aid of back-modelling the emission factors were calculated.

Table 4-17: Measured TSP and PM10 concentrations at three fixed locations at the fine crusher.

Location	Measured maximum daily TSP concentrations (µg/m³)	Measured maximum daily PM10 concentrations (µg/m³)
F1	1539	1285
F3	3203	2719
Mechanical Workshop (outside)	956	682

For this assessment, the emissions were assumed to emanate from fixed dust collector (DC) points located at the fine crusher (i.e. DC2, DC3, DC4, DC5, DC6, DC8, DC9, DC10, DC11). The emissions at the fine crusher were determined with the aid of back-modelling using the European ADMS Gaussian plume model and meteorological data supplied by Rössing personnel. Assuming that the emissions are evenly distributed between the DC points, with modelling the concentrations at the F1 site and mechanical workshop are predicted to be in the range of measured concentrations. However, modelled concentrations at the F3 site are under predicted. It was assumed that additional fugitive dust sources were responsible for high concentrations at the F3. An additional emission point source was therefore added just north of the F3 monitoring site to locally increase concentrations within this area. Modelled TSP and PM10 ground level concentrations at the fine crusher are provided in Figure 4-26 and Figure 4-27 respectively.

The emissions calculated for the period August 2009 were based on an ore throughput into the fine crusher plant of 12 640 000 tpa. For the current operations (Basecase 2010), the ore throughput through the plant was given as 13 000 000 tpa. The calculated emissions were therefore adjusted to reflect the increased production through the plant.

Based on the methodology followed (back-modelling), the emission factor are as follows:

TSP = 0.003 kg dust per tonne ore;
PM10 = 0.004 kg dust per tonne ore.

When compared to the EPA emission factors for crushing operations (not controlled) it equates to a 99.5% (high moisture ore) - 90% (low moisture ore of <4%) control efficiency (CE) for TSP and 70% CE for PM10. This is in line with what the Australian NPi indicates for enclosure where CE of up to 100% can be achieved.

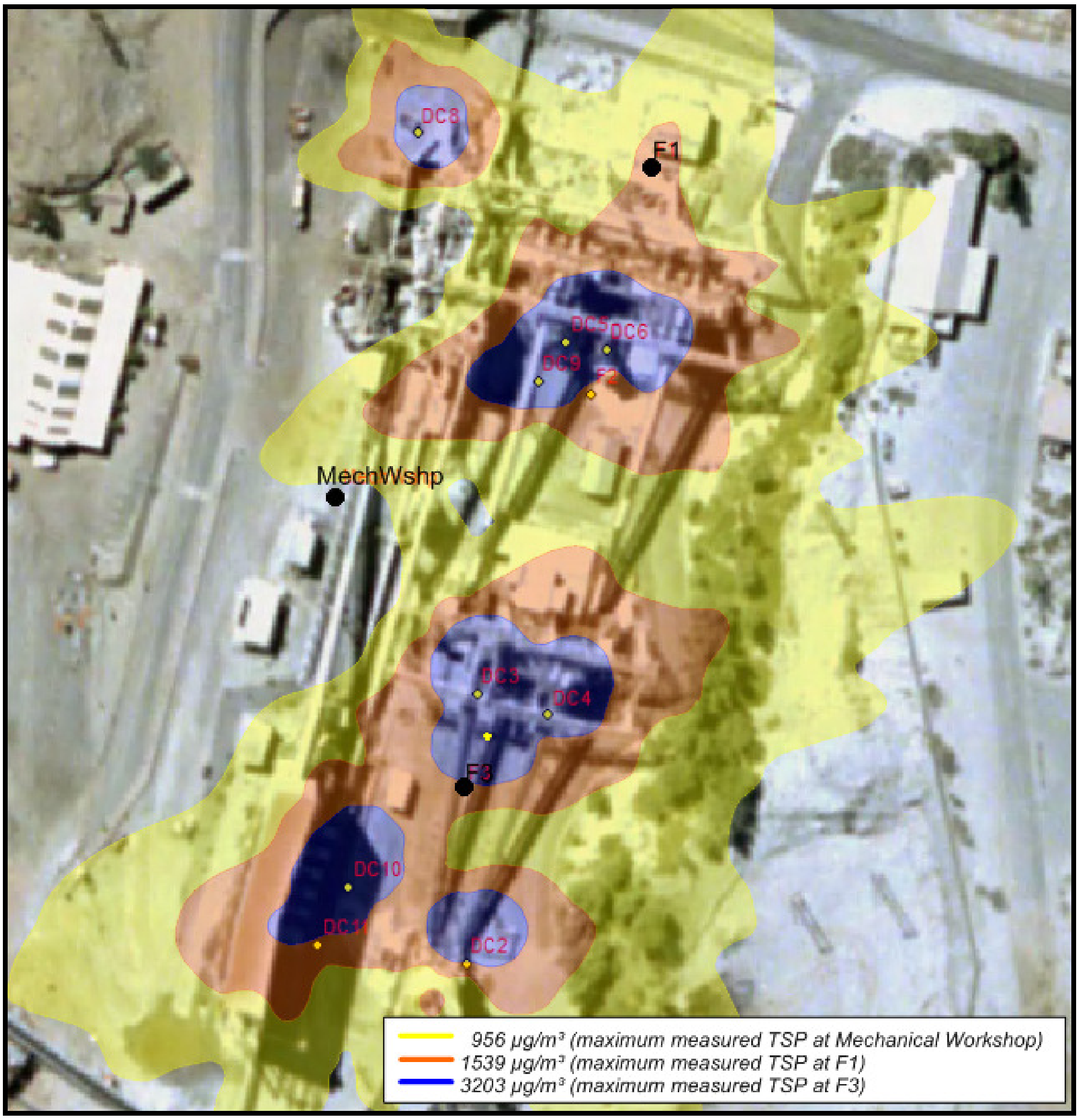

Figure 4-26: Predicted TSP ground level concentrations at the fine crusher, using as guidance measurements obtained for the period August 2009.

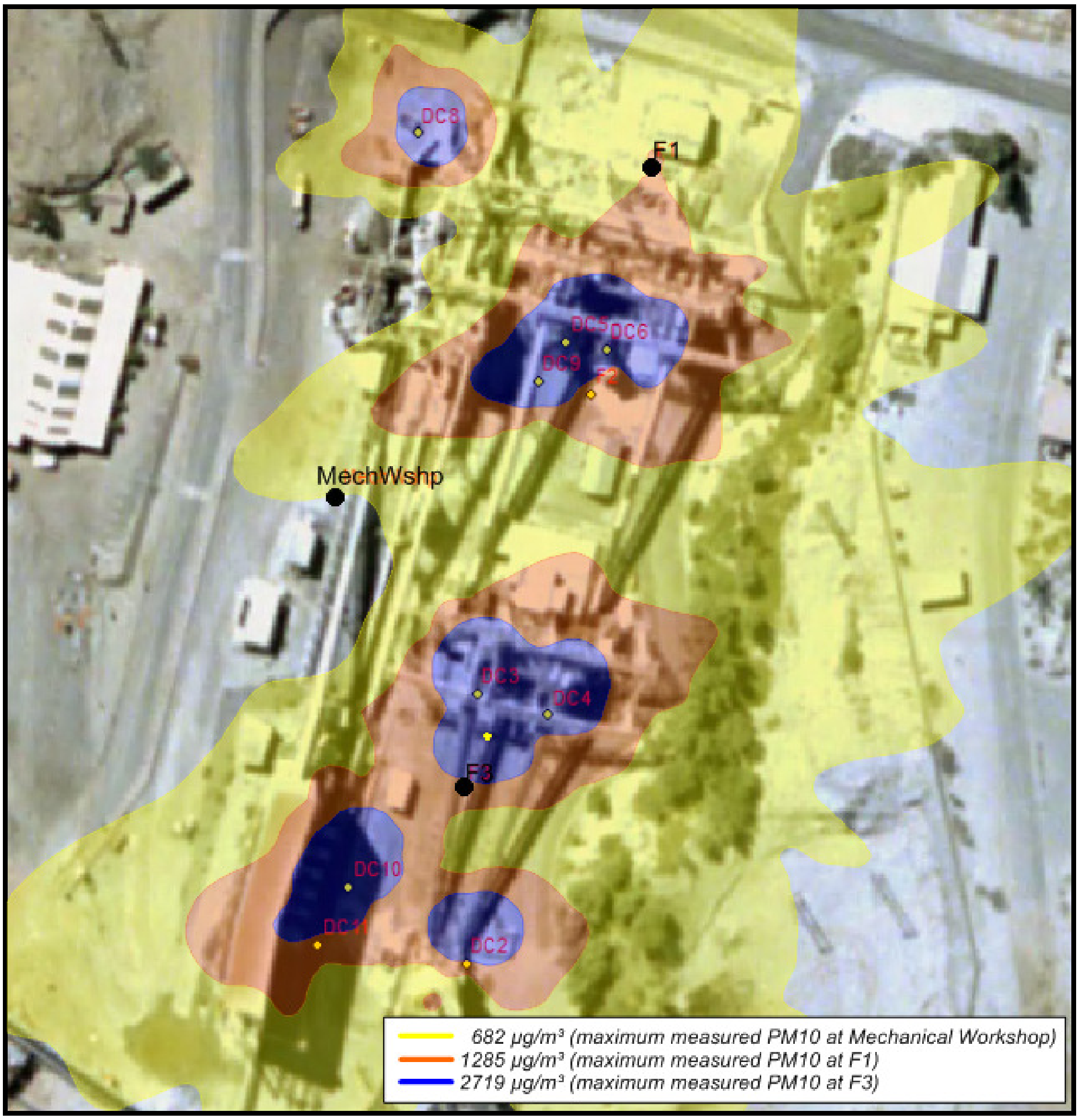

Figure 4-27: Predicted PM10 ground level concentrations at the fine crusher, using as guidance measurements obtained for the period August 2009.

4.2.2.8 Stacks

Currently Rössing Uranium Mine operates two roaster stacks, two scrubber stacks and one baghouse. The parameters required for the stacks for dispersion modelling purposes was provided by Rössing Uranium personnel (Table 4-18).

Table 4-18: Parameters and emission rates for the stack sources at Rössing Mine

Source name	Source Description	Latt (UTM)	Long (UTM)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temp (K)	Actual Gas Volumetric Flow (m^3/s)	Actual Gas Exit Velocity (m/s)	Run Time (Days)	Emission rate (g/s)	
										TSP	PM10
Roaster 1	Roaster Stack No.1	4693.7	-51420	23.055	0.47	458.85	0.86	4.94	214.9	9.20E-04	5.52E-04
Roaster 2	Roaster Stack No.2	4680.8	-51418	23.014	0.47	473.35	1.22	7.06	299.4	1.28E-03	7.69E-04
Scrubber 1	Scrubber Stack No.1 outlet	4698.8	-51410	25.958	0.43	344.15	1.87	13.9	214.9	4.75E-02	2.85E-02
Scrubber 2	Scrubber Stack No.2 outlet	4683.4	-51408	25.952	0.43	343.65	1.86	13.9	299.4	4.50E-02	2.70E-02
Baghouse	FPR Baghouse Stack	4683.4	-51433	23.136	0.6	312.95	4.67	16.5	365	1.07E-03	6.44E-04

4.2.2.9 Synopsis of Particulate Emissions from Various Sources at the Rössing Uranium Mine

TSP and PM10 emissions calculated for various source types are given in Table 4-19. Emissions from vehicle entrained dust on unpaved road surfaces represent the largest source of emissions, constituting ~84% of total TSP emissions. The second largest source of emissions is due to materials handling operations contributing ~10% of total TSP emissions.

Table 4-19: Calculated TSP and PM10 emissions (tpa) due to current routine operations at Rössing Mine

Sources	TSP	PM10	%TSP	%PM10	TSP RANK
Wind Erosion					
Tailings	98.22	21.07	0.433	0.171	5
Precipitates	58.39	23.49	0.257	0.191	9
Open Pit	73.3	25.77	0.323	0.210	6
P Stockpiles	3.29	1.49	0.015	0.012	17
Waste	54.86	10.1	0.242	0.082	10
Coarse Ore Stockpile	10.16	3.23	0.045	0.026	15
Coarse Ore Stockpile Plume	168.17	48.77	0.741	0.397	4
Fine Ore Stockpile Plume	3.48	1.4	0.015	0.011	16
Conveyor Plume	58.52	23.19	0.258	0.189	8
Mn Mill Area Road	29.20	17.25	0.129	0.140	12
Fine Ore Crusher Plume	0.53	0.35	0.002	0.003	19
Drilling and Blasting					
Drilling	18.70	9.73	0.082	0.079	14
Blasting	69.42	36.10	0.306	0.294	7
Material Handling					
Tipping	2381.28	997.19	10.495	8.109	2
Vehicle Entrainment					
Unpaved Roads	19157.69	10949.43	84.438	89.039	1
Paved Roads	432.55	82.86	1.906	0.674	3
Dozers and Graders					
Dozers and Graders	20.00	5.68	0.088	0.046	13
Fine Crushing Plant					
Crushing and screening	48.65	38.92	0.214	0.317	11
Stacks					
Stacks	2.13	1.28	0.009	0.010	18
TOTAL	**22688.55**	**12297.30**	**100.00**	**100.00**	

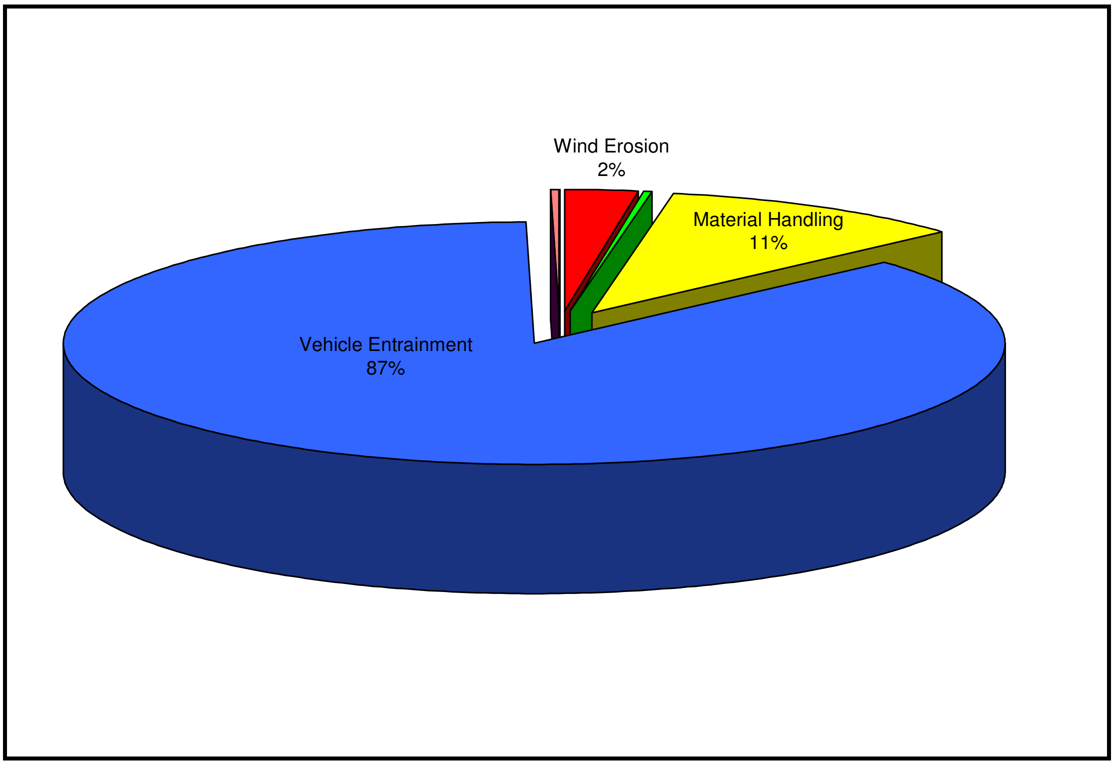

Figure 4-28: TSP emission contribution due to current routine operations

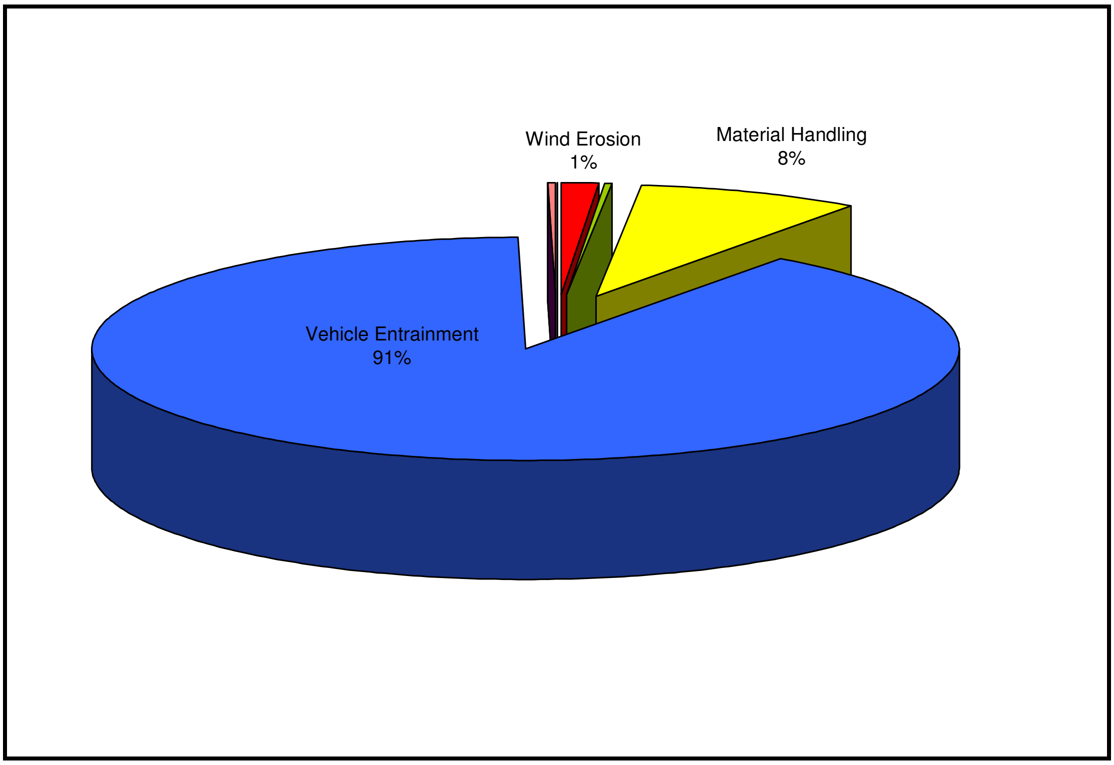

Figure 4-29: PM10 emission contribution due to current routine operations

4.2.2.10 Greenhouse Gas Emissions

The prevailing international scientific opinion on climate change is that human activities resulted in substantial global warming from the mid-20th century, and that continued growth in greenhouse gas concentrations caused by human-induced emissions would generate high risks of dangerous climate change.

The Intergovernmental Panel on Climate Change (IPCC) has predicted an average global rise in temperature of 1.4°C to 5.8°C between 1990 and 2100[1].

With global warming becoming a growing international concern, the Kyoto Protocol was initialised. The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at combating global warming. The UNFCCC is an international environmental treaty with the goal of achieving "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[2]

The Protocol was initially adopted on 11 December 1997 in Kyoto, Japan and entered into force on 16 February 2005. As of November 2009, 187 states have signed and ratified the protocol.[3]

Under the Protocol, 37 industrialized countries (called "Annex I countries"[4]) commit themselves to a reduction of four greenhouse gases (GHG) (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by them, and all member countries give general commitments. Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2% from the 1990 level. Emission limits do not include emissions by international aviation and shipping, but are in addition to the industrial gases, chlorofluorocarbons, or CFCs, which are dealt with under the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.

The benchmark 1990 emission levels were accepted by the Conference of the Parties of UNFCCC were the values of "global warming potential" calculated for the IPCC Second Assessment Report. These figures are used for converting the various greenhouse gas emissions into comparable CO_2 equivalents when computing overall sources and sinks.

The Protocol allows for several "flexible mechanisms", such as emissions trading, the clean development mechanism (CDM) and joint implementation to allow Annex I countries to meet their GHG emission limitations by purchasing GHG emission reductions credits from elsewhere, through financial exchanges, projects that reduce emissions in non-Annex I countries, from other Annex I countries, or from annex I countries with excess allowances.

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[1] http://www.grida.no/climate/ipcc_tar/wg1/339.htm

[2] The United Nations Framework Convention on Climate Change. http://unfccc.int/essential_background/convention/background/ items/1353.php.

[3] United Nations Framework Convention on Climate Change. 2009-01-14. http://unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification.pdf.

[4] Namibia, at this stage does not form part of the Annex I countries.

The GHG contributions due to Rössing Mine were provided for analysis (Figure 4-30). The base case operations, assuming no expansion is illustrated with the green bar chart. With proposed activities the total calculated CO_2 emissions in illustrated with the yellow bar chart.

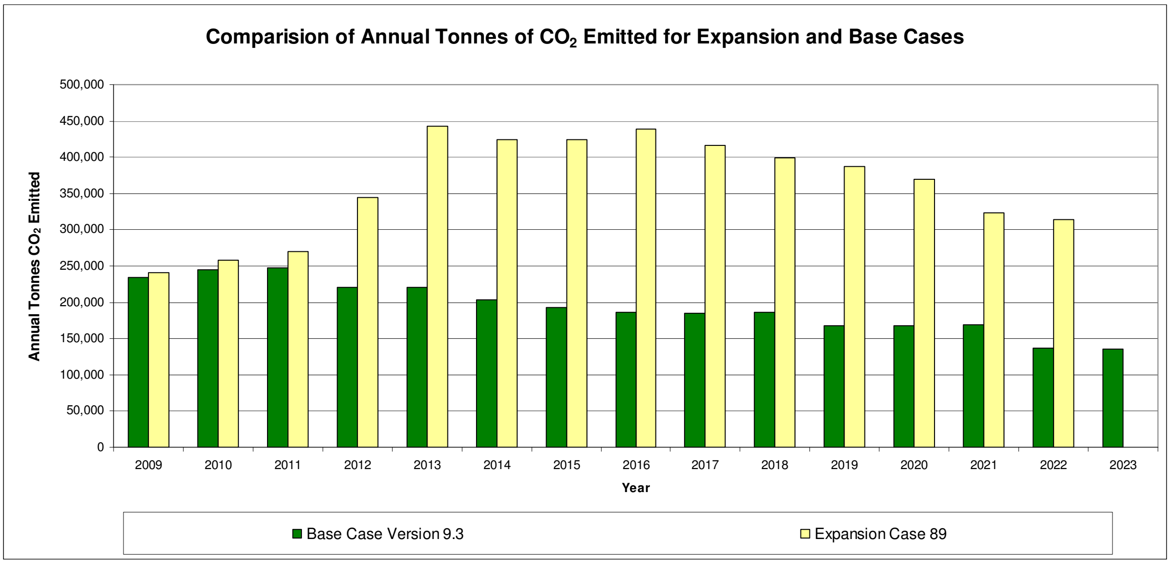

Figure 4-30: Annual CO_2 emissions due to Basecase (2010) and Expansion Case (year 2013)

The estimated carbon dioxide emissions from Rössing Mine for current operations for the year 2010 are ~0.258 million metric tons per year. This should be seen in the perspective of the annual Namibian and global emission rate of GHGs, which is ~2.83 million metric tons and 30 176.7 million metric tons, respectively expressed as carbon dioxide (CO_2) equivalent (Marland, et al. 2006). Rössing Mine's emissions therefore contribute approximately 9.1% of Namibia's GHG emissions and 0.0009% of global GHG emissions.

4.2.2.11 Radon Emissions

Rössing Uranium personnel provided exhalation rates (Table 4-20) for various radon sources at the mine (Figure 4-31). These sources were simulated with the aid of dispersion models and the impacts were provided to Radiological Specialists for further analysis.

Table 4-20: Exhalation rates for various radon sources (Basecase)

Facility	Subdivision	Sub-subdivision	Exhalation Rate (Bq/m^2/s)	Area	Name
Current tailings storage facility	Old benches		2.188	Tailings Benches	TAILB
	New benches				
	Paddies x,y,z		1.543	Tailings Beach yz & old beach	TAILYZ TAILOLD
	Operating paddies	dry proportion	1.263	Tailings operational beaches	TAILOP
		chemical precipitate areas			
		Moist proportion			
		Wet proportion			
Open Pit	Walls		0.773	Outline of open pit rim	PIT
	Benches				
	P Stockpiles		1.543	Stockpiles	PSTOCK
Rock dumps	Waste rock dumps		0.472	Waste	WASTE
	Low grade and high calc stockpiles		1.155	Low grade	LORE
Plant area	Contaminated areas A to I	A	0.975	A	A
		B	0.521	B	B
		C	1.493	C	C
		D	2.103	D	D
		E	2.922	E	E
		F	4.886	F	F
		G	0.961	G	G
		H	1.503	H	H
		I	0.507	I	I
	Coarse Ore stockpile		1.543	COS	COS
	Coarse ore stockpile plume		ignore		
	Fine ore stockpile		1.543	FOS	FOS
	Fine ore stockpile plume		ignore		
	Conveyor plume	C1 (along conveyor from primary crusher)	ignore		
		C2 (from COS to fine crusher)	ignore		
		C3 (from fine crusher to fine stockpile)	ignore		

Facility	Subdivision	Sub-subdivision	Exhalation Rate (Bq/m²/s)	Area	Name
	Manganese mill area road		ignore		

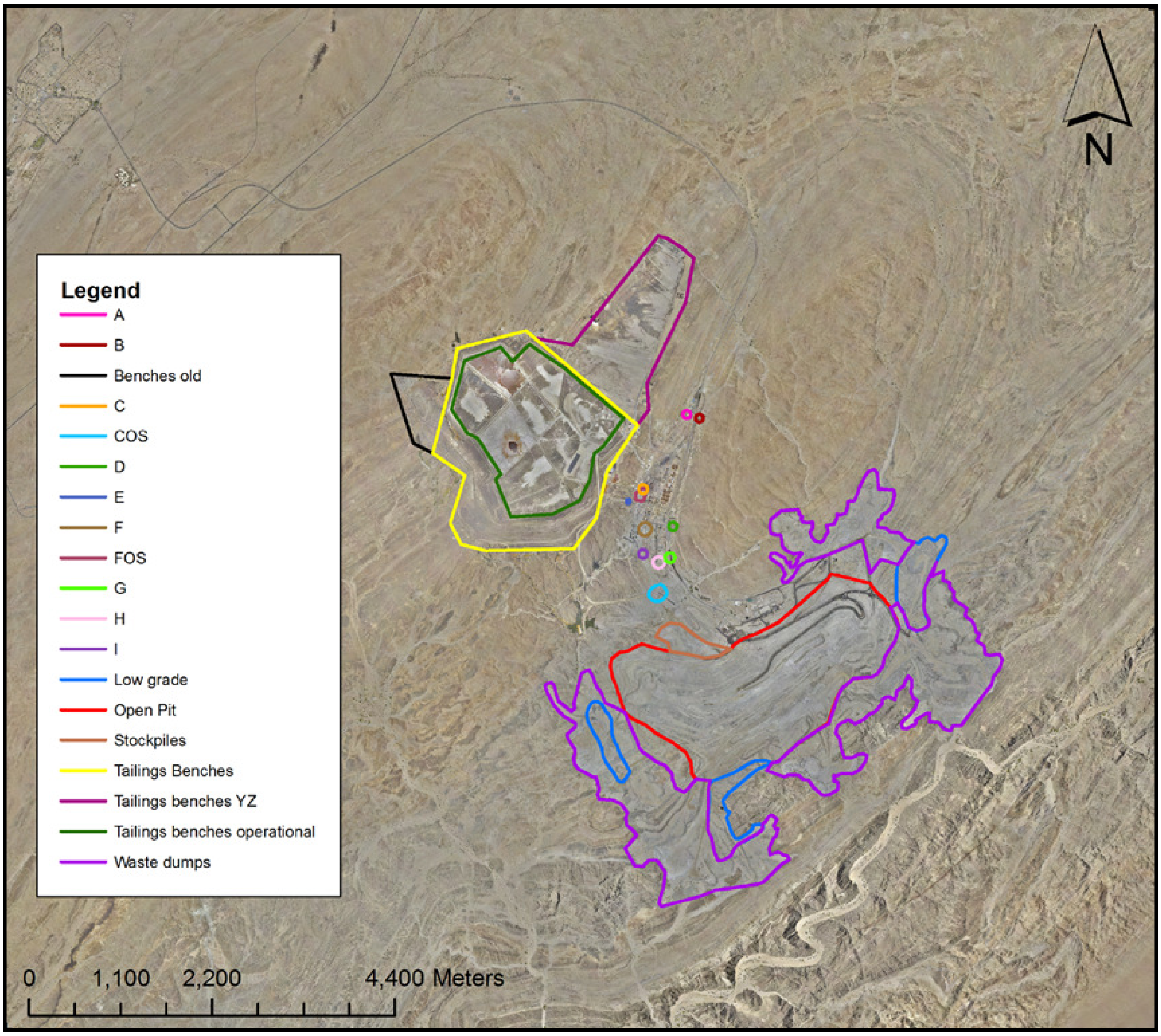

Figure 4-31: Radon sources identified for the Basecase scenario

4.2.3 Dispersion Simulation Results

Dispersion modelling was undertaken to determine highest daily and annual average PM10 ground level concentrations and dustfall levels from current routine operations. These averaging periods were selected to facilitate the comparison of predicted pollutant concentrations with relevant air quality guidelines and standards.

Ground level concentration isopleths presented in this section depict interpolated values from the concentrations predicted by Aermod for each of the receptor grid points specified. Plots reflecting daily averaging periods contain only the 99.9th percentile (selected for the analysis to eliminate any “spikes” in the data set) of predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily average concentration is predicted to occur at certain locations, that this may only be true for one day during the year.

The plots provided for the relevant pollutants of concern during the operational phase are given in Table 4-21. The PM10 daily impacts due to the largest contributing sources (i.e. vehicle entrainment, materials handling and wind erosion) are also included in the following section.

Table 4-21: Isopleth plots presented in the current section.

Scenario	Pollutant	Averaging Period	Figure
All Sources	PM10	Highest daily Frequency of exceedance of highest daily Annual average	4-32 4-36 4-37
	TSP	Maximum deposition	4-38
Vehicle Entrainment	PM10	Highest daily	4-33
Materials Handling	PM10	Highest daily	4-34
Wind Erosion	PM10	Highest daily	4-35

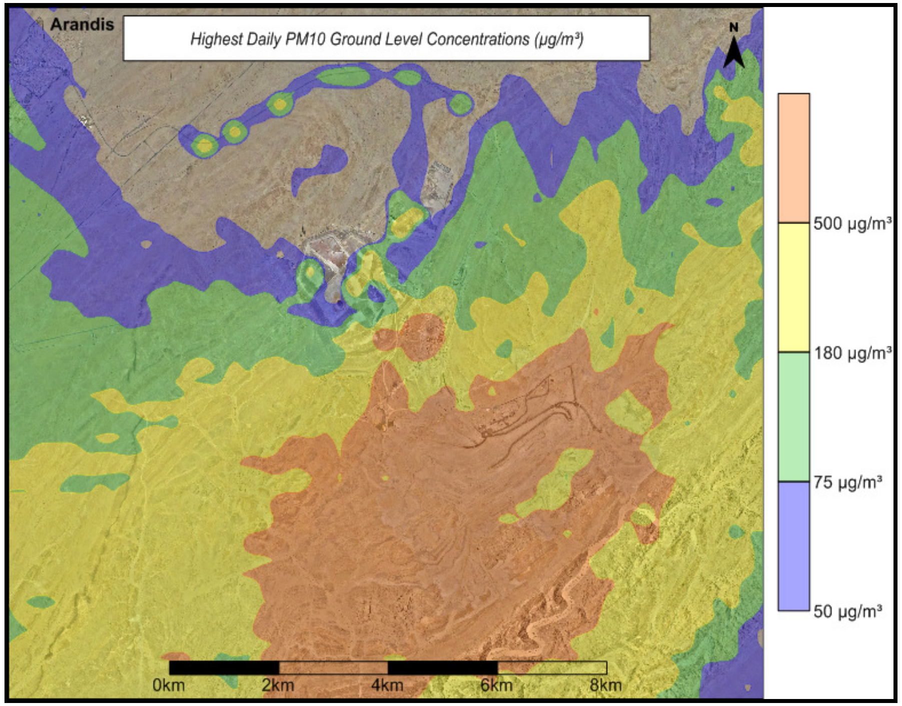

Figure 4-32: Highest daily PM10 ground level concentrations due to current (Basecase 2010) operations (all sources)

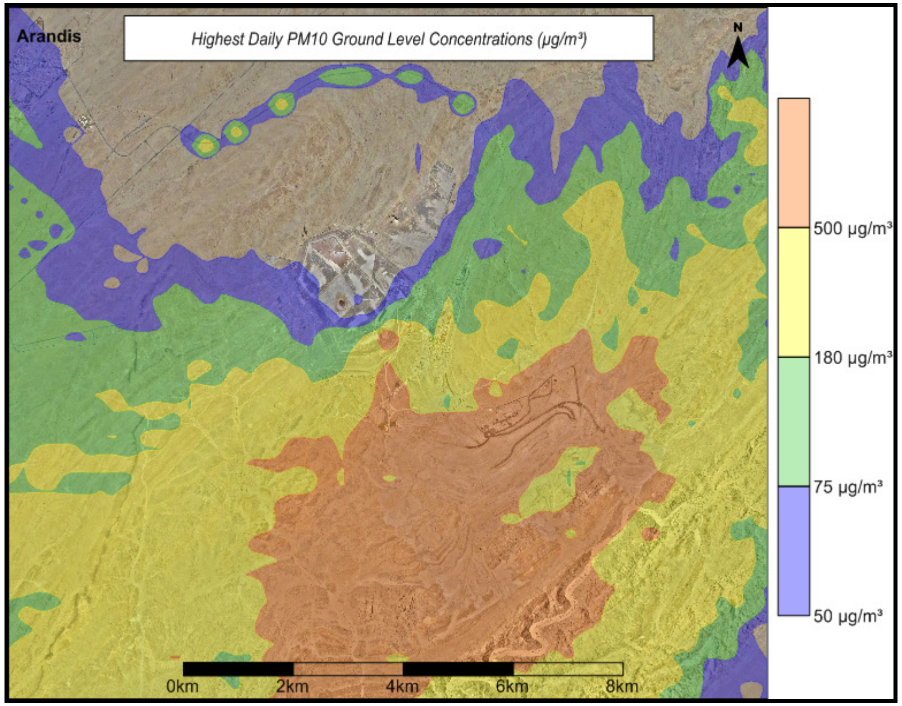

Figure 4-33: Highest daily PM10 ground level concentrations due to current vehicle entrainment sources

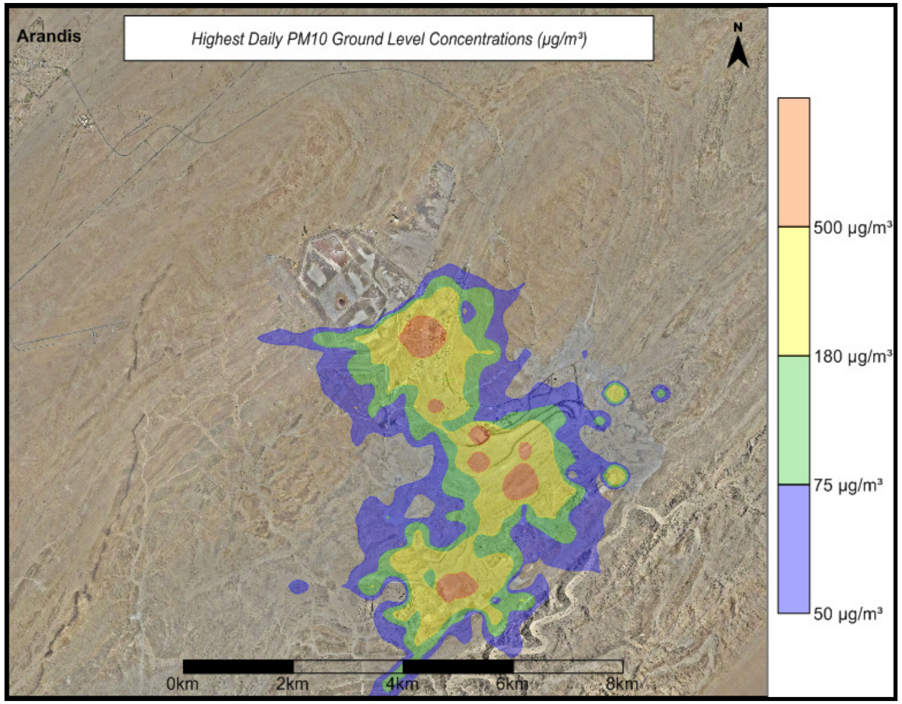

Figure 4-34: Highest daily PM10 ground level concentrations due to current materials handling sources

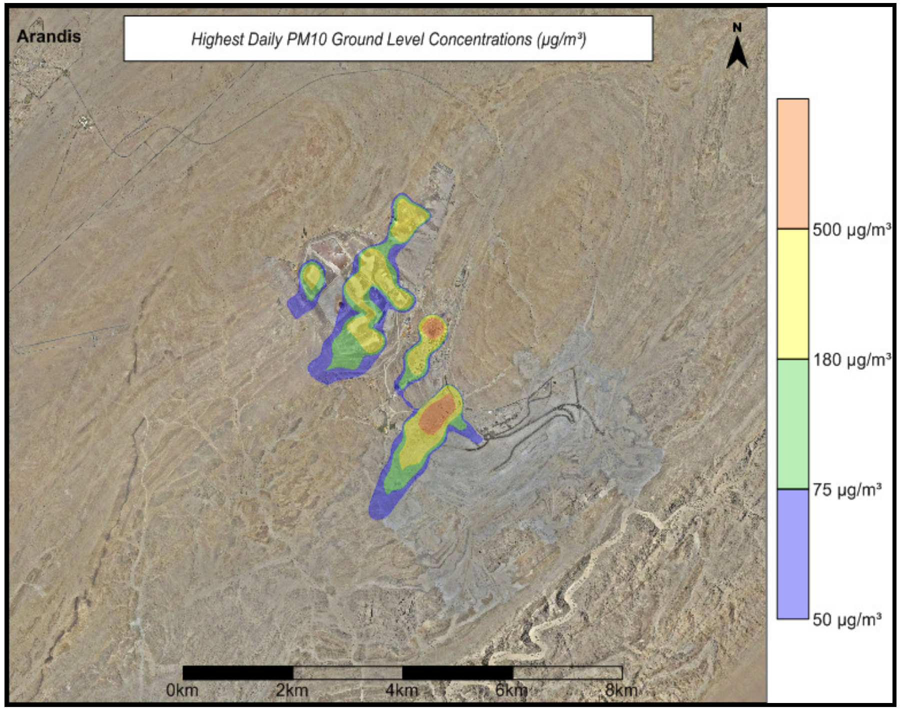

Figure 4-35: Highest daily PM10 ground level concentrations due to current wind erosion sources

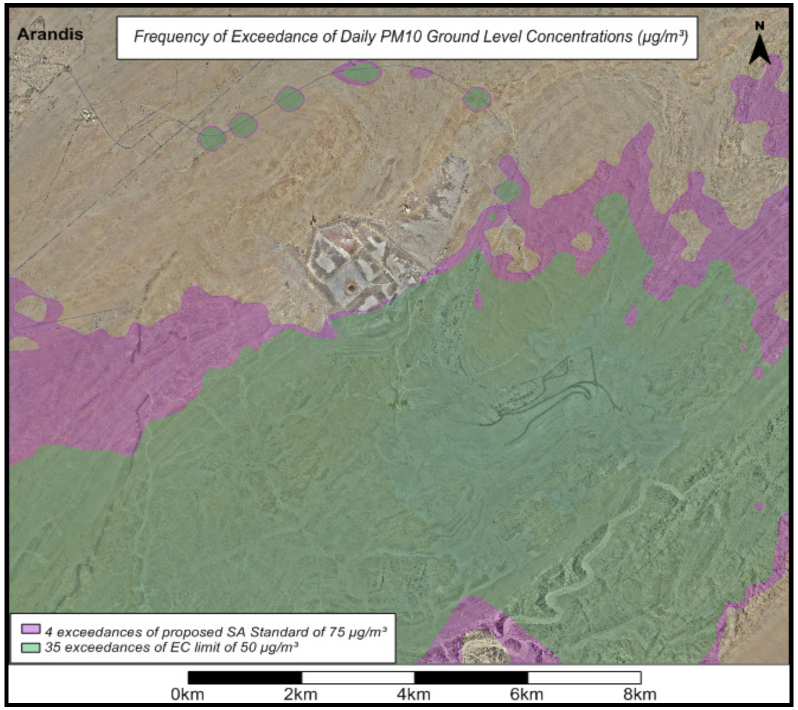

Figure 4-36: Frequency of exceedance of highest daily PM10 ground level concentrations due to current (Basecase 2010) operations (all sources)

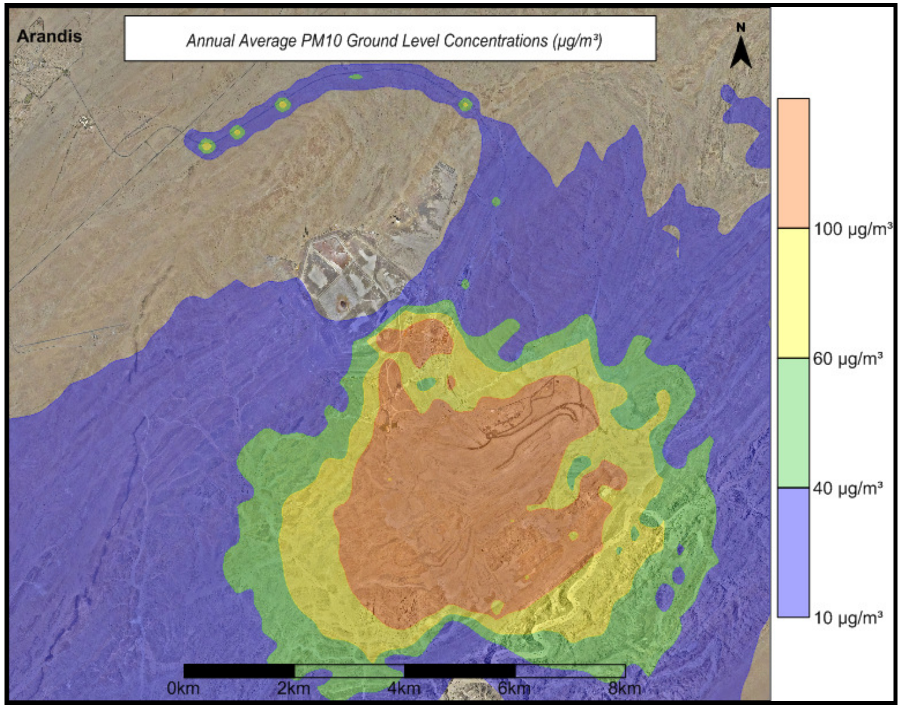

Figure 4-37: Annual average PM10 ground level concentrations due to current (Basecase 2010) operations (all sources)

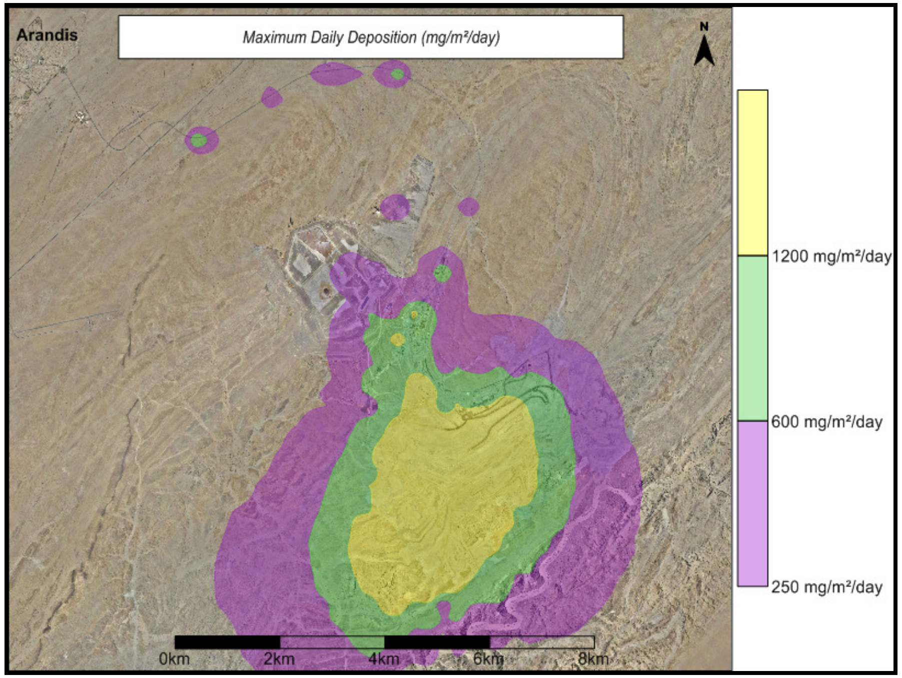

Figure 4-38: Maximum daily deposition due to current (Basecase 2010) operations (all sources)

4.2.4 Impact Assessment

Ambient air quality guidelines and standards aim to protect the health of the public and do not apply to on-site impacts that are covered by the occupational health and safety guidelines. Thus, the focus of the impact assessment is on the receptors where people reside, specifically including the residential receptor of Arandis.

This section focuses on potential impacts at human sensitive receptor sites close to the current mining activities. The Aermod model is able to model point, area, line and volume sources. The sources at the current development were grouped and modelled as follows:

In-pit operations (incl. drilling and blasting) – area sources
Vehicle entrainment – area sources
Materials handling – volume sources
Crushing– volume source
Wind erosion sources – area sources

4.2.4.1 Inhalable Particulate Matter of less than 10µm (PM10)

The highest daily and annual average PM10 ground level concentrations for current routine operations are provided in Table 4-22 (with particular reference to the sensitive receptor of Arandis).

Highest predicted daily ground level concentrations due to routine operations at Rössing Mine are 480 µg/m³ at the mine boundary exceeding all relevant ambient guidelines. The predicted off-site annual average PM10 ground level concentrations at the mine boundary (56 µg/m³) exceed all relevant ambient guidelines.

At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing Basecase operations are 73 µg/m³ which is within the US-EPA guideline and SA Limits but exceeds the WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year. The frequency of exceedance of the EC daily limit at the sensitive receptor of Arandis is predicted to be 2. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m³) is well within all relevant ambient guidelines.

The main contributing sources to highest daily PM10 concentrations are vehicle entrainment (Figure 4-33) with the second highest contributing source being materials handling (Figure 4-34).

Table 4-22: Highest predicted PM10 concentrations directly off-site due to routine Basecase (2010) operations at Rössing Mine(a)

Highest Daily				Annual Average			In compliance (Y/N)
Predicted conc. µg/m³	Guideline µg/m³	Factor of guideline	Frequency of Exceedance (days/year)	Predicted conc. µg/m³	Guideline µg/m³	Factor of guideline	
At Mine Boundary							
480	150 (b)	**3.20**	40	56	-	-	N
	120 (c)	**4.00**	56		50 (c)	**1.12**	N
	75 (d)	**6.40**	90		40 (d)(f)	**1.40**	N
	50 (e)(f)	**9.60**	125		20 (e)	**2.80**	N
At the sensitive receptor of Arandis							
73	150 (b)	0.49	0	5.4	-	-	Y
	120 (c)	0.61	0		50 (c)	0.11	Y
	75 (d)	0.97	0		40 (d)(f)	0.14	Y
	50 (e)(f)	**1.46**	2		20 (e)	0.27	Y

Note:

(a) Exceedance of the guideline is provided in bold

(b) US-EPA guideline not to be exceeded more than 1 day/year

(c) Current SA Limit (compliance data – immediate to 31 December 2014) not to be exceeded more than 4 days/year

(d) Proposed SA Limit (compliance data – 1 January 2015) not to be exceeded more than 4 days/year

(e) WHO guideline

(f) EC limit not to be exceeded more than 35 days/year. It should be noted that the EC stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit

4.2.4.2 Dust Deposition

The predicted maximum deposition directly off-site due to current routine operations at Rössing is below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas) (Table 4-23).

Table 4-23: Predicted maximum dust fallout (TSP) off-site due to routine operations at Rössing Mine [(a)]

Highest total daily dust fallout		
Max deposition (mg/m²/day)	Guideline mg/m²/day	Factor of guideline
At Mine Boundary		
250	1 200 (b) 600 (c)	0.21 0.42
At the sensitive receptor of Arandis		
13	1 200 (b) 600 (c)	0.01 0.02

Note:
(a) Exceedance of the guideline is provided in bold
(b) Upper limit for SANS for industrial areas
(c) SANS limit for residential areas and lower limit for industrial areas

4.2.5 Easterly Wind Episode

The highest hourly PM10 ground level concentrations and hourly dust depositions for a high easterly wind episode (9 June 2004) was simulated (Figure 4-39 and Figure 4-42 respectively). The highest on-site hourly PM10 concentration due to Rössing MIne operations only was predicted to be 10612 µg/m³. The main contributing sources to the predicted PM10 concentrations are wind erosion (Figure 4-40) and vehicle entrainment (Figure 4-41).

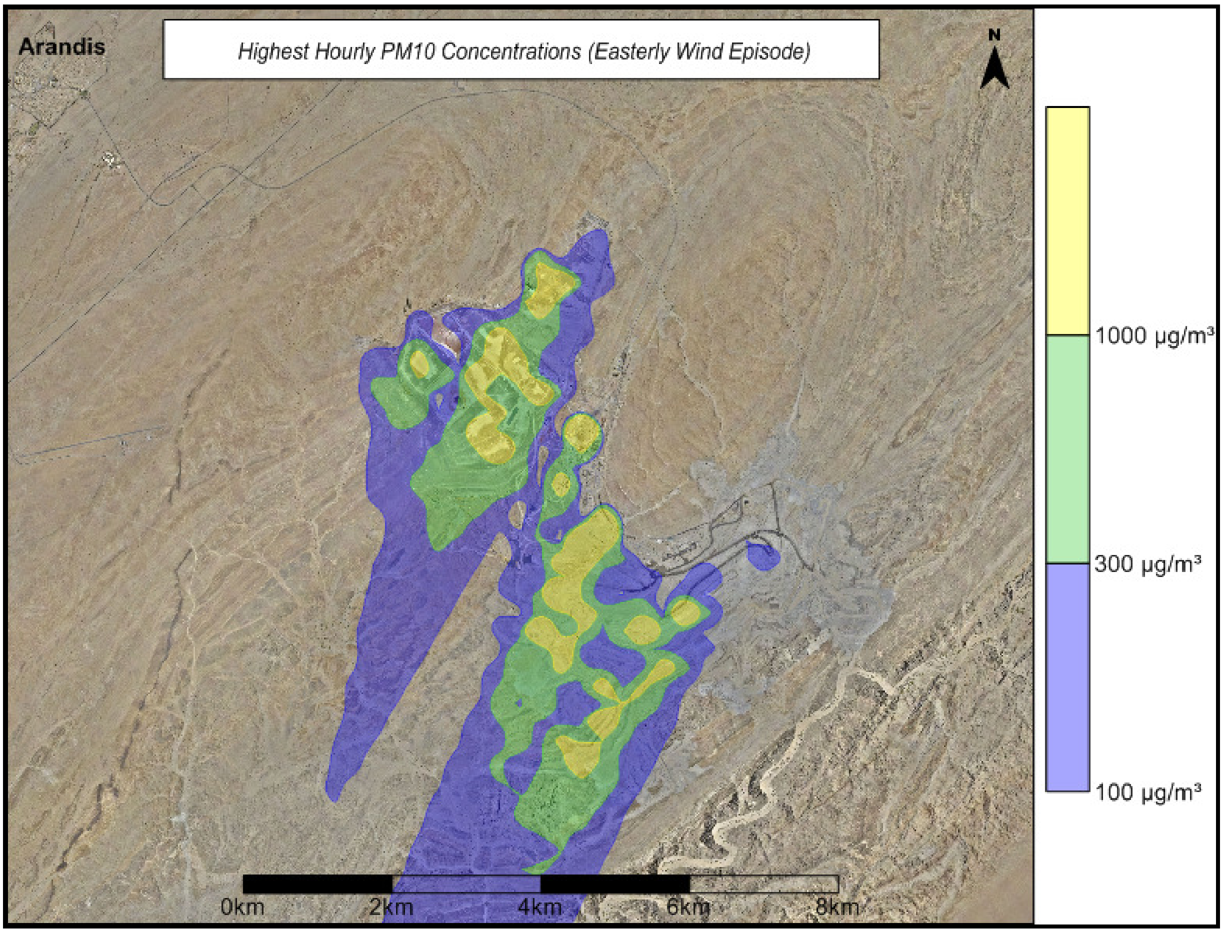

Figure 4-39: Highest hourly PM10 ground level concentrations due to current Rössing Uranium operations as modelled for a high easterly wind episode (9 June 2004)

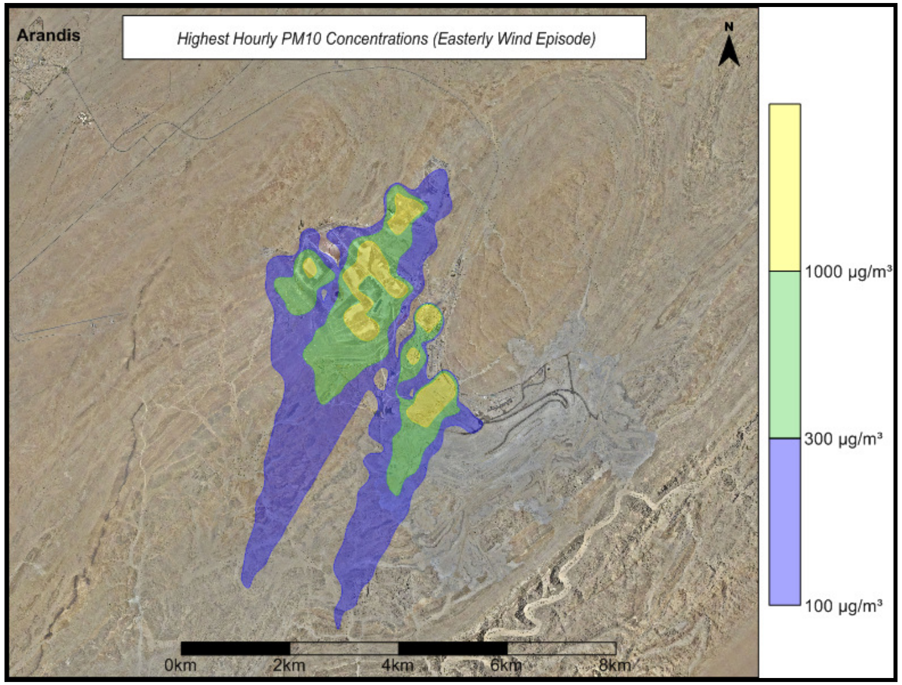

Figure 4-40: Highest hourly PM10 ground level concentrations due to current wind erosion sources as modelled for a high easterly wind episode (9 June 2004)

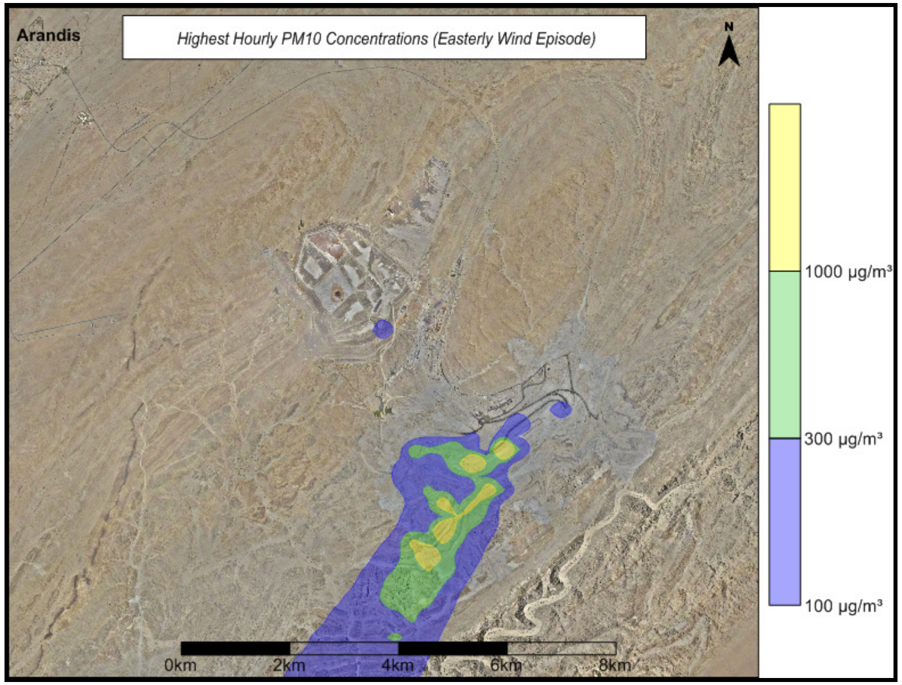

Figure 4-41: Highest hourly PM10 ground level concentrations due to Rössing vehicle entrainment sources as modelled for a high easterly wind episode (9 June 2004)

The highest hourly dust deposition rate for a high easterly wind episode (9 June 2004) is provided in Figure 4-42. The highest on-site hourly dust deposition due to Rössing Mine operations only was predicted to be 3915 mg/m²/hr. The main contributing sources to the predicted deposition are wind erosion (Figure 4-43) and vehicle entrainment (Figure 4-44).

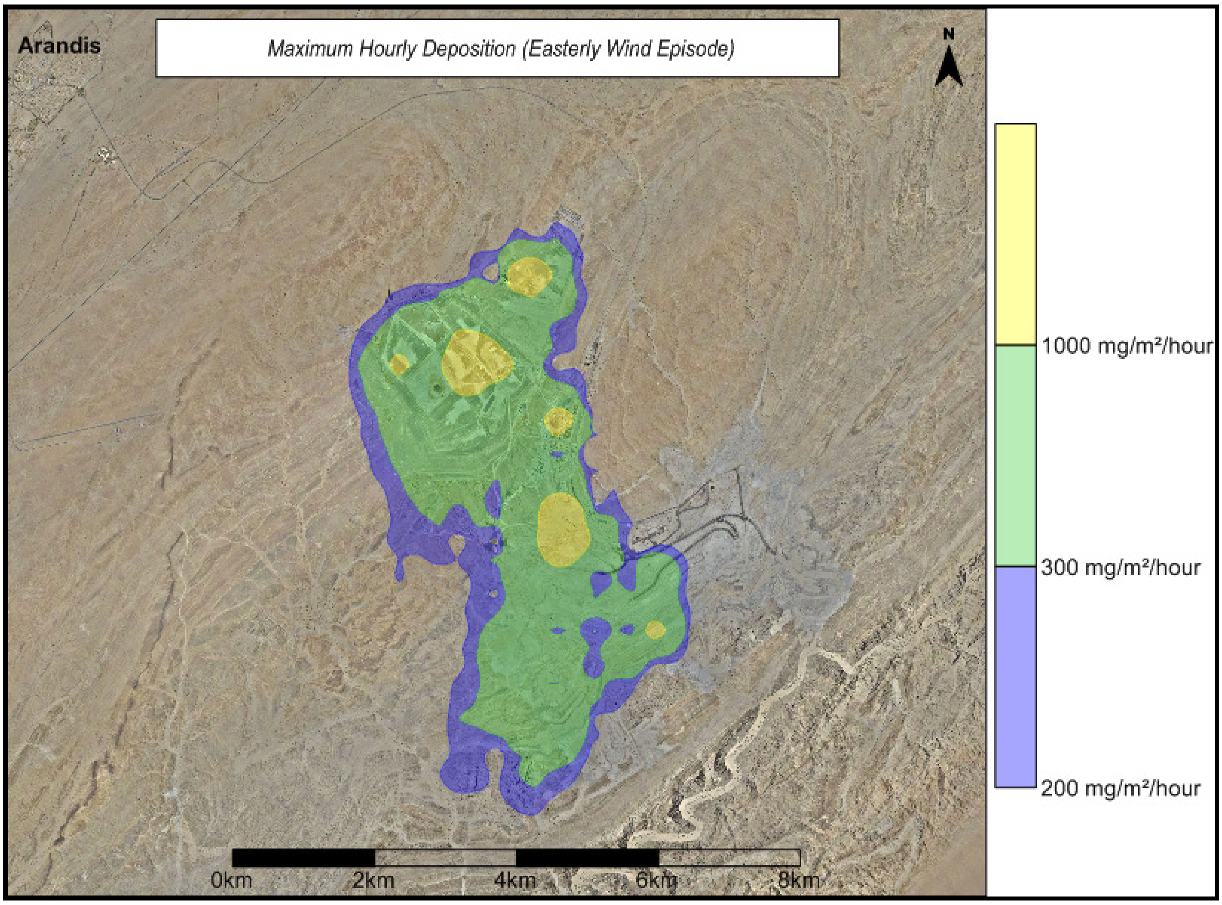

Figure 4-42: Highest hourly dust deposition due to current operations as modelled for a high easterly wind episode (9 June 2004)

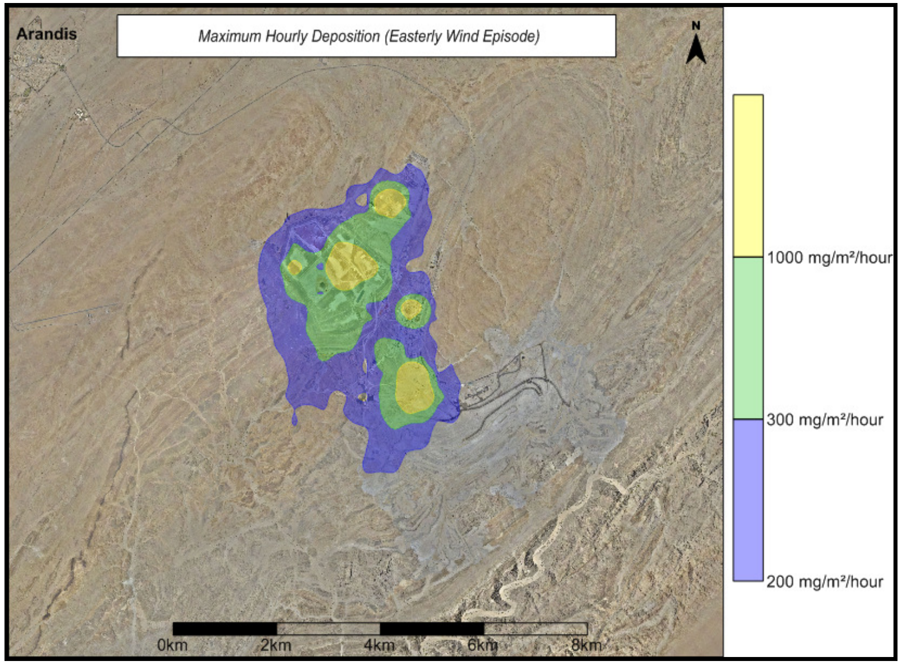

Figure 4-43: Highest hourly dust deposition due to current wind erosion sources at Rössing Mine as modelled for a high easterly wind episode (9 June 2004)

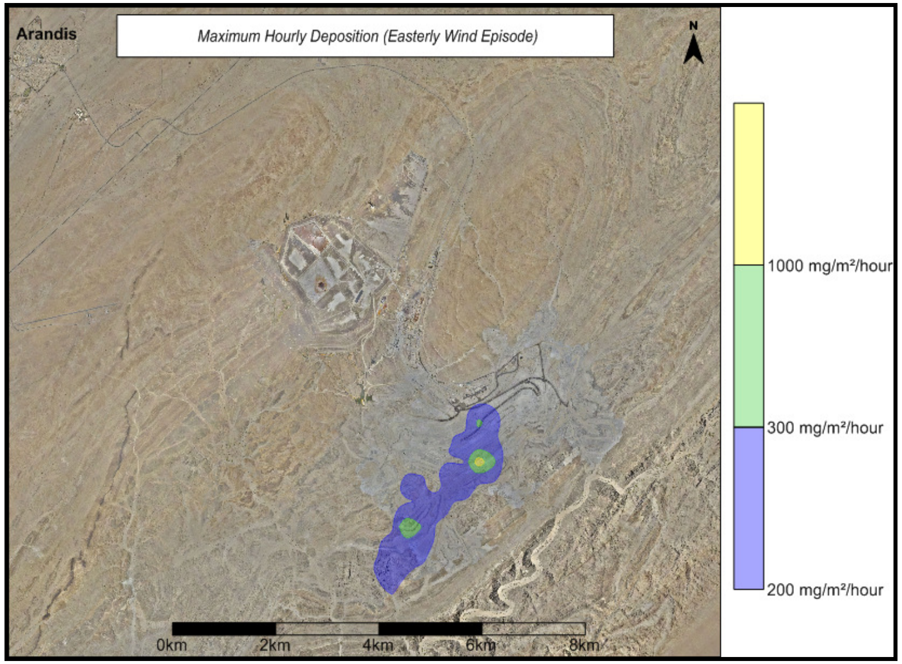

Figure 4-44: Highest hourly dust deposition due to current vehicle entrainment sources at Rössing Mine as modelled for a high easterly wind episode (9 June 2004)

5. EMISSIONS INVENTORY FOR THE PROPOSED EXPANSION PROJECT FACILITIES ASSESSED IN THE PHASE 2 SEIA

5.1 Construction Phase

The construction phase normally comprises a series of different operations including land clearing, material loading and hauling, grading, bulldozing, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. For the Heap Leach Pad construction activities, Rössing Uranium personnel provided detailed information (Table 5-1 and Figure 5-1).

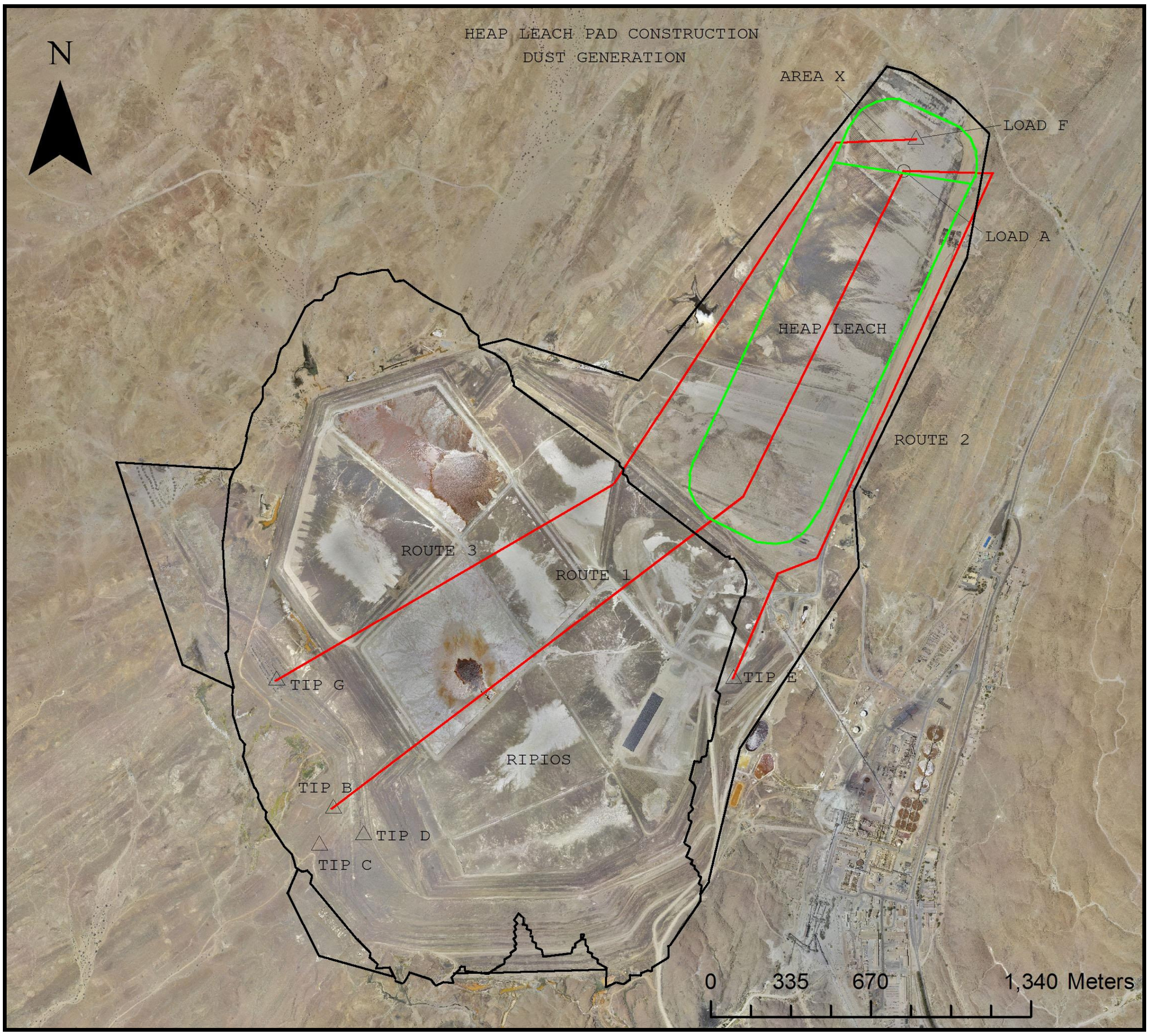

Figure 5-1: Heap Leach Pad construction dust generation sources

Table 5-1: Material Movements During the Construction of a 60 Day Heap Leach Pad

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	Location / Route and Additional Comments (See image of heap leach pad for actual locations)
Operations to do with sand												
1)	Excavate fines from pad and load onto tipper truck	2,231,519	1.8	4,016,734	17,166	12	234	143				Whole Pad area (445,284 m^2). Load A, points over whole pad area
	Transport fines from pad	2,231,519	1.8	4,016,734	17,166		234		15	267,782	1,144	Route 1 from Pad (Load Point A) to Tip Point B (3,670m)
	Tip fines	2,231,519	1.8	4,016,734	17,166		234					Tip point B
	Screen fines	2,231,519	1.8	4,016,734	17,166		234					At tip point B
	Tip fines to "Good" Pile	1,338,911	1.8	2,410,041	10,299		234					Tip Point C
	Tipe Fines to "Bad" Pile	892,608	1.8	1,606,694	6,866		234					Tip Point D
	Grade pad											Whole Pad area (445,284 m^2)

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	Location / Route and Additional Comments (See image of heap leach pad for actual locations)
1)	Load good fines + additional good fines	16,301	1.8	29,342	1,129	2	26	56				From Tip point C (assume all fines come from this point as current alternative source location is not known)
	Transport Fines Back to Pad	16,301	1.8	29,342	1,129		26		15	1,956	75	From Tip point C to whole pad Area (assume as Route 1 and 3,670m)
	Tip fines on pad (single layer)	16,301	1.8	29,342	1,129		26					Whole Pad area (445,284 m^2)
	Grade Fines											Whole Pad area (445,284 m^2)
	Compact Fines											Whole Pad area (445,284 m^2)

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	Location / Route and Additional Comments (See image of heap leach pad for actual locations)
Operations to do with placing aggregate												
2)	Mine RoM											Assume this operation is part of the existing mining process
	Load RoM											Assume this operation is part of the existing mining process
	Transport RoM											Assume this operation is part of the existing mining process
	Tip RoM into new primary crusher											Assume this operation is part of the existing mining process

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	Location / Route and Additional Comments (See image of heap leach pad for actual locations)
2)	Convey aggregate on belt to sampler location (adjacent to new agglomeration plant)											Conveyor route from primary crusher to tip point D. This operation is identical to that used for the expansion case mining operation.
	Tip aggregate at sampler	534,341	1.55	828,229	3,982		208					Tip point E
	Load aggregate at sampler to trucks	534,341	1.55	828,229	3,982	8	208	50				Tip Point E
	Transport aggregate to pad area	534,341	1.55	828,229	3,982		208		15	55,215	265	Route 2 (Total length 2800m) from sampler discharge to load point A (points over whole pad area)
	Tip aggregate over pad area (1 layer 100mm deep)	48,576	1.55	75,294	362		208					Whole pad area

2)	Grade pad area											Whole pad

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	Location / Route and Additional Comments (See image of heap leach pad for actual locations)
												area
	Tip aggregate over pad area (4 layers 1,100mm deep)	485,765	1.55	752,935	3,620		208					Whole Pad Area
	Compact pad area (light compaction only)											Whole Pad Area
Other operations to do with pad preparation												
3a)	Blast hard rock	395,212	1.7	671,860	12,920		52					Pad Area X
	Load hard rock	395,212	1.7	671,860	12,920	11	52	117				Load Point F
	Transport hard rock	395,212	1.7	671,860	12,920		52		25	44,791	861	Route 3 (3670m) From Load Point F to tip point G
	Tip hard rock	395,212	1.7	671,860	12,920		52					Tip point G
3b)	Rip softer rock	790,424	1.7	1,343,721	12,920		104					Pad Area X
	Load softer rock	790,424	1.7	1,343,721	12,920	11	104	117				Load Point F
	Transport softer rock	790,424	1.7	1,343,721	12,920		104		25	89,581	861	Route 3 From Load Point F to Tip point G
	Tip softer rock	790,424	1.7	1,343,721	12,920		104					Tip Point G
3c)	Construct haul roads											Assume construction of routes 1,2 and 3

Description of Steps Required for Heap Leach Pad Preparation		Material Volume (m^3)	Density (t/m^3)	Tonnes	Tonnes Moved Daily	No. of Shovels	Total Time Required (days)	Shovel Load Rate (tonnes/hour)	Truck Payload (tonnes)	Truck Cycles	Truck Cycles/Day	**Location / Route and Additional Comments** (See image of heap leach pad for actual locations)
3c)	Grade haul roads											Once per week
	Water haul roads and load/tip points											Routes twice per day + load and tip points
	Ancillary vehicle traffic (fuel, maintenance, supervision)											Assume 8 return trips * 3km =48km daily each bakkie (x20) gives total 960km daily

The vehicle fleet for the construction operations (as provided by Rössing Uranium personnel) is given in Table 5-2.

Table 5-2: Typical vehicle fleet for the construction operations

Item	Quantity	Description	Make & Model	Operating weight (tonnes)	Unladen Wt (tonnes)	Laden Weight (tonnes)	Payload (tonnes)
1	8	Bulldozer	Komatsu D65	21			
2	8	Wheeled Loader	Komatsu WA140	7.5			
3	8	Grader	Cat 14H	15.1			
4	10	Compactor	Bomag 212	14.5			
5	4	Water Tanker 7000litre	M/Benz	12			7
6	10	Water Tanker 14000litre	M/Benz	24			14
7	11	Excavator 30 ton	Daewoo	30			
8	5	Excavator 40 ton	Daewoo	40			
9	55	Tipper Truck (12m^3)	M/Benz		10	25	15
10	15	Articulated Dump Truck	Bell ADT		19	46	25
11	20	Bakkies		2			
12	1	Truck		7			
13	3	Tractor Trailers					

The calculated emissions due to the construction operations are provided in Table 5-3.

5.2 Operational Phase

The proposed expansion case (Phase 2) will comprise of:

- Extension of the current mining activities in the existing SJ open pit;
- Increased waste rock disposal capacity;
- Establishing an additional fine crushing plant;
- Increased tailings disposal capacity;
- Establishing an acid heap leaching facility; and
- Ripios stockpile.

The emissions inventory for the proposed operations (which include the expansion (Phase 2 SEIA) operations for the highest production year 2013) forms the focus of the current section.

5.2.1 Fugitive Dust Emissions from Materials Handling Operations

Materials handling operations associated with proposed activities at Rössing Mine for the Expansion Case (in the year 2013) were provided by Rössing personnel (Table 5-4).

Table 5-3: Calculated emissions due to construction activities

Description of Steps Required for Heap Leach Pad Preparation	Emission Factor (TSP)	Emission Factor (PM10)	Units	Source of Emission Factor	TSP Emissions (Total tonnes)	PM10 Emissions (Total tonnes)	TSP Emissions (tonnes/day)	PM10 Emissions (tonnes/day)
Operations to do with sand								
Excavate fines from pad and load onto tipper truck	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	10.320	4.881	0.044	0.021
Transport fines from pad	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	6129.396	1887.471	26.194	8.066
Tip fines	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	10.320	4.881	0.044	0.021
Screen fines	E=0.08	E=0.06	kg/t	Australian Npi	321.339	241.004	1.373	1.030
Tip fines to "Good" Pile	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	6.192	2.929	0.026	0.013
Tipe Fines to "Bad" Pile	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	4.128	1.952	0.018	0.008
Grade pad	E=0.0034 x s^2.5	E=0.0034 x s^2.0	kg/VKT	Australian Npi	0.081	0.023		
Load good fines + additional good fines	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	0.075	0.036	0.003	0.001
Transport Fines Back to Pad	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	44.775	13.788	1.722	0.530

Description of Steps Required for Heap Leach Pad Preparation	Emission Factor (TSP)	Emission Factor (PM10)	Units	Source of Emission Factor	TSP Emissions (Total tonnes)	PM10 Emissions (Total tonnes)	TSP Emissions (tonnes/day)	PM10 Emissions (tonnes/day)
Tip fines on pad (single layer)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	0.075	0.036	0.003	0.001
Grade Fines	E=0.0034xs^2.5; E=0.0034 x s^2.0	E=0.0034xs^2.5; E=0.0034 x s^2.0	kg/VKT	Australian Npi	0.081	0.023		
Operations to do with placing aggregate								
Tip aggregate at sampler	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	2.128	1.006	0.010	0.005
Load aggregate at sampler to trucks	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	2.128	1.006	0.010	0.005
Transport aggregate to pad area	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	964.244	296.927	4.636	1.428
Tip aggregate over pad area (1 layer 100mm deep)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	0.193	0.091	0.001	0.000
Grade pad area	E=0.0034 x s^2.5	E=0.0034 x s^2.0	kg/VKT	Australian Npi	0.081	0.023		
Tip aggregate over pad area (4 layers 1,100mm deep)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	1.934	0.915	0.009	0.004
Other operations to do with pad preparation								
Blast hard rock	E=0.00022A^1.5	E=0.00022A^1.5*0.52	kg/blast	US-EPA	13.761	7.156		
Load hard rock	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	1.726	0.816	0.033	0.016

Description of Steps Required for Heap Leach Pad Preparation	Emission Factor (TSP)	Emission Factor (PM10)	Units	Source of Emission Factor	TSP Emissions (Total tonnes)	PM10 Emissions (Total tonnes)	TSP Emissions (tonnes/day)	PM10 Emissions (tonnes/day)
	k=0.74)							
Transport hard rock	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	1382.363	425.681	26.584	8.186
Tip hard rock	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	1.726	0.816	0.033	0.016
Rip softer rock	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	3.452	1.633	0.033	0.016
Load softer rock	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	3.452	1.633	0.033	0.016
Transport softer rock	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	2764.725	851.363	26.584	8.186
Tip softer rock	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.74)	E=k x 0.0016 x (U/2.2)^1.3 x (M/2)^-1.4 (where k=0.35)	kg/t	Australian Npi	3.452	1.633	0.033	0.016
Construct haul roads								
Grade haul roads	E=0.0034 x s^2.5	E=0.0034 x s^2.0	kg/VKT	Australian Npi	1.444	0.411	0.019	0.005
Ancillary vehicle traffic (fuel, maintenance, supervision)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=4.9, a=0.7 and b=0.45)	E=k(s/12)^a x (W/3)^b x 281.9 (where k=1.5, a=0.9 and b=0.45)	g/VKT	US-EPA	26.395	8.128	0.056	0.017

W: Mean vehicle weight

s: silt content (%)
U: mean wind speed (m/s
A: area blasted (m^2)
M: mean moisture content

Table 5-4: Parameters and calculated particulate matter emissions for material handling sources for the Expansion Case (year 2013)

Description	Name	Annual Tonnage of Ore Material Passing Through Point	Annual Tonnes Tailings to be Distributed at Each Point	% Moisture	Control Efficiency (%)	TSP (tpa)	PM10 (tpa)	X	Y
Material (tailings sand dressing) loaded at the tailings dam for use as dressing for roads, loading and tipping areas	HDTSL	1,129,971		2.05	0	4	1	7663	-47550
Phase 2 in Pit (RUL)	P2L	20,000,000	135,226	0.67	0	335	117	5422	-53423
Phase 2 to Waste	W2TP2	5,300,000	35,835	0.67	0	89	31	4255	-55157
Phase 2 to LG	LG5TP2	2,000,000	13,523	0.67	0	33	12	3543	-53472
Phase 3 in Pit	P3L	30,000,000	202,839	0.67	0	502	176	6093	-53598
Phase 3 to Waste	W2TP3	20,800,000	140,635	0.67	0	348	122	4892	-55557
Phase 3 to LG	LG5TP3	3,000,000	20,284	0.67	0	50	18	3599	-53722
Phase 4 in Pit	P4L	28,000,000	189,317	0.67	0	469	164	6583	-52401
Phase 4 to Waste	W7TP4	21,200,000	143,340	0.67	0	355	124	7998	-53395
Phase 4 to LG	LG7TP4	2,800,000	18,932	0.67	0	47	16	8215	-52723
Reclaimed from ROM Stockpiles	ROML	9,750,000	65,923	0.67	0	163	57	4825	-52723
Tipped at ROM "P" Stockpiles	ROMT	3,550,000	24,003	0.67	0	59	21	4661	-52755
Ore crusher	CrushT	14,000,000	67,642	0.67	50	118	41	5417	-52901
Ore crusher	CrushT2	15,000,000	72,474	0.67	50	126	44	5372	-52868
Manganese Offloading Point	MnMT	21,000		0.33	0	1	0	4490	-50980
Coarse Ore Stockpile	COSTR	14,000,000		0.67	0	232	81	4650	-52313

Description	Name	Annual Tonnage of Ore Material Passing Through Point	Annual Tonnes Tailings to be Distributed at Each Point	% Moisture	Control Efficiency (%)	TSP (tpa)	PM10 (tpa)	X	Y
	1								
Coarse Ore Stockpile	COSTR2	15,000,000		0.67	0	249	87	4371	-52297
Fine Ore Stockpile	FOSTR	14,000,000		0.32	0	654	229	4353	-51142

The PM10 fraction of the TSP was assumed to be 35%. Hourly emission rates, varying according to the wind speed, were used as input in the dispersion simulations.

The predictive US-EPA equation was used to estimate emissions from materials handling operations is provided in Section 4.2.2.1.

The materials handling points for the Expansion Case (year 2013) is illustrated in Figure 5-2.

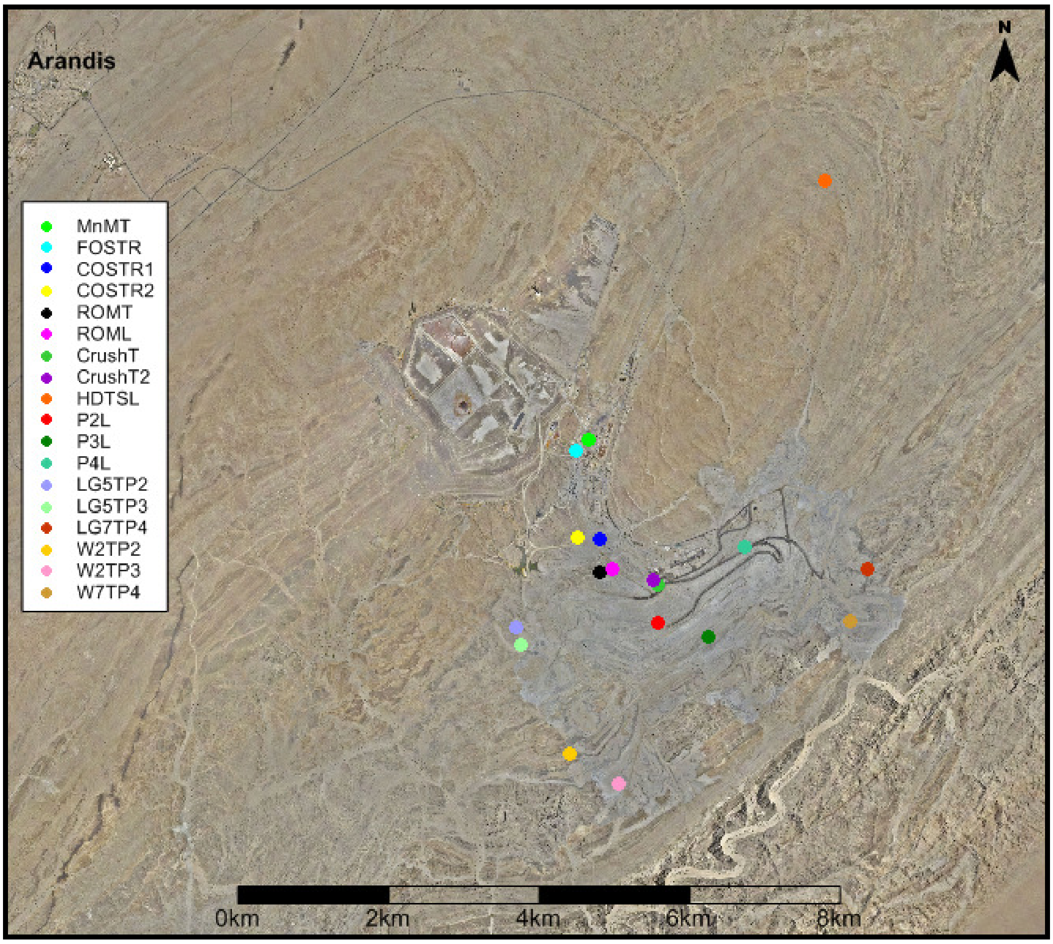

Figure 5-2: Location of materials handling points for the Expansion Case (2013)

5.2.2 *Wind Erosion*

A detailed description of the ADDAS model utilised to calculate emissions from this fugitive dust source is provided in Section 4.2.2.2.

Numerous samples were taken at Rössing Mine in order to assist in the quantification of these fugitive dust sources. The particle size sample analysis as well as moisture content and bulk density are given in Table 4-8. For the proposed ripios material, Rössing Uranium supplied a particle size distribution profile that was determined based on a based on a crushing experiment for the economic feasibility for heap Leach that was conducted (Figure 5-3). Small size fraction (<1mm), however, could not be determined and the data was therefore extrapolated to determine the smaller size fractions (Table 5-5).

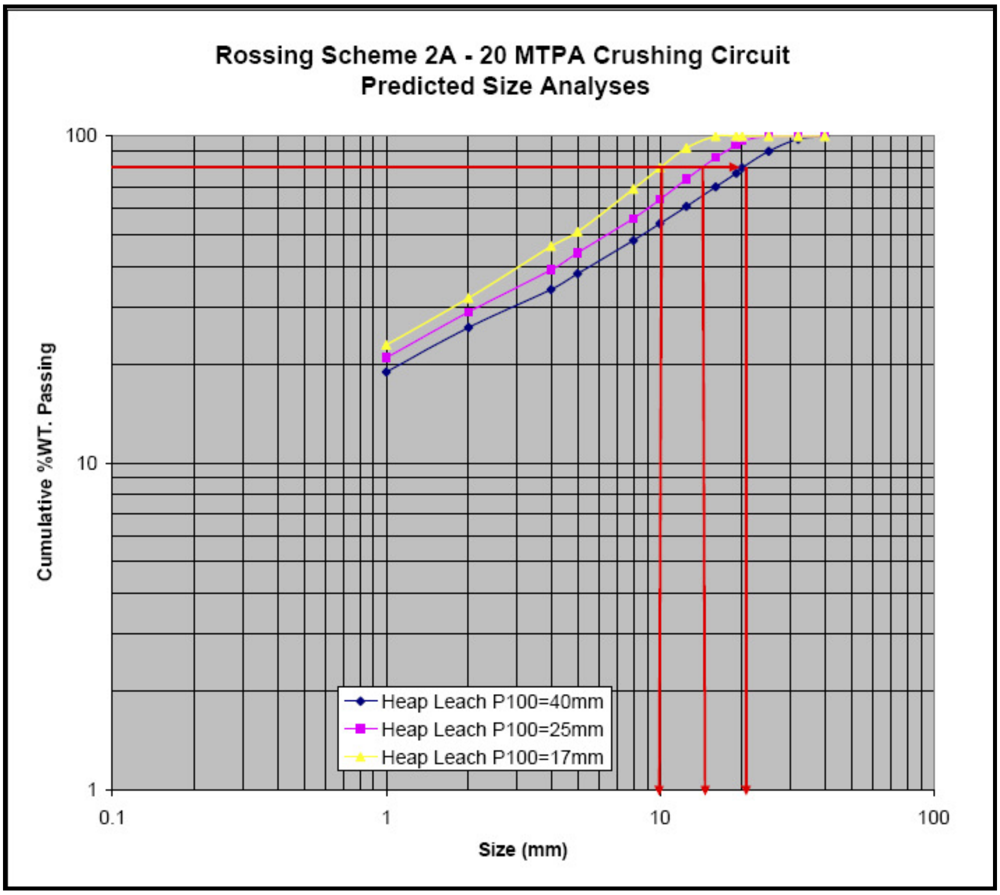

Figure 5-3: **Predicted particle size distribution for the ripios material**

Table 5-5: **Extrapolated particle size distribution for the ripios material**

Particle Size (µm)	Fraction
40000	0.0000
32000	0.0200
25000	0.0800
20000	0.1000
19000	0.0300
16000	0.0700
12500	0.0900
10000	0.0700
8000	0.0600
5000	0.1000
4000	0.0400
2000	0.0800
1000	0.0700
100	0.1289
75	0.0078

Particle Size (µm)	Fraction
30	0.0189
15	0.0097
10	0.0043
5	0.0057
2	0.0146

The wind erosion sources as provided by Rössing are illustrated in Figure 5-4. The parameters required to calculate the emissions from the Rössing Mine, as provided by Rössing personnel, are provided in Table 5-6.

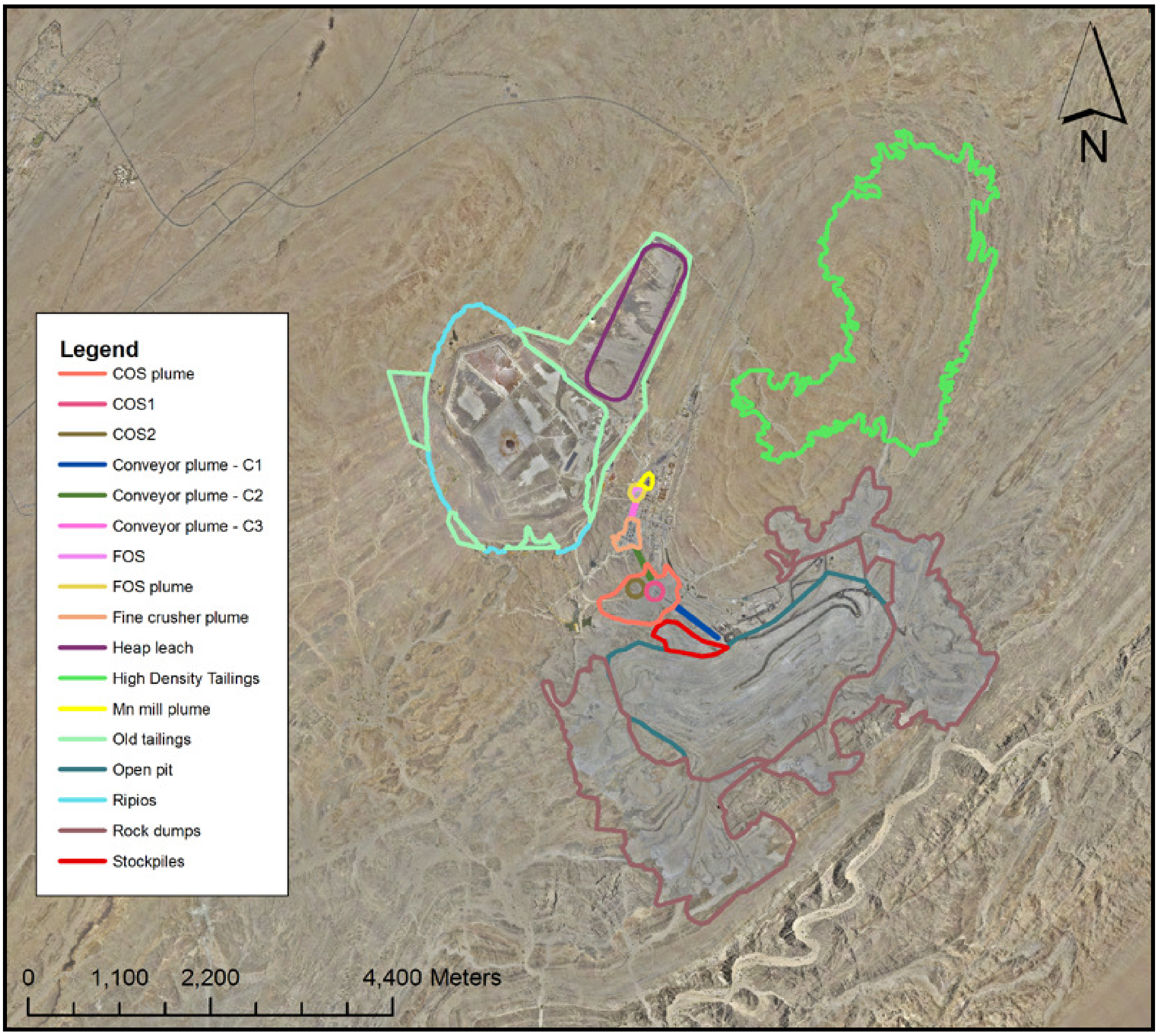

Figure 5-4: Wind erosion sources for the Expansion Case (2013)

As part of the air quality assessment, an alternative for the position of the proposed Tailings and Ripios stockpiles were also assessed. The detailed assessment of this alternatives is provided in Appendix C.

Table 5-6: Parameters provided by Rössing Uranium to calculate emissions due to wind erosion

Facility	Subdevision	Sub-subdevision	Sample	Area [a]	Percentage >1.18mm	Reference for percentage >1.18mm	Crusting (mm)	Name code
New high density tailings facility on the dome	Dry		#9-12	High density tailings	32.04	SGS lab results	4	HDTAIL
Open pit	Benches		#4	Open pit	98.8	ROM particle size distribution [b]	0	PIT
	P Stockpiles		#5	Stockpiles			0	STOCKP
Rock dumps	Waste rock dumps		EnviroSolutions, 2001 - "waste"	Rock dumps			0	WASTE
	Low grade and high calc stockpiles							
Plant area	Coarse Ore stockpile		#6	COS1	95	Assumption	0	COS1
	Coarse ore stockpile plume			COS plume	6.67	SGS lab results	4	COSP
	Fine ore stockpile plume		#7	FOS plume	21.48	SGS lab results	1	FOSP
	Conveyor plume	C1 (along conveyor from primary crusher)	#1	C1	0.27	SGS lab results	0	C1
		C2 (from COS to fine crusher)	#2	C2	0.12	SGS lab results	0	C2
		C3 (from fine crusher to fine stockpile)	#3	C3	0.15	SGS lab results	0	C3
	Manganese mill area road		#20	Mn Mill Plume	20.51	SGS lab results	0	MN
	Fine ore crusher		#14	Fine crushing plume	31.53	SGS lab results	0	FOCP
	New coarse ore stockpile		#6	COS2	95	Assumption	0	COS2
Ripios Pile			[c]	Ripios	65	Assumption	0	RIPIOS
Old tailings			#9-12	Old tailings	32.04	SGS lab results	4	TAIL

Notes:

(a) Plot layouts of the wind erosion sources were provided by Rössing personnel

(b) Run Of Mine (ROM) particle size distribution was provided by Rössing personnel

(c) Scheme 2 Based Mesto 20MTPA PSD - 20 November 2008.pdf (provided by Rössing)

5.2.3 Vehicle-Entrained Emissions from Unpaved Roads

Vehicle-entrained dust emissions from unpaved haul roads represent a significant source of fugitive dust as predicted for current routine operations. For proposed operations Rössing Uranium provided information that was required to calculate emissions due to vehicle entrainment on unpaved road surfaces (Appendix B).

The unpaved road size-specific emission factor equation of the US-EPA is provided in Section 4.2.2.3.

5.2.4 Vehicle-Entrained Emissions from Paved Roads

The quantity of dust emitted from vehicle traffic on paved roads was estimated based on the EPA emission equation (discussed in Section 4.2.2.4).

Rössing Uranium provided the parameters required for the quantification of this source (Table 5-7).

Table 5-7: Parameters provided to calculate emissions from vehicle entrainment on paved road surfaces for the expansion case

Scenario	No of trips per day (K94 Buss)	No of trips per day (K114 Buss)	No of trips per day (Mini Buss)	K94 Buss weight full (t)	K114 Buss weight full (t)	Mini Buss weight full (t)	Basil Read Buss weight full (t)	Basil Read Mini Buss weight full (t)	Ave Weight (t)
Week day	71	35	6	21.5	24.5	7.4	13.6	7.4	21.4
Week-end	38	30	4	21.5	24.5	7.4	13.6	7.4	22.0

5.2.5 Graders

Emission factors, published by the Australia National Pollutant Inventory (NPi) for the quantification of fugitive dust emissions due to grading were used in the quantification of these emissions. These emission factors are provided in Section 4.2.2.5.

The parameters required to calculate the emissions from the fugitive dust source were provided by Rössing personnel (Table 7 and Table 8 in Appendix B).

5.2.6 Blasting and Drilling Operations

Drilling and blasting operations for the expansion case were assumed to be similar in magnitude and nature to current operations. A detailed discussion on the quantification of these sources is provided in Section 4.2.2.6.

5.2.7 Fine Crushing Plant

A detailed discussion on the quantification of the emission from the fine crusher plant due to current operations is discussed in Section 4.2.2.7. For the expansion case it was provided that an additional fine crusher plant would be located in proximity to the existing fine crusher plant.

It was provided that the quantity of ore through both fine crusher plants would be 29 000 000 tpa. The quantity of ore through the current fine crusher plant was assumed to remain at 13 000 000 tpa with 16 000 000 tpa ore moving through the proposed fine crusher plant. The emissions through the proposed fine crusher were therefore adjusted to reflect the increase in production through the plant.

5.2.8 Stacks

The proposed emissions at the roaster stacks, scrubber stacks and baghouse currently operated at Rössing Mine is provided in Table 5-8.

5.2.9 Synopsis of Particulate Emissions from Various Proposed Sources at the Rössing Uranium Mine

TSP and PM10 emissions calculated for various source types are given in Table 5-9 and illustrated in Figure 5-5 and Figure 5-6 respectively. Emissions from vehicle entrained dust on unpaved road surfaces represent the largest source of emissions, constituting ~74% of total TSP emissions. The second largest source of emissions is due to materials handling operations contributing ~18% of total TSP emissions.

It should be noted that the highest emission sources do not always necessarily provide the highest impacts. The emissions should thus be assessed in conjunction with the impact predicted in order to identify the main sources of pollution from operations.

5.2.10 Greenhouse Gas Emissions

The GHG contributions due to Rössing Uranium's expansion case are provided Figure 4-30. The estimated carbon dioxide emissions from Rössing Mine for the expansion case for the year 2013 (which projects the highest CO_2 emissions) is ~0.443 million metric tons per year. When this is assessed in terms of the annual Namibian and global emission rate of GHGs, which is ~2.83 million metric tons and 30 176.7 million metric tons respectively expressed as carbon dioxide (CO_2) equivalent (Marland, et al. 2006), Rössing's contribution is approximately 15.65% of Namibia's GHG emissions and 0.0015% of global GHG emissions.

Table 5-8: Proposed parameters and emission rates for the stack sources at Rössing Mine

Source name	Source Description	Latt (UTM)	Long (UTM)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temp (K)	Actual Gas Volumetric Flow (m^3/s)	Actual Gas Exit Velocity (m/s)	Run Time (Days)	Emission rate (g/s)	
										TSP	PM10
Roaster 1	Roaster Stack No.1	4693.7	-51420	23.055	0.47	458.85	0.86	4.94	313.2	9.20E-04	5.52E-04
Roaster 2	Roaster Stack No.2	4680.8	-51418	23.014	0.47	473.35	1.22	7.06	330.0	1.28E-03	7.69E-04
Scrubber 1	Scrubber Stack No.1 outlet	4698.8	-51410	25.958	0.43	344.15	1.87	13.9	313.2	4.75E-02	2.85E-02
Scrubber 2	Scrubber Stack No.2 outlet	4683.4	-51408	25.952	0.43	343.65	1.86	13.9	330.0	4.50E-02	2.70E-02
Baghouse	FPR Baghouse Stack	4683.4	-51433	23.136	0.6	312.95	4.67	16.5	365	1.07E-03	6.44E-04

Table 5-9: Calculated TSP and PM10 emissions (tpa) due to the Expansion Case (year 2013) at Rössing Mine

Sources	TSP	PM10	%TSP	%PM10	TSP RANK
Wind Erosion					
High Density Tailings	90.23	19.36	0.502	0.221	6
Tailings	38.05	8.16	0.212	0.093	12
Open Pit	73.3	25.77	0.408	0.294	7
P Stockpiles	3.29	1.49	0.018	0.017	17
Waste	61.93	11.4	0.344	0.130	10
Coarse Ore Stockpiles	20.32	6.46	0.113	0.074	14
Coarse Ore Stockpile Plume	248.64	72.1	1.383	0.823	4
Fine Ore Stockpile Plume	3.48	1.4	0.019	0.016	16
Conveyor Plume	58.52	23.19	0.325	0.265	11
Mn Mill Area Road	29.20	17.25	0.162	0.197	13
Ripios	69.53	28.09	0.387	0.321	8
Fine Ore Crusher Plume	0.53	0.35	0.003	0.004	20
Drilling and Blasting					
Drilling	18.70	9.73	0.104	0.111	15
Blasting	69.42	36.10	0.386	0.412	9
Material Handling					
Tipping	3181.82	1319.28	17.697	15.067	2
Vehicle Entrainment					
Unpaved Roads	13376.95	6985.84	74.401	79.783	1
Paved Roads	521.13	99.84	2.898	1.140	3
Graders					
Graders	1.62	0.48	0.009	0.005	19
Fine Crushing Plant					
Crushing and screening	110.24	88.19	0.613	1.007	5
Stacks					
Stacks	2.66	1.60	0.015	0.018	18
TOTAL	**17979.58**	**8756.07**	**100.00**	**100.00**	

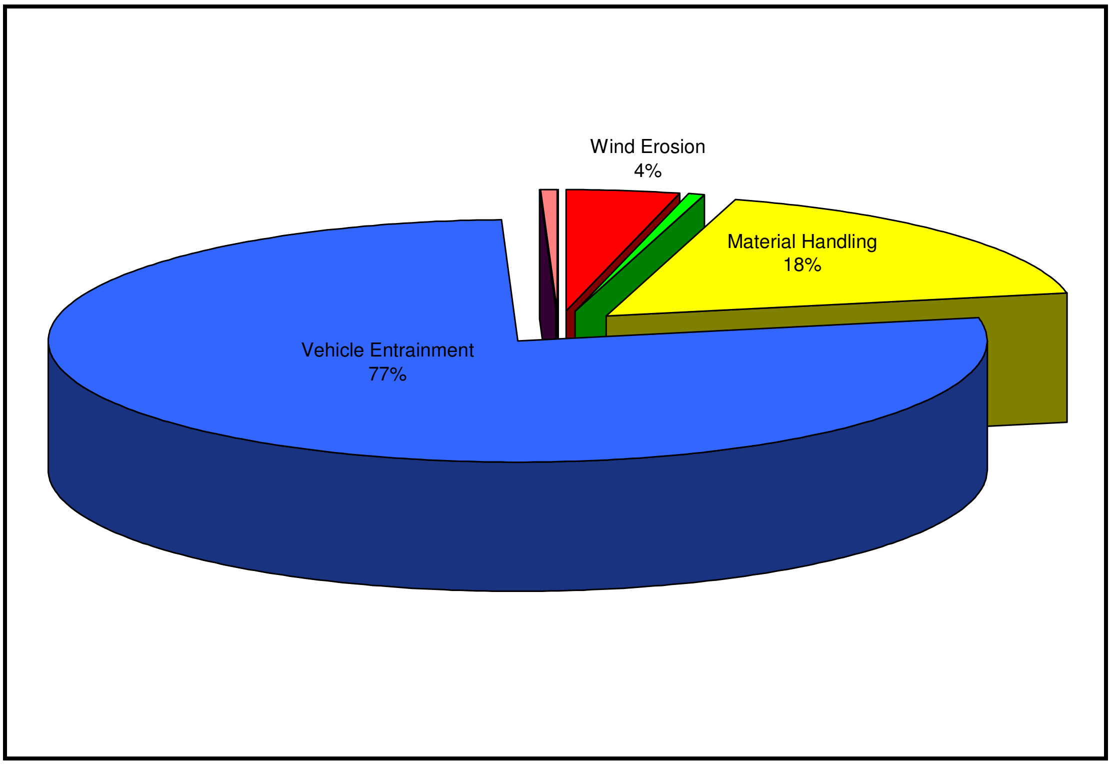

Figure 5-5: TSP emission contribution due to proposed routine operations

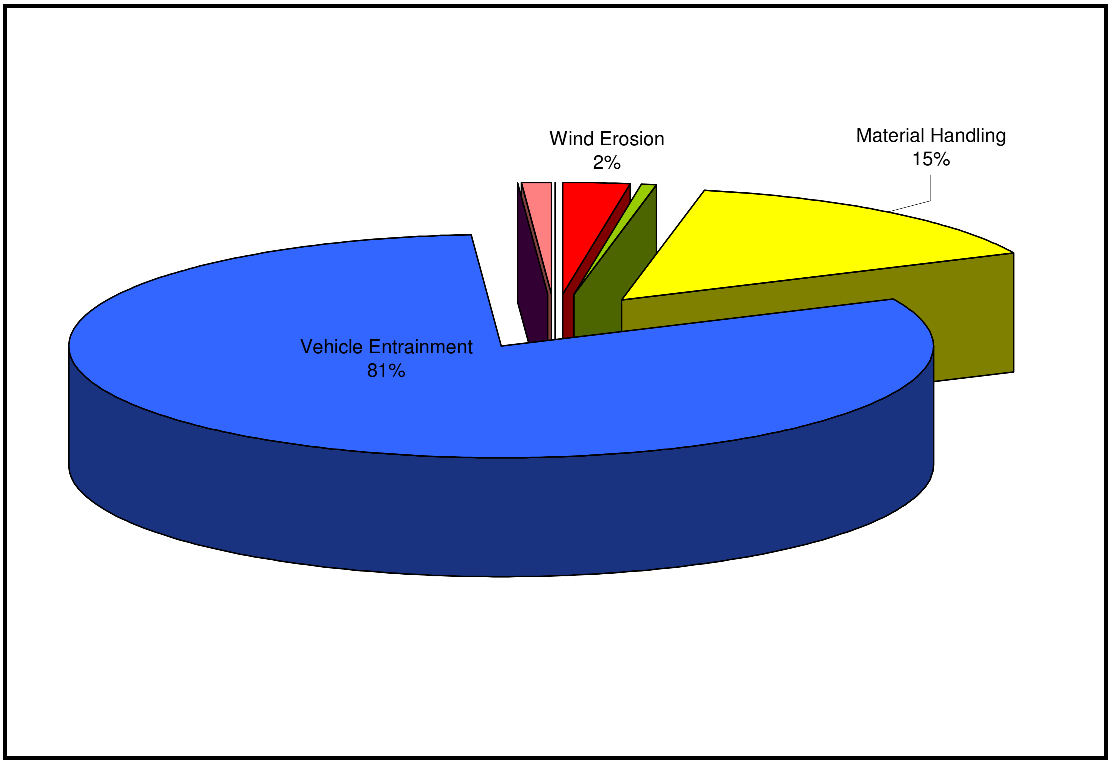

Figure 5-6: PM10 emission contribution due to proposed routine operations

5.2.11 Radon Emissions

Rössing Uranium personnel provided exhalation rates (Table 5-10) for various radon sources at Rössing Mine (Figure 5-7) for the Expansion Case. These sources were simulated with the aid of dispersion models and the impacts were provided to Radiological Specialists for further analysis.

Table 5-10: Exhalation rates for various radon sources (Expansion Case)

Facility	Subdivision	Sub-subdivision	Exhalation Rate (Bq/m²/s)	Area	Name
New high density tailings facility on the dome	Wet & dry		1.26	High density tailings	HDTAIL
Open pit	Walls & benches		0.77	Open pit	PIT
	P stockpile		1.5429807	Stockpiles	PSTOCK
Rock dumps	Waste rock dumps		0.4715593	Waste	WASTE
	Low grade and high calc stockpiles		1.1553713	Low grade	LORE
Plant area	Contaminated areas A to I	A	0.975	A	A
		B	0.521	B	B
		C	1.493	C	C
		D	2.103	D	D
		E	2.922	E	E
		F	4.886	F	F
		G	0.961	G	G
		H	1.503	H	H
		I	0.507	I	I
	Coarse Ore stockpile		1.543	COS	COS
	Coarse ore stockpile plume		ignore		
	Fine ore stockpile		1.543	FOS	FOS
	Fine ore stockpile plume		ignore		
	Conveyor plume	C1 (along conveyor from primary crusher)	ignore		

Facility	Subdivision	Sub-subdivision	Exhalation Rate (Bq/m²/s)	Area	Name
Plant area	Conveyor plume	C2 (from COS to fine crusher)	ignore		
		C3 (from fine crusher to fine stockpile)	ignore		
	Manganese mill area road		ignore		
	New coarse ore stockpile		1.5429807	COS2	COS2
Heap leach pad			1.543	Heap leach (ignoring turnaround areas)	HEAP
Ripios pile			1.46	Ripios	RIPIOS
Old tailings			1.543	Old tailings	TAILOLD

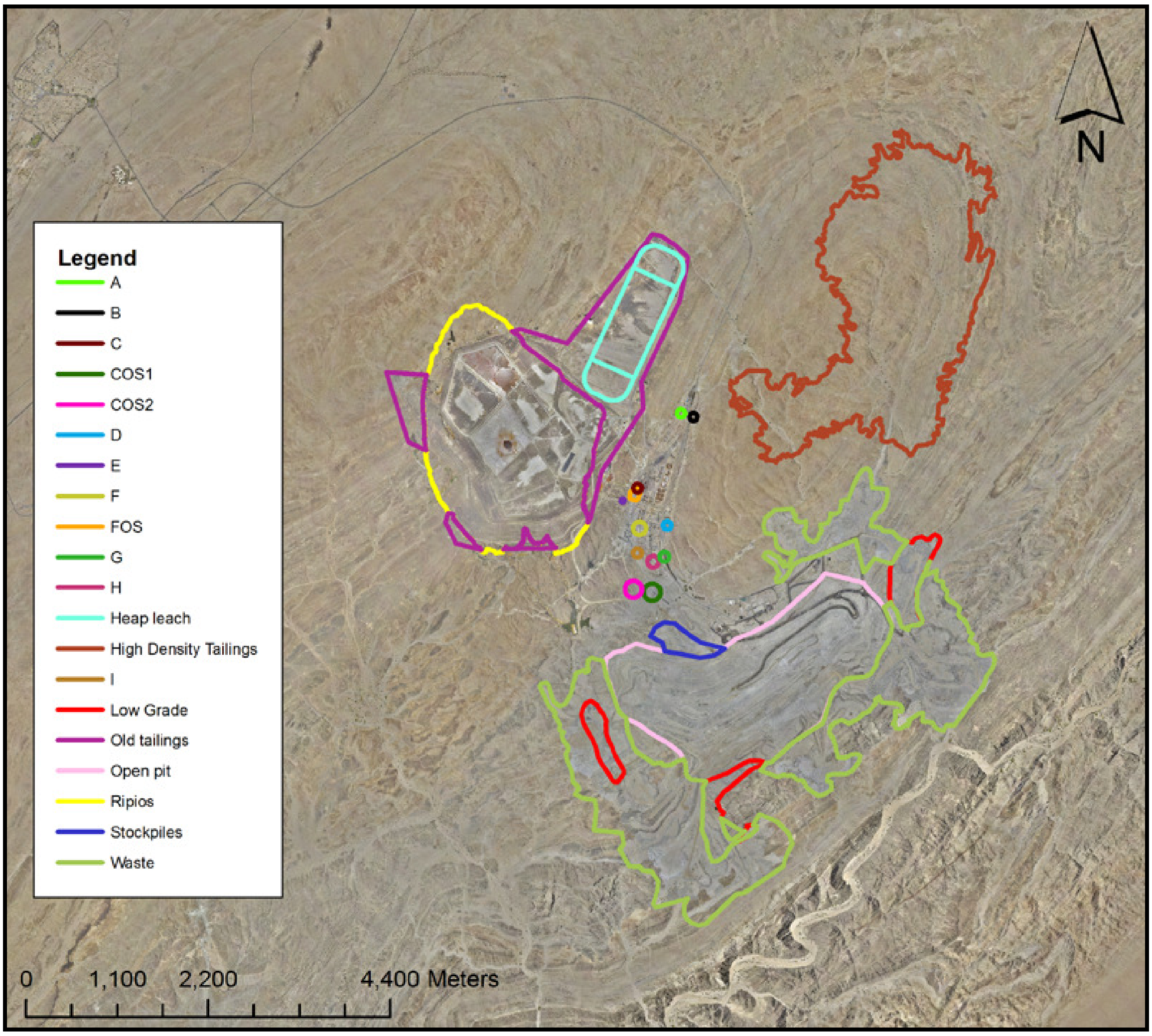

Figure 5-7: Radon sources identified for the Expansion Case

5.3 Closure and Post-Closure Phase

All mining activities will have ceased by the closure phase of the project. The potential for impacts during this phase will therefore depend on the extent of rehabilitation efforts during closure and thus ultimately the rehabilitation efforts during operation. It is expected that all disturbed areas will be rehabilitated back to their pre-mining land capability potential as far as practicable.

Aspects and activities associated with the closure phase of the proposed project are as follows:

- Fugitive dust from the demolition and stripping away of all facilities
- Wind entrainment from the tailings dams, waste rock dumps and exposed surfaces.

During the post-closure phase, atmospheric emissions will be restricted to possible wind-blown dust from the tailings dam and exposed surfaces. The extent of such emissions will be dependent on how successfully these storage and open areas were managed.

6. COMPLIANCE AND AIR QUALITY IMPACT ASSESSMENT

6.1 Dispersion Model Results

Simulations were undertaken to determine particulate matter (PM10) concentrations and total daily dust deposition from proposed operations at Rössing Mine (Expansion Case 2013).

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. *It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period. The isopleths for daily ground level concentrations are thus a conservative prediction of the impacts and should be assessed with frequency of occurrence.*

In addition, high PM10 (inhalable particulate matter <10µm in diameter) impacts predicted in the current assessment may not necessarily be visible (in terms of a visible plume) due to the size of the particulate matter.

The plots provided for the relevant pollutants of concern during the proposed operational phase are given in Table 6-1. The PM10 daily impacts due to the largest contributing sources (i.e. vehicle entrainment, materials handling and wind erosion) are also included in the following section.

Table 6-1: Isopleth plots presented in the current section.

Scenario	Pollutant	Averaging Period	Figure
All Sources	PM10	Highest daily Frequency of exceedance of highest daily Annual average	6-1 6-5 6-6
	TSP	Maximum deposition	6-7
Vehicle Entrainment	PM10	Highest daily	6-2
Materials Handling	PM10	Highest daily	6-3
Wind Erosion	PM10	Highest daily	6-4

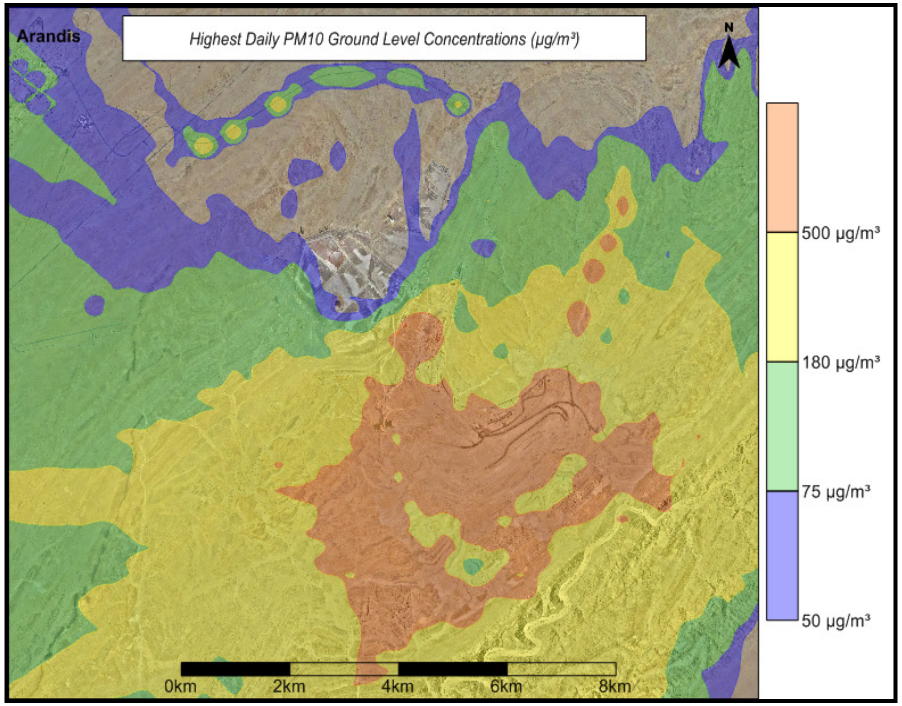

Figure 6-1: **Highest daily PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) operations (all sources)**

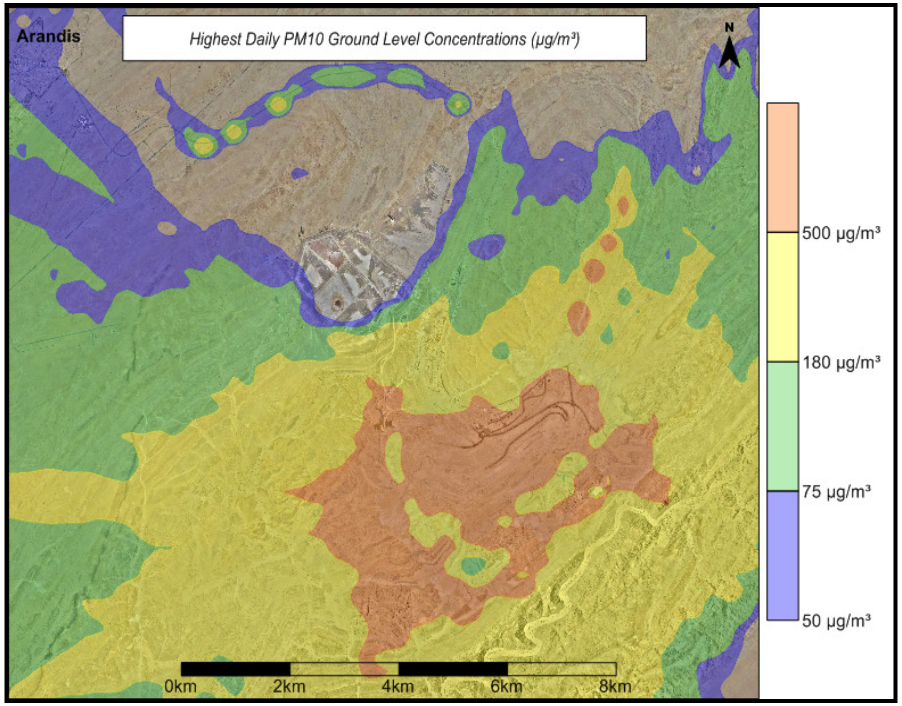

Figure 6-2: **Highest daily PM10 ground level concentrations due to proposed vehicle entrainment sources (Expansion Case for the year 2013)**

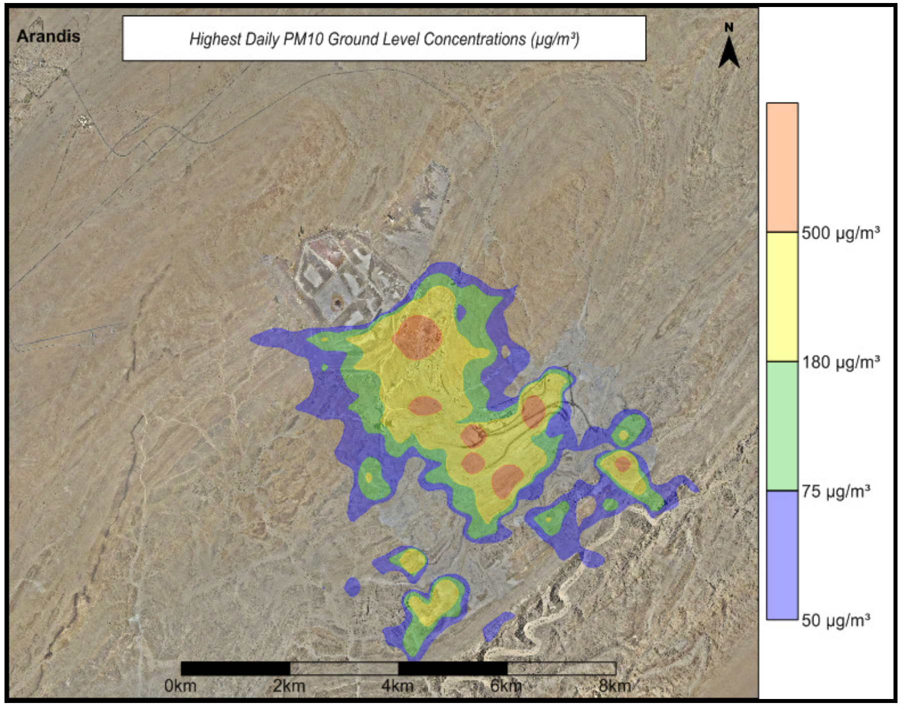

Figure 6-3: Highest daily PM10 ground level concentrations due to proposed materials handling sources (Expansion Case for the year 2013)

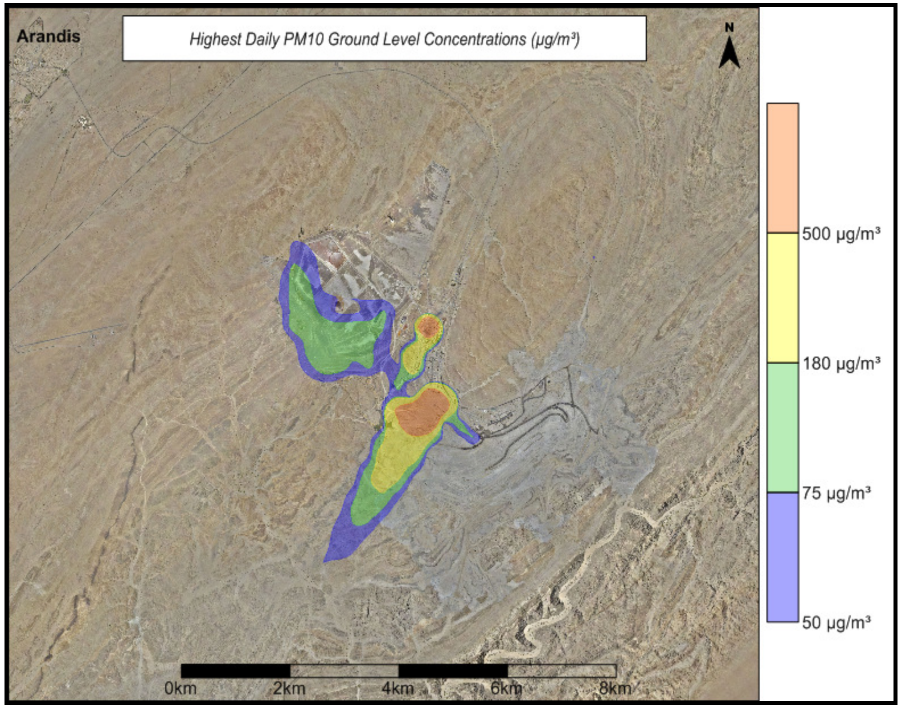

Figure 6-4: Highest daily PM10 ground level concentrations due to proposed wind erosion sources (Expansion Case for the year 2013)

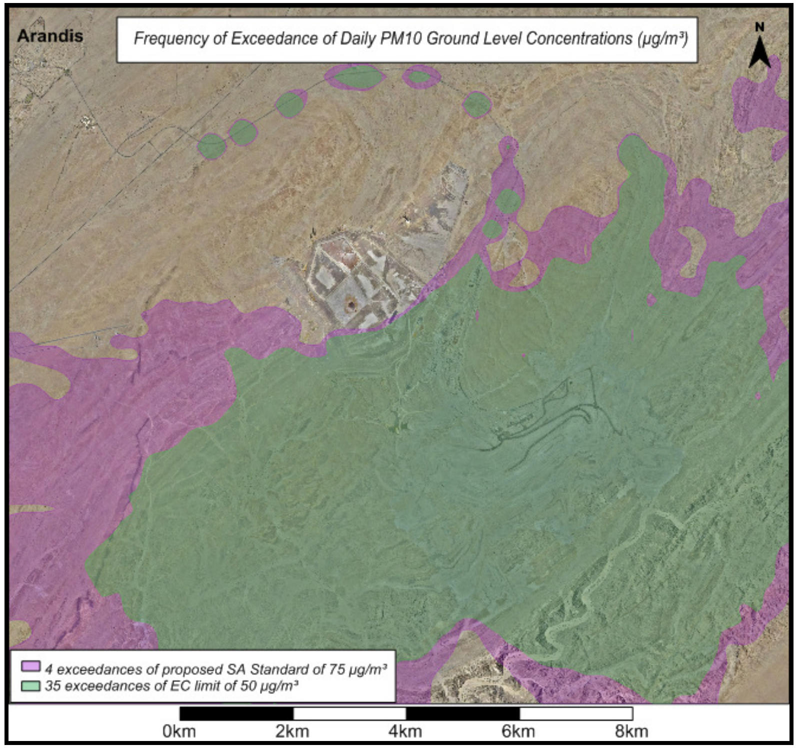

Figure 6-5: **Frequency of exceedance of highest daily PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) operations (all sources)**

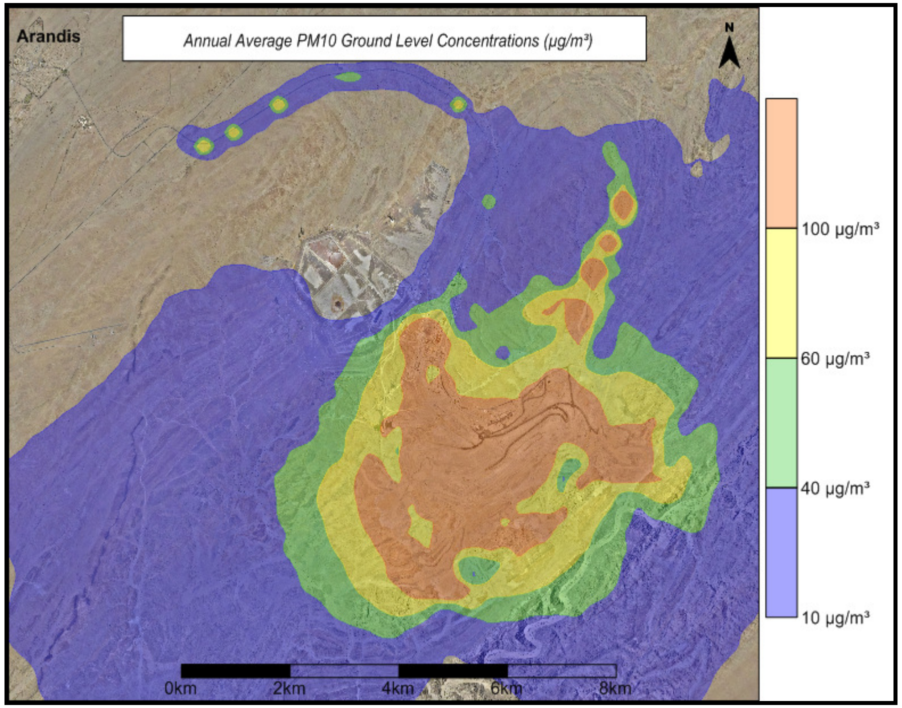

Figure 6-6: **Annual average PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) operations (all sources)**

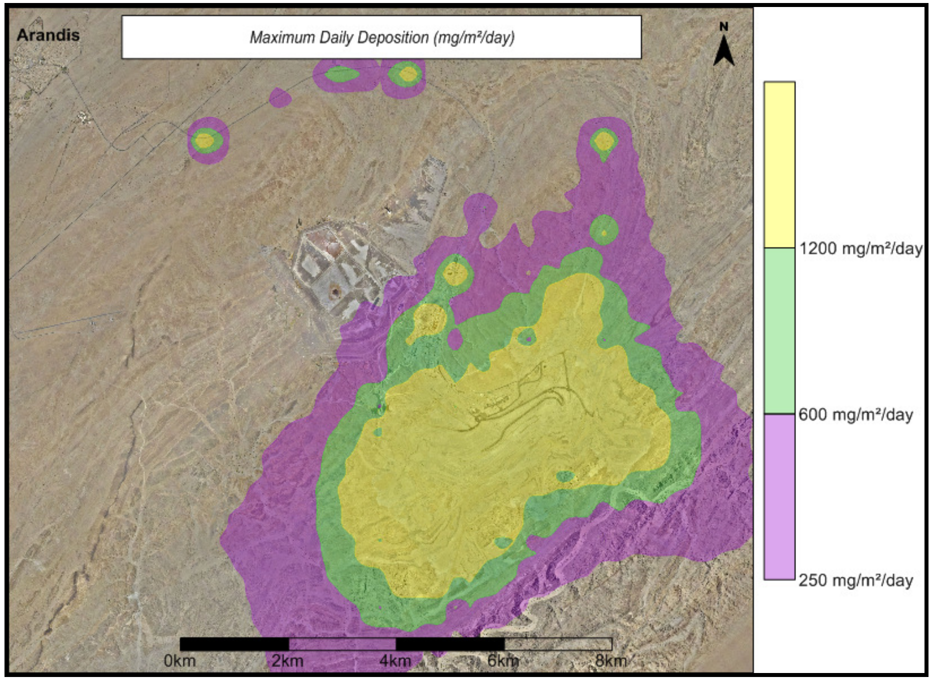

Figure 6-7: Maximum daily deposition due to proposed (Expansion Case for the year 2013) operations (all sources)

6.2 Compliance with Ambient Air Quality Criteria

In assessing “compliance” with air quality limits it is important to note the following:

- Variations in where air quality limits are applicable. The EC (and UK) stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit. In the US, the approach is frequently adopted of applying air quality limits within all areas to which the public has access (i.e. everywhere not fenced off or otherwise controlled for public access). In South Africa the Act defines “ambient air” as excluding air regulated by the Occupational Health and Safety Act of 1993. This implies that air quality limits may be required to be met beyond the fencelines of industries.

- Air quality standards typically comprise: thresholds, averaging periods, monitoring protocols, timeframes for achieving compliance and typically also permissible frequencies of exceedance. (Thresholds are generally set based on health risk criteria, with permissible frequencies and timeframes taking into account the existing air pollutant concentrations and controls required for reducing air pollution to within the defined thresholds. The practice adopted in Europe is to allow increasingly more limited permissible frequencies of exceedance, thus encouraging the progressive reduction of air pollution levels to meeting limit values.)

The concentrations simulated are depicted in Table 6-2. These concentrations reflect emissions from all sources due to the expansion (Phase 2 of the SEIA) at Rössing. Impacts were assessed at the mine boundary and at the nearest sensitive receptor (in terms of human settlement) of Arandis. Concentrations were referenced against the current SA Standards, the proposed SA Standards, the WHO guidelines, the US-EPA guideline and the EC limits as a fraction. Thus where this value is greater than one an exceedance of the relevant guideline in indicated.

6.2.1 Inhalable Particulate Matter of less than 10 µm (PM10)

Predicted daily PM10 ground level concentrations due to proposed routine operations at Rössing are predicted to be 440 µg/m^3 at the mine boundary exceeding all relevant ambient guidelines. The highest predicted off-site annual average PM10 ground level concentrations at the mine boundary (45 µg/m^3) are within the proposed SA annual limit of 50µg/m^3 but exceed the current SA annual limit and EC limit of 40 µg/m^3 and the WHO annual PM10 guideline of 20 µg/m^3.

At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing are 80 µg/m^3 which is within the US-EPA guideline and current SA Limit but exceeds the proposed SA Limit, WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year and the daily PM10 SA Standards allow for 4 exceedances in a calendar year. The frequency of exceedance of the EC daily limit and proposed SA daily limit at the sensitive receptor of Arandis is predicted to be 2 and 1 respectively. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m^3) is well within all relevant ambient guidelines.

Table 6-2: Highest predicted PM10 concentrations directly off-site due to proposed routine operations at Rössing Mine (a)

Highest Daily				Annual Average			In compliance (Y/N)
Predicted conc. µg/m^3	Guideline µg/m^3	Factor of guideline	Frequency of Exceedance (days/year)	Predicted conc. µg/m^3	Guideline µg/m^3	Factor of guideline	
At Mine Boundary							
440	150 (b)	**2.93**	22	45	-	-	N
	120 (c)	**3.67**	30		50 (c)	0.90	N
	75 (d)	**5.87**	62		40 (d)(f)	**1.13**	N
	50 (e)(f)	**8.80**	100		20 (e)	**2.25**	N
At the sensitive receptor of Arandis							
80	150 (b)	0.53	0	5.4	-	-	Y
	120 (c)	0.67	0		50 (c)	0.11	Y
	75 (d)	**1.07**	1		40 (d)(f)	0.14	Y
	50 (e)(f)	**1.60**	2		20 (e)	0.27	Y

Note:

(a) Exceedance of the guideline is provided in bold

(b) US-EPA guideline not to be exceeded more than 1 day/year

(c) Current SA Limit (compliance data – immediate to 31 December 2014) not to be exceeded more than 4 days/year

(d) Proposed SA Limit (compliance data – 1 January 2015) not to be exceeded more than 4 days/year

(e) WHO guideline

(f) EC limit not to be exceeded more than 35 days/year. It should be noted that the EC stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit

The main contributing sources to highest daily PM10 concentrations are vehicle entrainment (Figure 6-2) with the second highest contributing source being materials handling (Figure 6-3).

6.2.2 Dust Deposition

The predicted maximum deposition directly off-site due to proposed routine operations at Rössing Mine is below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas) (Table 6-3).

Table 6-3: Predicted maximum dust fallout (TSP) off-site due to proposed routine operations at Rössing Mine (a).

Highest total daily dust fallout		
Max deposition (mg/m²/day)	**Guideline mg/m²/day**	**Factor of guideline**
At Mine Boundary		
510	1 200 (b) 600 (c)	0.43 0.85
At the sensitive receptor of Arandis		
13.5	1 200 (b) 600 (c)	0.01 0.02

Note:
(a) Exceedance of the guideline is provided in bold
(b) Upper limit for SANS for industrial areas
(c) SANS limit for residential areas and lower limit for industrial areas

6.2.3 Easterly Wind Episode

The highest hourly PM10 ground level concentrations and hourly dust depositions for a high easterly wind episode (9 June 2004) was simulated (Figure 6-8 and Figure 6-11 respectively). The highest on-site hourly PM10 concentration due to Rössing operations only was predicted to be 10466 µg/m³. The main contributing sources to the predicted PM10 concentrations are wind erosion (Figure 6-9) and vehicle entrainment (Figure 6-10).

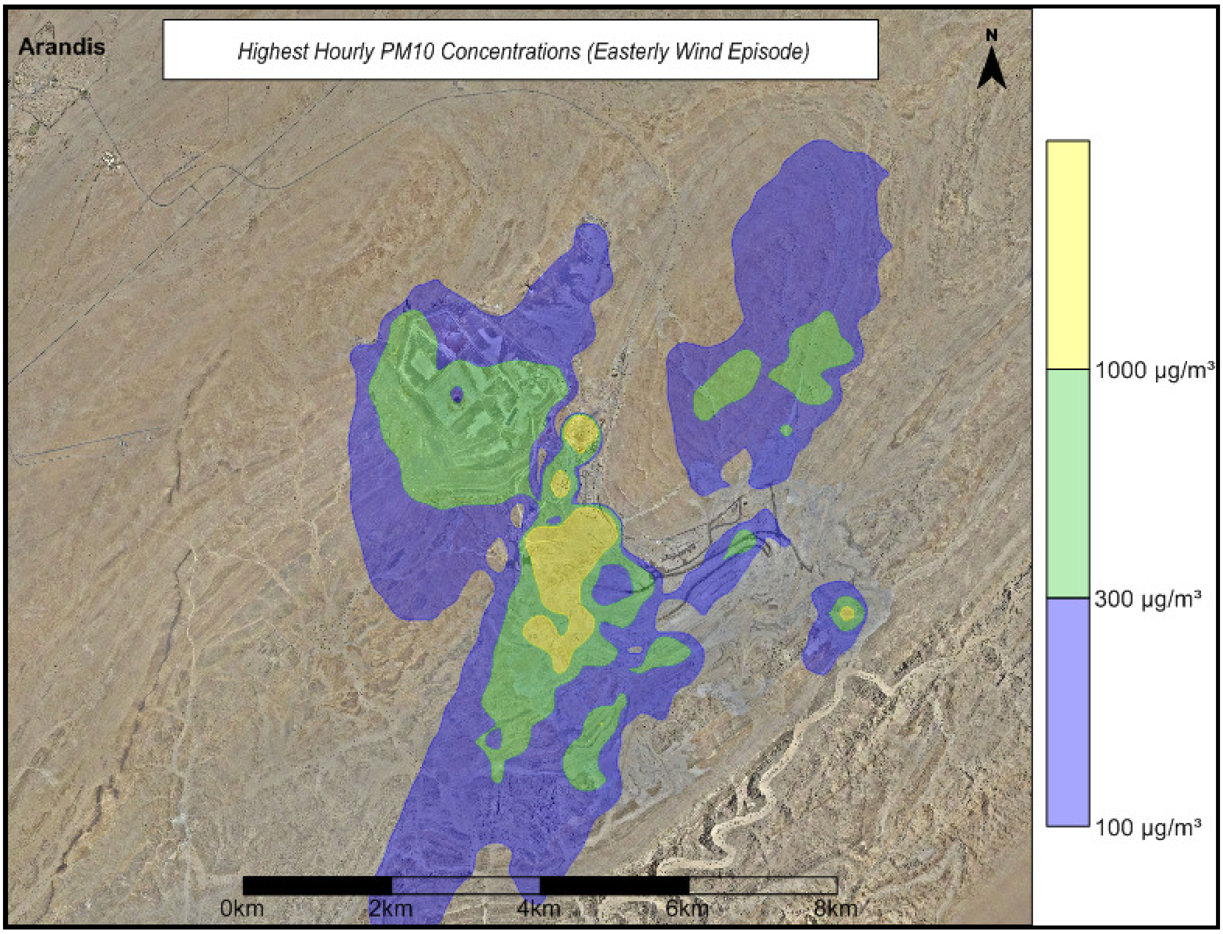

Figure 6-8: Highest hourly PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) Rössing Uranium operations as modelled for a high easterly wind episode (9 June 2004)

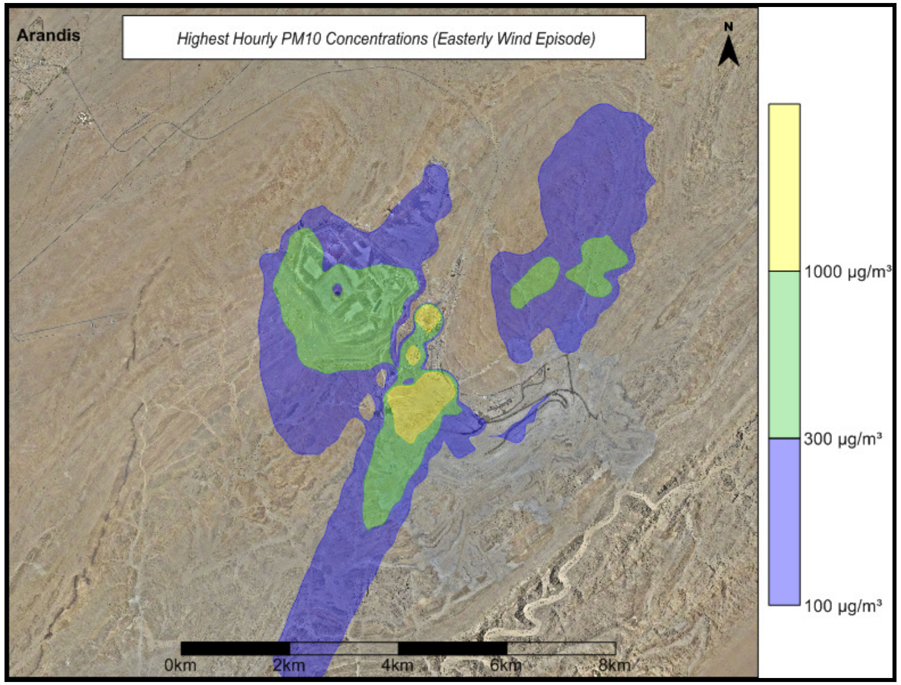

Figure 6-9: Highest hourly PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) wind erosion sources as modelled for a high easterly wind episode (9 June 2004)

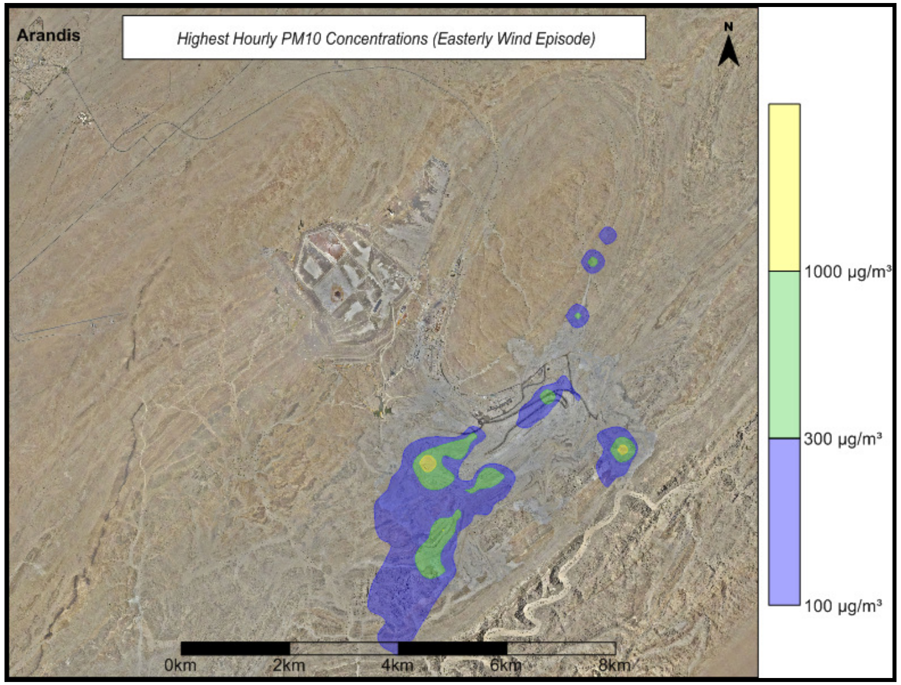

Figure 6-10: Highest hourly PM10 ground level concentrations due to proposed (Expansion Case for the year 2013) vehicle entrainment sources as modelled for a high easterly wind episode (9 June 2004)

The highest hourly dust deposition rate for a high easterly wind episode (9 June 2004) is provided in Figure 6-11. The highest on-site hourly dust deposition due to operations only was predicted to be 7129 mg/m²/hr. The main contributing sources to the predicted deposition are wind erosion (Figure 6-12) and vehicle entrainment (Figure 6-13).

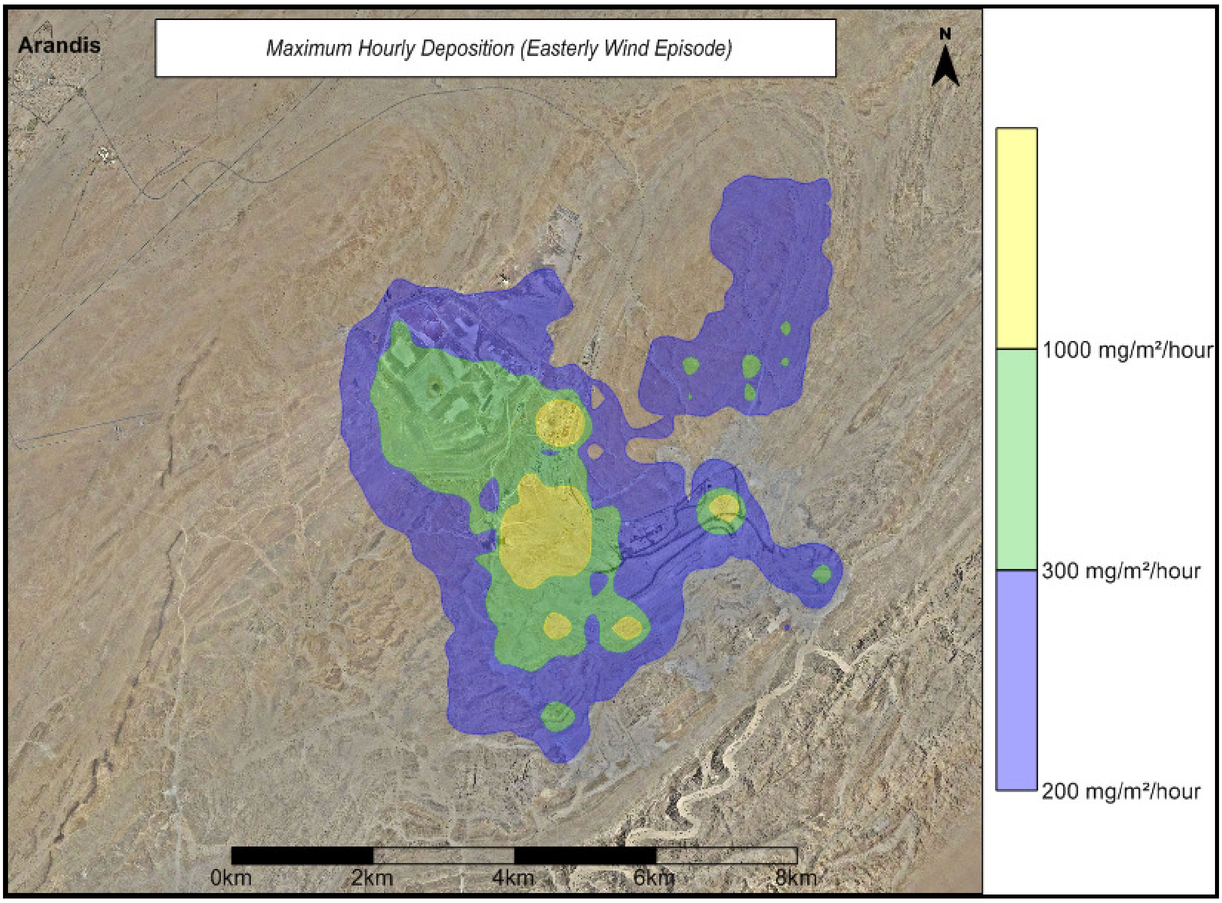

Figure 6-11: Highest hourly dust deposition due to proposed (Expansion Case for the year 2013) operations as modelled for a high easterly wind episode (9 June 2004)

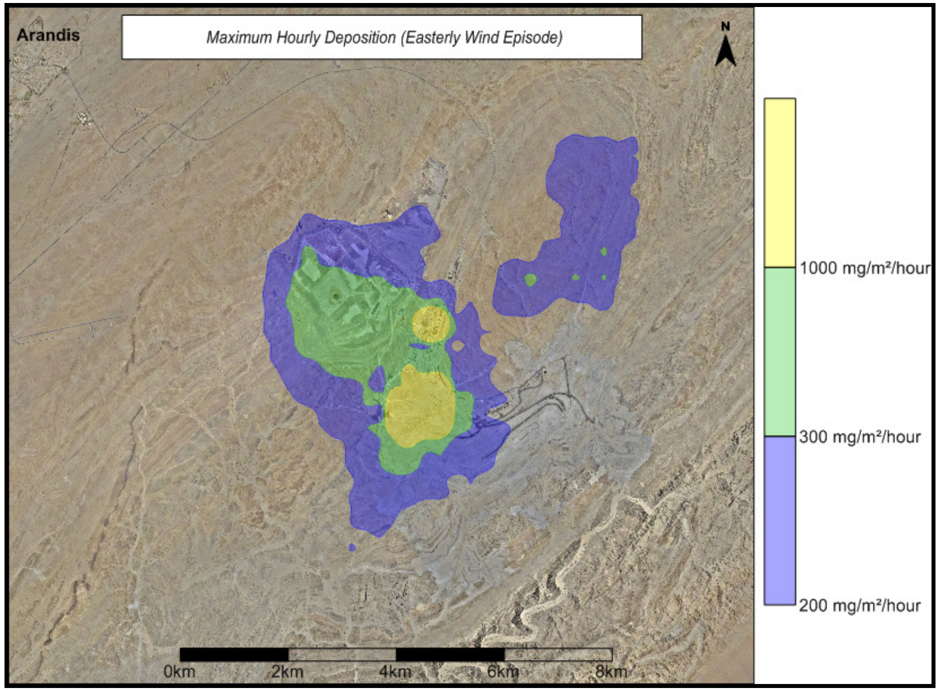

Figure 6-12: Highest hourly dust deposition due to proposed (Expansion Case for the year 2013) wind erosion sources as modelled for a high easterly wind episode (9 June 2004)

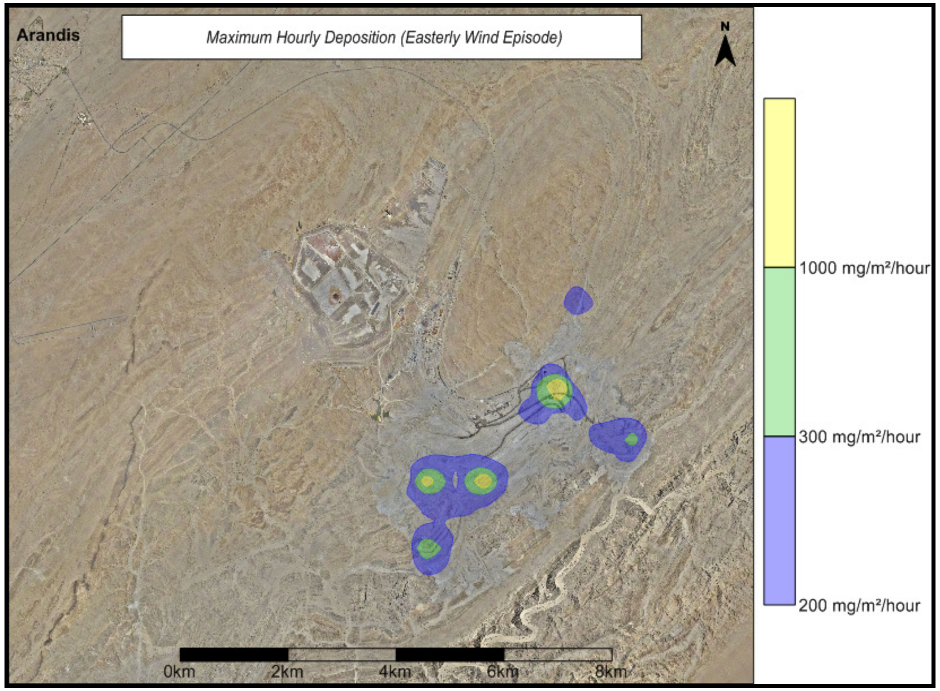

Figure 6-13: Highest hourly dust deposition due to proposed (Expansion Case for the year 2013) vehicle entrainment sources as modelled for a high easterly wind episode (9 June 2004)

7. CONCLUSIONS AND RECOMMENDATIONS

An air quality impact assessment was conducted for the current and proposed operations at Rössing. The main objective of this study was to determine the significance of the predicted impacts from fugitive emissions on the surrounding environment and on human health.

Emission rates were quantified for the fugitive sources and dispersion modelling executed. In the absence of locally derived ambient Air Quality Standards, ground level concentrations and depositions levels were screened against existing SA standards, WHO guidelines and EC limits pertaining to health risk. Nuisance dust (dust deposition) was assessed by comparison to the SANS (proposed SA) target levels for residential areas.

7.1 Conclusions

The following conclusions for ***current*** operations at Rössing were reached:

- The prevailing wind direction at the Rössing Mine is from the north-northeast (with ~10% frequency of occurrence) and is characterised by the occurrence of high wind speeds (>10m/s). Dominant winds during the period also occur from the north-western, western and south-western sectors.

- A two month monitoring campaign was undertaken to assist in the understanding of baseline and background ambient air quality levels at Rössing. From the measured PM10 daily concentrations at Arandis and Arandis Airport, all measured concentrations were within the current SA Limit of 120 µg/m³, with two exceedances of the proposed SA Limit of 75 µg/m³ occurring at the Arandis sampling site. The measured daily PM10 concentrations at Arandis and Arandis Airport were in exceedance of the EC and WHO guideline of 50 µg/m³ on a number of occasions during the monitoring campaign.

- Monthly measured SO_2 and NO_2 concentrations (undertaken by passive diffusive monitoring) levels for the two month monitoring campaign were generally low and well below the SA annual standard and EC annual limit of 19 ppb and 21 ppb respectively.

- Highest predicted daily ground level concentrations due to routine operations at Rössing were 480 µg/m³ at the mine boundary exceeding all relevant ambient guidelines. The predicted off-site annual average PM10 ground level concentrations at the mine boundary (56 µg/m³) exceeded all relevant ambient guidelines.

- At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing Basecase operations were 73 µg/m³ which is within the US-EPA guideline and SA Limits but exceeds the WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year. The frequency of exceedance of the EC daily limit at the sensitive receptor of Arandis was predicted to be 2. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m³) was well within all relevant ambient guidelines.

- The predicted maximum deposition directly off-site due to current routine operations at Rössing was below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas).

The following conclusions for ***proposed*** operations at Rössing were reached:

- Predicted daily PM10 ground level concentrations due to proposed routine operations at Rössing were predicted to be 440 µg/m³ at the mine boundary exceeding all relevant ambient guidelines. The highest predicted off-site annual average PM10 ground level concentrations at the mine boundary (45 µg/m³) were within the proposed SA annual limit of 50µg/m³ but exceeded the current SA annual limit and EC limit of 40 µg/m³ and the WHO annual PM10 guideline of 20 µg/m³.

- At the sensitive receptor of Arandis, the predicted daily PM10 ground level concentrations due to Rössing were 80 µg/m³ which is within the US-EPA guideline and current SA Limit but exceeds the proposed SA Limit, WHO guideline and EC limit. The EC daily PM10 limit allows for 35 exceedances in a calendar year and the daily PM10 SA Standards allow for 4 exceedances in a calendar year. The frequency of exceedance of the EC daily limit and proposed SA daily limit at the sensitive receptor of Arandis was predicted to be 2 and 1 respectively. The highest predicted annual average PM10 concentrations at the sensitive receptor of Arandis (5.4 µg/m³) was well within all relevant ambient guidelines.

- The predicted maximum deposition directly off-site due to proposed routine operations at Rössing was below all relevant guidelines (SANS upper range of 1 200 mg/m²/day for industrial areas and SANS target of 600 mg/m²/day for residential areas).

It should be noted that no significant increase in ambient PM10 concentrations and dust deposition were predicted from current to proposed operations at Rössing.

7.2 Recommendations

- It is recommended that the dust fallout network (as established for the two month monitoring campaign) be continued to monitor increases in dust fallout in the surrounding area due to the proposed expansion activities;

- As exceedances of the PM10 EC daily limit and WHO daily guideline was measured at Arandis, it is recommended that continued PM10 monitoring be undertaken at this sensitive receptor in order to establish emission contributions from Rössing Uranium;

- Although the predicted PM10 concentrations and deposition rates are provided for a high easterly wind episode, a confidence level cannot be attributed to the results. Therefore, depending on the level of detail required for assessment of impacts during high easterly wind episodes, the assessment of this incident should perhaps be repeated with updated meteorological data and deposition measurements in the field.

- As the main source of fugitive particulate emissions (also predicted to contribute to the highest impacts) is from vehicle entrainment on unpaved road surfaces within and around the open pit, it is recommended that dust control products such as Hydro Tac or Hydro Sperse be investigated to further reduce emissions from this fugitive dust source;

8. REFERENCES

Burger L W (1994). Ash Dump Dispersion Modeling, in Held G: *Modeling of Blow-Off Dust From Ash Dumps*, Eskom Report TRR/S94/185, Cleveland, 40 pp.

Burger L W, Held G and Snow N H (1995). *Ash Dump Dispersion Modeling Sensitivity Analysis of Meteorological and Ash Dump Parameters*, Eskom Report TRR/S95/077, Cleveland, 18 pp.

CEPA/FPAC Working Group (1998). *National Ambient Air Quality Objectives for Particulate Matter. Part 1: Science Assessment Document*, A Report by the Canadian Environmental Protection Agency (CEPA) Federal-Provincial Advisory Committee (FPAC) on Air Quality Objectives and Guidelines.

Cowherd, C., and Englehart, J. (1984). *Paved Road Particulate Emissions,* EPA-600/7-84-077, US Environmental Protection Agency, Cincinnati, OH.

Cowherd, C., and Englehart, J. (1985). *Size Specific Particulate Emission Factors for Industrial and Rural Roads,* EPA-600/7-85-038, US Environmental Protection Agency, Cincinnati, OH.

Cowherd C, Muleski GE and Kinsey JS (1988). *Control of Open Fugitive Dust Sources*, EPA-450/3-88-008, US Environmental Protection Agency, Research Triangle Park, North Carolina.

Dockery D. W. and Pope C. A. (1994). Acute Respiratory Effects of Particulate Air Pollution*, Annual Review of Public Health,* 15, 107 - 132.

Ecoserv (2009). *Air Quality Monitoring in Namibia,* Revision 4, August.

EnviroSolutions (2001). An Assessment of the Airborne and Deposited Dust Levels Attributable to Dust Sources at a Number of Receptor Locations Surrounding Rössing Uranium Mine, December.

EPA (1996). Compilation of Air Pollution Emission Factors for Miscellaneous Sources (AP-42), 6th Edition, Volume 1, as contained in the *AirCHIEF (AIR Clearinghouse for Inventories and Emission Factors) CD-ROM (compact disk read only memory)*, US Environmental Protection Agency, Research Triangle Park, North Carolina.

EPA (1998). Compilation of Air Pollution Emission Factors for Western Surface Coal Mining (AP-42), 6th Edition, Volume 1, as contained in the *AirCHIEF (AIR Clearinghouse for Inventories and Emission Factors) CD-ROM (compact disk read only memory)*, US Environmental Protection Agency, Research Triangle Park, North Carolina.

EPA (2006). Compilation of Air Pollution Emission Factors for Paved and Unpaved Roads (AP-42), as contained in the *AirCHIEF (AIR Clearinghouse for Inventories and Emission Factors)*, US Environmental Protection Agency, Research Triangle Park, North Carolina.

Gillette D. A., Muhs D., Adams J. and Kihl R. (1982). Threshold Friction Velocities and Rupture Moduli for Crusted Desert Soils for the Input of Soil Particles into the Air, Journal of Geographical Research, Vol. 87, No. CII, Pages 9003 – 9015, October 20, 1982.

Godish T. (1990). *Air Quality,* Lewis Publishers, Michigan, 422 pp.

Goldreich Y and Tyson P D (1988). Diurnal and Inter-Diurnal Variations in Large-Scale Atmospheric Turbulence over Southern Africa, *South African Geographical Journal,* 70(1), 48-56.

Hanna S. R., Egan B. A. Purdum J. and Wagler J. (1999). *Evaluation of the ADMS, AERMOD, and ISC3 Dispersion Models with the Optex, Duke Forest, Kincaid, Indianapolis, and Lovett Field Data Sets,* International Journal of Environment and Pollution (Volume 16, Nos. 1-6, 2001).

Holmes Air Sciences (1998). *Review of Load Based Licensing Requirements and Exploration of Alternative Approaches*. Report to the Minerals' Council of NSW, April 1998.

IFC (2007). *Environmental, Health, and Safety Guidelines; General EHS Guidelines: Environmental Air Emissions and Ambient Air Quality*. International Finanace Corporation, World Bank Group. 30 April 2007. http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironemntalGuidelines

Jones, A.D., and Tinker, J.A. (1984). Quantified appraisal of pollutants dispersing from road surfaces by airborne mechanisms, *Science of the Total Environment*, 33, 193-201.

Marticorena B. and Bergametti G. (1995). *Modeling the Atmospheric Dust Cycle. 1. Design of a Soil-Derived Dust Emission Scheme.* Journal of Geophysical Research, 100, 16 415 - 16430.

Oke T T (1990). *Boundary Layer Climates*, Routledge, London and New York, 435 pp.

Pasquill F and Smith F B (1983). *Atmospheric Diffusion: Study of the Dispersion of Windborne Material from Industrial and Other Sources*, Ellis Horwood Ltd, Chichester, 437 pp.

Preston-Whyte R A And Tyson P D (1988). The Atmosphere and Weather over South Africa, Oxford University Press, Cape Town, 374 pp.

Shaw R W and Munn R E (1971). Air Pollution Meteorology, in BM McCormac (Ed), *Introduction to the Scientific Study of Air Pollution*, Reidel Publishing Company, Dordrecht-Holland, 53-96.

WHO (2000). *Guidelines for Air Quality*, World Health Organisation, Geneva.

WHO (2005). *WHO Air Quality Guidelines Global Update*, World Health Organisation, October 2005, Germany.

APPENDIX A

Vehicle Information Provided by Rössing personnel for the Quantification of Emissions from Current Operations

Table 1: Ore Tonnages to be Mined 2010										Pioneering SK4 2010		
(Data source is V9.3 mine plan spreadsheet 5RUL BR2011 V9.3 data for year 2010, all information in annual tonnes)										(Additional Minning not covered by V9.3)		
Trolley 10 Waste	Trolley 10 LG	Trolley 10 Ore	Phase 2 Waste	Phase 2 LG	Phase 2 Ore	Phase 3 Waste	Phase 3 LG	Phase 3 Ore	Total Material Mined V9.3 (te)	SK4 Waste	SK4 LG	SK4 Ore
0.0	0.0	0.0	1924626.0	0.0	0.0	202471.0	0.0	0.0				
22703.5	38312.2	648469.3	464042.3	274062.0	854353.7	0.0	0.0	0.0				
0.0	0.0	0.0	5398564.0	0.0	0.0	8997447.0	0.0	0.0				
22301.5	28383.7	339200.8	1013494.2	534405.5	1687000.4	335482.7	171242.7	215208.5				
0.0	0.0	0.0				2325807.0	0.0	0.0				
24497.5	45102.0	879915.6				2310.4	3364.4	3736.2				
0.0	0.0	0.0				9672327.0	0.0	0.0				
21994.8	34275.3	554697.8				159128.8	112710.1	218845.1				
0.0	0.0	0.0				7996394.0	0.0	0.0				
203426.0	244612.6	3133404.5				8231.9	10955.9	18281.1				
11000.0	0.0	0.0				827068.0	0.0	0.0				
194425.9	264065.0	3566890.1				8194.3	3881.7	1563.0				
53665.0	0.0	0.0				3935685.0	0.0	0.0				
138054.4	173496.3	3063863.3				0.0	0.0	0.0				
						974820.0	0.0	0.0				
Total T10 to Waste	**Total T10 to LG**	**Total T10 Crush**	**Total P2 Waste**	**Total P2 to LG**	**Total P2 to Crush**	**Total P3 Waste**	**Total P3 to LG**	**Total P3 to Crush**				
692,069	**828,247**	**12,186,441**	**8,800,726**	**808,468**	**2,541,354**	**35,445,367**	**302,155**	**457,634**	**62,062,461**	**489,341**	**489,341**	**94,427**
Total Material Sent to the Primary Crusher		16,385,429	(see note 5)									

Table 2: Ore Haul Truck and Shovel Movements and Routes 2010														
Route	Total Route Length (m)	Material Moved (te)	Material Moved by RUL (te)	RUL Truck Payload (te)	No. of Cycles	Avg No. RUL Shovels per Area	Avg Annual Shovel Operating Hours Assuming 50% Operational	Avg Tonnes/hour per RUL Shovel	Material Moved by Basil Read (te)	Basil Read Average Payload (te)	No. of Cycles	Avg No. Basil Read Shovels per Area	Avg Annual Shovel Operating Hours Assuming 50% Operational	Avg Tonnes/hour per Basil Read Shovel
Trolley 10 to Waste	6966	692,069	692,069	170	4,071	1.25	4380	2,504	0					
Trolley 10 to LG7	6380	828,247	828,247	170	4,872				0					
Trolley 10 to Ore crusher	5900	12,186,441	12,186,441	170	71,685				0					
Phase 2 to Waste	3999	8,800,726	8,800,725	170	51,769	1.00	4380	2,774	4,500,000	70.9	63,470			
Phase 2 to LG	4385	808,468	808,468	170	4,756				0		0	3	4380	342
Phase 2 to Ore crusher	2476	2,541,354	2,541,354	170	14,949				0		0			
Phase 3 to Waste	2700	35,445,367	35,445,365	170	208,502	2.50	4380	3,306	7,500,000	70.9	105,783			
Phase 3 to LG	3535	302,155	302,155	170	1,777				0		0	6	4380	285
Phase 3 to Ore crusher	3954	457,634	457,634	170	2,692				0		0			
SK4 to waste	1525	489,341	0	-	-				489,341	70.9	6,902			
SK4 to LG7	2392	489,341	0	-	-				489,341	70.9	6,902	1	4380	112

Table 2: Ore Haul Truck and Shovel Movements and Routes 2010

Route	Total Route Length (m)	Material Moved (te)	Material Moved by RUL (te)	RUL Truck Payload (te)	No. of Cycles	Avg No. RUL Shovels per Area	Avg Annual Shovel Operating Hours Assuming 50% Operational	Avg Tonnes/hour per RUL Shovel	Material Moved by Basil Read (te)	Basil Read Average Payload (te)	No. of Cycles	Avg No. Basil Read Shovels per Area	Avg Annual Shovel Operating Hours Assuming 50% Operational	Avg Tonnes/hour per Basil Read Shovel
SK4 to Ore Stockpile	3439	94,427	0	-	-				94,427	70.9	1,332			
Reclaimed from ROM Stockpiles	500 (estimated)	1,200,000	1,200,000	170	7,059	2.00	500	1,200	0					

Table 3: JJD Tailings Sand Hauling for Dressing of Roads, Loading and Tipping Areas 2010

Route	Total Route Length (m)	Material Moved (annual te)	JJD Truck Payload (te)	JJD Unladen Wt (te)	JJD Gross Wt (te)	No. of Cycles Annually	Proportion of Sand Distributed
Tailings Sand Dressing to Primary Crusher Area	4989	724,340	39.52	30.3	69.82	18,328	
Tailings Sand Used at Crusher		89,907	39.52	30.3	69.82	2,275	12.4
Tailings Sand Distributed over other roads		634,433				16,053	87.6
Trolley 10 to Waste	6966	3,797	39.52	30.3	69.82	96	0.52
Trolley 10 to LG7	6380	4,545	39.52	30.3	69.82	115	0.63
Trolley 10 to Ore crusher	5900	75,209	39.52	30.3	69.82	2,052	10.38
Phase 2 to Waste	3999	48,290	39.52	30.3	69.82	1,222	6.67
Phase 2 to LG	4385	4,436	39.52	30.3	69.82	112	0.61
Phase 2 to Ore crusher	2476	66,671	39.52	30.3	69.82	1,687	9.20
Phase 3 to Waste	2700	194,490	39.52	30.3	69.82	4,921	26.85
Phase 3 to LG	3535	1,658	39.52	30.3	69.82	42	0.23
Phase 3 to Ore crusher	3954	198,659	39.52	30.3	69.82	5,027	27.43
SK4 to waste	1525	2,685	39.52	30.3	69.82	68	0.37
SK4 to LG7	2392	2,685	39.52	30.3	69.82	68	0.37
SK4 to Ore Stockpile	3439	518	39.52	30.3	69.82	13	0.07
ROML Reclaim P Stockpiles	500 (estimated)	6,584	39.52	30.3	69.82	167	0.91
ROMT Tip Point P Stockpiles	500 (estimated)	18,317	39.52	30.3	69.82	463	2.53

Table 4: Basil Read Tailings Sand Hauling for Dressing of Roads, Loading and Tipping Areas 2010

Route	Total Route Length (m)	Material Moved (annual te)	Basil Read Truck Payload (avg) (te)	Basil Read Avg Unladen Wt (te)	Basil Read Avg Gross Wt (te)	No. of Cycles Annually
Tailings Sand Dressing to Primary Crusher Area	4989	116,741	55	43.1	98.1	2,123
Phase 2 to Ore crusher	2476	40,188	55	43.1	98.1	731
Phase 3 to Ore crusher	3954	66,979	55	43.1	98.1	1,218
SK4 to waste	1525	4,367	55	43.1	98.1	79
SK4 to LG7	2392	4,367	55	43.1	98.1	79
SK4 to Ore Stockpile	3439	839	55	43.1	98.1	15

Table 5: Treatment of Routes with Dust-A-Side

Route	Route Treatment Description	Total Length (m)	Length Untreated (m)		Total Treated Length (m)	Total Untreated Length (m)
			Pit Bottom	Top		
Trolley 10 to Waste	All treated except for across the pit bottom and from end Trolley 8 to waste pile at top	6966	1477	1201	4288	2678
Trolley 10 to LG7	All treated except for across the pit bottom and road to LG pile at top	6380	1477	1013	3890	2490
Trolley 10 to Ore crusher	All treated except for across the pit bottom	5900	1477		4423	1477
Phase 2 to Waste	All untreated except for section around pit rim	3999	1096	not determined	1107	2892
Phase 2 to LG	All untreated except for section around pit rim	4385	1096	not determined	1107	3278
Phase 2 to Ore crusher	All untreated except for section around pit rim to crusher	2476	1096	n/a	1380	1096
Phase 3 to Waste	All untreated	2700	not determined	not determined	0	2700
Phase 3 to LG	All untreated	3535	not determined	not determined	0	3535
Phase 3 to Ore crusher	All untreated except final section to crusher	3954	2675	n/a	1279	2675
SK4 to Waste	All untreated	1525	not determined	not determined	0	1525
SK4 to LG7	All untreated	2392	not determined	not determined	0	2392
SK4 to Ore Stockpile	All untreated	3439	not determined	not determined	0	3439
ROM Stockpile to Crusher	All untreated	500 (estimated)	n/a	500	0	500
Primary Crusher to Tailings	All untreated		n/a	n/a		
Permeter Tailings Area	All untreated		n/a	n/a		
Perimeter Tailings CDIII Paddy	All untreated		n/a	n/a		

Table 6: RUL Auxillary Vehicle Movements within the Open Pit Area

Vehicle Description	Vehicle Type and Approx Quantities (Typical based on RUL actual 2008/9)		Operating Weight (kg)	Base Case Annual Distance Travelled in Pit 2010 (km)
	Make (Typical)	Quantity		
Bakki*	Toyota Double Cab	43	2,000	1,555,775
Mini Bus	Toyota Quantum	9	3,200	520,200
Maintenance/Heff Trucks	Various	17	7500 (Est)	111,409
Wheeled Dozer	Cat 824C	2	28,724	18,167
Wheeled Dozer	Cat 834H	2	47,106	27,358
Grader	Cat 14G/14H	2	15,130	58,268
Grader	Cat 16M	2	26,060	27,822
Water Truck*	Cat777F/631E	4	165,000	90,327
Wheeled Loader	Cat 926	1	15,000	374
Wheeled Loader	Cat 992D	1	97,295	11,956
Wheeled Loader	Cat 994F	1	195,400	10,572

Table 7: RUL Vehicle Movements Within the Tailings Dam Area

Vehicle Description	Make and Model	Operating Weight (kg)	Description of Journey	Route Taken	Route Distance (km)	Frequency (Annual)	Annual Distance (km)
Bakki*	Toyota Double Cab	2,000	Daily, 2 hourly, visual inspection of tailings perimeter.	Perimeter tailings Area	11.697	4380	51,233
Grader*	Cat 14G	15,130	Maintenance of roads around active paddy.	Perimeter Tailings Area CDIII Paddy	2.282	52	119
Dozer			Construct 20m wide	Perimeter Tailings Area	2.282	see journey description	

Table 7: RUL Vehicle Movements Within the Tailings Dam Area

Vehicle Description	Make and Model	Operating Weight (kg)	Description of Journey	Route Taken	Route Distance (km)	Frequency (Annual)	Annual Distance (km)
			Roadway around paddy (daily for two weeks, once every 3 months)	CDIII paddy.			
Grader*	Cat 14G	15,130	Construct 20m wide Roadway around paddy (daily for two weeks, once every 3 months)	Perimeter Tailings Area CDIII paddy.	2.282	see journey description	
Water Truck*	20,000 litre estimate	35,000	Routine water spray to suppress dust	Perimeter tailings Area and Perimeter of Paddy CDIII	13.979	730	10,205

Table 8: JJD Vehicle Movements Within the Tailings Dam Area (in addition to sand haul trucks)

Vehicle Description	Make and Model	Operating Weight (kg)	Description of Journey	Route Taken	Distance (km)	Frequency (Annual)	Annual Distance Traveled(km)
Grader*	14G	15,130	Road maintenance 7 hours a day, 26 days a month	Primary Crusher to tailings	4.989	see journey description	
Water Truck	18,000 litre capacity	32,500	Routine water spray to suppress dust, days only	Primary Crusher to tailings	4.989	730	3642

Table 9: Manganese Delivery Vehicle Movements Within the Plant (does not include tarmac roads)

Vehicle Description	Make and Model	Unladen Weight (kg)	Payload (kg)	Gross Wt (kg)	Total Annual Tonnes Moved	Route Taken	Distance (km)	No. Of Cycles(Annual)	Annual Distance Traveled(km)
Delivery Truck (Flat Bed)	Various	32,000	31,500	63,500	19,500	Manganese Road to Manganese Tip point	0.545	619	337

General Information and Assumptions Used to Generate Annual Tonnages and Movements

1) The predicted mining tonnage for the base case has been chosen from the busiest mining year from the Version 9.3 mine plan (spreadsheet 5RUL BR2011).

2) Mining is carried out by RUL and Basil Read. All mining at Trolley 10 (T10) is by RUL. Some areas of Phase 2 (P2) and Phase 3 (P3) are mined by both RUL and Basil Read but Basil Read only mines the waste material. All of the SK4 area is mined by Basil Read

3) It is indicated that all material mined is sent to the primary crusher. This is not in fact true. 11.8 Mt is sent direct to the crusher, the balance of material is sent to the ROM "P" stockpiles just behiond the primary crusher. In terms of dust generated from journeys this distance is not significant. The material that is fed to the primary crusher from the P stockpiles is shown. Consequently the amount of material shown as being fed to the primary crusher is overstated in Table 1 and 2

Notes Specific to Table 2

1) RUL Haul trucks have a laden weight of 320 tonnes, payload of 170 tonnes and an unladen weight of 150 tonnes

2) There are 4 RUL shovels in the pit for the first 6 months of the year and 5 for the second half of the year. Shovel distribution through out the mining areas will be varied and has been averaged. Basil Read have their own loading shovels. These have also been averaged.

3) There are two machines loading reclaim at the "P" Stockpiles (a Marion shovel and a Cat994), these have lower operating hours or other duties, hence the operating hour have been estimated to obtain shovel throughput. All other shovels have been estimated as operating for 50% of the annual hours to allow a figure for tonnes per hour to be calculated. Note operating hours in this case means hours actually "shoveling" and was a figure provided by mine management.

4) Basil Read will mine 4.5 Mtonnes waste from P2 and 7.5Mt waste from P3 to make up the total of 12Mt from the open pit. A further approx 1Mtonnes will come from pioneering SK4. The split of material with regards to waste and low grade for SK4 cannot be determined at this stage and as the mining is pioneering there is likely to be dilution of grade. The split between low grade and waste has therefore been estimated as 1:1

5) Basil Read has a range of haul trucks. They have 15 Komatsu 465's with a 55Te payload and 14 Komatsu 785's with an 88te payload. An average payload of 70.9 tonnes has been used. The unladen weight of a Komatsu 465 is 43.1te and the Komatsu 785 is 72te. Average unladen weight is 57.0te

6) Basil Read have 10 loaders in the pit for 2009. Planned material mined by Basil Read is 15Mt. The planned amount for 2010 is 12Mt but there is an additional mining centre so the number of shovels for 2010 is kept constant (7 X Leibherr 984 tracked excavators, 2 X Cat 988 front end loader and 1 X Komatsu front end loader.

7) The routes shown are typical for waste, low grade and ore from each mining centre. The mining centers are in the central position of each mining area

8) None of the SK4 ore will be sent to the crusher. It all goes to a high grade stockpile

Notes Specific to Tables 3 and 4

1) All tailings sand for RUL mining operations (surface dressing or roads, loading and tipping areas) is hauled by JJD using Komatsu HM400 haul trucks. Unladen weight is 30.3te. Real data used from Nov 08 to Oct 09. RUL Sand usage in 2010 is estimated to 15% higher based on the increase in tonnage mined. Tailings sand for the Basil Read mining operation is loaded and transported by Basil Read. They are not required to track this information but advise that there have been 804 Komatsu 465 truck loads over a 5 month period of 2009. This has been factored for the year and a 10% margin added to make some allowance for inaccurate recording.

2) Distribution of sand vehicle traffic has been assumed to take place over the same roads as the ore haul routes and is distributed according to the tonnage moved over the road.

3) The sand is all hauled down the route from the sand dump to the primary crusher. Some of the sand hauled by JJD is used to dress the area around the primary crusher. The balance is distributed among the haul roads, loading and tipping points throughout the pit and rock dump areas. All the sand hauled by Basil Read is distributed around the areas mined by Basil Read.

Notes Specific to Tables 5

1) Open pit roads are partially treated with Dust-A-Side as shown in table 5. All other roads are considered as untreated

Notes Specific to Tables 6,7 and 8

1) Specific vehicle types are identified where possible. Assumptions have been made where the exact identity is not known or is subject to change. In these cases a typical vehicle is used (Marked with *)

2) Light vehicle km in the pit has been estimated from plant records for vehicles used in the mining operating sector in 2009. It has been assumed that 90% of the distance travelled is in the pit. It has been assumed that Mini Buses are always full and Bakkies have a driver and passenger. Maintenance trucks have been estimated at an average 7.5 tonne operating weight. In the tailings dam area an allowance has only been made for the supervision vehicle which tours the perimeter road every two hours. No other light vehicles have been allowed for in the tailings area.

3) It has been assumed that no dust is generated from the movement of tracked vehicles. Wheeled dozers and front end loader travel in the pit has been generated from operating hours, an assumed speed of 2 km/h and 90% of the time in the pit.

4) The light vehicle traffic has been determined from the RUL data. This has been used to arrive at an auxiliary figure per tonne of material mined. This has then been scaled up to predict the traffic in 2010. This should over state the vehicle traffic because Basil Read does not duplicate all of the tasks undertaken by RUL and also some tasks are independent of tonnes mined. It is assumed that this overstatement will account for the additional traffic by external contractors, which have not been separately accounted for.

Geographic Information provided for the Basecase (2010) Roads used at Rössing

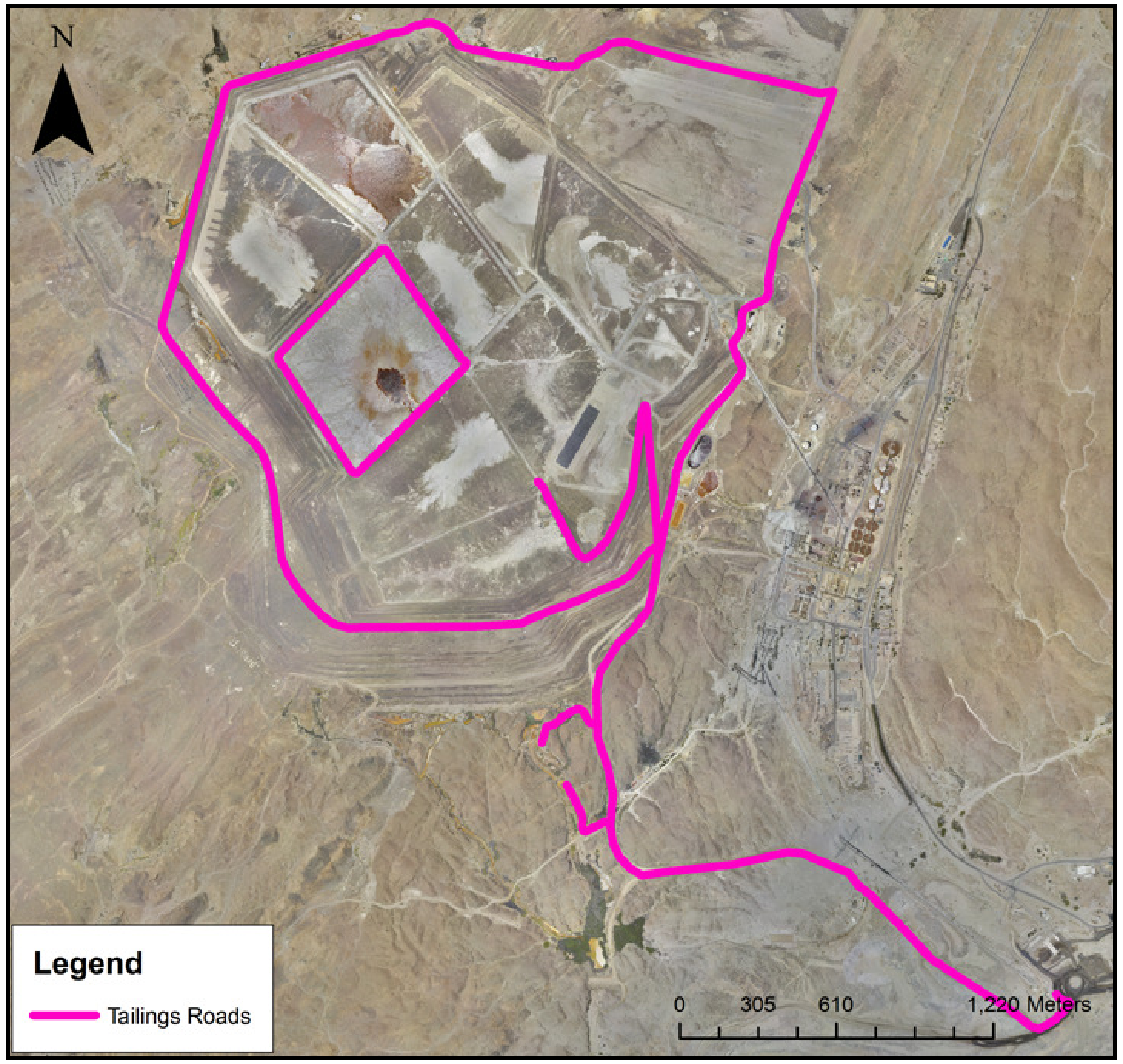

Figure A-1: Geographical information provided for tailings roads

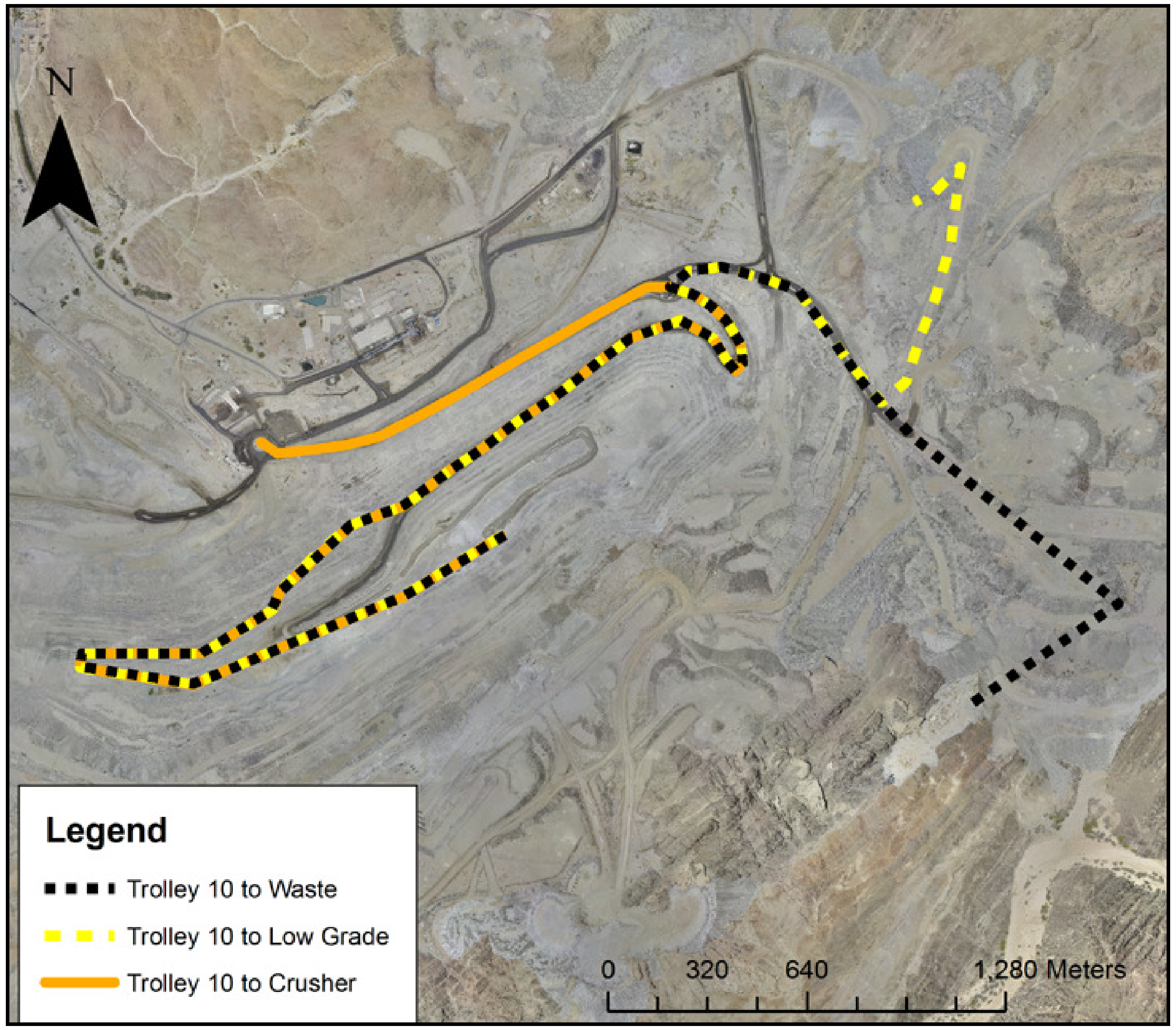

Figure A-2: Geographical information provided for Trolley 10 roads

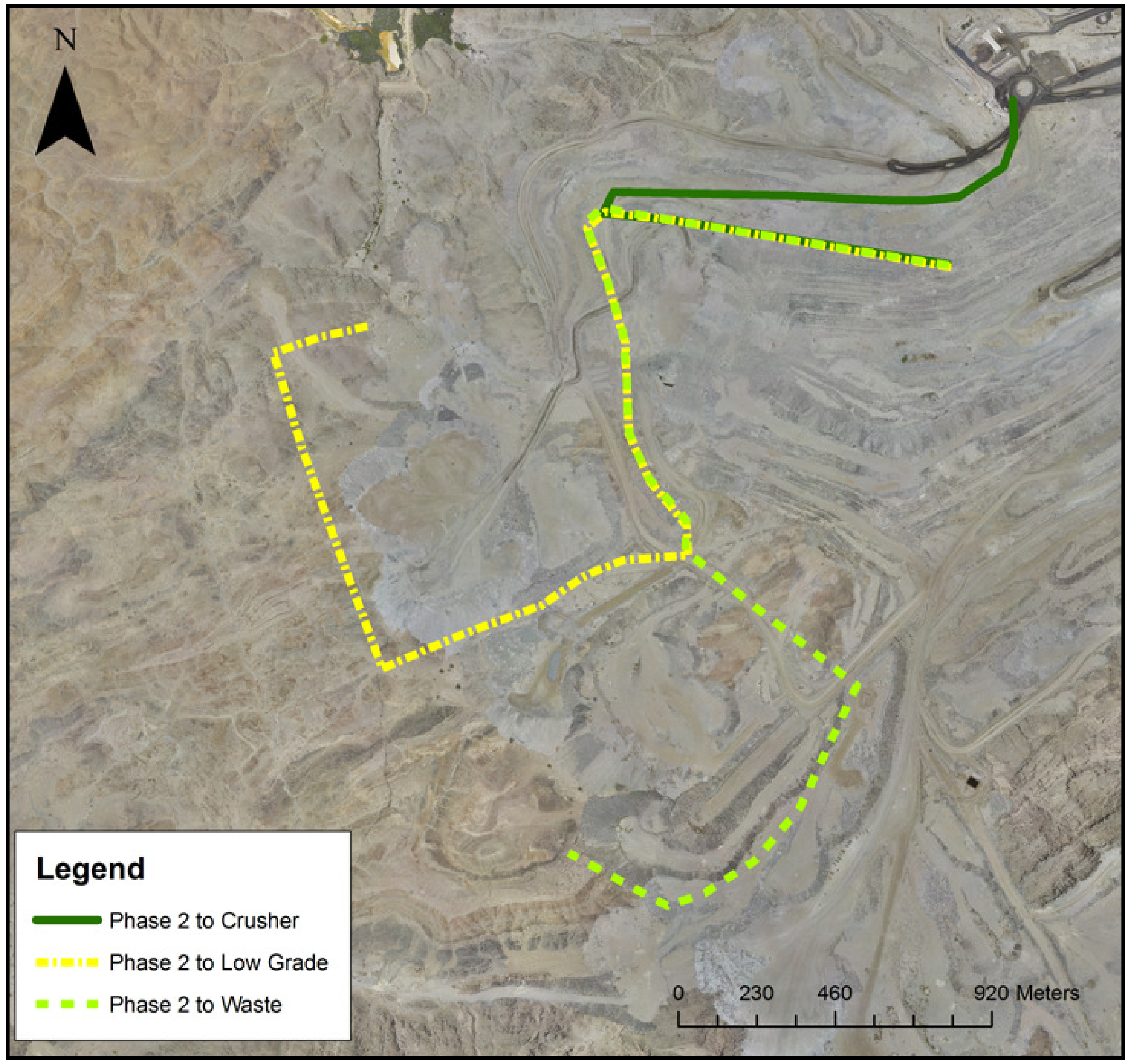

Figure A-3: Geographical information provided for Phase 2 roads

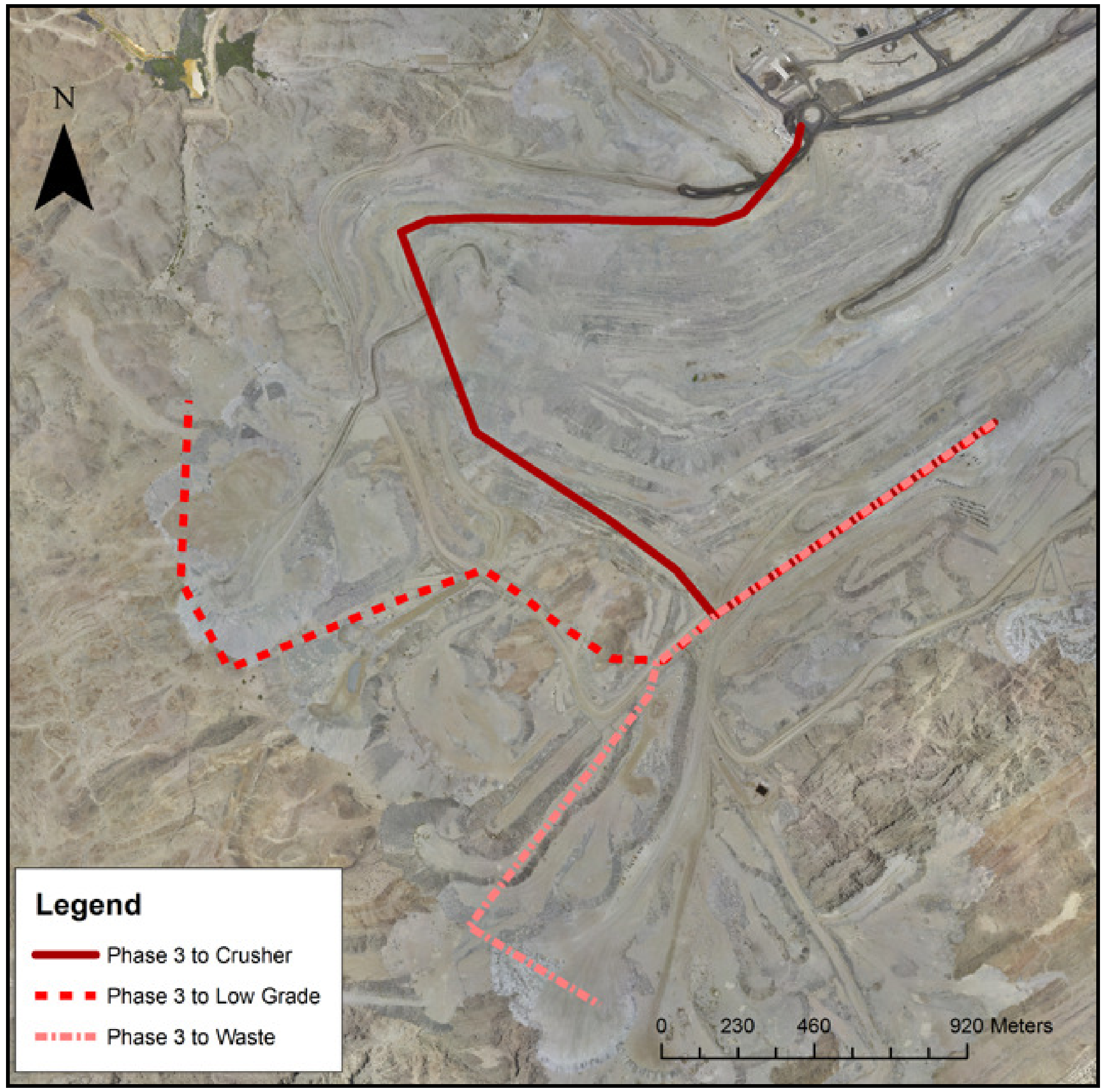

Figure A-4: Geographical information provided for Phase 3 roads

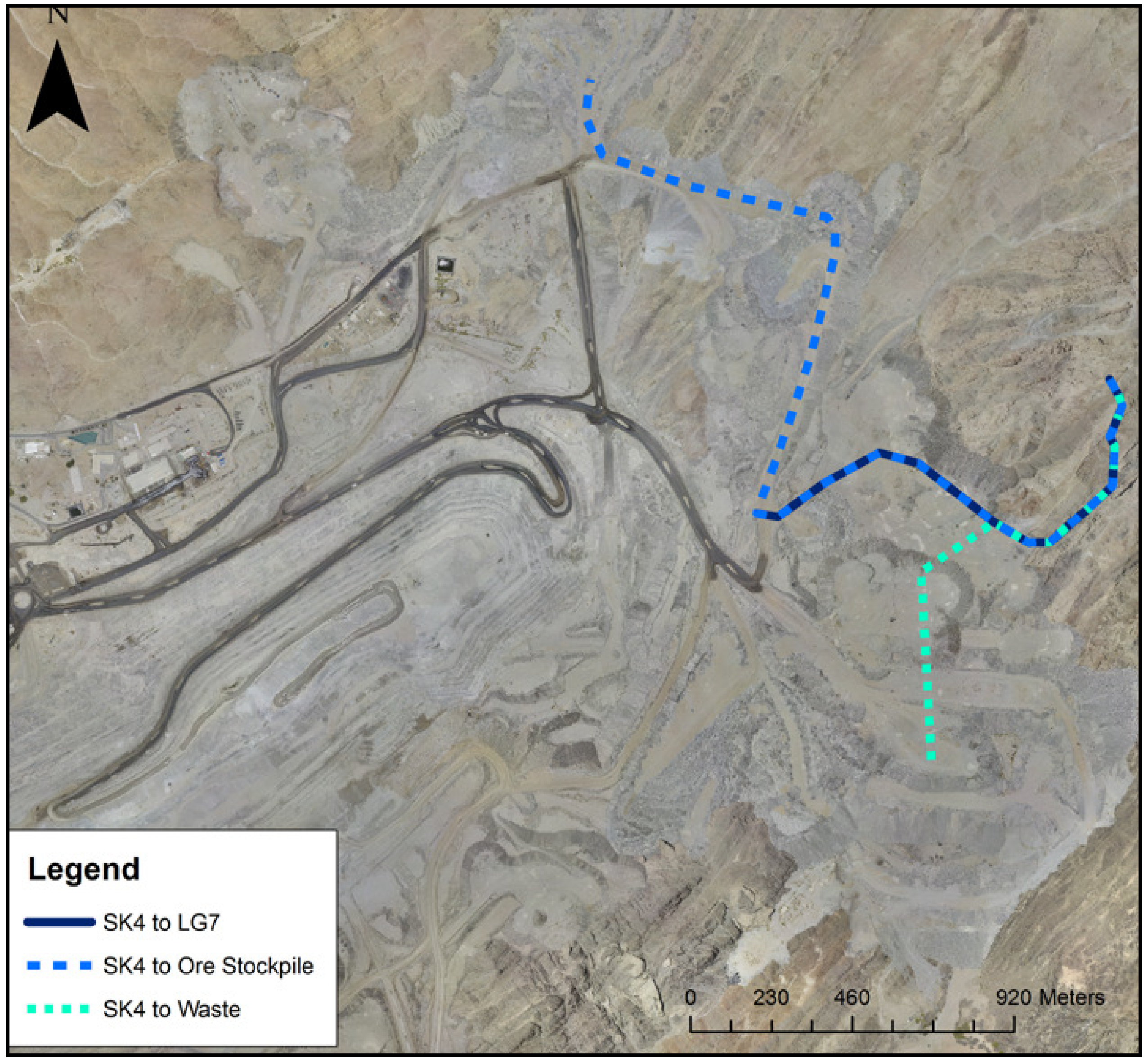

Figure A-5: Geographical information provided for SK4 roads

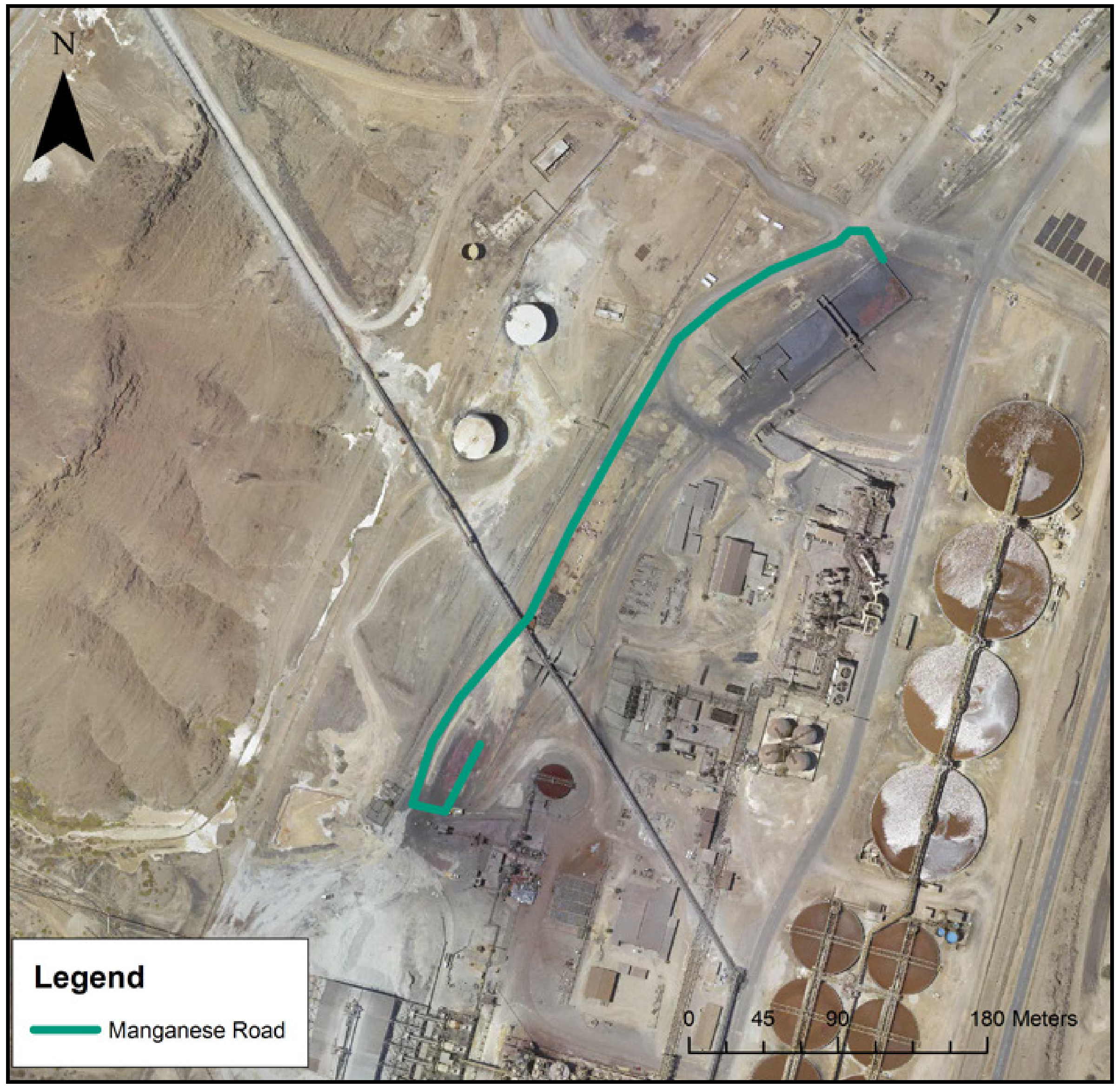

Figure A-6: Geographical information provided for Manganese roads

APPENDIX B

Vehicle Information Provided by Rössing personnel for the Quantification of Emissions from the Expansion Case

Table 1: Ore Tonnages to be Mined 2013 Expansion Case 89

(Data source is Case 89 mine plan spreadsheet data for year 2013, all information in annual tonnes)

Phase 2 NW Waste*	Phase NW 2 Ore to Crusher	Phase 2 NWTotal	Phase 3 NW Waste*	Phase 3 NW Ore to Crusher	Phase 3NW Total	Phase 4 NE Waste*	Phase 4 NW Ore to Crusher	Phase 4 NE Total	Total Material Mined Case 89 (te)	Total Ore Mined	Total Waste Mined	Reclaimed North LC to Crusher	Reclaimed South LC to Crusher	Total to Crushers	Total Existing Primary Crusher Feed	Total New Primary Crusher Feed
7,300,000	12,700,000	20,000,000	23,800,000	6,200,000	30,000,000	24,000,000	4,000,000	28,000,000	78,000,000	22,900,000	55,100,000	5,500,000	700,000	29,100,000	14,000,000	15,100,000

*Note: Case 89 does not specifically quote the proportion of the Waste that is treated as Low Grade. It has been estimated at 10% to predict haul truck movements/material handling tip points. (see See General Information and Assumptions Notes). Consequently tonnage to Waste is shown as a reduced quantity in table 2.

Table 2: Ore Haul Truck and Shovel Movements and Routes 2013

Route	Total Route Length (m)	Mined Ore or Waste Material Moved Annually (te)	Material Moved by RUL (te)	RUL Truck Payload (te)	No. of Cycles	Avg No. RUL Shovels per Area	Avg Annual Shovel Operating Hours Assuming 50% Operational	Avg Tonnes/hour per RUL Shovel
Phase 2 NW to Waste	5074	5,300,000	5,300,000	170	31,176	2.00	4380	2,283
Phase 2 NW to LG	5575	2,000,000	2,000,000	170	11,765			
Phase 2NW Ore to Crusher	3577	12,700,000	12,700,000	170	74,706			
Phase 3 NW to Waste	4104	20,800,000	20,800,000	170	122,353	3.00	4380	2,131
Phase 3 NW to LG	5158	3,000,000	3,000,000	170	17,647			
Phase 3 NW Ore to Crusher	3664	6,200,000	6,200,000	170	36,471			
Phase 4 NW to Waste	3604	21,200,000	21,200,000	170	124,706	3.00	4380	2,131
Phase 4 NW to LG	3312	2,800,000	2,800,000	170	16,471			
Phase 4 NW Ore to crusher	2165	4,000,000	4,000,000	170	23,529			
Reclaim from ROM Stockpiles	500	9,750,000	9,750,000	170	57,353	2.00	2200	2,216

Table 3: JJD Tailings Sand Hauling for Dressing of Roads, Loading and Tipping Areas 2013

Route	Tonnage of Ore or Waste Moved (annual te)	Tonnage of Tailings Sand Moved for Dressing (annual te)	JJD Truck Payload (te)	JJD Unladen Wt (te)	JJD Gross Wt (te)	No. of Cycles Annually	Proportion of Sand Distributed
Total Amount of Tailings Sand Used by RUL for dressing Roads in 2010 (50Mtonnes Ore mined)		724,340	39.52	30.3	69.82	18,328	
Predicted Total Amount Tailings Sand for 2013 (78Mtonnes Ore mined) - all hauled from high density tailings to crusher		1,129,971	39.52	30.3	69.82	28,592	
Tailings Sand Used at Crushers		140,116	39.52	30.3	69.82	3,545	12.4
Tailings Sand Distributed over other roads		989,854				25,047	87.6
Phase 2 NW to Waste	5,300,000	59,786	39.52	30.3	69.82	1,513	5.29
Phase 2 NW to LG	2,000,000	22,561	39.52	30.3	69.82	571	2.00
Phase 2NW Ore to Crusher	12700000	143,261	39.52	30.3	69.82	3,625	12.68
Phase 3 NW to Waste	20,800,000	234,632	39.52	30.3	69.82	5,937	20.76
Phase 3 NW to LG	3000000	33,841	39.52	30.3	69.82	856	2.99
Phase 3 NW Ore to	6200000	69,938	39.52	30.3	69.82	1,770	6.19

Table 3: JJD Tailings Sand Hauling for Dressing of Roads, Loading and Tipping Areas 2013

Route	Tonnage of Ore or Waste Moved (annual te)	Tonnage of Tailings Sand Moved for Dressing (annual te)	JJD Truck Payload (te)	JJD Unladen Wt (te)	JJD Gross Wt (te)	No. of Cycles Annually	Proportion of Sand Distributed
Crusher							
Phase 4 NW to Waste	21200000	239,144	39.52	30.3	69.82	6,051	21.16
Phase 4 NW to LG	2800000	31,585	39.52	30.3	69.82	799	2.80
Phase 4 NW Ore to crusher	4,000,000	45,122	39.52	30.3	69.82	1,142	3.99
Reclaim from ROM Stockpiles	9,750,000	109,984	39.52	30.3	69.82	2,783	9.73
Total Tonnes Ore Moved	87,750,000						

Table 4: Treatment of Routes with Dust-A-Side

Route	Route Treatment Description	Total Length (m)	Total Treated Length (m)	Total Untreated Length (m)
Phase 2 NW to Waste	The treated areas have been estimated by laying the route strings over an image of the pit. The strings have been assumed to be untreated in the mining areas at the pit bottom and also at the top after the strings have split to go to the waste or LG areas. There is a separate string showing the dustasided routes for Phase 2. (Phase 2 DAS strings.dxf)	5074	1786	3288
Phase 2 NW to LG		5575	1786	3789
Phase 2NW Ore to Crusher		3577	1994	1583
Phase 3 NW to Waste	The treated areas have been estimated by laying the route strings over an image of the pit. The strings have been assumed to be untreated in the mining areas at the pit bottom and also at the top after the strings have split to go to the waste or LG areas. There is a separate string showing the dustasided routes for Phase 3. (Phase 3 DAS strings.dxf)	4104	851	3253
Phase 3 NW to LG		5158	1736	3422
Phase 3 NW Ore to Crusher		3664	2091	1573
Phase 4 NW to Waste	The treated areas have been estimated by laying the route strings over an image of the pit. The strings have been assumed to be untreated in the mining areas at the pit bottom and also at the top after the strings have split to go to the waste or LG areas. There is a separate string showing the dustasided routes for Phase 4. (Phase 4 DAS strings.dxf)	3604	2000	1604
Phase 4 NW to LG		3312	2000	1312
Phase 4 NW Ore to crusher		2165	1734	431
ROM Stockpile to Crusher	All untreated	500 (estimated)	n/a	500
Primary Crusher to High Density Tailings Sand Loading Point	Trated adjacent to the pit. There is a separate string showing the dustasided part of the route to the High Density Tailings. (HD Tailings DAS strings.dxf)	6685	2324	4361
Permeter Old Tailings Area	All untreated		n/a	n/a
Manganese Road	All untreated	545		

Table 5: RUL Auxiliary Vehicle Movements within the Open Pit Area				
Vehicle Description	Vehicle Type and Approx Quantities (Typical based on RUL actual 2008/9)		Operating Weight (kg)	Expansion Case Annual Distance Traveled in Pit 2013 (km)
	Make (Typical)	Quantity		
Bakki*	Toyota Double Cab	43	2,000	1,954,114
Mini Bus	Toyota Quantum	9	3,200	653,392
Maintenance/Heff Trucks	Various	17	7500 (Est)	139,935
Wheeled Dozer	Cat 824C	2	28,724	22,816
Wheeled Dozer	Cat 834H	2	47,106	34,362
Grader	Cat 14G/14H	2	15,130	58,268
Grader	Cat 16M	2	26,060	27,882
Water Truck*	Cat777F/631E	4	165,000	113,454
Wheeled Loader	Cat 926	1	15,000	470
Wheeled Loader	Cat 992D	1	97,295	11,956
Wheeled Loader	Cat 994F	1	195,400	10,572

Table 6: RUL Vehicle Movements Within the Old Tailings Dam Area							
Vehicle Description	Make and Model	Operating Weight (kg)	Description of Journey	Route Taken	Route Distance (km)	Frequency (Annual)	Annual Distance (km)
Bakki*	Toyota Double Cab	2,000	Twice Weekly inspection of tailings perimeter.	Perimeter tailings Area	11.697	104	1,216
Grader*	Cat 14G	15,130	Monthly maintenance of roads around perimeter.	Perimeter Tailings Area	11.697	12	140

Table 7: RUL Vehicle Movements Within the High Density Tailings Area							
Vehicle Description	Make and Model	Operating Weight (kg)	Description of Journey	Route Taken	Route Distance (km)	Frequency (Annual)	Annual Distance (km)
Bakki*	Toyota Double Cab	2,000	3 times daily supervision of sand loading and inspection of seepage/pumping facilities	High Density Tailings Sand Route	9.125	1095	9,992
Grader*	Cat 14G	15,130	Twice weekly maintenance of roads.	High Density Tailings Sand Route	9.125	104	949

Table 8: Manganese Delivery Vehicle Movements Within the Plant (does not include tarmac roads)									
Vehicle Description	Make and Model	Unladen Weight (kg)	Payload (kg)	Gross Wt (kg)	Total Annual Tonnes Moved	Route Taken	Distance (km)	No. Of Cycles(Annual)	Annual Distance Traveled (km)
Delivery Truck (Flat Bed)	Various	32,000	31,500	63,500	21,000	Manganese Road to Manganese Tip point	0.545	667	363

General Information and Assumptions Used to Generate Annual Tonnages and Movements

1) The predicted mining tonnage for the expansion case has been chosen from the busiest mining year from the Case 89 mine plan and is 2013

2) Mining is all carried out by RUL

3) It is indicated that all material mined is sent to the primary crusher. This is not in fact true. Some is sent direct to the crusher, the balance of material is sent to the ROM "P" stockpiles just behind the primary crusher. In terms of dust generated from journeys this distance is not significant. The material that is fed to the primary crusher from the P stockpiles is shown. There will be two primary crushing plants in the expansion case (the two existing crushers and one large new one). They are likely to be in similar locations so for the purposes of vehicle movements it has been assumed that the vehicles are traveling to a single primary crusher. It has been assumed that 20% of the ore going to the tank leach plant is double handled at the P stockpiles and that 5% of the ore going to the new heap leach plant is double handled at the at the P stockpiles

Notes Specific to Table 2

1) RUL Haul trucks have a laden weight of 320 tonnes, payload of 170 tonnes and an unladen weight of 150 tonnes

2) There are a total of 8 RUL shovels in the pit based on a figure of about 10Mtonnes per shovel. Shovel distribution through out the mining areas will be varied and has been averaged. All ore mined is assumed to go directly to the crusher. There is also material reclaimed from ROM "P" stockpiles and fed to the crusher.

3) There are currently two machines loading reclaim at the "P" Stockpiles (a Marion shovel and a Cat994). It is assumed that the same loading arrangement will be made for the expansion case. These machines have lower operating hours or other duties; hence the operating hours have been estimated to obtain a reasonable shovel throughput. All other shovels have been estimated as operating for 50% of the annual hours to allow a figure for tonnes per hour to be calculated. Note operating hours in this case means hours actually "shoveling" and was a "real" figure provided by mine management for the Base Case. The same percentage operational hours have been used for the Expansion Case.

4) The routes shown are typical for waste, low grade and ore from each mining centre. The mining centers are in the central position of each mining area.

5) Case 89 does not specifically state the proportion of mined material treated as waste or low grade. This figure has been estimated at 10% of the total tonnes mined being Low Grade. This has been made in conjunction with mine management and considering the proportion of low grades obtained for all the mining areas in the base case for years 2009 to 2021.

Notes Specific to Tables 3

1) All tailings sand for RUL mining operations (surface dressing or roads, loading and tipping areas) is hauled by JJD using Komatsu HM400 haul trucks. Unladen weight is 30.3te. Sand usage in 2013 expansion case is estimated based on the 2010 base case figure but increased in proportion to the increase in tonnage mined.

2) Distribution of sand vehicle traffic has been assumed to take place over the same roads as the ore haul routes from the pit and is distributed according to the tonnage moved over the road.

3) The sand is all hauled down the route from the sand loading point on the high density tailings to the primary crusher. Some of the sand hauled is used to dress the area around the primary crusher. The balance is distributed among the haul roads, loading and tipping points throughout the pit and rock dump areas. The location of the end of the sand road is a conservative estimate at the northerly end of the high density tailings area. An additional side road has been included to give access to seepage areas and any pumping facility. The method of deposition of the tailings does not require vehicular equipment so there should be no other vehicle generated dust from this area.

Notes Specific to Tables 4

1) Open pit roads are partially treated with Dust-A-Side as shown in table 5. All other roads are considered as untreated. The estimate has been made by laying the vehicle strings over an image of the pit and making an assessment of the extent of the Dust-A-Side areas, based on current practice.

Notes Specific to Tables 5, 6 and 7

1) Specific vehicle types are identified where possible. Assumptions have been made where the exact identity is not known or is subject to change. In these cases a typical vehicle is used (Marked with *)

2) Light vehicle km in the pit has been estimated from plant records for vehicles used in the mining operating sector in 2009. It has been assumed that 90% of the distance traveled is in the pit. It has been assumed that Mini Buses are always full and Bakkies have a driver and passenger. Maintenance trucks have been estimated at an average 7.5 tonne operating weight. In the high density tailings area an allowance has only been made for the supervision vehicle. It is assumed it will tour the sand road and the pumping and seepage facility 3 times per day.

3) The tailings dam area will have changed for the 2013 expansion case and the tailings dam will no longer be active. However the exact location of all the roads and frequency of inspection is not known. There will certainly be some activity around the seepage collection area and some occasional movement of vehicles around the perimeter of the tailings dam and heap. In order to make some sort of estimate it has been assumed that the activity will equate to a twice weekly inspection of the entire tailings perimeter as used for the base case and a monthly grading operation to maintain the road.

4) It has been assumed that no dust is generated from the movement of tracked vehicles. Wheeled dozers and front end loader travel in the pit has been generated from operating hours, an assumed speed of 2 km/h and 90% of the time in the pit. The base case has been factored to take account of the increased tonnage mined in the expansion case.

5) The light vehicle traffic has been determined from the RUL data. This has been used to arrive at an auxiliary figure per tonne of material mined. This has then been scaled up to predict the traffic in 2013. This should over state the vehicle traffic because some tasks are independent of tonnes mined. It is assumed that this overstatement will account for the additional traffic by external contractors, which have not been separately accounted for.

Geographic Information provided for the Expansion Case (2013) Roads used at Rössing

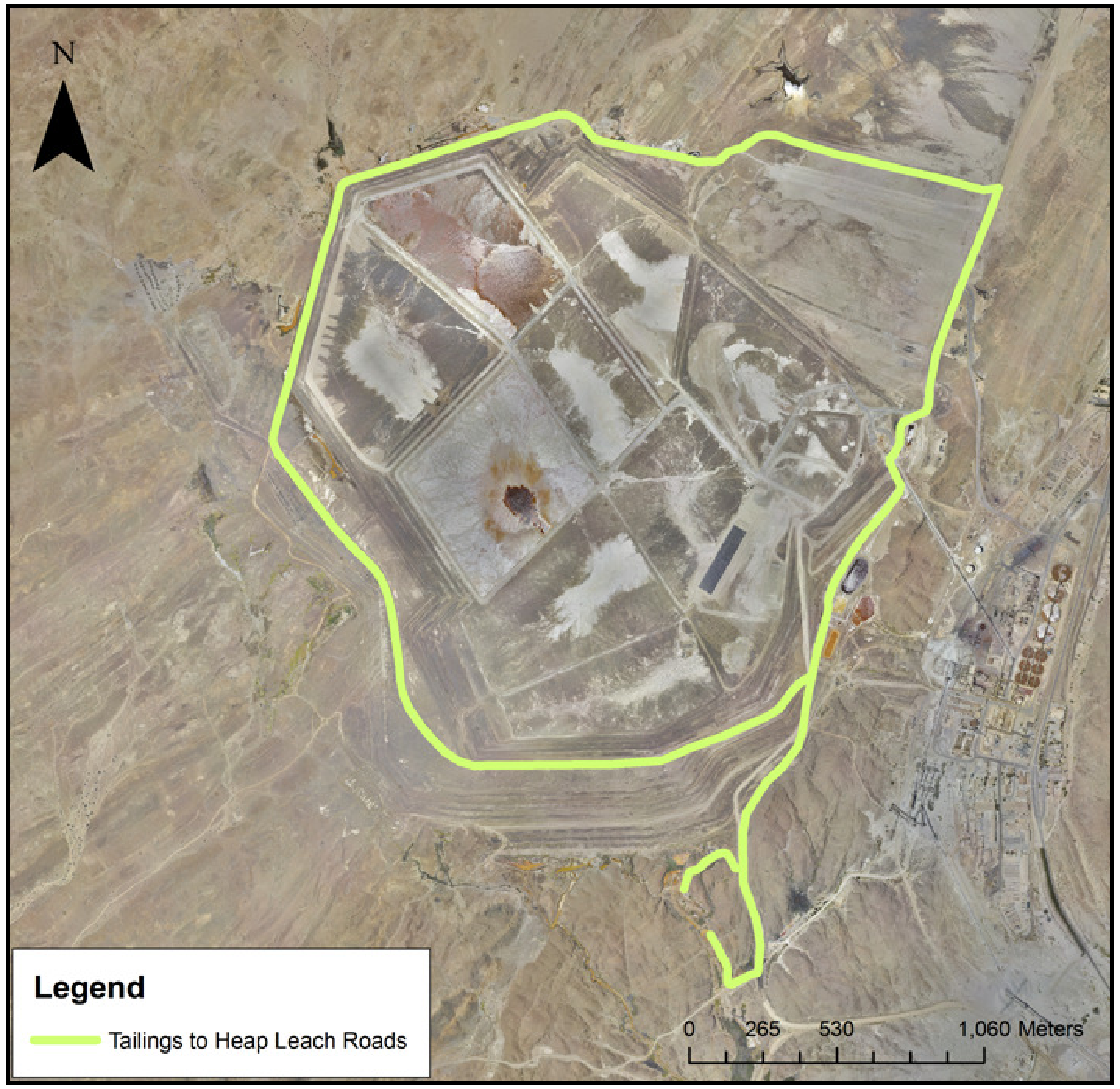

Figure B-1: Geographical information provided for tailings roads

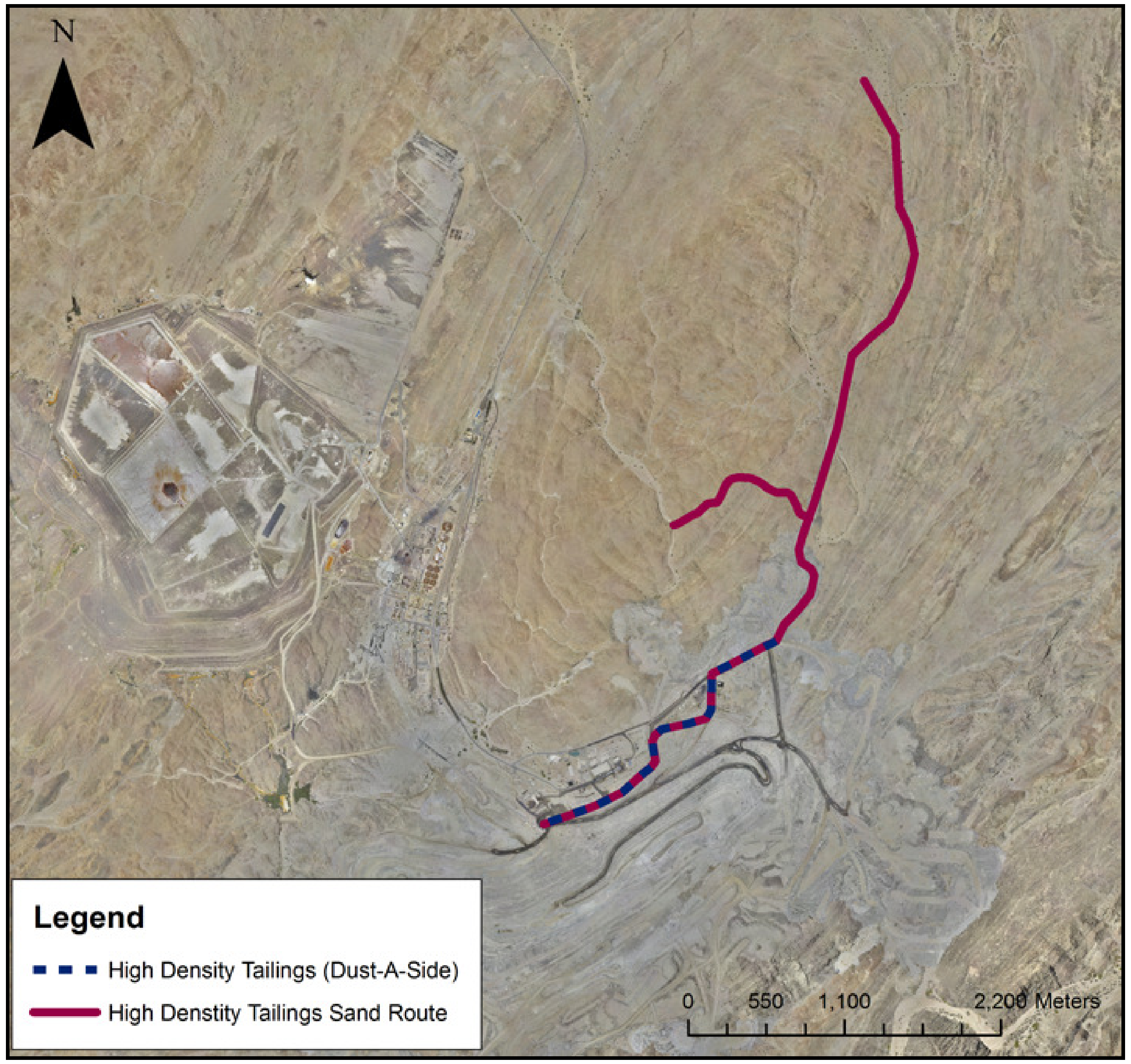

Figure B-2: Geographical information provided for High Density Tailings roads

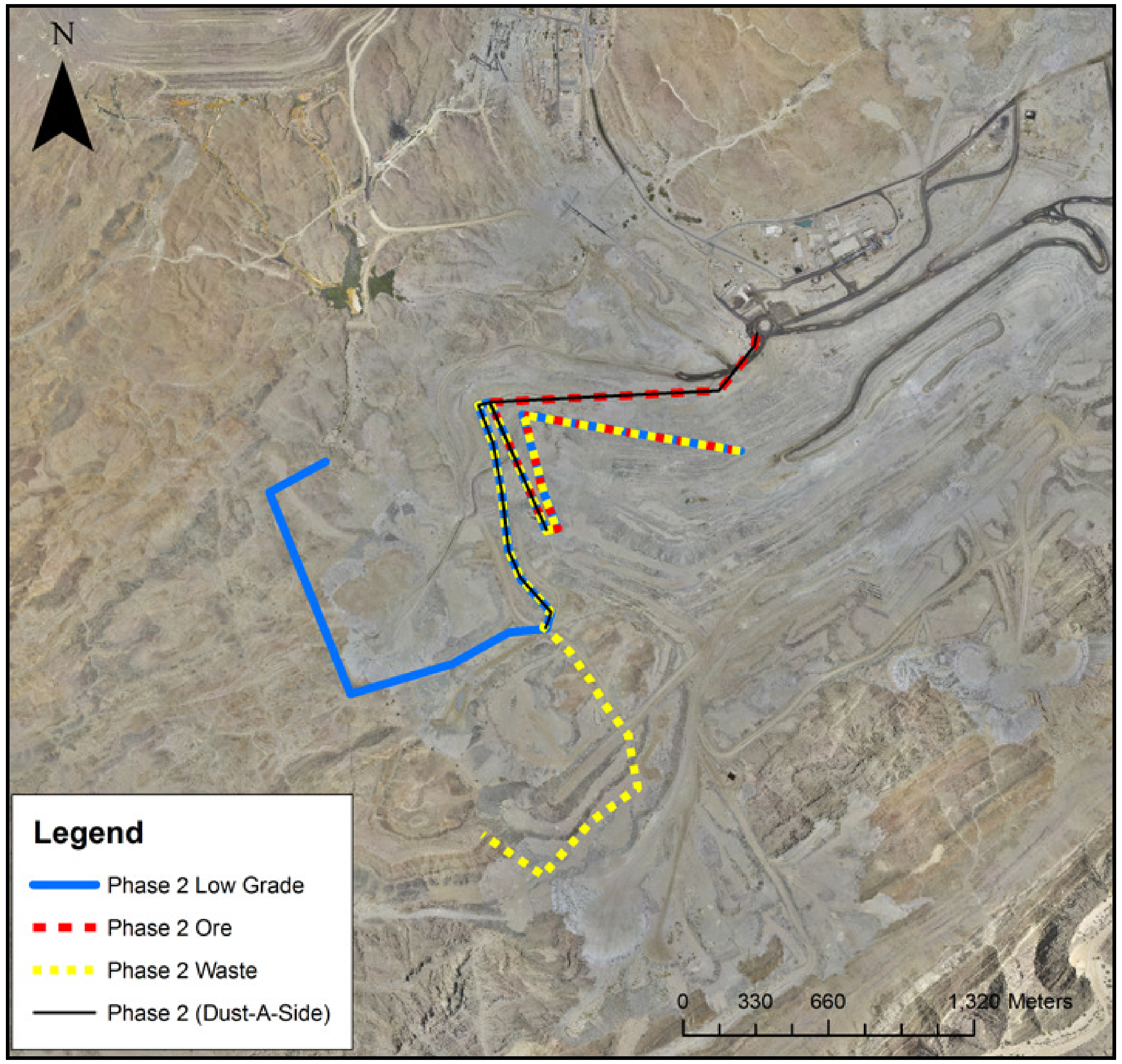

Figure B-3: Geographical information provided for Phase 2 roads

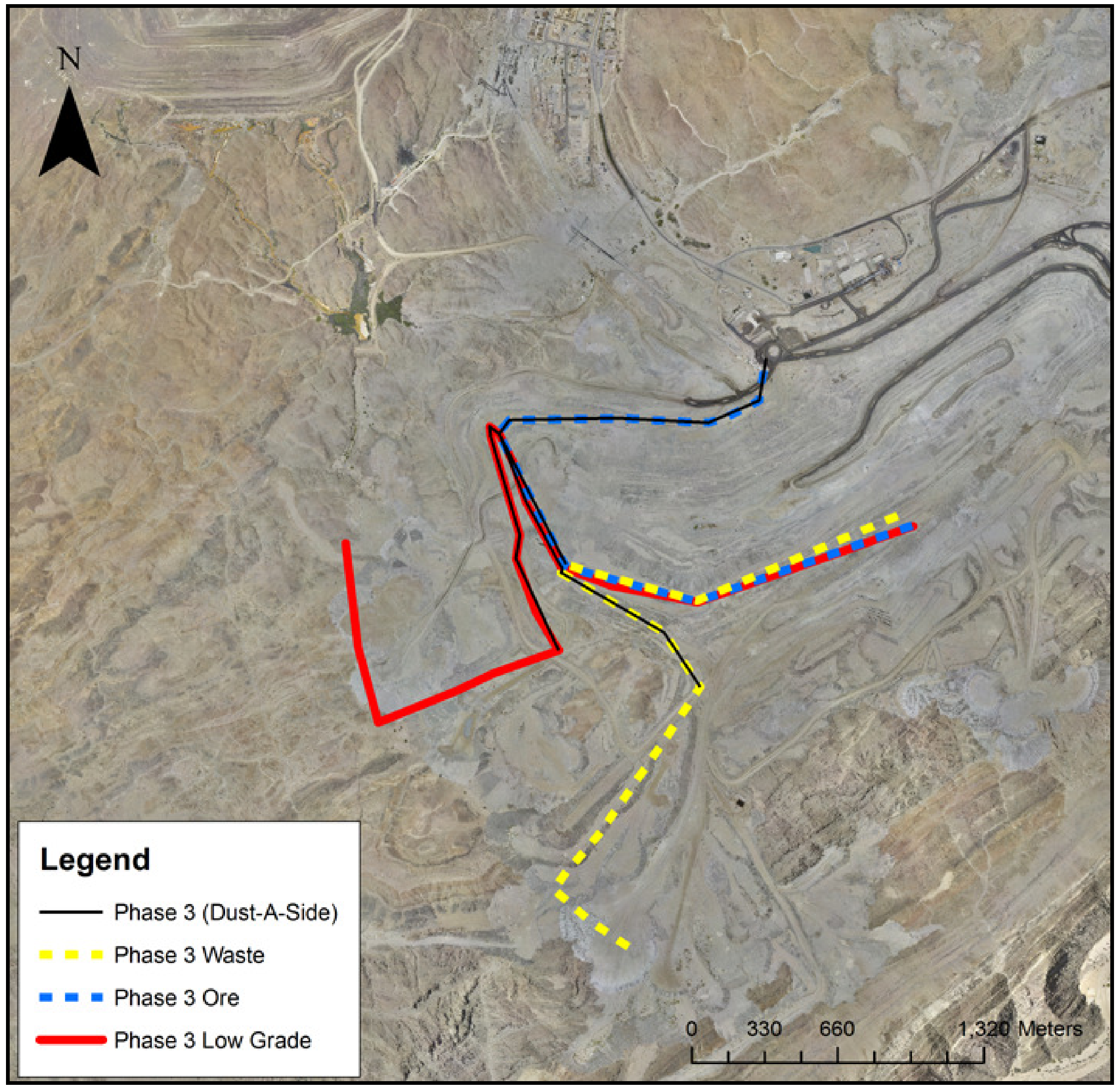

Figure B-4: Geographical information provided for Phase 3 roads

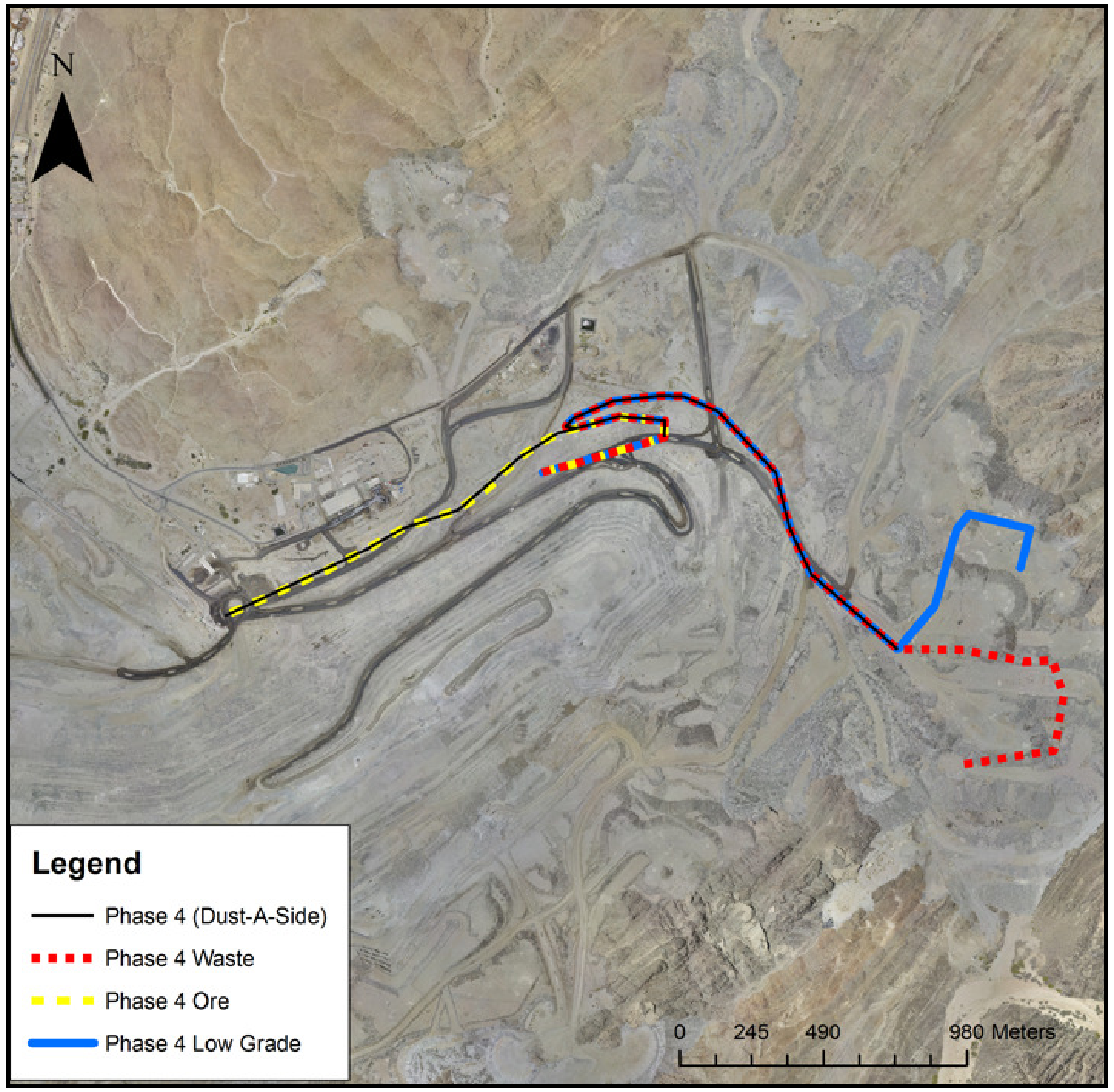

Figure B-5: Geographical information provided for Phase 4 roads

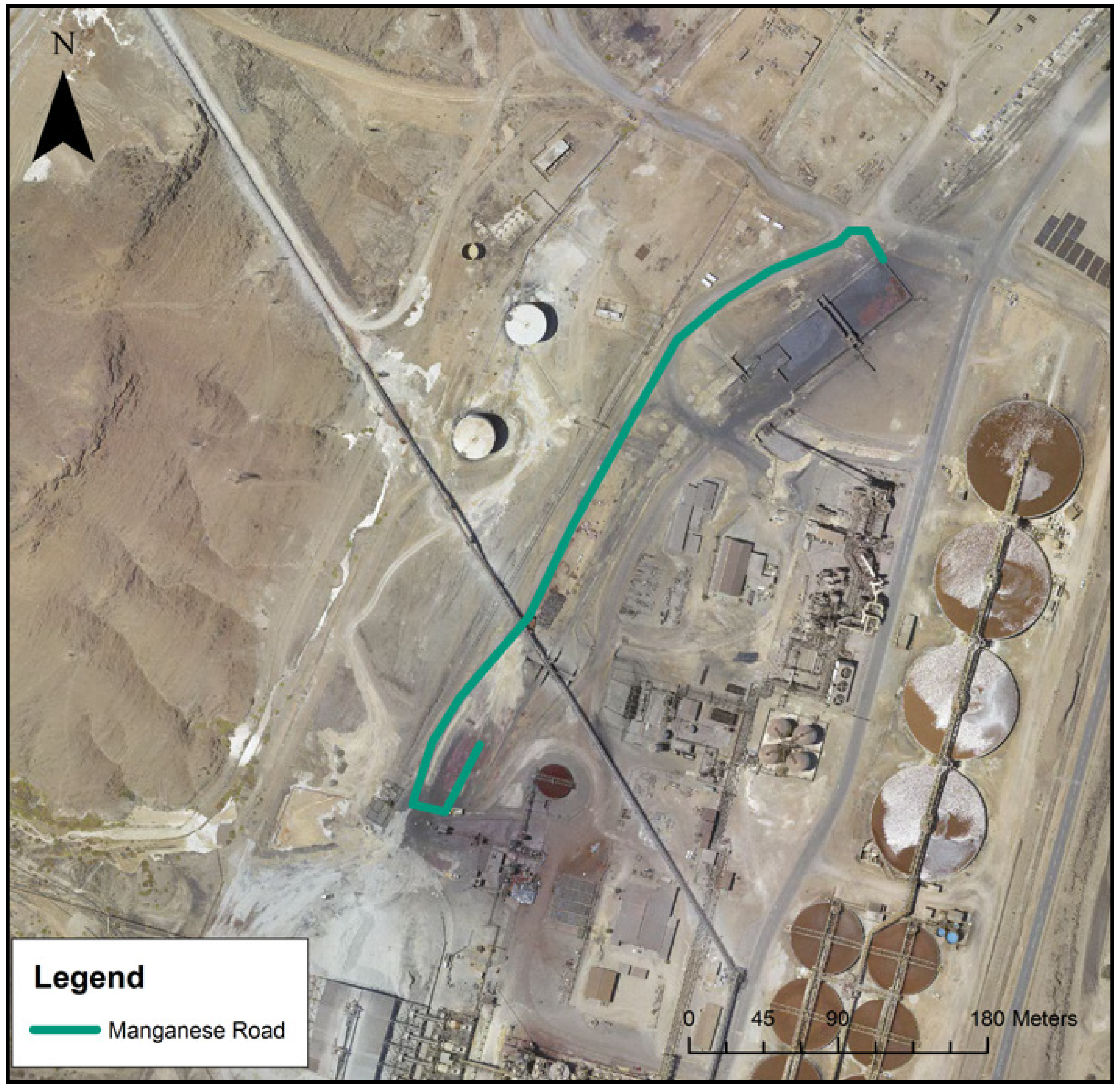

Figure B-6: Geographical information provided for Manganese roads

APPENDIX C

Air Quality Impact Assessment for the Alternative Central Case Assessed for the Expansion Case (2013)

C.1. Alternative Assessed for the Expansion Case (2013)

An alternative location for the proposed Ripios stockpile and tailings facility was assessed for the Expansion Case (2013). This alternative (known as the Central Case) considered the alternative position of the ripios disposal on the dome where the material is transferred via rope conveyor and the proposed alternative disposal of conventional tailings on the existing tailings dam (Figure C-1).

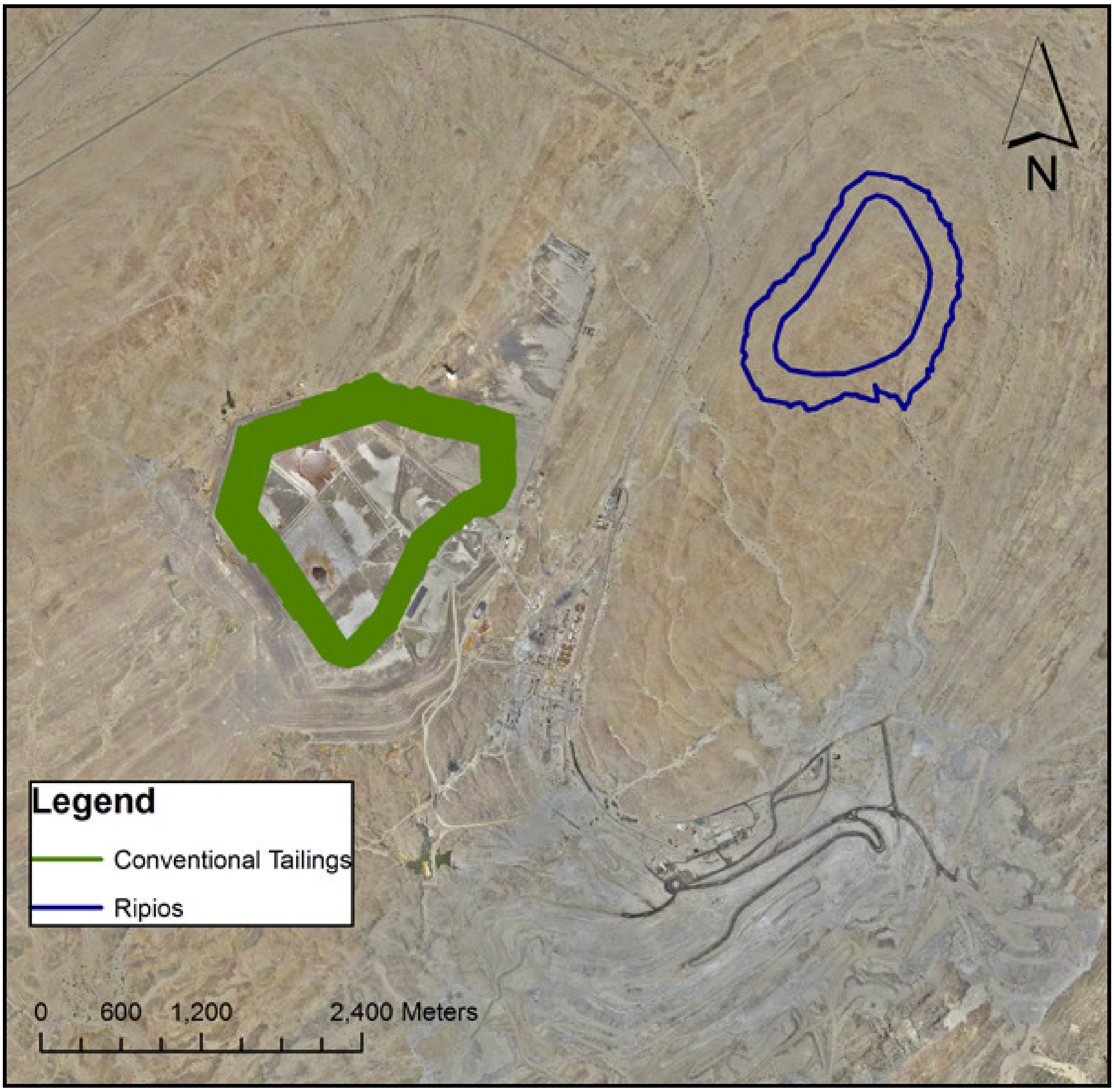

Figure C-1: Position of the Ripios disposal and conventional tailings facility for the Expansion Case (2013) alternative (Central Case)

The fugitive dust sources due to the Expansion Case Alternative includes the wind blown dust from the tailings facility and ripios stockpiles as well as vehicle entrainment, materials handling operations, wind blown dust from various other stockpiles (i.e. waste dumps), etc.

as discussed in Section 5 of the report. All potential fugitive dust sources for the Expansion Case Alternative were simulated to predict the potential ground level impacts.

C.2. Dispersion Model Results

Simulations were undertaken to determine particulate matter (PM10) concentrations and total daily dust deposition from proposed operations at Rössing (Expansion Case 2013 Alternative).

It should be noted that isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations for that averaging period, over the entire period for which simulations were undertaken. *It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period. The isopleths for daily ground level concentrations are thus a conservative prediction of the impacts and should be assessed with frequency of occurrence.*

In addition, high PM10 (inhalable particulate matter <10µm in diameter) impacts predicted in the current assessment may not necessarily be visible (in terms of a visible plume) due to the size of the particulate matter.

The plots provided for the relevant pollutants of concern during the proposed operational phase are given in Table C-1.

Table C-1: Isopleth plots presented in the current section.

Alternative	Scenario	Pollutant	Averaging Period	Figure
Central Case	*All Sources*	PM10	Highest daily Frequency of exceedance of highest daily Annual average	C-3 C-4 C-5
		TSP	Maximum deposition	C-6

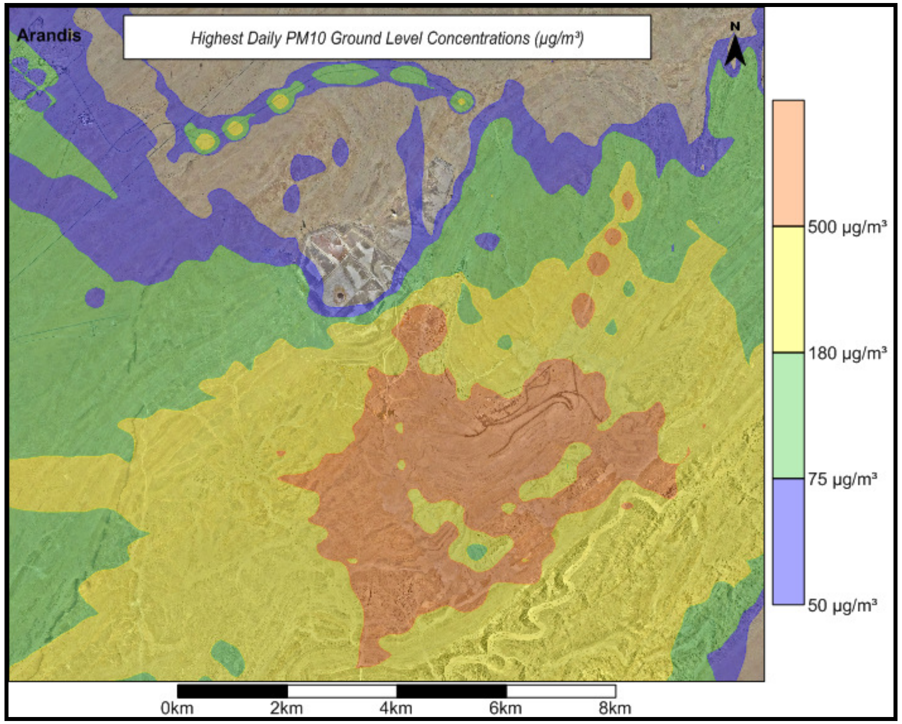

Figure C-3: Highest daily PM10 ground level concentrations due to proposed (alternative Expansion Case for the year 2013 – Central Case) operations (all sources)

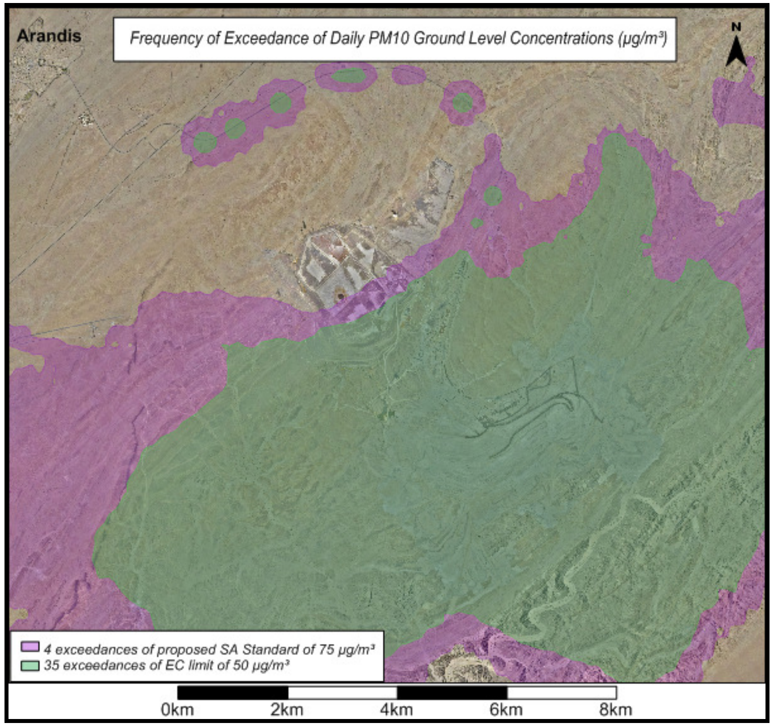

Figure C-4: Frequency of exceedance of highest daily PM10 ground level concentrations due to proposed (alternative Expansion Case for the year 2013 – Central Case) operations (all sources)

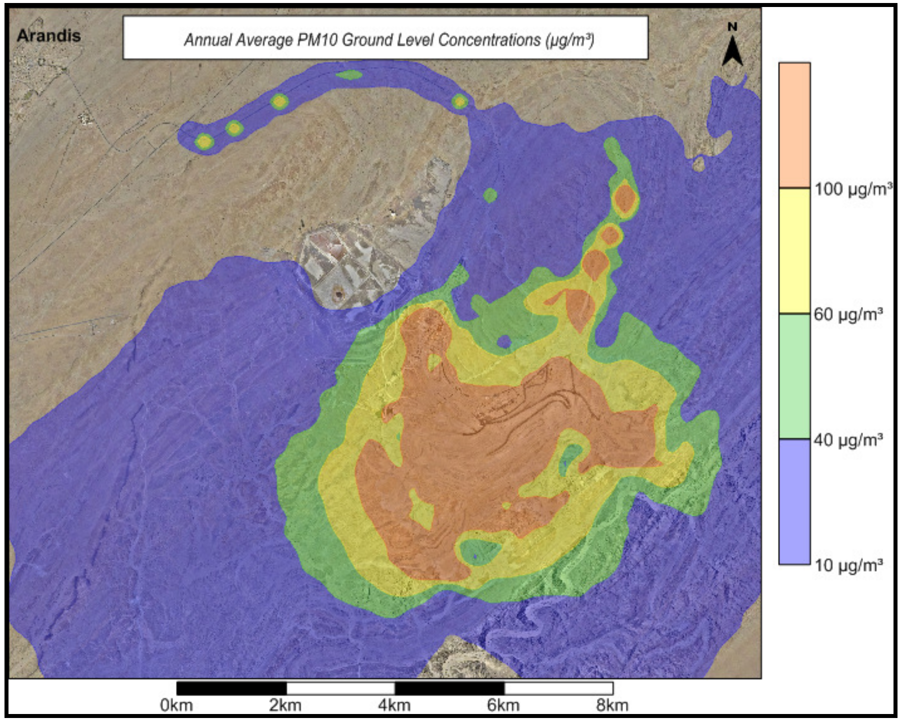

Figure C-5: Annual average PM10 ground level concentrations due to proposed (alternative Expansion Case for the year 2013 – Central Case) operations (all sources)

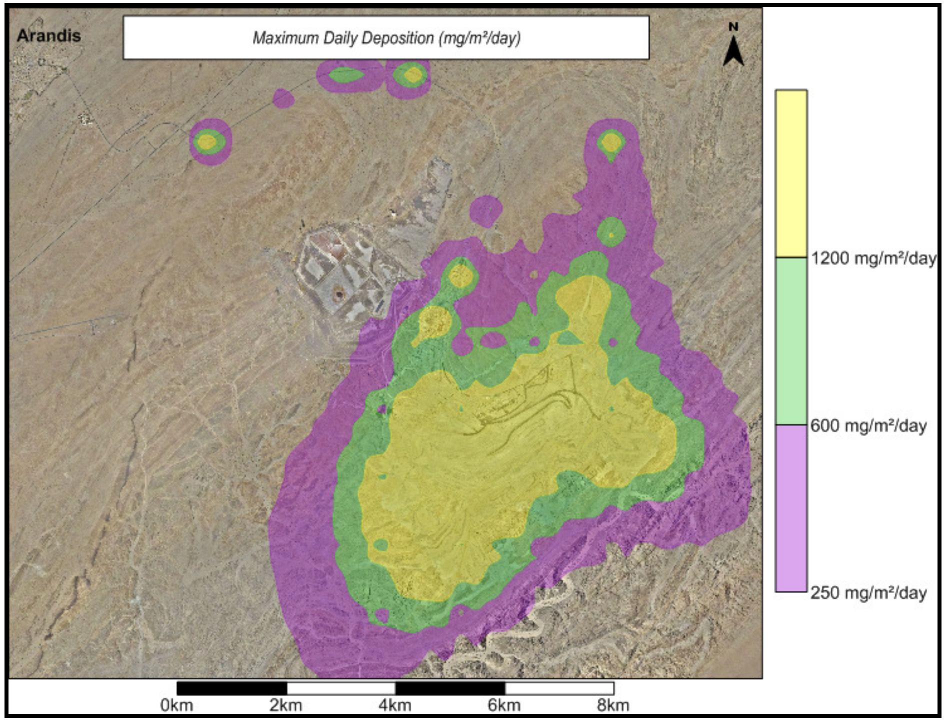

Figure C-6: Maximum daily deposition due to proposed (alternative Expansion Case for the year 2013 – Central Case) operations (all sources)

C.3. Compliance Assessment

For the alternative Expansion Case (2013), the predicted impacts are similar in magnitude and spatial distribution to the Expansion Case (2013) as discussed in Section 6. The highest predicted PM10 concentrations due to Central Expansion Case (2013) are provided in Table C-2. Predicted dust deposition due to Central Expansion Case (2013) is provided in Table C-3.

Table C-2: Highest predicted PM10 concentrations directly off-site due to proposed routine operations (Central Case) at Rössing (a)

Highest Daily				Annual Average			In compliance (Y/N)
Predicted conc. µg/m^3	Guideline µg/m^3	Factor of guideline	Frequency of Exceedance (days/year)	Predicted conc. µg/m^3	Guideline µg/m^3	Factor of guideline	
At Mine Boundary							
440	150 (b)	**2.93**	22	45	-	-	N
	120 (c)	**3.67**	30		50 (c)	0.90	N
	75 (d)	**5.87**	62		40 (d)(f)	**1.13**	N
	50 (e)(f)	**8.80**	100		20 (e)	**2.25**	N
At the sensitive receptor of Arandis							
80	150 (b)	0.53	0	5.4	-	-	Y
	120 (c)	0.67	0		50 (c)	0.11	Y
	75 (d)	**1.07**	1		40 (d)(f)	0.14	Y
	50 (e)(f)	**1.60**	2		20 (e)	0.27	Y

Note:

(a) Exceedance of the guideline is provided in bold

(b) US-EPA guideline not to be exceeded more than 1 day/year

(c) Current SA Limit (compliance data – immediate to 31 December 2014) not to be exceeded more than 4 days/year

(d) Proposed SA Limit (compliance data – 1 January 2015) not to be exceeded more than 4 days/year

(e) WHO guideline

(f) EC limit not to be exceeded more than 35 days/year. It should be noted that the EC stipulate that air quality limits are applicable in areas where there is a reasonable expectation that public exposures will occur over the averaging period of the limit

Table C-3: Predicted maximum dust fallout (TSP) off-site due to proposed routine operations (Central Case) at Rössing (a).

Highest total daily dust fallout		
Max deposition (mg/m²/day)	**Guideline mg/m²/day**	**Factor of guideline**
At Mine Boundary		
510	1 200 (b) 600 (c)	0.43 0.85
At the sensitive receptor of Arandis		
13.5	1 200 (b) 600 (c)	0.01 0.02

Note:

(a) Exceedance of the guideline is provided in bold

(b) Upper limit for SANS for industrial areas

(c) SANS limit for residential areas and lower limit for industrial areas