Project done for

Aurecon Namibia (Pty) Ltd and SLR Namibia (Pty)Ltd

Mining of the Z20 Uranium Deposit -

Air Quality Assessment

Report No.: APP/12/AUR-14 Rev 1

Scoping Phase of SEIA

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REPORT DETAILS

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Executive Summary

Airshed Planning Professionals (Pty) Ltd was appointed by Aurecon Namibia (Pty) Ltd in conjunction with SLR Namibia (Pty) Ltd to determine the potential for dust impacts on the surrounding environment and human health from the proposed Z20 Infrastructure Corridor operations.

The study includes a baseline evaluation, impacts assessment and dust management plan including mitigation and monitoring recommendations.

Project Scope

The scope of the study includes the identification and quantification of all current sources of air pollution from the Z20 Infrastructure Corridor operations. The Rössing Uranium Mine is located approximately 55 km to the northeast of Swakopmund and comprises of open-pit mining and processing operations. The current operations are focused to the north of the Khan River, including mining the present Rössing open pit (blast, load and haul operation), waste rock disposal, ore processing, tailings disposal and ancillary activities. The proposed Z20 Z20 ore body is located on the opposite side of the Khan River in relation to the current Rössing Uranium mining operations. The infrastructure corridor will include an overland conveyor; an access road; a water supply pipeline; diesel line and power line.

The baseline was taken from the Rössing Phase II SEIA expansion project conducted in 2010. This include reporting on a monitoring campaign conducted over two months in 2009 and the baseline dispe4rsion modelling results accounting for all the current (based on 2010) Rössing mining activities. Meteorological data from the Rössing weather station for the persio 2000 to 2004 were used in the assessment.

The main pollutant of concern in the study is particulates, both due to the potential health and nuisance impacts associated with it. The main sources identified to result in particulate emissions during operational phase are the conveyor transfer points, the potential for wind-blown dust from the conveyor and, to a lesser extent, dust generation from the paved access road. Construction operations will primarily relate to the construction of the access road and conveyor support structures.

In the quantification of fugitive dust emissions, emission factors were used that associate the quantity of a pollutant to the activity associated with the release of that pollutant. Use was made of the comprehensive set of emission factors published by the US Environmental Protection Agency (US.EPA) in its AP-42 document compilation of Air Pollution Emission Factors and to the Australian National Pollutant Inventory (NPI) emission factors.

Simulated PM10 ground level concentrations and dust fallout rates were compared to selected international ambient air quality guidelines and standards and Dust fallout Limits, respectively. This informed the significance rating and proposed mitigation measures. A dust management plan for all three phases (viz. construction; operational and decommissioning) were compiled with specific monitoring recommendations.

Impact Assessment

Baseline evaluation: The baseline evaluation was based on monitoring conducted over a short period of two months and dispersion modelling. The monitoring indicated average PM10 daily concentrations of 21 µg/m³ and 40 µg/m³ at Arandis Town and Arandis Airport. Simulated concentrations from the Rössing 2010 baseline indicate similar daily PM10 concentrations of 35 µg/m³ for Arandis Town and 54 µg/m³ for Arandis Airport. The highest GLCs are at the Khan River. Dust fallout rates at both Arandis and Arandis Airport were low and well below the SANS residential limit of 600 mg/m²/day. Again, this was only over a period of two months (March and April 2009). Dust fallout is the highest near the mine activities with the highest of 225 mg/m²/day predicted at the Khan River.

Construction operations: This was only qualitatively assessed with the main dust generating activities during construction identified to include clearing of vegetation, blasting, wind erosion from exposed surfaces, grading of the access road surface and asphalt application. Calculations indicate TSP emission rates to be slightly lower than that of the operational phase. This is based on the assumption that all construction activities will occur simultaneously and over the entire area. This is very unlikely and it is expected that the impacts will be similar or lower than that of the operational phase, for the unmitigated scenario. With water sprays in place at most of the construction activities, the emissions could be halved ensuring impacts to be restricted to the mine property.

Operational phase: windblown dust from the conveyor is likely to be the main source of emissions with roads the lowest contributor.

The prevailing wind field is from the north-east and south-west with infrequent winds from the north-west. Field studies indicate that winds blowing at an angle towards a valley will accelerate downwind and likely to reach a maximum at the downwind valley wall after which the wind speeds will decrease rapidly. The potential for wind speeds to increase at the downwind valley wall, were accounted for in the study.

Assuming a conventional conveyor system with no side walls or roof cover and no controls at the transfer points, the predicted daily PM_{10} GLCs exceed the air quality limit of 75 µg/m³ around the two transfer points. With mitigation in place (two side covers and a roof at the conveyor and enclosure at the transfer points reducing the emissions by 70%) the GLCs reduce to only impact at the transfer point. No exceedances were predicted over an annual average. Cumulatively, the predicted GLCs (with no mitigation) are slightly higher than the baseline situation with only a slight increase at the Khan River. With mitigation measures in place, the cumulative concentrations decrease slightly, reflecting very similar concentrations as the baseline.

Dust fallout can be high around the conveyor with no mitigation in place, exceeding the vegetation limit of 400 mg/m²/day. With mitigation in place, the dust fallout rates decrease significantly to be well below the vegetation and residential limits.

Decommissioning: impacts from the decommissioning phase were assessed qualitatively. These impacts would depend on the extent of demolition activities, but are expected to be localised and cease once rehabilitation starts.

Conclusion

It can be concluded that the proposed Z20 Infrastructure Corridor Project will have high PM10 impacts near the conveyor transfer points with no mitigation in place. With the recommended mitigation measures applied, concentrations will be retained at the source. Dust fallout can be high along the conveyor if not controlled; but is expected to be low based on the proposed RopCon design and enclosure of the transfer points.

Recommendations

It is recommended that the proposed conveyor system be designed as per the RopCon description, ensuring a roof cover. It is further recommended that the transfer points be enclosed with an extraction system and bag filter attached. This will ensure >95% control efficiency in comparison to the 70% from enclosure only.

It is further recommended that that four single dust fallout buckets be installed along the conveyor system in order to monitor the impacts from this source. The proposed locations are to be south of Transfer Point 1; one located in the Khan River “down-wind” from the conveyor; one to be located south if Transfer Point 2; and another to be located south of the final transfer point. Also, it is recommended that a passive diffusive sampling campaign be conducted during the access road building phase to sample concentrations of SO_2 and VOCs.

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List of Acronyms and Symbols

Airshed	Airshed Planning Professionals (Pty) Ltd
amsl	above mean sea level
APIA	Air Pollution Impact Assessment
AQG	Air quality guidelines
ASTM	American Society for Testing And Materials
CERC	Cambridge Environmental Research Consultants
EC	European Community
EMP	Environmental Management Programme
EU	The European Union
IFC	International Finance Corporation
IT	Interim Target
m	metre
m^3	Cubic metre
NPI	National Pollutant Inventory (Australia)
PM10	Particulate Matter with an aerodynamic diameter of less than 10µ
PM2.5	Particulate Matter with an aerodynamic diameter of less than 2.5µ
ROM	Run Of Mine
SA	South Africa
SABS	South African Bureau of Standards
SANS	South African National Standards
SEIA	Social and Environmental Impact Assessment
tpa	Tonnes per annum
tpd	Tonnes per day
TSP	Total Suspended Particles
UK	United Kingdom
US	United States
µ	Microns
µg	Micrograms

US-EPA	United States Environmental Protection Agency
WB	The World Bank
WHO	The World Health Organisation

Glossary

“**air pollution**” means any change in the composition of the air caused by smoke, soot, dust (including coal), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

“anabatic flow” is where the warm upslope airflow results from local surface heating.

“**ambient air**” is defined as any area not regulated by Occupational Health and Safety regulations.

“atmospheric emission” or **“emission”** means any emission or entrainment process emanating from a point, non-point or mobile source that results in air pollution.

“averaging period” means a period of time over which an average value is determined.

“baseline air quality” means the contribution from the current Rössing Uranium Mine operations to the proposed project.

“background air quality” means the current air quality within the region due to all natural and anthropogenic sources.

“katabatic flow” is where cool air flows down sloping terrain.

“particulates” comprises a mixture of organic and inorganic substances, ranging in size and shape. These can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst thoracic particles or PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) fall in the finer fraction. PM_{10} is associated with health impacts for it represents particles of a size that would be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung. TSP, on the other hand, is usually of interest in terms of dust deposition (nuisance).

1 Introduction

Rössing Uranium Mine, located approximately 55 km to the northeast of Swakopmund comprises of open-pit mining and processing operations. The current operations are focused to the north of the Khan River, including mining the present Rössing open pit (blast, load and haul operation), waste rock disposal, ore processing, tailings disposal and ancillary activities.

A new ore body, the Z20, was explored and is now considered for mining. The Z20 ore body is located on the opposite side of the Khan River in relation to the current Rössing Uranium mining operations (Figure 1-1). Mining of the Z20 ore body will be open pit mining operations and the waste rock will be disposed near to the Z20 pit. The ore will be transported to the existing processing plant at Rössing Mine and this will require additional infrastructure development. The infrastructure corridor will include an overland conveyor; an access road; a water supply pipeline, diesel line and power line. At Rössing Mine, the processing plant will be modified; a new high density tailings storage facility (TSF) will be developed with changes made to the existing TSF. An acid production capacity approved for 1,200 tpd is being upgraded to 2,000 tpd.

The Social and Environmental Impact Assessment (SEIA) for the proposed Z20 project is being conducted in two phases:

- Scoping Phase addressing the potential impacts from the Infrastructure corridor, and
- SEIA Phase addressing the potential impacts from the Z20 mining and processing operations.

Airshed Planning Professionals (Pty) Ltd was appointed by Aurecon Namibia (Pty) Ltd in conjunction with SLR Namibia (Pty) Ltd to determine the potential for dust impacts on the surrounding environment and human health from the proposed operations. Practical mitigation measures need to be considered for the planning/construction and operational phases of the project. The rehabilitation of the site also needs to be assessed.

This report addresses the air quality assessment conducted for the Z20 Infrastructure Corridor.

1.1 Project Description

1.1.1 Product transport

The infrastructure corridor will be developed to transport ore from the Z20 open pit to the Rössing processing plant on the opposite side of the Khan River. Four options were considered namely: hauling; conventional conveyor options; tunnelling and conveying; slurry pumping and the RopeCon© overland conveying (OLC) system. The latter option is favoured and will consist of two sections with Section 1 being a combination between a RailCon© and RopeCon©. The RailCon©, with a length of approximately 1,480 m, will transport the ore from the Primary Crusher to the first transfer point where it will go onto RopeCon©. The RopeCon© will run over the Khan River towards the second transfer point covering a distance of approximately 8,360 m. Section 2 will also be a RopeCon© system with a length of approximately 2,711m transferring ore from the transfer point to the coarse ore stockpile close to the milling circuit located on the processing plant premises.

The system has a capacity of 2,250 tons of ore per hour in one direction, operating at speeds of up to 4.65 m/s with a total length of approximately 12,550 m. The belt has 200 mm high corrugated sidewalls and is covered by a roof cover to protect the material from the effects of the weather.

1.1.2 Road

A new asphalt surfaces access road will be constructed to link the existing Rössing mining operations with the proposed Z20 site. The road will be approximately 14.4 km long, 7.2 m wide with a 2.4 m wide shoulder.

The route will start behind the coarse ore stockpile, continuing on an existing track around the seepage dam toe wall and then in the dry river bed before crossing the Khan River via a reinforced concrete bridge. It will then go up the mountainous terrain to the end point.

1.1.3 Water supply

The proposed water pipeline will follow the proposed access road alignment and will only impact on air quality as part of the construction phase.

1.2 Site Description

Rössing Uranium Mine boundary is located approximately 2 km south-east of the town of Arandis and 70 km inland from the coastal town of Swakopmund in the Erongo Region of Namibia.

Residential areas in the vicinity of the proposed operations include Arandis with a few homesteads further to the south-west (approximately 21 km) along the Khan River. The E-Camp at Rössing Uranium Mine and Arandis Airport next to the min were both included as a receptor points. The Khan River is also a popular tourist attraction, with tourists mainly passing the area and unlikely to stay for more than a day.

The old Khan Mine is about 5 km from where the Z20 conveyor will cross the Khan River and the proposed Husab Mine boundary borders onto the Rössing Uranium Mine boundary near the Z20 proposed pit. The Big Welwitschia (Welwitschia Miräbilis), located approximately 12 km south of the Z20 Project boundary, is a major tourism attraction.

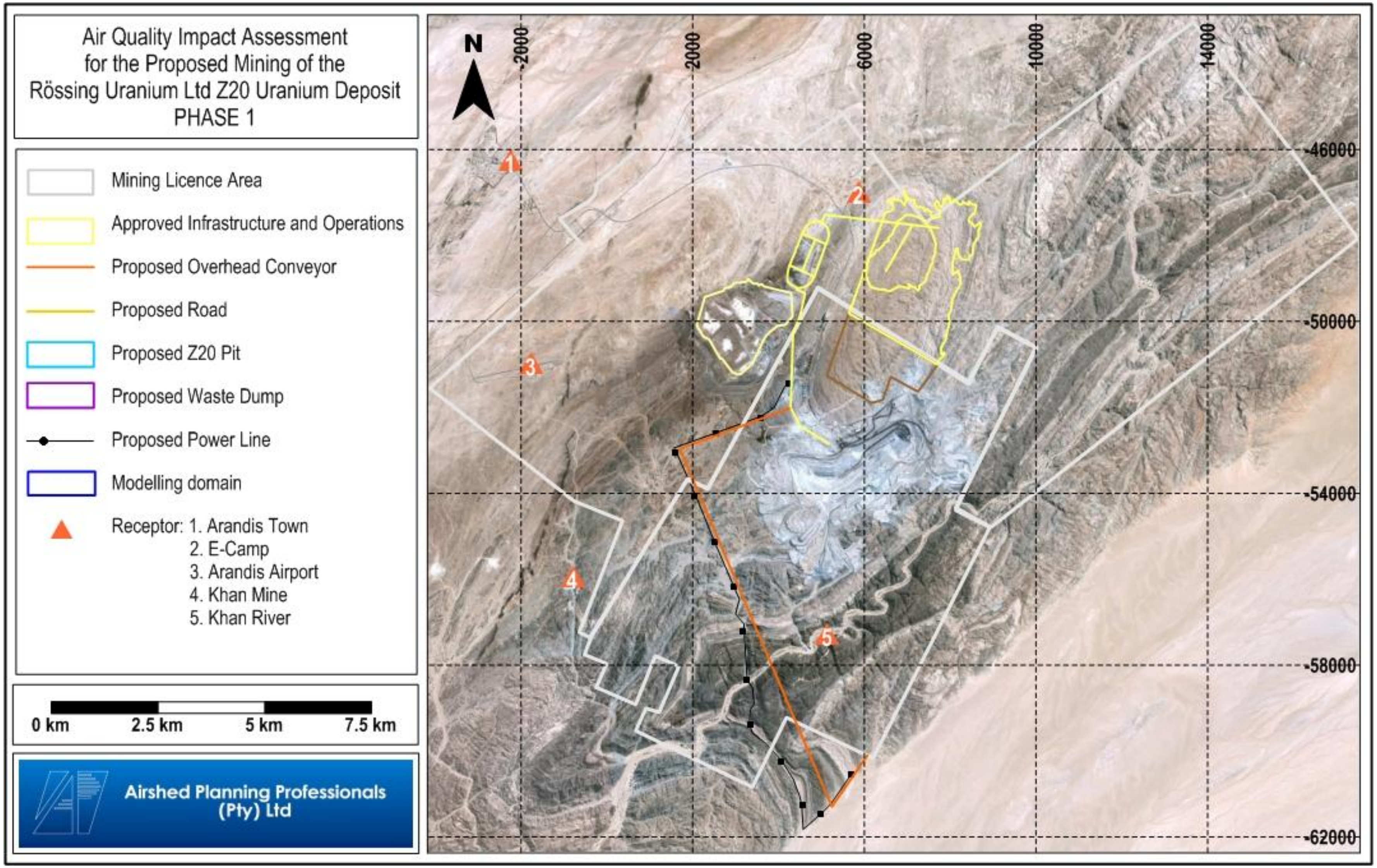

Figure 1-1: Modelling domain and receptors included in the Air Quality Assessment.

1.3 Study scope for the Infrastructure Corridor

The work for this aspect of the study involves the following:

A ***baseline*** air quality characterisation, including the assessment of:

- The regional climate and site-specific atmospheric dispersion potential;
- Identification of the potential sensitive receptors within the vicinity of the site;
- 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 to data (if available);
- Preparation of baseline air quality maps;
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and dustfall classifications.

The ***impact*** prediction study includes the following:

- Compilation of an emissions inventory, comprising the identification and quantification of all potential routine sources of emission from the Z20 infrastructure corridor operations.
- Dispersion simulations of ambient inhalable particulate concentrations and dust fallout from the routine current mining activities and proposed Z20 infrastructure corridor operations.
- Analysis of dispersion modelling results from the current and proposed mining operations. Particulate (radionuclides) and gaseous (radon) concentrations per source group per grid point to be provided to the radiological specialist for the dose response assessment.
- Evaluation of potential for human health and environmental impacts.

1.4 Air Quality Assessment Approach

The study followed a quantitative approach, using available design information on the proposed activities and historical meteorological data to evaluate the potential for off-site impacts. Based on the qualitative evaluation, mitigation measures are proposed.

1.4.1 Baseline Characterisation

It is necessary to obtain local meteorological data to determine the conditions specifically applicable to the project. For Phase I of the project, use was made of historical Rössing meteorological data as applied in the Rössing Phase II SEIA expansion project (von Gruenewaldt and Burger, 2010). The 2010 mining operations as per the Phase II SEIA of expansion project were applied to a larger modelling domain inclusive of the proposed Z20 project to represent the baseline scenario. No additional dust fallout or ambient monitoring data were obtained for this phase of the project. Sensitive receptor areas were confirmed to ensure the study accounts for all potential impacted areas.

The legislative and regulatory context include emission limits and guidelines, ambient air quality guidelines and dustfall classifications with specific reference to the Namibian legislation, the new South African legislation and the World Bank requirements.

1.4.2 Emission quantification

The modelling scope includes the dispersion of air pollutants arising from all potential sources from the Z20 infrastructure corridor operations. From an air quality perspective this is limited to the proposed conveyor system and access roads since the water pipeline, diesel line and power distribution and supply will not result in any emissions to air during operations.

The main pollutant of concern associated with the proposed mining operations is particulates. Particulates are divided into different particle size categories with Total Suspended Particulates (TSP) associated with nuisance impacts and the finer fractions of PM_{10} (particulates with a diameter less than 10 µm) and $PM_{2.5}$ (diameter less than 2.5 µm) linked with potential health impacts. Gaseous pollutants (such as sulphur dioxide, oxides of nitrogen, carbon monoxide etc.) will derive from vehicle exhausts but are regarded as negligible in comparison to particulate emissions.

In the quantification of fugitive dust emissions, emission factors are used that 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, use was made of the comprehensive set of emission factors published by the US Environmental Protection Agency (US.EPA) in its AP-42 document compilation of Air Pollution Emission Factors. The US.EPA AP-42 emission factors are of the most widely used in the field of air pollution. In addition, reference is made to the Australian National Pollutant Inventory (NPI) emission factors. Empirically derived predictive emission factor equations are available for vehicle-entrained dust from roadways and for materials handling operations. Single-valued emission factors are also available for general surface preparation and topsoil stripping which is applicable to construction activities. In the quantification of wind-blown dust from the conveyor system, literature on coal mining[1] operations was referenced. The US.EPA emission factors facilitate the quantification of various particle size fractions. This is important given that ambient air quality standards make a distinction between Total Suspended Particulates (TSP), thoracic particulates (PM_{10}), and respirable particulates ($PM_{2.5}$).

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[1] No literature is available on other mining types and applying the coal mining equations is regarded a conservative approach.

1.4.3 Dispersion modelling

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 (GLCs), arising from emissions of various sources. Increasing reliance is 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.

Gaussian plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The topography of the study area is fairly flat comprising of undulating hills, making it suitable for using a Gaussian plume model. The most widely used Gaussian plume model, the US.EPA Regulatory AERMOD model, was used in this study.

AERMOD is a model 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). AERMOD is a dispersion modeling 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 (Trinity Consultants, 2004). 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 preprocessor for the AERMOD. 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.
- The AERMAP is a terrain preprocessor designed to simplify and standardize the input of terrain data for the AERMOD. Input data include receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

As with most Gaussian Plume models, a disadvantage is that spatial varying wind fields, due to topography or other factors cannot be included. Also, the range of uncertainty of the model predictions could to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

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. 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.

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. For this study, only the 2003 and 2004 were used in the dispersion modelling for these represent the years with the highest incidences of high wind speeds.

Source Data Requirements

The AERMOD model is able to model point, area, volume and line sources. The materials handling points were simulated as volume sources whereas the road and conveyor were modelled as area sources.

Modelling Domain

The dispersion of pollutants was modelled for an area covering about 17.25 km (north-south) by about 6.46 km (east-west). This area was divided into a grid with a resolution of 250 m (north-south) by 250 m (east-west), and a total of 3 640 receptor points. The AERMOD model simulates ground-level concentrations for each of the receptor grid points.

Aside from the mine boundary included as a receptor area, all nearby farm houses and homesteads were included as discrete receptors. This was to allow for the evaluation of predicted impacts from the proposed operations at each of these locations. Figure 1-1 indicates the modelling domain and the receptors accounted for in the air quality assessment.

Topography

The topography in the study area is undulating, especially between the current Rössing mine and the proposed Z20 mining area (Figure 1-2). Digital Elevation Model (DEM) data, provided by Rössing personnel and obtained from Visual Resource Management Africa cc, were included for dispersion modelling purposes.

Figure 1-2: Undulating topography at the Rössing site (after von Gruenewaldt, 2010).

1.4.4 *Assumptions and Limitations of the Project*

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:

- Historical meteorological data (2000-2004) were used for the current study as this dataset was sufficiently comprehensive for dispersion modelling purposes. Only the period 2003 to 2004 was used for the Phase I assessment since these years represent the highest incidences of high wind speeds.
- The impact assessment is limited to airborne particulates (including TSP and PM_{10}). Although the proposed activities will also emit gaseous pollutants from vehicle exhausts, the impact of

these compounds are regarded to be low and omitted from this study.

- Emissions were based on the process description and mine layout plan as provided. Since this is a proposed project, no site specific particle size fraction data for the various sources are available and use was made of information obtained from the existing Rössing mining operations. Particle size distribution for the conveyor and transfer points were based on the Rössing Mine primary crusher particle size distribution. The emission equation used to calculate wind-blown dust from the conveyor were taken from literature on coal transport and regarded as a conservative approach when applied to ore transport. In addition, this emission quantification method is based on conventional conveyor systems with less dust expected to be generated from the RopeCon© design.
- Dispersion models don't contain all the features of a real system but contain the feature of interest for the management issue or scientific problem to be solved (MFE, 2001). Gaussian plume and puff models are regarded to have an uncertainty range of between -50% to 200%. It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. The duration of these short-term, peak concentrations are often only for a few minutes and on-site meteorological data are then essential.
- The construction, closure and post closure phases were assessed qualitatively.
- Radiation associated with wind-blown dust is covered under the Radiation Specialist study. Predicted PM_{10} concentrations were used to determine the potential impacts from radionuclide concentrations within the modelling domain.
- Only the RopeCon© and the access road were assessed as part of the specialist air quality study with no alternatives considered.

1.5 Interested and Affected Party Concerns

Initial concerns have been raised about potential dispersion of radioactive dust and radiation exposure. The question whether wind speed will be influenced by topography of the Khan valley needs to be answered specifically with regard to the effect this may have on wind-blown dust from the proposed conveyor. In addition, the conveyor will cross the Khan River at 121 m above ground level and the influence this may have on the dispersion potential needs to be accounted for in the air quality assessment (Scoping Report, 2012).

The main concerns from the public relating to air quality are listed in Table 1-1. The table provides comments and relevant sections of the report where these concerns are addressed.

Table 1-1: Summary of I&AP concerns related to Air Quality

Issue Raised	Comment & Section of report where addressed
Swakop Uranium, letter dated 1st November 2012	
Dust from conveyor : 1.) What are the public health risks, potential damage to vegetation?	With no mitigation in place no exceedances of the air quality limit was predicted at any of the receptors from the Z20 project alone. With mitigation in place this will be even lower. Cumulatively, the potential health impacts remain similar to that of the baseline (Section 4.3.1). With no mitigation in place the European vegetation dust fallout limit of (400 mg/m²/day) is matched only in the Khan River. With mitigation in place the dust fallout will be well below this limit (Section 4.3.2).
2.) Is there a way in which this dust fall-out could be cleaned up effectively?	Recommended dust fallout units to be placed along the conveyor line to determine the amount of dust from the system (Section 6.2).
3.) Transportation of radioactive dust downstream in rain/flood events?	Radiation specialist to respond.
Bernd Seafeldt, letter dated 31 October 2012	
1.) Air quality decreases and poisons when strong winds blow uranium salts/ particles over the whole Namib.	The SEA study conducted in 2010 investigated the cumulative impacts from windblown dust from natural and anthropogenic sources within the Erongo Region (Liebenberg-Enslin et al.,, 2010).
Bertchen Kohrs, Earthlife Namibia, letter dated 30 October 2012	
No comments on air quality	
Comments raised during the public meetings and focus group meetings	
General concerns raised with regard to impacts from the project on the surrounding environment	Refer to reply on first comment.

1.6 Report Outline

A legislative overview pertaining to the proposed Z20 project is provided in Section 2 of this report.

Section 3 of the report provides a description on the site specific dispersion potential through the discussion of near-site surface meteorology.

Section 4 describes the expected process and the associated sources of air pollution followed by the emissions quantification and impact assessment of the proposed operations on the surrounding environment.

A management plan is provided for the Z20 Infrastructure Corridor Project is provided in Section 5.

Section 6 concludes the report with main findings and recommendations.

The references are provided in Section 7.

2 Legislation and Ambient Air Quality Criteria

Prior to assessing the potential impacts from the operations at the proposed Z20 Uranium project, reference needs be made to the environmental regulations and guidelines governing the emissions and impact of such operations.

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 Atmospheric Pollution Prevention Act (Act No 45 of 1965) (APPA). Based on the stipulations of this 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 Namibian Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) does not include any ambient air standards to comply with, but the Chief Air Pollution Officer (CAPCO) provides air quality guidelines for consideration during the issuing of Air Pollution Certificates (APC). APCs are only issued for so called “Scheduled Processes” which are processes resulting in noxious or offensive gases and typically pertain to point source emissions. The air pollution guidelines included in the APC are primarily for criteria pollutants namely, SO_2, NOx, CO, ozone, lead and PM. Power generation will be a “Scheduled Processes” and would therefore require an APC specifying the operational criteria. This, however, does not seem to be implemented in Namibia.

2.2 International Requirements

Typically when no local ambient air quality criteria exists, or are in the process of being developed, reference is made to international criteria. This serves to provide an indication of the severity of the potential impacts from proposed activities. The most widely referenced international air quality criteria are those published by the World Bank Group (WB), the World Health Organisation (WHO) and the European Community (EC). The newly promulgated South African ambient air quality standards can also be referenced since these have been developed recently after a thorough review of international criteria. The South African standards can also be regarded as representative indicators for Namibia due to the similar environmental, social and economic characteristics between the two countries.

Best practice is usually a standard implemented and required by developed countries, often with very different environmental, social and economic characteristics. Due to the lack of emission and ambient standards in Namibia, minimum standards to be adopted by an industry/mine are a voluntary commitment and not a legally enforceable standard, even though it must under scribe the legal requirements of Namibia. In general, the minimum standards should be a politically feasible and economic viable standard to be met by both industry and mining companies. The standards used must however meet the ultimate objective of ambient air quality improvement and management throughout the various phases of the project.

2.2.1 World Bank Group

The WB Pollution Prevention and Abatement Handbook (1998) provides guidelines on ambient air quality and emission limits for specific processes and for individual pollutants (such as particulates, SO_2 and NOx). Ambient standards provide the maximum allowable level of a pollutant in the receiving environment whereas emission standards set the maximum amount of pollutant that may be released.

As of April 30, 2007, new versions of the WB Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') are now in use. These replace those documents previously published in Part III of the Pollution Prevention and Abatement Handbook and on the International Finance Corporation (IFC) website. The EHS Guidelines are technical reference documents and intended to be used together with the Industry Sector EHS Guidelines for specific industry sectors. They provide performance levels and measures on what is considered achievable by existing technology at reasonable costs. It is made clear that these guidelines should be adapted to site-specific variables considering the sensitivity of the environment and other project factors as indicated by the environmental assessment, and in context of the host country. In general, the most stringent guidelines need to be applied. Thus if the host country has more lenient guidelines, the EHS Guidelines should be applied. 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 (IFC, 2007).

According to the WB 1998 Handbook, ambient air quality standards should be set once an agreement has been reached on the environmental quality objectives that are desired and the cost that society is willing to accept in order to meet the set objectives. Typically the set of ambient air quality standards aim to protect human health but lately ambient standards for the protection of ecosystems have been established by some countries. Emission standards on the other hand may be established in terms of what can be achieved with available technology or in terms of the impacts resulting from the emissions.

General Guidelines

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

(IFC, 2007). The EHS provides a general approach to air quality management for a facility, including the following:

- Identify possible risks and hazards associated with the project as early on as possible and understand the magnitude of the risks, based on:
  - the nature of the project activities; and
  - the potential consequences to workers, communities, or the environment if these hazards are not adequately managed or controlled.
- Prepare project- or activity-specific plans and procedures incorporating technical recommendations relevant to the project or facility;
- Prioritise the risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts;
- When impact avoidance is not feasible, implement engineering and management controls to reduce or minimise the possibility and magnitude of undesired consequence; and
- Continuously improve performance through a combination of ongoing monitoring of facility performance and effective accountability.

Significant impacts to air quality should be prevented or minimised by ensuring that:

- Emissions to air do not result in pollutant concentrations exceeding the relevant ambient air quality guidelines or standards. These guidelines or standards can be national guidelines or standards or in their absence WHO Air Quality Guidelines or any other international recognised sources such as the relevant European Council Directives or the United States National Ambient Air Quality Standards. These standards are presented in Table 2-1.
- Emissions do not contribute significantly to the relevant ambient air quality guidelines or standards. It is recommended that 25% of the applicable air quality standards are allowed to enable future development in a given airshed.

The EHS recognises the use of dispersion models to assess potential ground level concentrations. The models used should be internationally recognised or comparable.

Table 2-1: Ambient Air Quality Guidelines for various international organisations as accepted by the World Bank (IFC, 2007).

Pollutant	Averaging Period	*WHO Guideline Value (µg/m^3)*	EC Directive Limits (µg/m^3)	US NAAQS (µg/m^3)	South Africa NAAQS (µg/m^3)
Sulphur Dioxide (SO_2)	1-year	-	20 (d)	-	50
	24-hour	*125 (IT-1)* *50 (IT-2) (a)* *20 (guideline)*	125 (c)	-	125 (f)
	1-hour	-	350 (b)	196 (e)	350 (g)
	10-minute	*500 (guideline)*	-	-	500 (h)
Carbon Monoxide (CO)	1-hour	*30 000 (guideline)*	10 000	40 000	30 000 (g)
Nitrogen Dioxide (NO_2)	1-year	*40 (guideline)*	40 (i)	100	40
	1-hour	*200 (guideline)*	200 (j)	188 (k)	200 (g)
Particulate Matter (PM_{10})	1-year	*70 (IT-1)* *50 (IT-2)* *30 (IT-3)* *20 (guideline)*	40 (n)	-	50 (l) (f) 40 (m) (f)
	24-hour	*150 (IT-1)* *100 (IT-2)* *75 (IT-3)* *50 (guideline)*	50 (o)	150 (p)	120 (l) 75 (m)
Particulate Matter ($PM_{2.5}$)	1-year	*35 (IT-1)* *25 (IT-2)* *15 (IT-3)* *10 (guideline)*	25 (u)	15 (p)	25 (q)(r) 20 (q)(s) 15 (q)(t)
	24-hour	*75 (IT-1)* *50 (IT-2)* *37.5 (IT-3)* *25 (guideline)*	-	35 (k)	65 (q)(r) 40 (q)(s) 25 (q)(t)

Notes:

(a) intermediate goal based on controlling motor vehicle emissions; industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvement.

(b) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).

(c) EC Directive 2008/50/(http://ec.europa.eu/environment/air/quality/standards.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).

(d) EC First Daughter Directive, 1999/30/EC (http://rod.eionet.europa.eu/instruments/517). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.

(e) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.

(f) 4 permissible frequencies of exceedance per year

(g) 88 permissible frequencies of exceedance per year

(h) 526 permissible frequencies of exceedance per year

(i) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Annual limit value for the protection of human health. Limit value entered into force 1 January 2010.

(j) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Not to be exceeded more than 18 times per year. Limit value entered into force 1 January 2010.

(k) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). 98th percentile, averaged over 3 years.

(l) Applicable immediately to 31 December 2014.

(m) Applicable from 1 January 2015.

(n) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Limit value entered into force 1 January 2005.

(o) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Not to be exceeded more than 35 times per calendar year. Limit value entered into force 1 January 2010.

(p) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year on average over three years.

(q) Proposed draft $PM_{2.5}$ regulations as published in the Government Gazette (no. 34493) on the 5th of August 2011.

(r) Applicable immediately to 31 December 2015.

(s) Applicable 1 January 2016 to 31 December 2029.

(t) Applicable 1 January 2030.

(u) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Target value entered into force 1 January .2010 and limit value enters into force 1 January 2015.

Degraded Airsheds or Ecological Sensitive Areas

The IFC provides further guidance on projects located in degraded airsheds, i.e. areas where the national/ WHO/ other recognised international Air Quality Guidelines are significantly exceeded or where the project is located next to areas regarded as ecological sensitive such as national parks. Even though the existing Rössing Uranium mining operations are not within a national park, the proposed Z20 project falls within the Namib Naukluft Park. The proposed site is therefore regarded as Ecologically Sensitive. The airshed is however not regarded as degraded.

Point source emissions

The IFC stipulates that emissions from point sources should be avoided and controlled according to good international industry practice (GIIP). Guidelines relevant to the industry sector are provided for specific pollutants which typically include SO_2, NO_x, CO, PM and greenhouse gases such as CO_2. Pollutants likely to be emitted in smaller quantities associated with some solid fuels, such as coal, include heavy metals (i.e. mercury, arsenic, cadmium, vanadium, nickel, etc.), halide compounds (including hydrogen fluoride), unburned hydrocarbons and other VOCs.

The proposed Z20 infrastructure corridor will have no point sources.

2.2.2 World Health Organisation

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 PM_{10} and $PM_{2.5}$ concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group for 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 explicit objectives when 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 target (IT) levels, which are in**

excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005).

2.2.3 European Community Directive

The European Community (EC) air quality criteria represent objectives/standards to be achieved by the year 2004/2005 which were designed primarily to protect human health (Table 2-1). The EC standards have superseded the European Union (EU) standards. The current EU standards were determined through consultation with due regard to environmental conditions, the economic and social development of various regions, and the importance of a phased approach to attaining compliance.

2.2.4 South African Legislation

It is not clear how the legal developments in South Africa will affect the Namibian legislation. It is however regarded more representative of the environmental, social and economic situation than the European criteria.

The South African Bureau of Standards (SABS) was engaged to assist the Department of Environmental Affairs (DEA) in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. Standards were determined based on international best practice for particulate matter less than 10 µm in aerodynamic diameter (PM_{10}), dust fall, SO_2, NO_2, O_3, CO, lead (Pb) and benzene (SANS 69, 2006). The final standards were published on the 24th of December 2009 and include a margin of tolerance (i.e. frequency of exceedances) and implementation timelines linked to it (Table 2-1). National ambient air quality standards for respirable particulates ($PM_{2.5}$) were published in 2011.

South Africa has also recently (1st of April 2010), as part of the Air Quality Act No. 39 of 2004, published Listed Activities and Associated Minimum Emission Standards for most significant industrial processes.

2.2.5 Dust fallout criteria

Foreign dust deposition standards issued by various countries are given in Table 2-2. 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 in South Africa. Based on a comparison of the annual average dustfall standards it is evident that in many cases a threshold of around 200 mg/m²/day to 300 mg/m²/day is given for residential areas.

Table 2-2: 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 Kentucky New York: Pennsylvania Washington: Wyoming:	 200 175 200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value) 267 183 (residential areas) 366 (industrial areas) 167 (residential areas) 333 (industrial areas)	

Air quality standards are not defined by all countries for dust deposition, although some countries may make reference to annual average dustfall thresholds above which a 'loss of amenity' may occur. In the South African context, widespread dust deposition impacts occur as a result of windblown mine tailings material and other fugitive dust sources. It is for this reason that the SABS Technical Committee on air quality standards has recommended the establishment of target levels and alert thresholds for dustfall. The South African Department of Minerals Resources (DMR) uses the uses the 1200 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.

According to the proposed SA 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. The SANS four-band scale is presented in Table 2-3. Proposed target, action and alert thresholds for ambient dust deposition are given in Table 2-4.

Table 2-3: Bands of dustfall rates proposed for adoption.

Band Number	Band Description Label	30 Day Average Dustfall Rate (mg/m^2-day)	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 2-4: Target, action and alert thresholds for ambient dust fall.

Level	Dustfall Rate (mg/m^2-day)	Averaging Period	Permitted Frequency of Exceedence
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.

The impact of dust on vegetation and grazing quality was raised as a concern during the public meetings. While there is little direct evidence of what the impact of dust fall on vegetation is under a South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in Sunflower and Cotton plants exposed to dust fall rates greater than 400 $mg/m^2/day$ (Farmer, 1991).

A summary of available literature information on the impacts from dust on plants and animals are provided in Appendix A.

2.3 Proposed Guidelines for the proposed Z20 Infrastructure Corridor

No ambient air quality guidelines or standards exist for Namibia and relevant international criteria were reviewed. As part of the Uranium Rush Strategic Environmental Assessment (SEA) for Erongo (MME, 2010), the WHO Interim Target-3 (IT-3) was selected for PM_{10} (Liebenberg-Enslin et al, 2010). The same approach was followed for selecting evaluation criteria for the proposed Z20 infrastructure corridor as depicted in Table 2-5.

It should be noted, that it is outside the scope of this project to determine guidelines for Namibia and this should become a priority for government to establish national ambient air quality standards. The WHO makes it very clear that their AQGs are not intended to be adopted by countries but merely to be used as guidelines in the process where countries need to develop their own standards. These guidelines are also aimed at urban environments within developed countries (WHO, 2005). The country specific standards should take into consideration risks to health, technological feasibility, economic considerations and other political and social factors.

It is also best practice (as per WB) that a specific industry only contributes 25% of the applicable air quality standards to allow for additional, future sustainable development in the same airshed.

It is recommended that the proposed guidelines as provided in Table 2-5 be used in this study as interim guidelines.

Table 2-5: Proposed evaluation criteria for the Z20 Infrastructure Corridor.

Pollutant	Averaging Period	Selected Criteria	Source
PM_{10}	24-hour Mean (µg/m³)	75(a)	WHO IT3 & SA Standard
	Annual Mean (µg/m³)	30	WHO IT3
$PM_{2.5}$	24-hour Mean (µg/m³)	25	WHO IT3
	Annual Mean (µg/m³)	10	WHO IT3
Dust fallout	30-day average (mg/m²/day)	600(c)	SA SANS residential action limit
		400(c)	European vegetation limit

Notes:

(a) Not to be exceeded more than 4 times per calendar year (SA Standard).
(b) Not to be exceeded more than 88 times per calendar year (SA Standard).
(c) Not to be exceeded more than 3 times per year or two consecutive months.
(d) European vegetation limit for Sunflower and Cotton plants.

3 Air Quality Baseline Evaluation

The baseline evaluation primarily comprises the assessment of near-site surface meteorology.

3.1 Regional Climate and Atmospheric Dispersion Potential

The meteorological characteristics of a site 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, determine 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 must be accounted for to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic climatology of the study region is provided based on a review of the pertinent literature. The analysis of meteorological data observed for the proposed site, where available, and data for neighbouring sites will provide the basis for the parameterisation of the meso-scale ventilation potential of the site.

The analysis of at least one year of hourly average meteorological data for the study site is required to facilitate a reasonable understanding of the ventilation potential of the site. The most important meteorological parameters to be considered are: wind speed, wind direction, ambient temperature, atmospheric stability and mixing depth. Atmospheric stability and mixing depths are not routinely recorded and frequently need to be calculated from diagnostic approaches and prognostic equations, using as a basis routinely measured data, e.g. temperature, predicted solar radiation and wind speed.

Meteorological data for the period 2000 - 2004 was obtained from Rössing and used in the Rössing Phase II SEIA of expansion project. The same dataset is used for this assessment. The data availability for the meteorological period is given in Table 3-1. Data availability of at least 80% is recommended for dispersion modelling purposes (von Gruenewaldt and Burger, 2010).

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*

In addition, more recent meteorological data from the newly installed weather station at the Tailings dam were obtained for the period 2011.

3.1.1 Local 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 night-time wind roses for Rössing Mine are provided in Figure 3-1 with the yearly wind roses provided in Figure 3-2. More recent data from the Tailings dam station are presented in Figure 3-3.

The prevailing wind direction at Rössing for the five year period is from the north-northeast (with approximately 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 night-time 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 south-westerly sector increases. Nocturnal flow reflects increases from the north-westerly sector and associated lower wind speeds. As is typical of night-time conditions, an increase in calm conditions from 1.7% (during daytime) to 4.9% is noted.

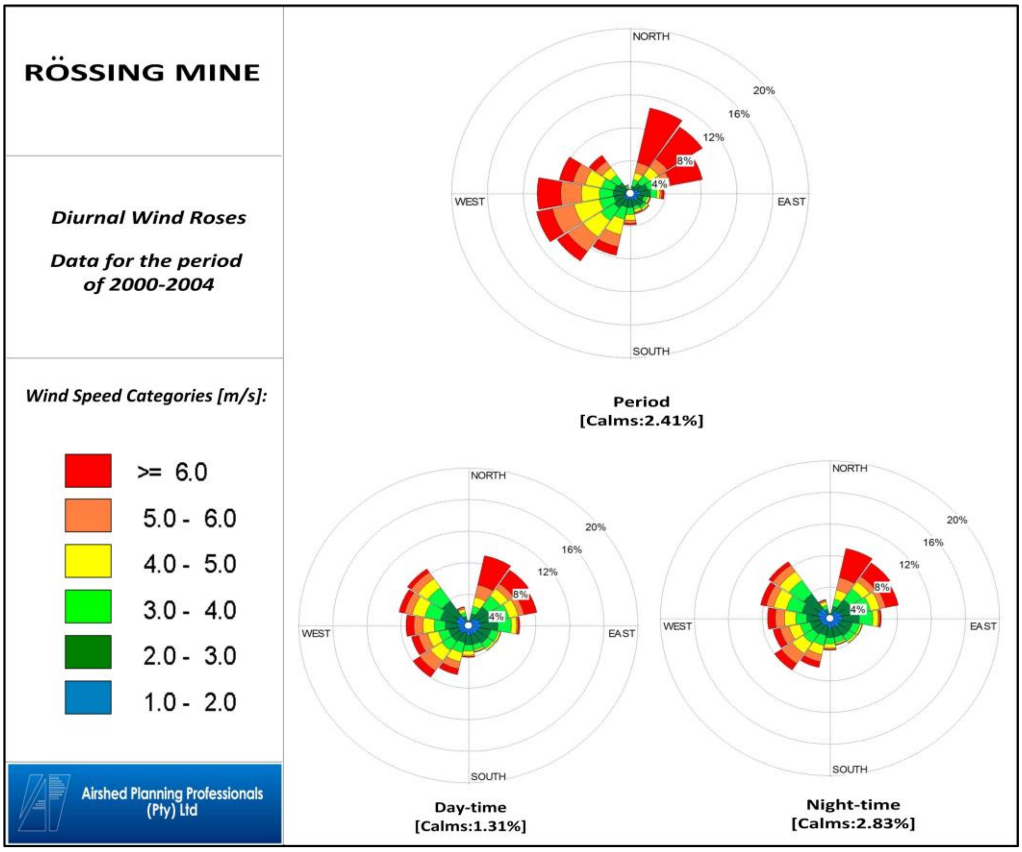

Figure 3-1: Period, daytime and night-time wind roses for Rössing (2000-2004).

Yearly wind roses reflect similar wind fields throughout 2001 to 2004 with a slight increase in frequency of north-easterly and south-westerly winds during 2004. The wind rose for the year 2011 from the tailings dam station also show prevailing north-easterly and south-westerly winds with infrequent flow from the south-east.

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 (around 14%). Springtime indicate a reduction of north-easterly wind flow 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 (von Gruenewaldt and Burger, 2010).

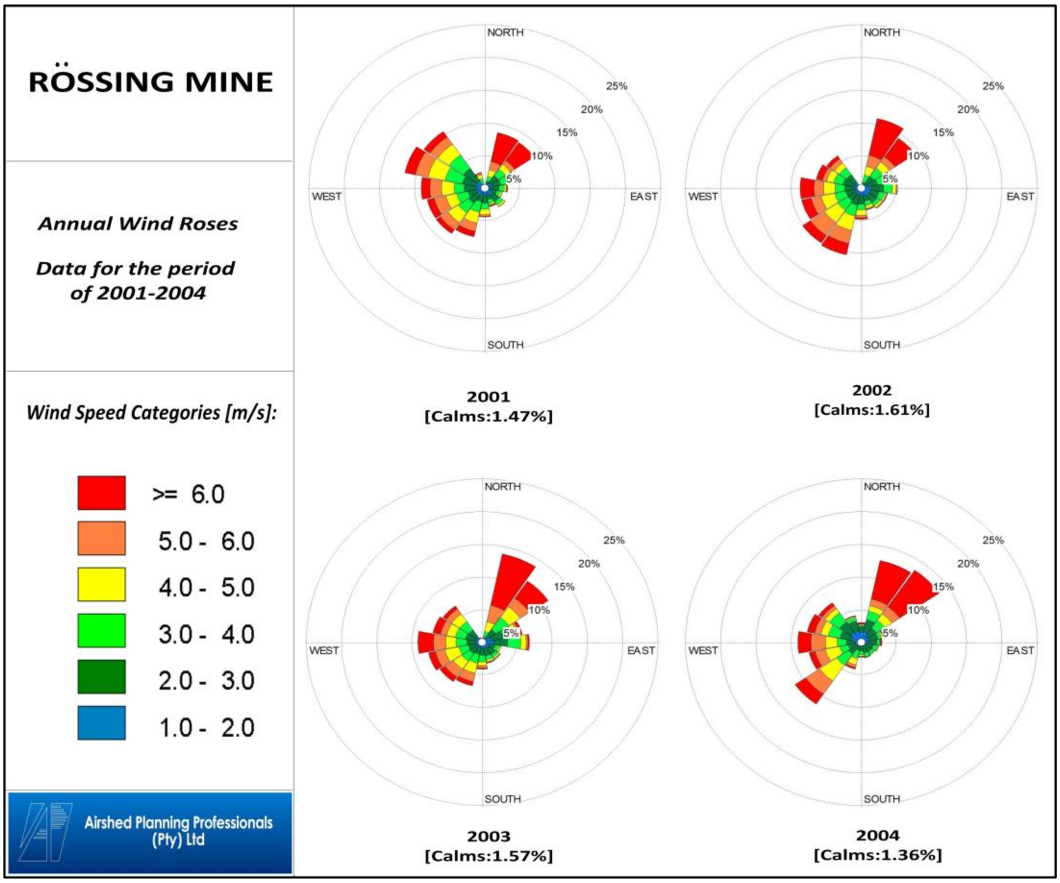

Figure 3-2: Yearly wind roses for Rössing (2000-2004).

Wind speed

The highest wind speed as recorded in the Rössing historical data used in this assessment is 18.7 m/s. Wind velocities above 17 m/s, classified as “Fresh Gales” according to the Beaufort scale, only occurred for 0.02% over the five years of data (2000 - 2004). A “fresh breeze” or “strong wind” is a wind above 14 m/s and these occurred for 0.2% over the time. Wind speed measurements in the area have been recorded for most of the time that Rössing is in operation. The highest wind speed was recorded on the 21st of July 1989 of 33 m/s.

Wind speed data from a number of weather stations in the region were included in the SEA Air Quality Report (Liebenberg-Enslin et al., 2010). Wind speeds in the Erongo Region vary mainly between 0-10 m/s with wind speeds between 13 m/s and 17 m/s only occurring for short periods. The highest wind speed recorded between 2007- 2009 was at Pelican Point of 23 m/s during 2008 with the highest wind speed recorded inland at Valencia Uranium Mine of 17 m/s (2008). These high wind speeds are mostly associated with east winds.

The US.EPA uses 5.4 m/s as the indicator threshold wind speed to initiate windblown dust and winds exceeding this threshold were recorded for 20% of the time.

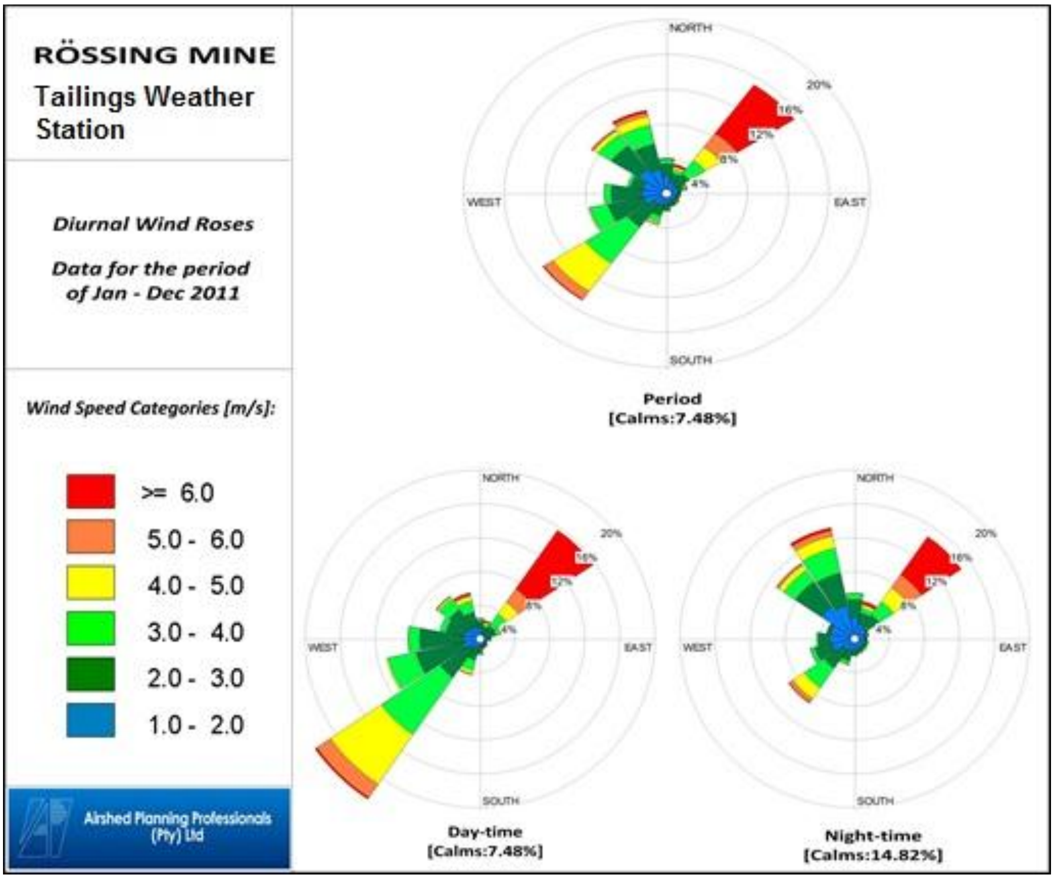

Figure 3-3: Period, daytime and night-time wind roses from Rössing Tailings weather station (2011).

3.1.2 Surface 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 3-4, reflecting the diurnal temperature profiles at Rössing. 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 (von Gruenewaldt and Burger, 2010).

The annual maximum, minimum and mean temperatures are given as 32.7°C, 16.4°C and 23.2°C respectively (Figure 3-5). A maximum temperature of 35.8°C for Rössing was recorded during May and a minimum temperature of 12.9°C was recorded in September.

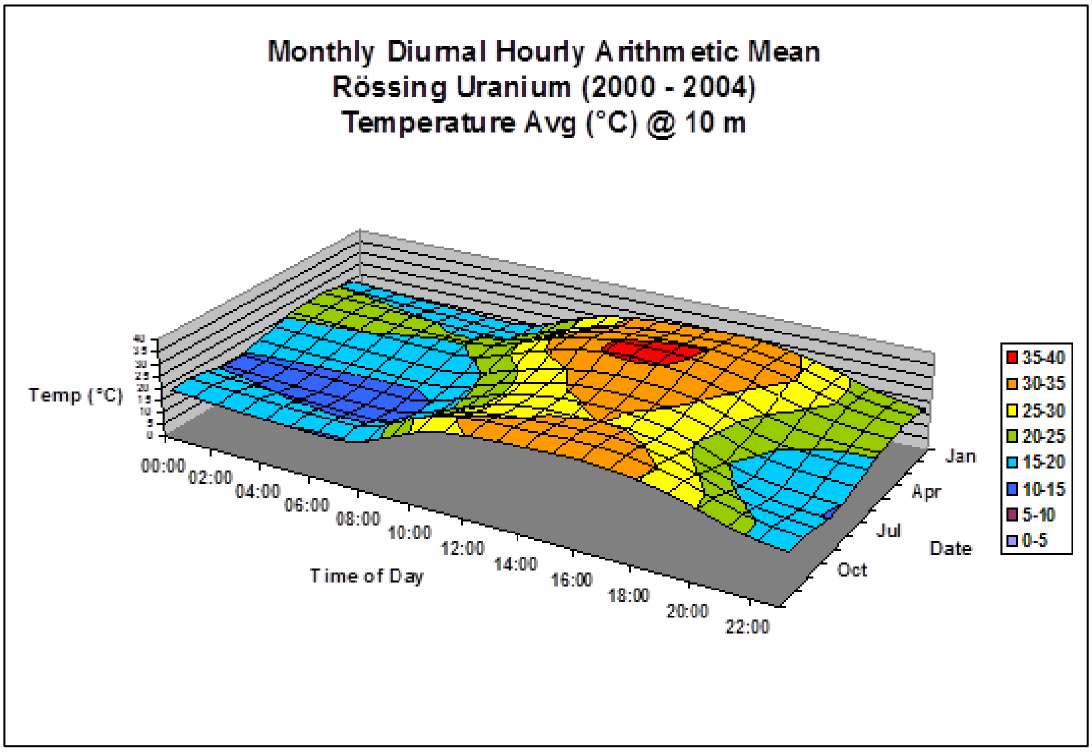

Figure 3-4: Minimum, maximum and average monthly temperatures for the site during the period 2009-2011.

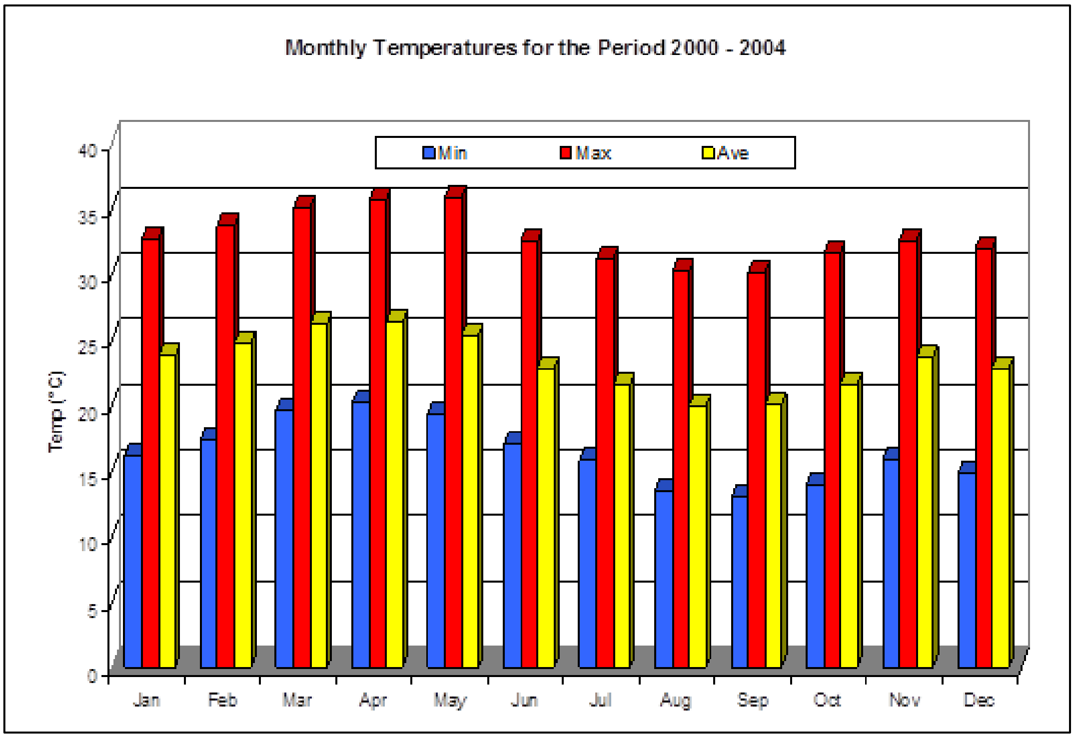

Figure 3-5: Maximum, minimum and mean monthly temperatures at Rössing (2000 - 2004).

3.1.3 *Atmospheric Stability*

The vertical component of dispersion is a function of the extent of thermal turbulence and the depth of the surface mixing layer. Unfortunately, the mixing layer is not easily measured, and must therefore often be estimated using prognostic models that derive the depth from some of the other parameters that are routinely measured, e.g. solar radiation and temperature. 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. The mixing layer ranges in depth from ground level (i.e. only a stable or neutral layer exists) during night-times to the base of the lowest-level elevated inversion during unstable, day-time conditions.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-2.

Table 3-2: Atmospheric Stability Classes

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 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a 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 low level releases, such as due to vehicle entrainment from unpaved roads, the highest ground level concentrations will occur during weak wind speeds and stable (night-time) atmospheric conditions. Wind erosion, on the other hand, requires strong winds together with fairly stable conditions to result in high ground level concentrations i.e. neutral conditions.

The variation of stability with wind direction for Rössing (for the period 2000 – 2004) is given in Figure 3-6. 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.

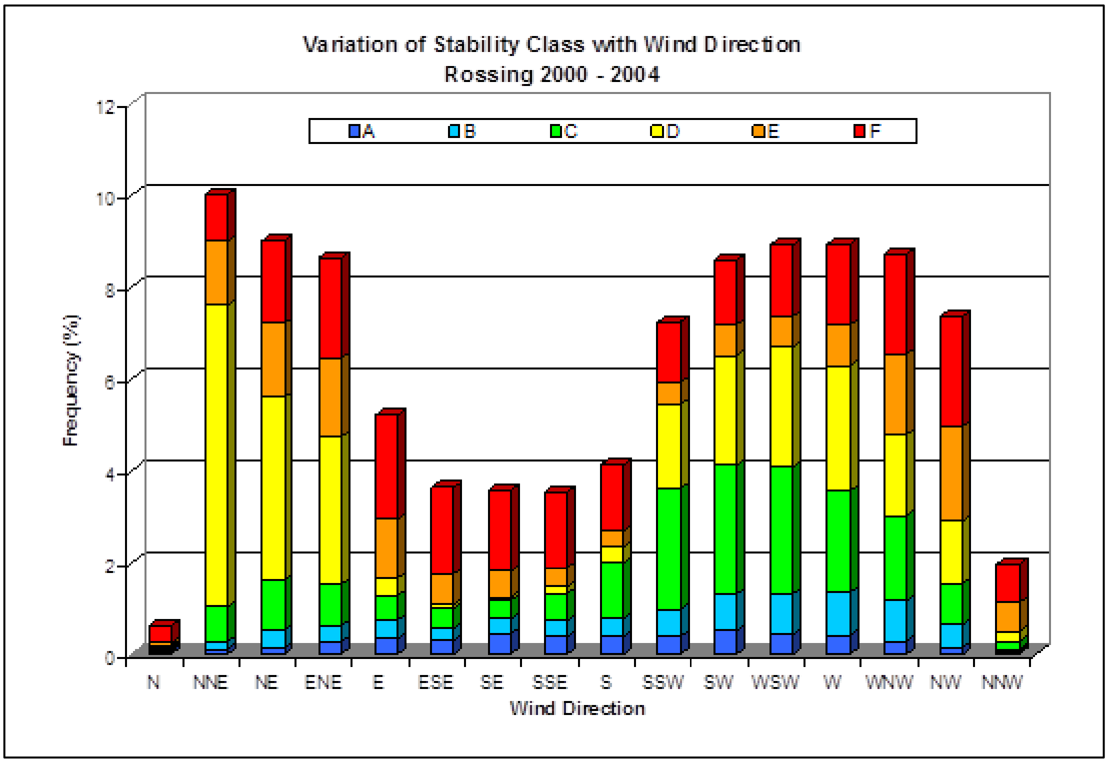

Figure 3-6: Variation of stability with wind direction for Rössing (2000 – 2004).

3.2 Topographical influences

3.2.1 Topography

Changes in terrain around an air pollution source can significantly influence the way the plume is dispersed. Hills or rough terrain influence the wind speed, wind direction and turbulence characteristics. Significant valleys can cause persistent drainage flows and restrict horizontal movement whereas sloping terrain may help provide katabatic or anabatic flows.

Land-sea breeze circulations also have a significant influence on local meteorological conditions. The wind flow pattern is influenced by the presence of the cold ocean, especially during weak wind periods when dilution is at a minimum. The large heat capacity of oceans reduces water-surface temperature change to near-zero values during a diurnal cycle. The land surface warms and cools more dramatically because of the small molecular conductivity and heat capacity in soil prevents the diurnal temperature signal from propagating rapidly away from the surface. As a result, the land is warmer than the water during the day and cooler at night.

During the morning, the nocturnal (stable) surface boundary layer gradually erodes as air begins to rise over the warm land, i.e. the development of an unstable layer close to the ground, known as the thermal internal boundary layer (TIBL). The cooler air from the ocean flows in to replace it (i.e. the sea-breeze). However, the unmodified ocean air may develop an elevated inversion cap above the warm air over land. Coastal fumigation is the turbulent dispersion process when a plume, released from a tall stack within the elevated stable (or neutral) onshore breeze, is entrained into the growing TIBL that forms over land. The plume is subsequently mixed to the ground by the convective turbulence within the TIBL.

At night, land surfaces usually cool faster than the neighbouring water bodies, reversing the temperature gradient that was present during the day. The result is a land breeze. Cool air from land flows out to sea at low levels, warms, rises, and returns aloft toward land (anti-land-breeze) where it eventually descends to close the circulation. The elevated release is then influenced by the stable land air – i.e. no fumigation occurs. Fumigation can increase the ground level impacts significantly.

The proposed Z20 site is situated on the eastern rim the Khan River valley characterised by steep inclines on the eastern side of the river and varying topography towards the western side. The topography around this site is likely to have a significant influence on the dispersion potential of the air emissions from the proposed conveyor and road as shown in Figure 3-7.

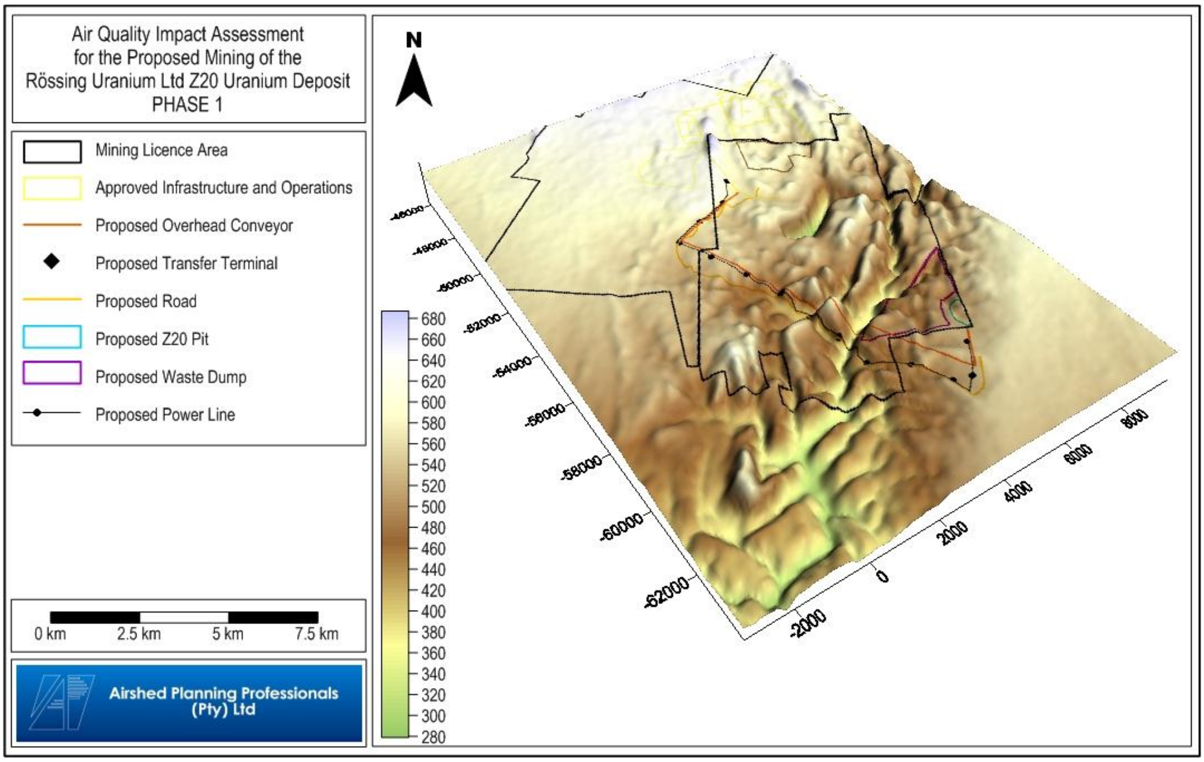

Figure 3-7: Topography of the area surrounding the Z20 Project.

3.2.2 Valley flows

Winds within valleys are complex and influenced by the orientation of the valley walls towards the sun. The area where the conveyor crosses the Khan River is indicated in Figure 3-7. The prevailing wind direction according to the Rössing weather station data is north-easterly and south-westerly with the river valley orientated the same.

As the sun rises in the east, the western slope warms up during the morning resulting in the air above the slope to heat and rise. In the afternoon, the same happens with the eastern slope whilst the western slope cools down. As the temperature gradient develops between the mount of the valley and the head of the valley, the up-slope winds start to weaken with valley winds initiated by early afternoon. These again weaken in the late afternoon as the slopes cool down. Typical of day-time airflow under cloudless skies, up-valley winds will prevail whereas the situation is reversed during the night (Preston-Whyte & Tyson, 1988).

A study done by Wiggs et al. (2002) on valley flow in the Gaub drainage basin in Namibia, (characterized by low relative relief with the slope gently grading down toward the north) have given some interesting insights into the implications for sediment transport in valleys. The study made use of measurement arrays for which the fractional speed-up ratio (defined by Jackson and Hunt, 1975) was calculated. The results compared well with existing wind tunnel studies (Beniston et al., 1989; Kalthoff et al., 2000) and suggested that, in areas of low relative relief, valley topography can have a marked impact on wind velocity and direction.

Field observations indicated that, for winds blowing perpendicular to the valley, wind acceleration takes place upwind of flow, followed by a minimum flow velocity in the center of the valley where after a maximum wind speed is achieved downwind at the valley edge. This is followed by deceleration of the wind velocities down to upwind values at distances of about 150m to 300m from the valley edge. Figure 3-8 shows the fractional speed-up ratio for distance travelled relative to the valley floor (Wiggs et. al., 2002).

For winds blowing at an angle to the long axis of the valley, similar results were found. Measurements showed acceleration from the valley floor up the down-wind valley slope to reach maximum acceleration near the surface (Wiggs et. al., 2002).

The study further found that winds approaching perpendicular to the valley axis are more likely to result in the creation of large roll-vortex features within the valley with little lateral flow deflection. On the other hand, winds that approached the valley axis at greater incident angles developed smaller, along-valley vortex features which deflected the incoming airflow parallel to the valley axis and allowed faster along-valley winds to influence the lower slopes and valley floor (Wiggs et. al., 2002). Figure 3-8 depicts the streamlines for wind crossing a valley cannel and shows the zone of recirculation within the channel.

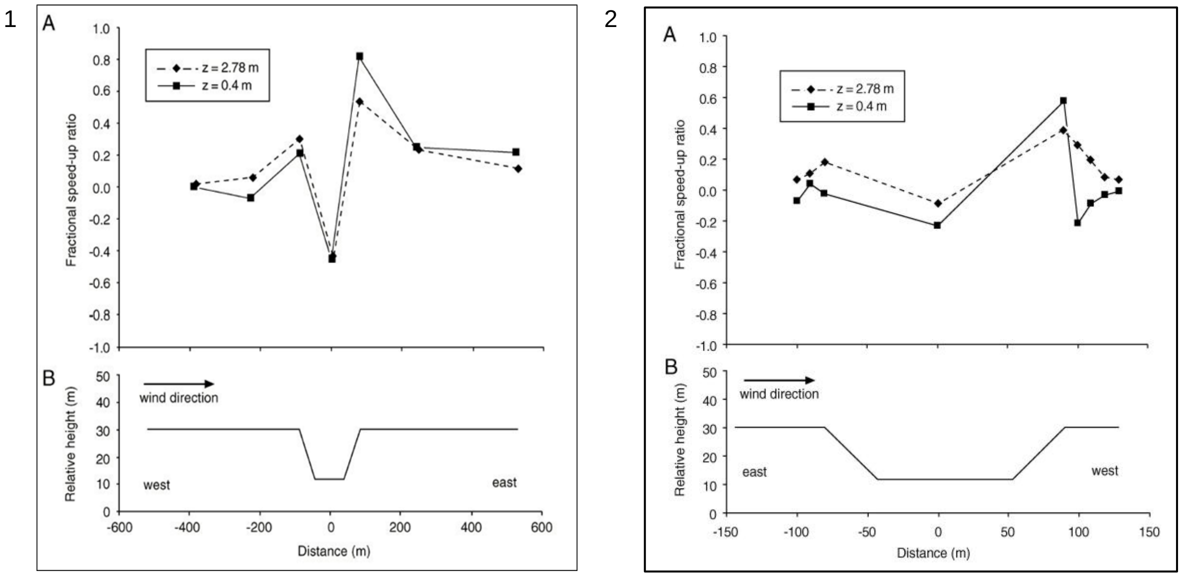

Figure 3-8: Fractional speed-up ratio (δs, relative to the upwind array) at two heights across the valley, 1 (A) in the case where air flow is perpendicular to the valley axis and 2(A) where the airflow is from the north-east to south-west. (B) Cross-section of the valley along the anemometer transects (Wiggs et. al., 2002).

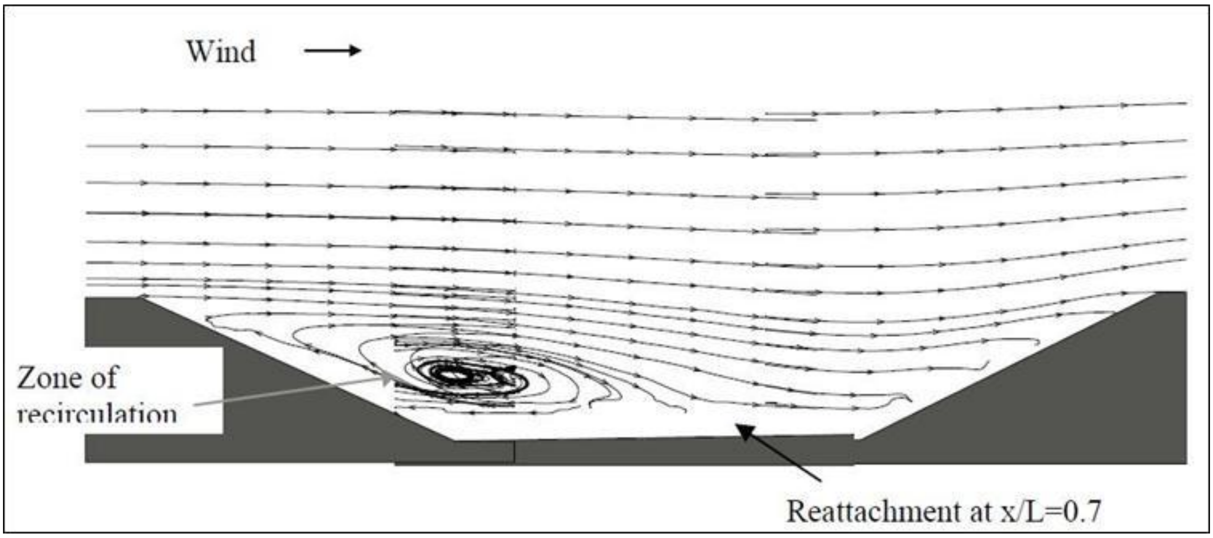

Figure 3-9: Streamlines for wind crossing a valley channel.

A significant influence on the measurements presented in the paper here appeared to depend on whether or not flow separation took place at the leading edge of the valley. A major control on such separation is likely to be atmospheric stability. This study was done under neutral atmospheric stability.

Aeolian dust transport depends on the friction velocity which is proportional to the gradient of the log-normal velocity profile. Acceleration of wind speed with height above the surface cannot accurately be determined from the mean wind speed profile within these types of valleys due to irregular flow accelerations. To overcome this problem, surface wind speed is used as a surrogate for the threshold friction velocity. Following this approach, the study proposed a model for sediment transport in valleys which highlights a sediment free and erosive zone upwind of the valley and a downwind sediment depositional zone. This model indicates the largest potential for erosion to be at the upwind valley edge with deposition within the valley (zone of recirculation as shown in Figure 3-9).

The area where the conveyor crosses the Khan River, the wind field is likely to be at an angle to the valley for most of the time with perpendicular winds for less than 4% of the time (based on the Rössing historical data). The flow characteristics are therefore more likely to increase towards the south-eastern slope of the Khan River valley with the highest potential for deposition on the south-eastern high lying areas.

3.3 Ambient Air Quality within the Region

Existing sources of air quality in the vicinity of the proposed Z20 project site is Rössing Uranium Mine to the north-west (approximately 10 km) and Husab Uranium approximately 1 km to the south. Rössing Uranium Mine comprises of open-pit mining and is one of the largest uranium mines in the world. Exploration activities at the Husab project has ceased and infrastructure development will commence soon. Fugitive dust sources associated with mining activities include drilling and blasting operations, materials handling activities, vehicle-entrainment by haul vehicles and wind-blown dust from tailings impoundments and stockpiles. Mining operations represent potentially the most significant sources of fugitive dust emissions ($PM_{2.5}$, PM_{10} and TSP) with small amounts of NO_x, CO, SO_2, methane, and CO_2 being released during blasting operations and from mine trucks.

The B2 main road between Swakopmund and Usakos will contribute to gaseous emissions such as CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulates and lead. To a lesser extent, vehicle entrainment on the paved road will add to the particulate load in the area.

3.3.1 Rössing Mine monitoring campaign

PM_{10} Concentrations

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 two months during 2009 at Rössing. 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 (Figure 3-10). The measured concentrations obtained from this monitoring campaign are indicative of ambient air quality levels but data of at least one year should be assessed in order to determine average ambient concentrations as this will take into consideration temporal variations (von Gruenewaldt and Burger, 2010).

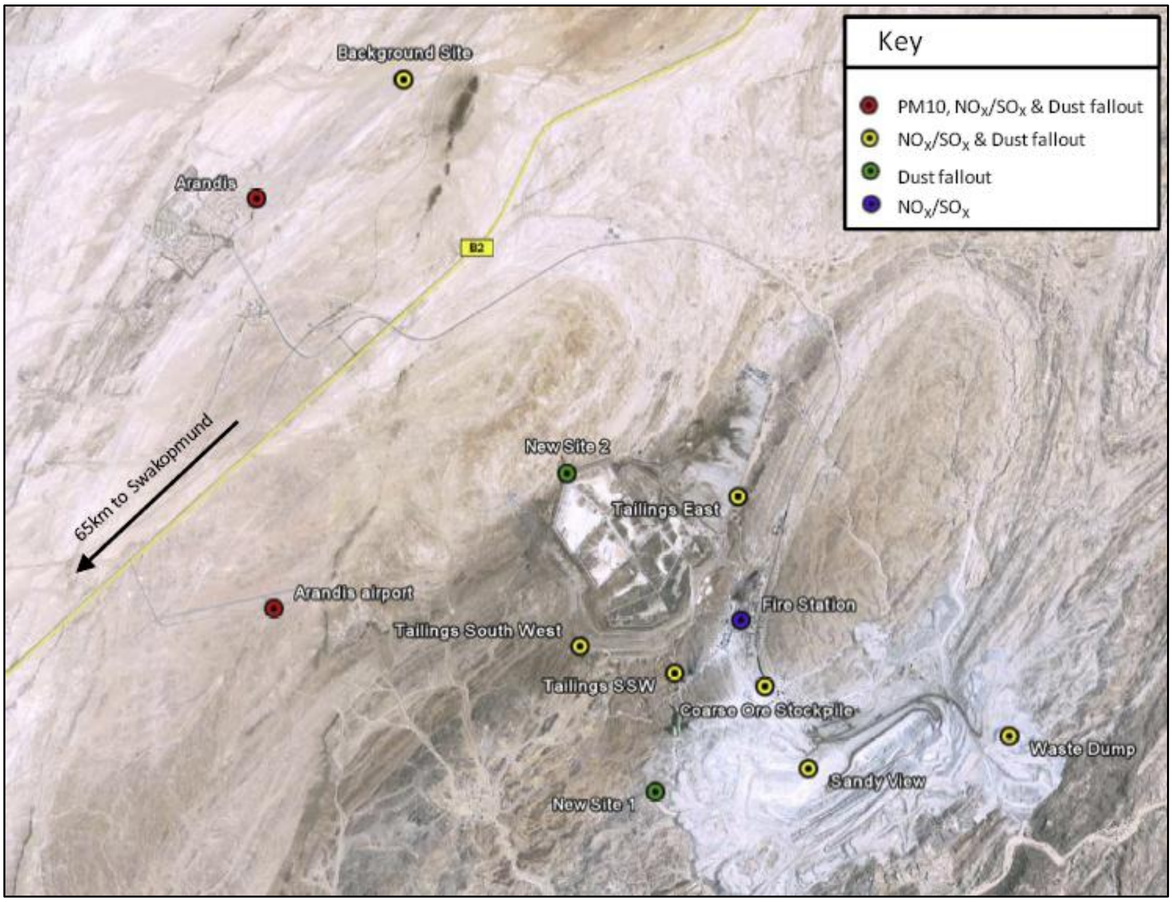

Figure 3-10: Location of the NOx, SOx, PM_{10} and dust fallout sites at Rössing (Ecoserv, 2009).

The contribution of daily and hourly PM_{10} readings were classified as background, baseline, Arandis town or mixed using the available wind data that was provided by Rössing. The hourly and daily PM_{10} results are presented in Table 3-3 and Table 3-4 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 PM_{10} collected at the site (von Gruenewaldt and Burger, 2010).

The daily PM_{10} readings for the two month monitoring campaign were compared against SA standards and WHO guidelines (Figure 3-11). From the measured PM_{10} daily concentrations at Arandis and Arandis Airport, the measured concentrations resulted in two exceedances of the WHO-IT3 (and SA 2015 limit) of 75 µg/m³ at the Arandis sampling site, on the 1st and 14th of April 2009. The measured daily PM_{10} concentrations at Arandis and Arandis Airport were in exceedance of the EC and WHO guidelines of 50 µg/m³ on a number of occasions during the monitoring campaign.

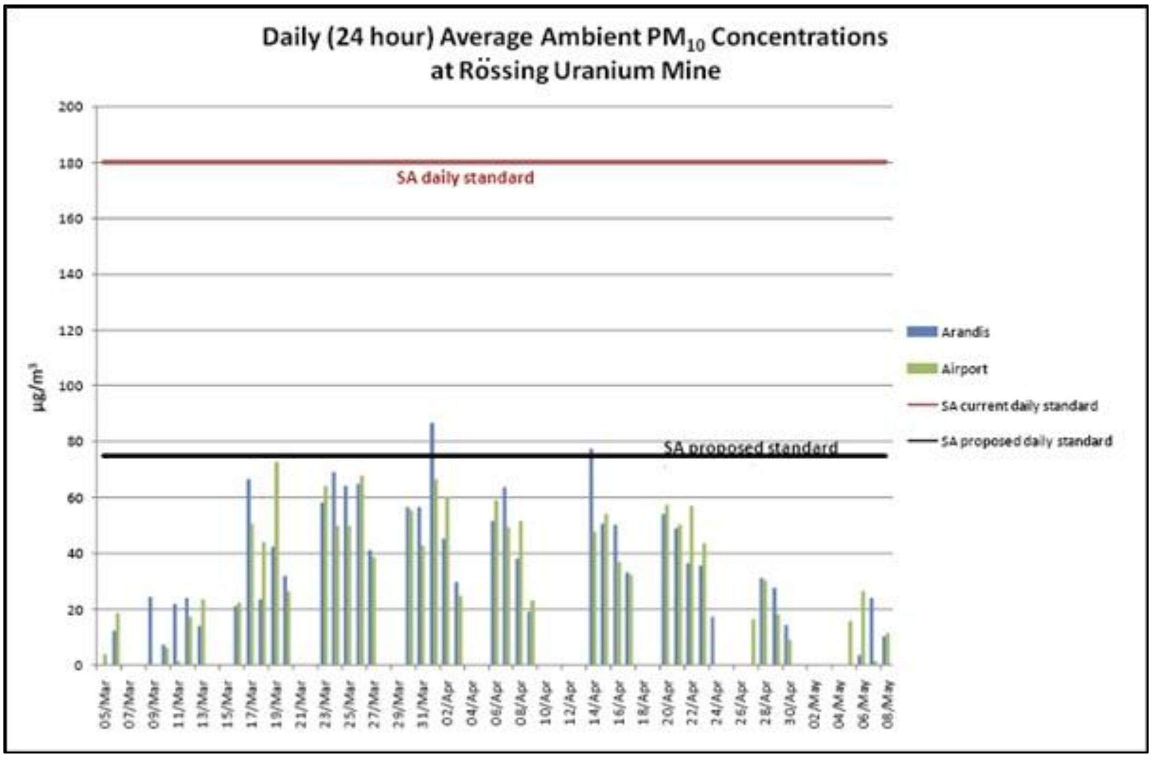

Figure 3-11: Daily PM_{10} averages at the Arandis and Arandis airport sites during March, April and early May 2009 (Ecoserv, 2009).

Table 3-3: Hourly background, baseline and Arandis town PM_{10} readings taken from the Arandis Airport monitoring site (Ecoserv, 2009).

Site	Classification	Mean PM_{10}	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 3-4: Daily background, baseline, Arandis town and mixed PM_{10} readings taken from the Arandis and Arandis Airport monitoring sites (Ecoserv, 2009)

Site	Classification	Mean PM_{10}	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 PM_{10} 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. Background levels of PM_{10} calculated using the hourly PM_{10} 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 PM_{10} readings which further reduces the data set. This was due to large amounts of missing weather data from the site (Ecoserv, 2009).

Dust fallout

The results of the monthly dust fallout monitoring data are shown in Figure 3-12. Highest dust deposition rates were collected at the Sandy’s View site (>800 mg/m²/day) during both March and April. Higher deposition rates were also collected at the Tailings 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).

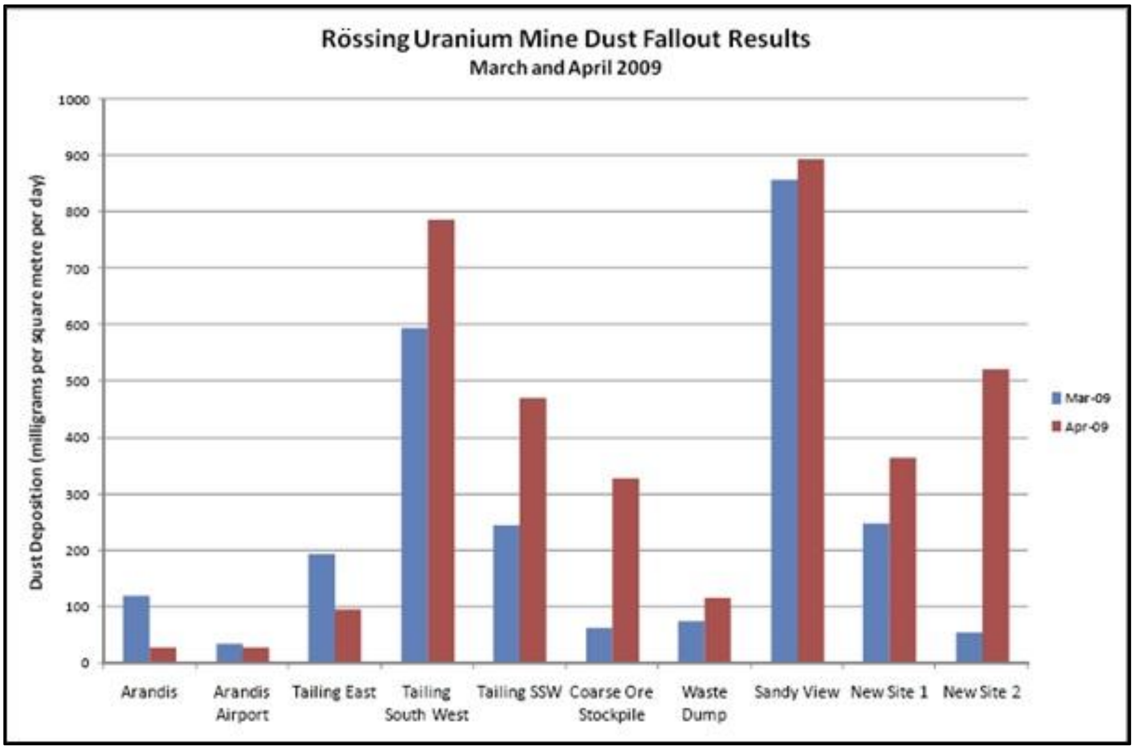

Figure 3-12: Monthly average dust fallout results at Rössing during March and April 2009 (Ecoserv, 2009).

3.3.2 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.

For the purpose of this assessment, the same baseline (i.e. for the year 2010) as used in the Rössing Phase II SEIA expansion project was used. The modelling domain had to be expanded to include the area in the southern part of the Rössing mine property where the Z20 infrastructure corridor is located (Figure 1-2). The process description of Rössing, a detailed emissions quantification discussion and modelling method can be found in Section 4.2 of the Air Quality Specialist report for the Rössing Phase II SEIA expansion project (von Gruenewaldt and Burger, 2010).

Dispersion modelling was undertaken to determine highest daily and annual average PM_{10} ground level concentrations and dustfall rates 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 (GLC) 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 isopleths plots are provided in Figures 3-13 and 3-14 for PM_{10} highest daily and annual averages and in Figure 3-15 for maximum daily dust fallout. The predicted concentrations and dust fallout rates at the various receptors are provided in Table 3-5, representing the concentration/ dust fallout rate as a fraction of the relative guideline/limit.

Table 3-5: Predicted PM_{10} and dust fallout impacts at each of the receptors for the baseline (figures in bold indicate exceedances of the selected guideline).

No.	Receptor	Highest daily PM_{10} GLC (µg/m³)	Fraction of guideline	Annual average PM_{10} GLC (µg/m³)	Fraction of guideline	Dust fallout rate (mg/m²/day) (a)	Fraction of guideline
1	Arandis	34.53	0.46	3.40	0.11	13	0.02
2	E-Camp	42.26	0.56	4.41	0.15	75	0.13
3	Arandis Airport	54.24	0.72	7.69	0.26	26	0.04
4	Khan Mine	225.04	**3.00**	20.08	0.67	170	0.28
5	Khan River	457.22	**6.10**	35.68	**1.19**	275	0.46
6	Husab Mine	77.66	**1.04**	4.55	0.15	6	0.01

<u>PM_{10} GLCs</u>: Figure 3-13 indicates the area of highest predicted daily PM_{10} GLCs. The selected ambient guideline of 75 µg/m³ is exceeded within the mine boundary around the main mining activities. The only exceedances of the daily guideline are at the Khan River, the Khan Mine, and at the Husab Mine (Table 3-5). Over an annual average, predicted PM_{10} GLCs are below the ambient guideline of 30 µg/m³ except at the Khan River located to the south of the pit operations (Figure 3-14).

<u>Dust fallout</u>: The majority of dust fall occurs within the mine boundary. The area around the road has higher dust fallout. The predicted dust fallout rate at the mine boundary is below 600 mg/m²/day, the maximum dust fall rate for residential areas. The highest dust fallout is at the Khan River (275 mg/m²/day).

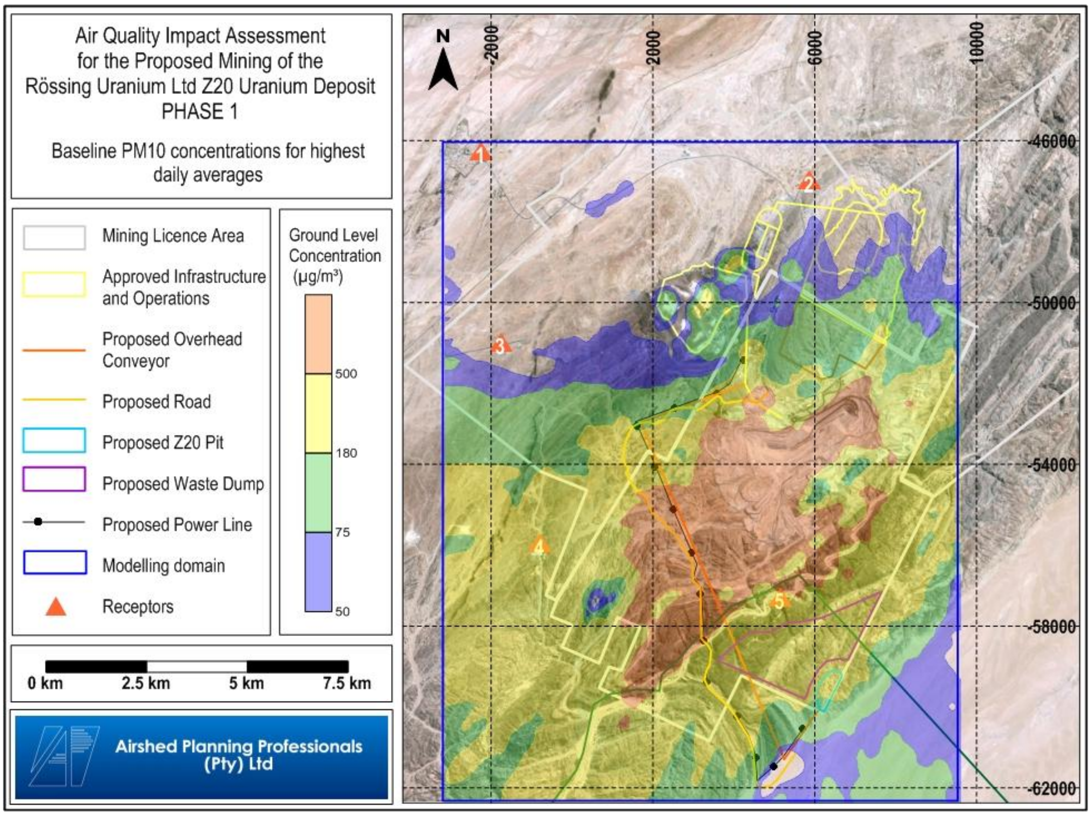

Figure 3-13: Highest daily PM_{10} ground level concentrations due to current (Baseline 2010) operations (all sources).

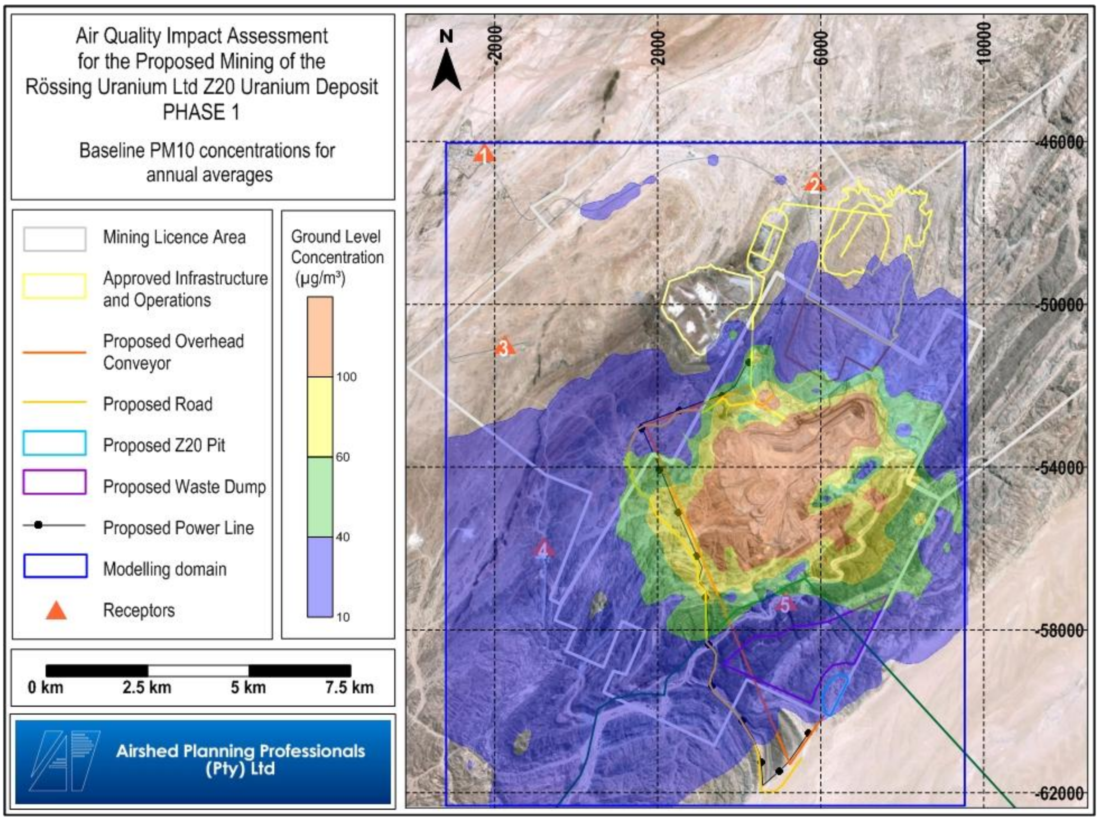

Figure 3-14: Annual average PM_{10} ground level concentrations due to current (Baseline 2010) operations (all sources).

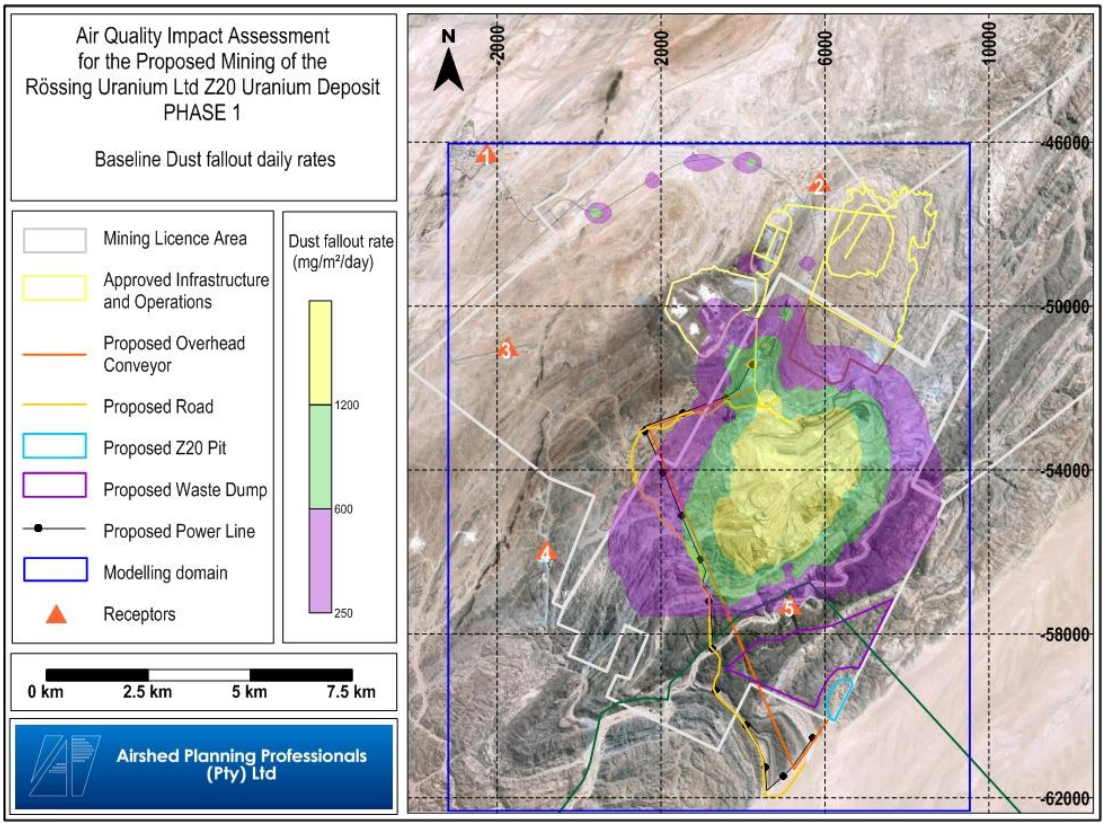

Figure 3-15: Maximum daily deposition due to current (Baseline 2010) operations (all sources).

4 Air Quality Evaluation

4.1 Source Identification

The project includes the continuous transport of ore with a RopeCon© conveyor from the Z20 area, over the Khan River towards Rössing Mine and the access road.

Table 4-1 provides a list of all sources of air pollution associated with the proposed project. The subsequent sections provide a generic description of the parameters influencing dust generation from the various aspects identified.

Table 4-1: Activities and aspects identified for the construction, operational and rehabilitation phases of the proposed operations.

Pollutant(s)	Aspect	Activity
Construction		
Gases and Particulates	Access road and Conveyor system	Clearing of groundcover
		Blasting
		Levelling and grading of surface
		Wind erosion from exposed areas
		Asphalt surface cover for access road
		Vehicle and construction equipment movement generating dust during construction operations
		Tailpipe emissions from vehicles and construction equipment such as graders, scrapers and dozers
Z20 Infrastructure Corridor operations		
Particulates	Ore transport via conveyor	Wind-blown dust from conveyor
	Ore transfer points	Dust generation from tipping
	Access road	Busses and cars driving on the access road causing dust emissions due to silt loading on road surface
Gaseous emissions		Tailpipe emissions from busses and cars driving on the access road
Rehabilitation		
Particulates	Rehabilitation access road and conveyor support systems	Demolition of asphalt road surface
		Removal of surface material
		Wind-blown dust from exposed cleared areas and exposed topsoil during rehabilitation
	Temporary unpaved roads	Truck activity at site during rehabilitation
Gaseous emissions		Tailpipe emissions from trucks and equipment used for rehabilitation

4.2 Emission Quantification

The establishment of an emissions inventory forms the basis for assessing the impact from source emissions on the receiving environment. The establishment of an emissions inventory comprises the identification of sources of emission, and the quantification of each source’s contribution to ambient air pollution concentrations.

4.2.1 Construction

The construction phase is mainly relevant to the road construction as the conveyor system will only require support towers not affecting large areas. The road construction would normally comprise a series of different operations including land clearing, blasting, topsoil removal, road grading, material loading and hauling, stockpiling, compaction, (etc.). Each of these operations has their own duration and potential for dust generation. It is anticipated that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions.

It is not anticipated that the various construction activities will result in higher off-site impacts than the operational phase activities. The temporary nature of the construction activities, and the likelihood that these activities will be localised and for small areas at a time, will reduce the potential for significant off-site impacts.

Emissions from the construction activities were estimated on an area wide basis since no detailed construction schedule is available at this stage. This approach estimates construction emissions for the entire affected area without regard to the actual plans of the individual construction project. In the quantification of releases from the construction phase, use was made of emission factors published by the US.EPA (EPA, 1996). The approximate emission factors for construction activity operations are given as:

$$\text{ETSP} = 2.69 \text{ Mg/hectare/month of activity}$$

This emission factor is most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semi-arid climates and applies to TSP. Thus, it will result in conservatively high estimates when applied to PM_{10}. Also, because the derivation of the factor assumes that construction activity occurs 30 days per month, it is regarded as conservatively high for TSP as well (EPA, 1995). The emission factor does not provide an indication of which type of activity during construction would result in the highest impacts thus not providing information to develop an effective dust control plan. For example, secondary dust sources during construction might be far more significant than the actual on-site construction operations. Such secondary sources may include vehicle activity on off-site roads, quarry operations and stockpiles located away from the actual site (EPA, 1996).

The total length of the access road is 14.4 km with a road width of 7.2 m and a shoulder of 2.4 m on each side. The road will have an asphalt surface and a reinforced bridge will be constructed across the Khan River.

The total TSP generated during the proposed construction phase when applying the above mentioned emission factor is 46.5 tons of TSP per month and 557.8 tpa, assuming a construction period of 12 months. This is assuming that all construction activities would take place simultaneously and over the entire area. This is unlikely to be the case.

According to the Australian Environmental Protection Agency on recommended separation distances from various activities, a buffer zone of 500 m from the nearest sensitive receptor is required when extractive-type materials handling activities occur with blasting (AEPA, 2007).

4.2.2 Operational Phase

The operational phase will include ore transport from the Z20 pit area to the Rössing processing plant via conveyor system, with two material transfer points along the way. A paved road will provide access for staff and equipment and parts to the Z20 site.

Information on the design of the proposed RopeCon©, transfer points and access road were provided by Rössing. A representation of the proposed layout is provided in Figure 1-2.

Conveyor

The RopeCon© conveyor is designed as such to ensure that limited dust should be generated from the conveying process. A picture of the RopeCon© conveyor roof cover is supplied in Figure 4-1. As a conservative approach, emissions from the conveyor were calculated assuming the conventional conveyor design with control efficiencies as provided for conveyors with enclosed sides and a roof.

The dust emissions from conventional conveyors are wind speed dependent with stronger wind speeds causing dust particles to be entrained by the wind. The degree of entrained dust also depends on the level of enclosure, i.e. roof cover and/or sides. The wind speed dependence has been based on the recommendations of Parrett (1992) where the dust emission rate (as grams per metre of conveyor) is equivalent to a constant multiplied by the difference between the friction velocity (u^*) and the threshold friction velocity of the coal (u^*_t):

$$E = c(u^* - u_t^*)$$

An estimate for the constant (c) has been made on data reported by GHD/Oceanics (1975) for measured conveyor emissions at a wind speed of 10 m/s. The PM_{10} fraction has been estimated as 45% of the TSP.

Figure 4-1: Example of the RopeCon© rood cover and customised roof cover (after Dopplemayr).

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10m (EPA, 1999): $u^* = 0.053\ u_{10}$. This equation assumes a typical roughness height of 0.5 cm for open terrain, and is restricted to large relatively flat piles or exposed areas with little penetration into the surface layer. Parrett's (1992) estimate of u* over coal surfaces was determined as typically 0.11 times the 10 metre level wind speed. Furthermore, the threshold wind speed (u^*_t) for coal dust to be lifted (particles in the 20-30 µm range) is 3.1 m/s. The value for u^*_t therefore is typically 0.34 m/s. Emissions for wind speeds below 3.1 m/s are likely to be negligible.

The friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus for particles to become airborne, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity (Shao, 2008). The particle density of coal is given to be roughly 1.3 g/cm³ (Robinson, 1986) in comparison to 1.9 g/cm³ for uranium ore. The threshold friction velocity for ore particles, when calculated, is therefore higher at 0.58 m/s indicating that higher wind speeds are required to lift the particles. For a conservative approach, the threshold friction velocity of coal was used for this assessment.

For the section where the conveyor crosses the Khan River, the logarithmic wind speed profile was used to estimate friction velocities from wind speed data at a reference height of 121 m. Here the surface wind speed was assumed to apply within the river valley (and not at surface) with increased wind speeds calculated at a height of 121 m above the valley floor. According to literature, as discussed in Section 3.2.2, the wind speed will decrease over the river valley and only increase at the downwind valley wall. Thus, the calculated increased wind speeds are only likely to occur at the conveyor crossing on the south-eastern part of the Khan River valley and not the entire river crossing as accounted for.

The conveyor information is listed in Table 4-2 with the calculated emissions provided in Table 4-3. As indicated, the approach is conservative since it assumes emissions from a conventional conveyor and based on emission factors provided for coal dust. Control efficiencies for conveyors with roofs and covered on both sides are given as 70%.

Table 4-2: RopeCon© conveyor parameters

Conveyor length (m)	Conveyor width (m)	Height of sides (mm)	Conveyor speed (m/s)	Design capacity (tph)	Height above ground (m)	Ore Moisture (%)
12 550	0.8	200	4.65	2 250	2 121 [a]	1% - 2%

Notes: [a] at Khan River crossing.

The particle size distribution of the crushed ore was based on the information as per the Rössing Phase II SEIA expansion project for "Conveyor from primary crusher" and is provided in Table4-3 (von Gruenewaldt and Burger, 2010).

Table 4-3: Emission rates and associated wind speeds from the conveyor.

Conveyor Sections	Wind speed (m/s)		Height above ground (m)	No Mitigation		With Mitigation [b]	
	Average	Max		TSP (tpa)	PM_{10} (tpa)	TSP (tpa)	PM_{10} (tpa)
Z20CNV1	3.44	18.7	2	50.43	22.70	15.13	6.81
Z20CNV2	3.44	18.7	2	116.96	52.63	35.09	15.79
Z20CNV3 [a]	6.52	49.4	121	40.10	18.04	12.03	5.41
Z20CNV4	3.44	18.7	2	174.09	78.34	52.23	23.50
Z20CNV5	3.44	18.7	2	93.40	42.03	28.02	12.61
TOTAL				**474.99**	**213.74**	**142.50**	**64.12**

Notes: [a] at Khan River crossing.

[b] Mitigation assumed to include roof and two sides resulting in 70% control efficiency.

Table 4-4: Particle size distribution for the crushed ore.

Particle size distribution													
Size (µm)	>1180	1180	850	600	300	150	75	38	25	10	5	2	1
Fraction	0.27	0.003	0.011	0.035	0.19	0.205	0.151	0.138	0.095	0.059	0.05	0.041	0.023

Material Transfer points

The material transfer points, where ore is transferred onto and from the conveyors, were calculated using the following equation (NPI, 2012):

$$E = k0.0016\left(\frac{U}{2.2}\right)^{1.3}\left(\frac{M}{2}\right)^{1.4}$$

where:

E = emission factor (kg dust / ton transferred)

k = 0.35 for particles less than 10 µm

U = mean wind speed (m/s)

M = material moisture content (%)

The conveyor transfer points are listed in Table 4-5 with the associated emission rates from each point. The moisture content of the material was given to be between 2% (when loaded) and 1% (when off-loaded), with the lower estimate applied in the calculations for a conservative estimate. The throughput as provided was applied 365 days per year, 24-hours per day. The average wind speed of 3.44 m/s was obtained from the Rössing weather data for the period 2000 to 2004.

The same particle size distribution as provided in Table 4-4 was used for the material transfer points.

Table 4-5: Emission rates from material transfer points.

Conveyor Sections	Throughput (tph)	No Mitigation		With Mitigation (b)	
		TSP (tpa)	PM_{10} (tpa)	TSP (tpa)	PM_{10} (tpa)
Z20TFP1	2 250	183.45	64.21	55.034	19.262
Z20TFP2	2 250	183.45	64.21	55.034	19.262
TOTAL		**366.89**	**128.41**	**110.07**	**38.52**

Notes: (a) Mitigation assumed to be enclosed with no fabric filters resulting in 70% control efficiency (NPI, 2012).

Access Road

Vehicle-entrained dust from unpaved and paved roads is a significant source of dust, especially where there is high traffic volume on a road and/or it is utilised by heavy equipment. The force of the wheels travelling on unpaved roads causes the 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 act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads will vary linearly with the volume of traffic expected on that road. The dust generation potential from paved roads are also much lower than from unpaved roads.

The extent of particulate emissions from both paved and unpaved roads is a function of the “silt loading” present on the road surface, and to a lesser extent of the average weight of vehicles travelling on the road (Cowhert and Engelhart,1984; EPA, 1995). Silt loading 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. Silt loading is the product of the silt fraction and the total loading. No on-site data were available and the same silt loadings as used in the Uranium Rush SEA study for paved roads were applied to the access road of 8.4 g/m^2 (Liebenberg-Enslin et al., 2010). The following emission equation was used to quantify emission from the access road:

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

where,

E = particulate emission factor (having units matching the units of k) 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 vehicle fleet exhaust, brake wear and tire wear (1980)

The particle size multiplier (k) is given as 4.6 for PM_{10} and as 24 for TSP. Generally, roads with a higher traffic volume tend to have lower surface silt loading (sL). The surface silt loading should preferably be measured to reflect site-specific conditions.

The information used is provided in Table 4-6 with the resulting emission rates in Table 4-7. No mitigation measures were assumed for the access road give the low traffic volumes.

Table 4-6: Vehicles and associated information.

Traffic	No of vehicles	Trips/day	Total trips
Busses (48 seater)	2	6	12
Busses (16 seater)	1	6	6
LDVs	2	2	4
Cars	3	1	3
Delivery Trucks (8 ton)	1	4	4
Interlink (30 ton)	0.25	2	0.5

Table 4-7: Paved access road emissions.

Road Type	Road length (m)	Road width (m)	Trips/hr	VKT/hr	TSP (tpa)[(a)]	PM_{10} (tpa) [(a)]
Access road to site	14 440	12	4.92	71.43	0.97	5.05

Notes: [(a)] Applied to six operating hours per day, 364 days per year.

4.3 Impact Assessment

4.3.1 PM_{10} Ground Level Concentrations

The isopleths plots are provided for the Z20 infrastructure corridor only in Figures 4-2 and 4-3 for PM_{10} highest daily averages without and with mitigation, respectively. The annual averages for the same scenario are provided in Figures 4-4 and 4-5. Table 4-8 provides the predicted impacts at the receptors from the Z20 infrastructure corridor only. The identified receptors are provided in Figure 1-2.

Table 4-8: Predicted PM_{10} concentrations and dust fallout rates at each of the receptors from the Z20 Infrastructure Corridor project only.

No.	Receptor	Highest daily PM_{10} GLC (µg/m³)	Fraction of guideline	Annual average PM_{10} GLC (µg/m³)	Fraction of guideline	Dust fallout rate (mg/m²/day)	Fraction of guideline
Unmitigated Z20 Infrastructure Corridor operations							
1	Arandis	1.46	0.04	0.11	0.03	3.05	0.19
2	E-Camp	0.86	0.02	0.10	0.02	14.06	0.16
3	Arandis Airport	4.98	0.08	0.38	0.05	9.36	0.26
4	Khan Mine	6.48	0.03	0.78	0.04	43.83	0.20
5	Khan River	4.91	0.01	1.33	0.04	131.12	0.32
6	Husab Mine	12.26	0.14	0.76	0.14	53.63	0.90
Mitigated Z20 Infrastructure Corridor operations[(a)]							
1	Arandis	0.44	0.01	0.03	0.01	0.26	0.02
2	E-Camp	0.26	0.01	0.03	0.01	1.29	0.02
3	Arandis Airport	1.49	0.03	0.12	0.01	0.90	0.03
4	Khan Mine	1.96	0.01	0.24	0.01	4.80	0.03
5	Khan River	1.49	0.00	0.40	0.01	10.89	0.04
6	Husab Mine	3.73	0.04	0.23	0.05	4.33	0.42

Notes: [(a)] Based on 70% control efficiency on ore transfer points and conveyor with side walls and a roof.

- Unmitigated scenario: Figure 4-2 indicates the area of highest predicted daily PM_{10} GLCs with no mitigation in place and assuming a conventional conveyor system. The air quality limit (75 µg/m³) is exceeded for a distance of up to 850m from the material transfer points with no exceedances along the conveyor system. The infrastructure corridor results in low PM_{10} concentrations at the various receptors that are well below the daily and annual air quality limits (Table 4-8).
- Mitigated scenario: With mitigation in place on material transfer points and on the conveyor, resulting in 70% control efficiency for both, the predicted incremental impacts reduce over a daily average to only exceed the air quality limit (75 µg/m³) for a small area around the two transfer points (Figure 4-3). This results in low GLCs off-site and at the various receptors (Table 4-8). The annual average footprint as shown in Figure 4-5 also reduces significantly.

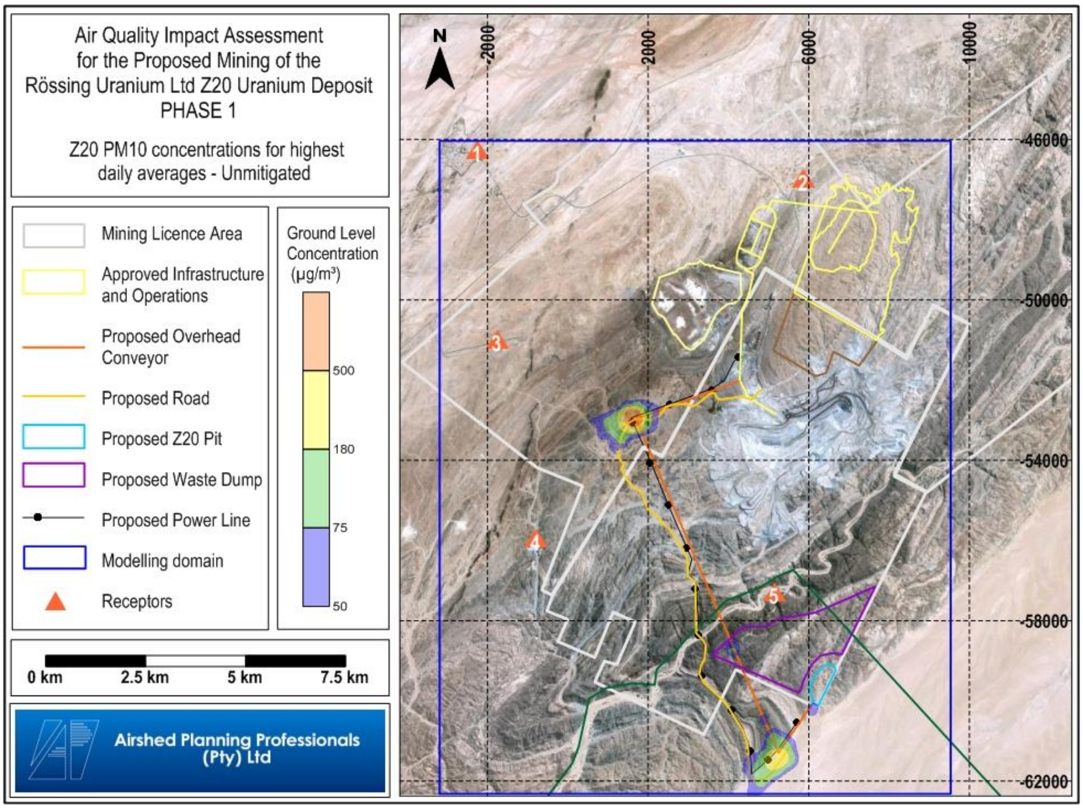

Figure 4-2: Highest daily PM_{10} ground level concentrations from Z20 Infrastructure Corridor – unmitigated.

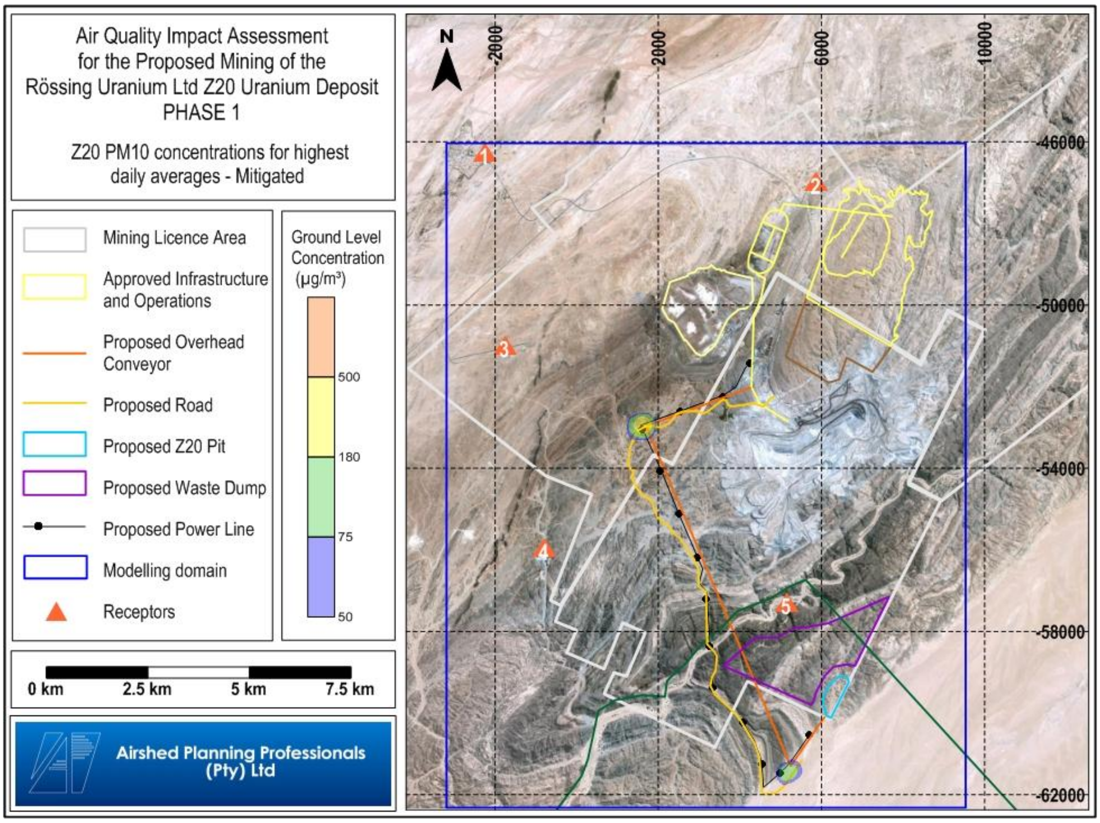

Figure 4-3: Highest daily PM_{10} ground level concentrations from Z20 Infrastructure Corridor – mitigated.

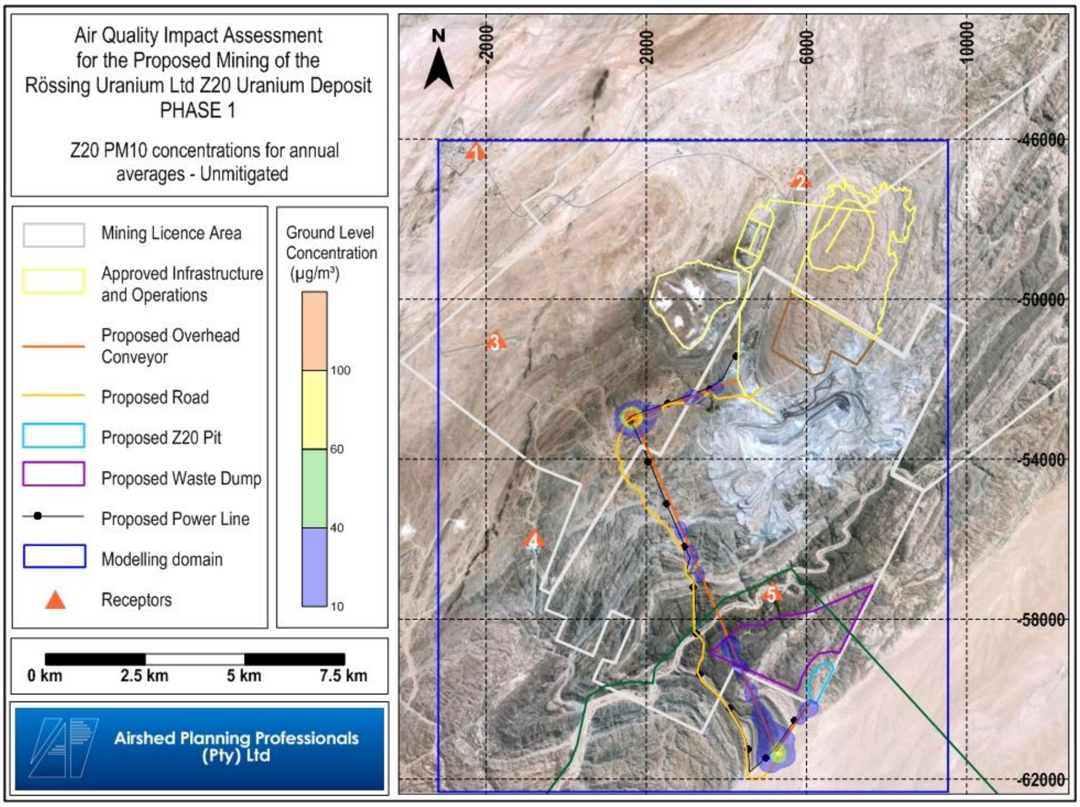

Figure 4-4: Annual average PM_{10} ground level concentrations from Z20 Infrastructure Corridor – unmitigated.

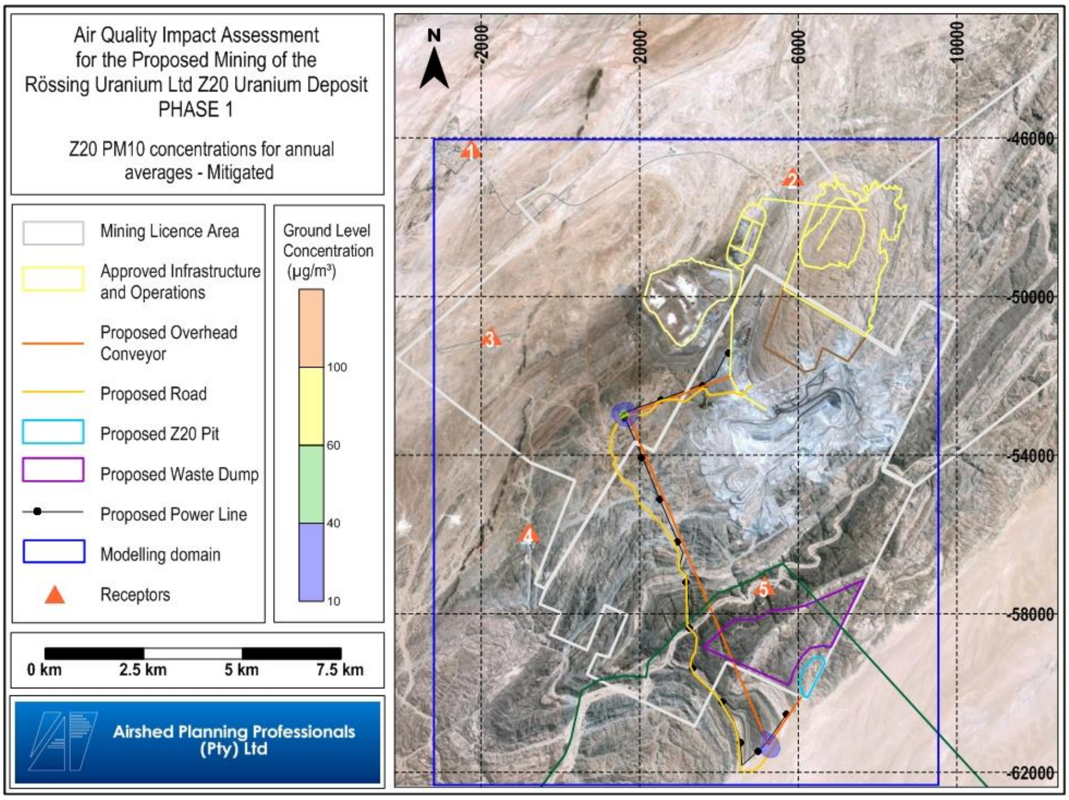

Figure 4-5: Annual average PM_{10} ground level concentrations from Z20 Infrastructure Corridor –mitigated.

The cumulative plots, reflecting PM_{10} GLCs and dust fallout rates from the 2010 Rössing baseline (Section 3.3.2) plus the Z20 infrastructure corridor, are provided in Figures 4-6 and 4-7 for highest daily PM_{10} concentrations and annual averages[2]. Predicted cumulative GLCs at each of the receptors are provided in Table 4-9 for the cumulative scenario.

Table 4-9: Predicted PM_{10} concentrations and dust fallout rates at each of the receptors for the cumulative impacts from the 2010 Rössing baseline plus the Z20 Infrastructure Corridor operations (figures in bold indicate exceedances of the selected guideline).

No.	Receptor	Highest daily PM_{10} GLC ($\mu g/m^3$)	Fraction of guideline	Annual average PM_{10} GLC ($\mu g/m^3$)	Fraction of guideline	Dust fallout rate ($mg/m^2/day$) (a)	Fraction of guideline
Unmitigated Z20 Infrastructure Corridor operations plus 2010 baseline							
1	Arandis	35.99	0.48	3.52	0.12	16.05	0.03
2	E-Camp	43.12	0.57	4.52	0.15	89.06	0.15
3	Arandis Airport	59.21	0.79	8.07	0.27	35.36	0.06
4	Khan Mine	231.52	**3.09**	20.86	0.70	213.83	0.36
5	Khan River	462.13	**6.16**	37.01	**1.23**	**406.12**	0.68
6	Husab Mine	89.92	**1.20**	5.31	0.18	59.63	0.10
Mitigated Z20 Infrastructure Corridor operations plus 2010 baseline							
1	Arandis	35.84	0.48	3.44	0.11	13.26	0.02
2	E-Camp	42.98	0.57	4.45	0.15	76.29	0.13
3	Arandis Airport	58.50	0.78	7.80	0.26	26.90	0.04
4	Khan Mine	230.22	**3.07**	20.32	0.68	174.80	0.29
5	Khan River	459.84	**6.13**	36.08	**1.20**	285.89	0.48
6	Husab Mine	89.12	**1.19**	4.78	0.16	10.33	0.02

Notes: (a) Estimated dust fallout based on baseline modelling.

- Unmitigated scenario: Cumulatively, the predicted impact zone is similar to the baseline scenario (Table 3-5), with only a slight increase in cumulative GLCs of between 1% (at the Khan River) and 14% (at Husab Mine) when compared to the baseline scenario (Table 3-5 versus Table 4-9). Over an annual average there are only exceedances of the air quality limit at the Khan River as is the case with the baseline (Table 3-5).
- Mitigated scenario: With mitigation in place on the Z20 Infrastructure Corridor material transfer points and on the conveyor, the predicted cumulative impacts remain similar to the baseline scenario. Annual concentrations remain low.

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[2] Due to the similarity between the "unmitigated" and "mitigated" plots when adding the baseline, only the unmitigated Z20 Infrastructure Corridor operations together with the 2010 Rössing baseline operations are provided in these plots.

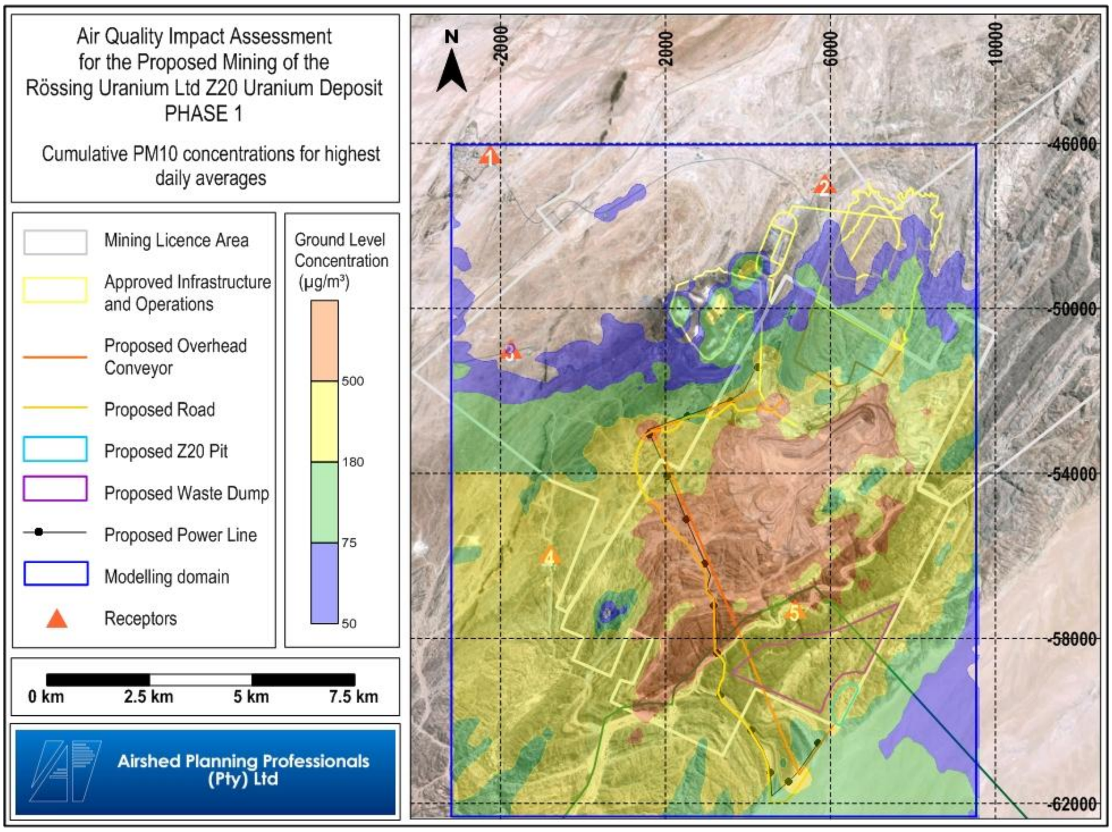

Figure 4-6: Highest daily PM_{10} ground level concentrations from all Rössing and Z20 Infrastructure Corridor sources – unmitigated.

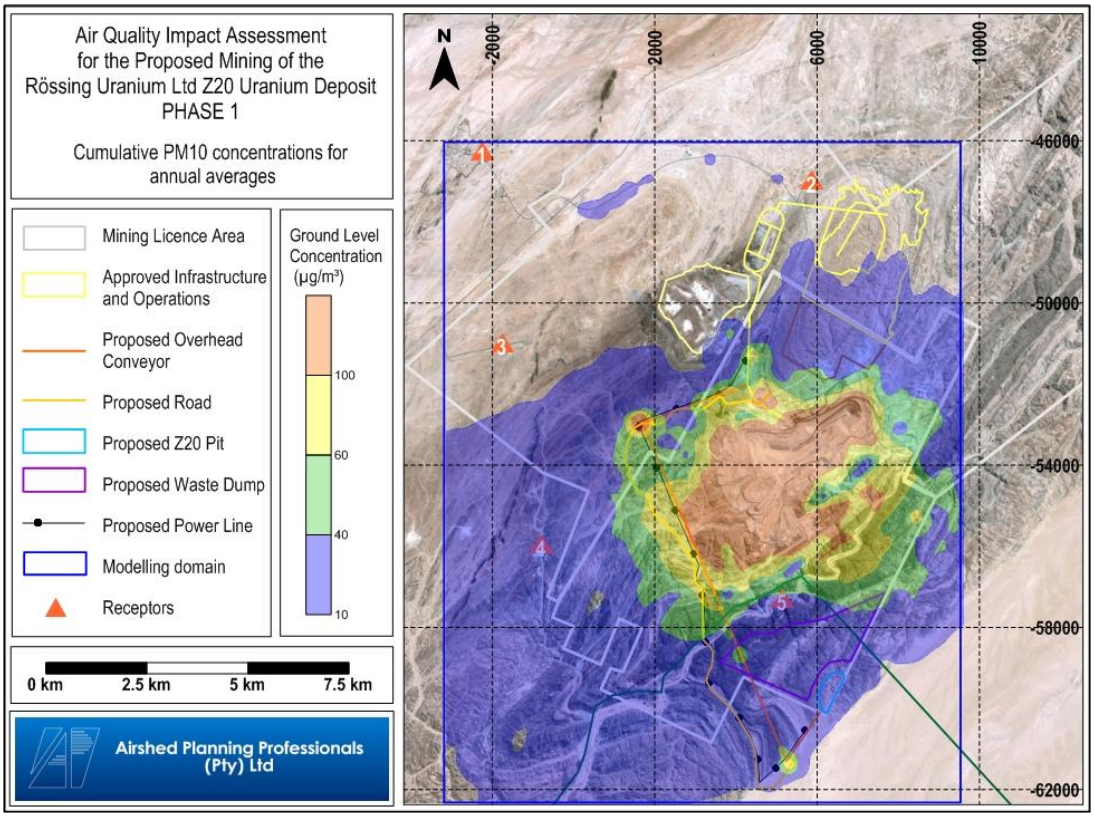

Figure 4-7: Annual average PM_{10} ground level concentrations from all Rössing and Z20 Infrastructure Corridor sources – unmitigated.

4.3.2 Dust fallout

Figure 4-8 provides the dust fallout rates for the year 2004 for the Z20 Infrastructure Corridor project with no mitigation in place. Figure 4-9 provides the dust fallout rates with mitigation considered. Dust fallout rates at the receptors are provided in Table 4-8, for the unmitigated and mitigated scenarios.

Unmitigated scenario: The majority of dust fall occurs within the site boundary. The area around the conveyor has higher dust fallout. The predicted dust fallout rate above the 600 mg/m²/day stretches up to about 600m from the conveyor. The area above the European vegetation limit of 400 mg/m²/day is roughly 1km from the transfer points. Cumulative impacts do not exceed the residential dust fallout limit of 600 mg/m²/day with a maximum of 400 mg/m²/day (European vegetation limit) at the Khan River.(Appendix A provides

Mitigated scenario: With mitigation in place on the material transfer points and the conveyor, the predicted dust fallout rates reduce to only have impact areas at the transfer points. Cumulatively the dust fallout rates remain similar to the baseline situation with no exceedances of either the residential limit (600 mg/m²/day) or the European vegetation limit (400 mg/m²/day) at any of the receptors.

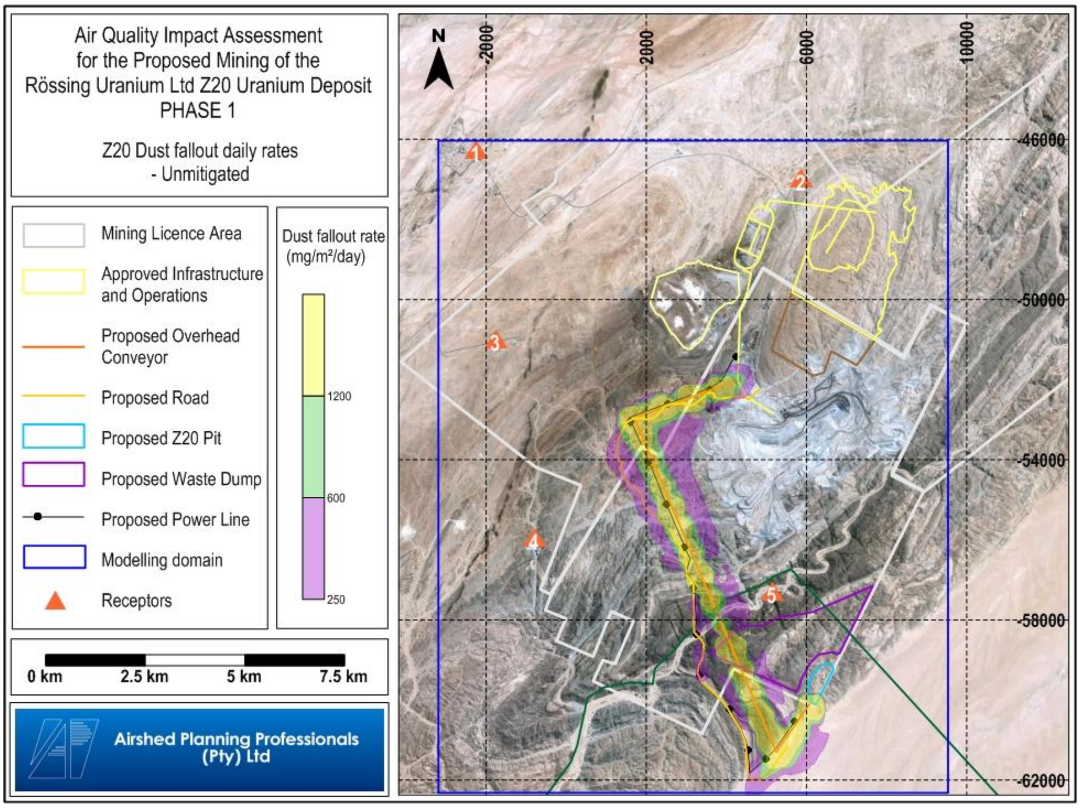

Figure 4-8: Maximum daily dust fallout rates from Z20 Infrastructure Corridor – unmitigated.

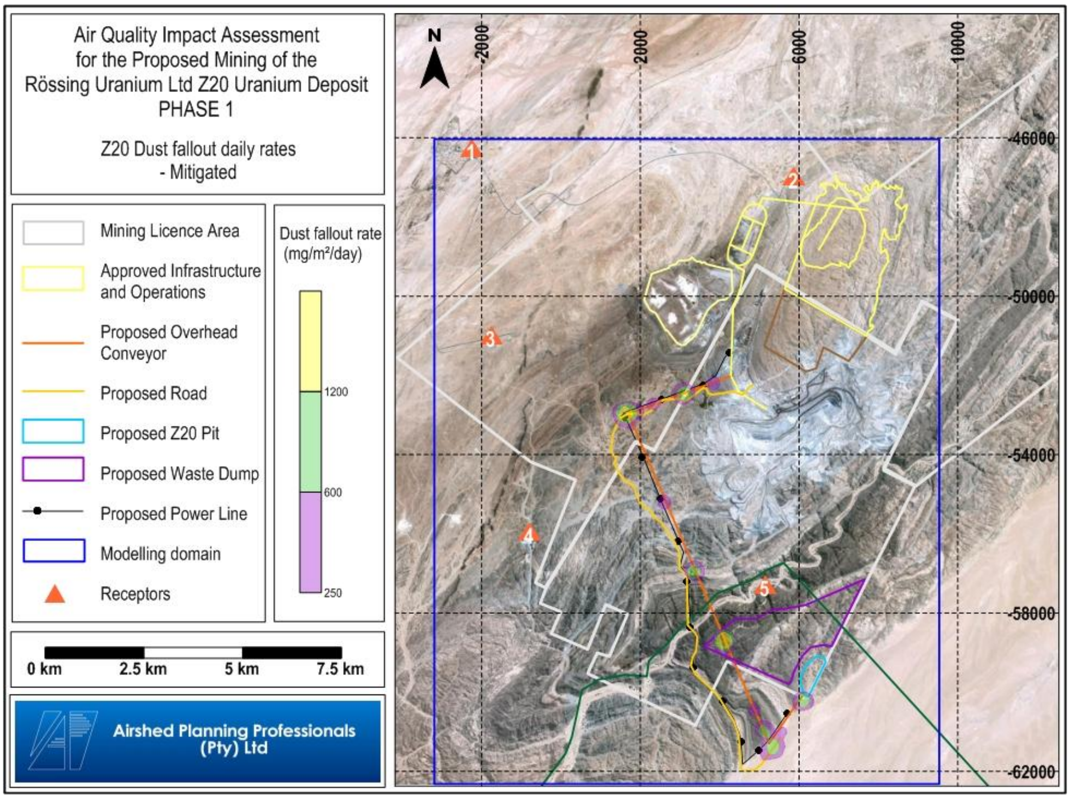

Figure 4-9: Maximum daily dust fallout rates from Z20 Infrastructure Corridor –mitigated.

4.4 Significance rating of operational phase activities

A standardised and internationally recognised methodology[3] has been applied to assess the significance of the potential environmental impacts of Rössing Uranium's project

For each impact, the EXTENT (spatial scale), MAGNITUDE (size or degree scale) and DURATION (time scale) is be described. These criteria are used to ascertain the SIGNIFICANCE of the impact, firstly in the case of no mitigation and then with the most effective mitigation measure(s) in place. Namibia's Environmental Assessment Policy requires that, "as far as is practicable", cumulative environmental impacts should be taken into account in all environmental assessment processes. The impact significance criteria and its interpretation from an **environmental air quality perspective** is summarised in Appendix B.

It should be noted that the air quality impact assessment methodology provides for the assessment of cumulative impacts i.e. the baseline scenario from the Rössing 2010 assessment plus the contribution from the Z20 Infrastructure Corridor emissions. The significance ratings are provided in Table 4-9.

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[3] As described, *inter alia*, in the South African Department of Environmental Affairs and Tourism's Integrated Environmental Management Information Series (Government of SA, 2004).

Table 4-10: Cumulative air quality impact significance for unmitigated and mitigated scenarios for the Z20 Infrastructure Corridor project.

Cumulative Phase 1 Air Quality Impact Significance										
Aspect	**Phase**	**Impact Description**	**Type**	**Extent**	**Magnitude**	**Duration**	**Probability**	**Confidence**	**Reversibility**	**Significance**
Unmitigated Z20 Infrastructure Corridor operations plus 2010 baseline										
PM_{10} GLCs	Construction Phase 1	Dust generation during access road construction resulting in additional inhalable particulate concentrations expected to be localised	Negative	Local	Low	Short Term	Probable	Unsure	Reversible	Low (-)
Dust fallout	Construction Phase 1	Dust generation during access road construction resulting in dust fallout expected to be localised	Negative	Local	Low	Short Term	Probable	Unsure	Irreversible	Low (-)
PM_{10} GLCs	Operational Phase 1	Increase in inhalable particulate concentrations to the existing baseline air quality in the region	Negative	Regional(a)	Medium	Long Term	Probable	Sure	Reversible	High (-)
Dust fallout	Operational Phase 1	Increase in dust fallout concentrations to the existing baseline air quality in the region, marginally exceeding the European vegetation limit at the Khan River	Negative	Regional(a)	High	Long Term	Probable	Sure	Reversible	High (-)
PM_{10} GLCs	De-comm. Phase 1	An increase in dust generation due to the demolition of existing infrastructure expected to have localised impacts	Negative	Local	Low	Short Term	Probable	Unsure	Reversible	Low (-)
Dust fallout	De-comm. Phase 1		Negative	Local	Low	Short Term	Probable	Unsure	Reversible	Low (-)

Notes: (a) Regional where the predicted impacts exceed the Mining License Area.

Aspect	Phase	Impact Description	Type	Extent	Magnitude	Duration	Probability	Confidence	Reversibility	Significance
Mitigated Z20 Infrastructure Corridor operations plus 2010 baseline										
PM$_{10}$ GLCs	Construction Phase 1	Dust generation during access road construction resulting in additional inhalable particulate concentrations expected to be very localised if mitigated with water sprays	Negative	Local	Low	Short Term	Probable	Unsure	Reversible	Low (-)
Dust fallout	Construction Phase 1	Dust generation during access road construction resulting in dust fallout expected to be localised if mitigated with water sprays	Negative	Local	Low	Short Term	Probable	Unsure	Irreversible	Low (-)
PM$_{10}$ GLCs	Operational Phase 1	Insignificant increase in inhalable particulate concentrations to the existing baseline air quality in the region with enclosed transfer points and conveyor	Negative	Local	Low	Long Term	Probable	Sure	Reversible	Low (-)
Dust fallout	Operational Phase 1	Insignificant increase in dust fallout rates to the existing baseline not exceeding the European vegetation limit at the Khan River due to enclosed transfer points and conveyor	Negative	Local	Low	Long Term	Probable	Sure	Reversible	Low (-)
PM$_{10}$ GLCs	De-comm. Phase 1	An increase in dust generation due to the demolition of existing infrastructure expected to have localised impacts	Negative	Local	Very Low	Short Term	Probable	Sure	Reversible	Very Low (-)
Dust fallout	De-comm. Phase 1		Negative	Local	Very Low	Short Term	Probable	Sure	Reversible	Very Low (-)

4.5 Decommissioning

For the sake of this discussion, decommissioning is regarded as the phase where all mining operations cease and rehabilitation takes place. It is assumed that all support activities will cease once the Z20 open pit operations end. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during decommissioning.

The significance of the rehabilitation activities is likely to be linked to impacts from windblown dust from the exposed surfaces where the infrastructure, such as the road surface, has been demolished. Windblown dust is likely to only impact off-site under conditions of high wind speed with no mitigation in place. If rehabilitation as indicated takes place, the impacts should be limited to be within the site boundary.

5 Dust Management Plan

In the light of the potential for air quality impacts from the proposed Z20 Infrastructure Corridor Project without mitigation in place, it is recommended that air quality management planning forms part of the construction, operational phase and decommissioning of the proposed project. The air quality management plan provides options on the control of dust and gases at the main sources with the monitoring network designed as such to track the effectiveness of the mitigation measures. The sources need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

Based on the qualitative evaluation of the proposed construction and decommissioning operations; and the quantitative assessment of the operational phase activities, management objectives are considered as summarised in Tables 5-1 to 5-3.

Table 5-1: Air Quality Management Plan: Construction operations

ASPECT	IMPACT	MANAGEMENT ACTIONS/OBJECTIVES	RESPONSIBLE PERSON(S)	TARGET DATE
Land clearing activities such as bulldozing and scraping of road and blasting	PM_{10} concentrations and dust fallout	• Water sprays at area to be cleared. • Moist topsoil will reduce the potential for dust generation when tipped onto stockpiles. • Ensure travel distance between clearing area and topsoil piles to be at a minimum.	Environmental Manager Contractor(s)	Pre- and during construction
Road construction activities such as road grading and asphalt mixing and application	PM_{10} concentrations and dust fallout, sulphur dioxide and VOCs	• Water sprays at area to be graded. • Freshly graded areas to be kept to a minimum. • Dust fallout bucket to be placed in the Khan River downwind of the bridge construction with monthly dust fallout rates not exceeding 400 mg/m²/day[(a)] • Asphalt production and application to be monitored with passive diffusive tubes for SOx and VOCs	Environmental Manager Contractor(s)	Pre- and during construction

Notes: [(a)] European dust fallout limit for vegetation of 400 mg/m²/day.

Table 5-2: Air Quality Management Plan: Z20 Infrastructure Corridor

ASPECT	IMPACT	MANAGEMENT ACTIONS/OBJECTIVES	RESPONSIBLE PERSON(S)	TARGET DATE
Wind erosion from conveyor system	PM_{10} concentrations and dust fallout	• Ensure RopCon has sides of 200 mm high and a roof covering the entire conveyor length. • Visual monthly inspections to ensure the conveyor is operational according to design specifications. • Dust fallout bucket to be placed downwind in the Khan River with monthly dust fallout rates not exceeding 400 mg/m²/day(a)	Environmental Manager	On-going during operational phase
Material transfer points	PM_{10} concentrations and dust fallout	• Ensure all transfer points are enclosed with dust extraction system and fitted with a bag filter. • Visual monthly inspections to ensure no visual dust generation from the enclosed transfer points. • Dust fallout buckets to be placed downwind (south) of all three transfer points with monthly dust fallout rates not exceeding 400 mg/m²/day(a) at Transfer points 1 and 2 and 600 mg/m²/day(b) at final transfer point on-site.	Environmental Manager	On-going during operational phase

Notes: (a) European dust fallout limit for vegetation of 400 mg/m²/day.

(b) Draft dust fallout regulation of 600 mg/m²/day for residential sites.

Table 5-3: Air Quality Management Plan: Rehabilitation activities

ASPECT	IMPACT	MANAGEMENT ACTIONS/OBJECTIVES	RESPONSIBLE PERSON(S)	TARGET DATE
Wind erosion from exposed areas	PM_{10} concentrations and dust fallout	• Demolition of infrastructure to have water sprays where a lot of vehicle activity is required. • Ensure site is restored to pre-mining conditions.	Contractor(s) Environmental Manager	Post-operational, can cease once rehabilitation is in place

6 Conclusion

An air quality impact assessment was undertaken to assess the possible impacts of all dust generating sources at the proposed Z20 Infrastructure Corridor. PM_{10} GLCs and dust fallout rates for the proposed operations were assessed in order to identify all possible detrimental impacts on the surrounding environment and human health.

Two scenarios were assessed namely (i) unmitigated and (ii) mitigated. Unmitigated assumed no controls on any of the activities whereas mitigated assumed dust control through the enclosure of the transfer points, and side walls and a roof on the conveyor system. The controls for the conveyor system were based on a conventional conveyor design. A control efficiency of 70% is given for both enclosure and sidewalls with a roof.

6.1 Main Findings

6.1.1 Baseline

Baseline monitoring (even though for a short period of two months) indicated average PM_{10} daily concentrations of 21 $\mu g/m^3$ and 40 $\mu g/m^3$ at Arandis Town and Arandis Airport. Simulated concentrations from the Rössing 2010 baseline indicate similar daily PM_{10} concentrations of 35 $\mu g/m^3$ for Arandis Town and 54 $\mu g/m^3$ for Arandis Airport. The highest GLCs are at the Khan River.

Dust fallout rates at both Arandis and Arandis Airport were low and well below the SANS residential limit of 600 $mg/m^2/day$. Again, this was only over a period of two months (March and April 2009). Dust fallout is the highest near the mine activities with the highest of 225 $mg/m^2/day$ predicted at the Khan River.

The prevailing wind field is from the north-east and south-west with infrequent winds from the north-west. According to a study conducted by Wiggs et al. (2002) on the influence of local topography on airflow characteristics, winds blowing at an angle towards a valley will accelerate downwind and likely to reach a maximum at the downwind valley wall after which the wind speeds will decrease rapidly.

6.1.2 Construction Phase Impacts

Construction operations were only qualitatively assessed. The main dust generating activities during construction include clearing of vegetation, blasting, wind erosion from exposed surfaces, grading of the access road surface and asphalt application. Calculations indicate TSP emission rates to be slightly lower than that of the operational phase. This is based on the assumption that all construction activities will occur simultaneously and over the entire area. This is very unlikely and it is expected that the impacts will be similar or lower than that of the operational phase, for the unmitigated scenario.

With water sprays in place at most of the construction activities, the emissions could be halved ensuring impacts to be restricted to the mine property.

6.1.3 Operational Phase Impacts

Emissions

From the emissions quantification, windblown dust from the conveyor is the main source of emissions with roads contributing less than 1% to the total TSP and PM_{10} emissions as shown in Table 6-1. The overall emissions reduce by 70% with the implementation of the control technologies.

Summary of emissions from the Z20 Infrastructure Corridor is provided in Table 6-1.

Table 6-1: Emission summary for the proposed Z20 Infrastructure Corridor Project.

Source Groups	Unmitigated		Mitigated		Mitigation assumed	CE
	PM_{10} (tpa)	TSP (tpa)	PM_{10} (tpa)	TSP (tpa)		
Transfer points	128.41	366.89	38.52	110.07	enclosed no fabric filters	70%
Conveyor	213.74	474.99	64.12	142.50	roof and two sides	70%
Roads	0.97	5.05	0.73	3.79	paved road sweeping	25%
TOTAL	**343.13**	**846.93**	**103.37**	**256.35**		

PM_{10} Concentrations

Assuming a conventional conveyor system with no side walls or roof cover and no controls at the transfer point, the predicted daily PM_{10} GLCs exceed the air quality limit of 75 µg/m³ around the two transfer points. With mitigation in place (two side covers and a roof at the conveyor and enclosure at the transfer points) the GLCs reduce to only impact at the transfer point. No exceedances are predicted over an annual average.

Cumulatively, the predicted GLCs (with no mitigation) are slightly higher than the baseline situation with an increase of between 1% and 14% in the short-term, with the latter at the Khan River. With mitigation measures in place, the cumulative concentrations decrease slightly, reflecting very similar concentrations as the baseline.

Dust fallout

Dust fallout can be high around the conveyor with no mitigation in place, exceeding the vegetation limit of 400 mg/m²/day. With mitigation in place, the dust fallout rates decrease significantly to be well below the vegetation and residential limits.

Decommissioning

Impacts from the decommissioning phase were assessed qualitatively. These impacts would depend on the extent of demolition activities, but are expected to be localised and cease once rehabilitation starts.

6.2 Conclusion

It can be concluded that the proposed Z20 Infrastructure Corridor Project will have high PM_{10} impacts near the conveyor transfer points with no mitigation in place. With the recommended mitigation measures applied, concentrations will be retained at the source. Dust fallout can be high along the conveyor if not controlled; but is expected to be low based on the proposed RopCon design and enclosure of the transfer points.

6.3 Recommendations

6.3.1 Design specifications

It is recommended that the proposed conveyor system be designed as per the RopCon description, ensuring a roof cover. It is further recommended that the transfer points be enclosed with an extraction system and bag filter attached. This will ensure >95% control efficiency in comparison to the 70% from enclosure only.

6.3.2 Ambient monitoring

It is recommended that four single dust fallout buckets be installed along the conveyor system in order to monitor the impacts from this source. The buckets locations are indicated in Figure 6-2.

The proposed locations are as follows:

1. Z20DB1: to be south of Transfer Point 1;
2. Z20DB2: to be located in the Khan River “down-wind” from the conveyor;
3. Z20DM3: to be located south if Transfer Point 2; and
4. Z20DB4: to be located south of the final transfer point.

It is further recommended that a passive diffusive sampling campaign be conducted during the access road building phase to sample concentrations of SO_2 and VOCs.

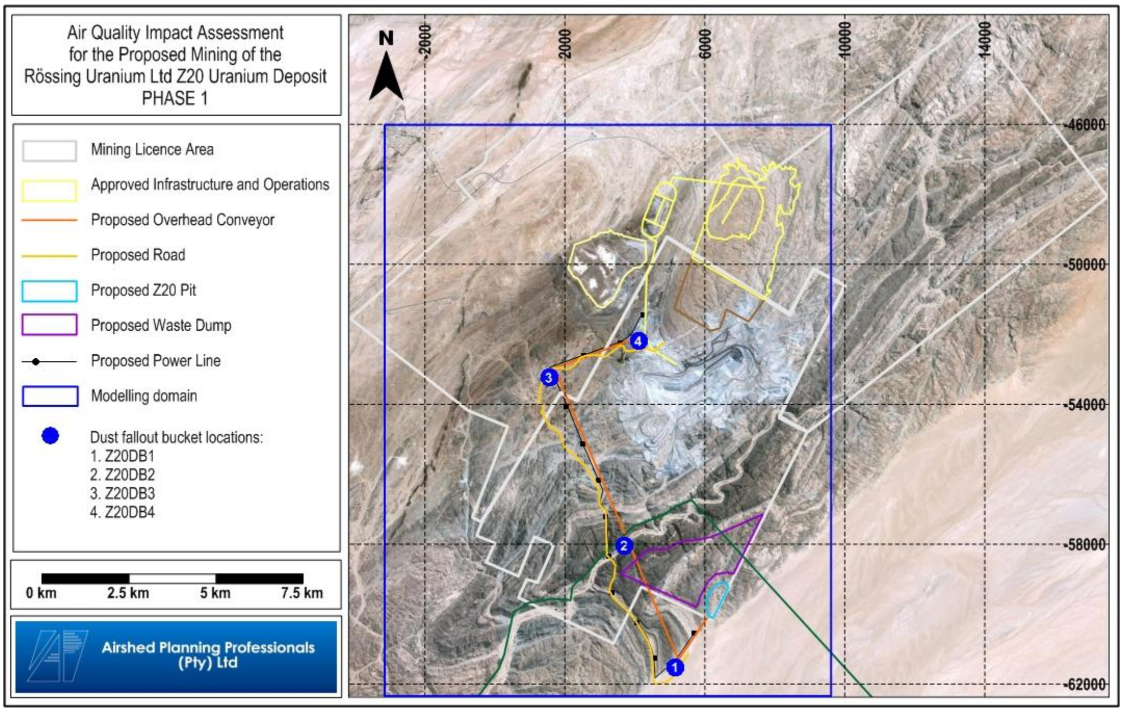

Figure 6-1: Proposed dust fallout network for the Z20 Infrastructure Corridor.

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8 Appendix A – Particulate Matter background Information

8.1 Impacts on Health

The impact of particles on human health is largely depended 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. 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 standards for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM_{10} (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of $PM_{2.5}$ (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. PM_{10} and $PM_{2.5}$ are of concern due to their health impact potentials. As indicated, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung.

Thoracic particulates or PM_{10} (i.e. particulate matter with an aerodynamic diameter of <10 µm) therefore needs to be considered for health risk purposes. PM_{10} represents particles of a size that would be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung. PM_{10} is primarily associated with mechanical processes such as mining operations, whereas $PM_{2.5}$ is associated with combustion sources.

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).

8.2 Dust Effects on Vegetation

Suspended particulate matter can produce a wide variety of effects on the physiology of vegetation that in many cases depend on the chemical composition of the particle. Heavy metals and other toxic particles have been shown to cause damage and death of some species as a result of both the phytotoxicity and the abrasive action during turbulent deposition (Harmens et al, 2005). Heavy loads of particle can also result in reduced light transmission to the chloroplasts and the occlusion of stomata (Harmens et al, 2005; Naidoo and Chirkoot, 2004, Hirano et al, 1995, Ricks and Williams, 1974), decreasing the efficiency of gaseous exchange (Harmens et al, 2005; Naidoo and Chirkoot, 2004, Ernst, 1981) and hence water loss (Harmens et al, 2005). They may also disrupt other physiological processes such as budbreak, pollination and light absorption/reflectance (Harmens et al, 2005). The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH (Spencer, 2001).

To determine the impact of dust deposition on vegetation, two factors are of importance: (i) Does dust collect on vegetation and if it does, what are the factors influencing the rate of deposition (ii) Once the dust has deposited, what is the impact of the dust on the vegetation?

Regarding the first question, there is adequate evidence that dust does collect on all types of vegetation. Any type of vegetation causes a change in the local wind fields, with an increase in turbulence which enhances the collection efficiency. The characteristics of the vegetation influence the rate; the larger the “collecting elements” (branches and leaves), the lower the impaction efficiency per element. This would seem to indicate that, for the same volume of tree/shrub canopy, finer leaves will have a better collection efficiency. However, the roughness of the leaves themselves and particularly the presence of hairs on the leaves and stems play a significant role, with veinous surfaces increasing deposition of 1-5 micron particles by up to seven times compared to smooth surfaces. Collection efficiency rises rapidly with particle size; for moderate wind speeds wind tunnel studies show a relationship of deposition velocity on the fourth power of particle size (Tiwary and Colls 2010). In wind tunnel studies, windbreaks or “shelter belts” of three rows of trees has shown a decrease in 35 to 56% in the downwind mass transport of inorganic particles.

On the effect of particulate matter once it is deposited on vegetation, this depends on the composition of the dust. South African ambient standards are set in terms of PM10 (particulate matter smaller than 10 µm aerodynamic diameter) but internationally it is recognised that there are major differences in the chemical composition of the fine PM (the fraction between 0 and 2.5 µm in aerodynamic diameter) and coarse PM (the fraction between 2.5 µm and 10 µm in aerodynamic diameter). The former is often the result of chemical reactions in the atmosphere and may have a high proportion of black carbon, sulphate and nitrate, whereas the latter often consist of primary particles resulting from abrasion, crushing, soil disturbances and wind erosion (Grantz et al. 2003). Sulphate is however often hygroscopic and may exist in significant fractions in coarse PM. This has been shown to be the case in South Africa, where the sulphate content of PM_{10} at the Eskom measuring station at Elandsfontein has been shown to have between 15% (winter) and 49% (spring) sulphate (Alade 2009). Grantz et al (op .cit.) do however indicate that sulphate is much less phototoxic than gaseous sulphur dioxide and that it is unusual for injurious levels of particular sulphate to be deposited upon vegetation".

Naidoo and Chirkoot conducted a study during the period October 2001 to April 2002 to investigate the effects of coal dust on Mangroves in the Richards Bay harbour. The investigation was conducted at two sites where 10 trees of the Mangrove species: Avicennia Marina were selected and mature, fully expose, sun leaves tagged as being covered or uncovered with coal dust. From the study it was concluded that coal dust significantly reduced photosynthesis of upper and lower leaf surfaces. The reduced photosynthetic performance was expected to reduce growth and productivity. In addition, trees in close proximity to the coal stockpiles were in poorer health than those further away. Coal dust particles, which are composed predominantly of carbon were found not to be toxic to the leaves; neither wasit found that it occlude stomata as these particles were larger than fully open stomatal apertures (Naidoo and Chirkoot, 2004).

In general, according to the Canadian Environmental Protection Agency (CEPA), air pollution adversely affects plants in one of two ways. Either the quantity of output or yield is reduced or the quality of the product is lowered. The former (invisible) injury results from pollutant impacts on plant physiological or biochemical processes and can lead to significant loss of growth or yield in nutritional quality (e.g. protein content). The latter (visible) may take the form of discolouration of the leaf surface caused by internal cellular damage. Such injury can reduce the market value of agricultural crops for which visual appearance is important (e.g. lettuce and spinach). Visible injury tends to be associated with acute exposures at high pollutant concentrations whilst invisible injury is generally a consequence of chronic exposures to moderately elevated pollutant concentrations. However given the limited information available, specifically the lack of quantitative dose-effect information, it is not possible to define a Reference Level for vegetation and particulate matter (CEPA, 1998).

Exposure to a given concentration of airborne PM may therefore lead to widely differing phytotoxic responses, depending on the mix of the deposited particles. The majority of documented toxic effects indicate responses to the chemical composition of the particles. Direct effects have most often been observed around heavily industrialised point sources, but even there, effects are often associated with the chemistry of the particulate rather than with the mass of particulate.

8.3 Dust Effects on Animals

Most of the literature regarding air quality impacts and animals, specifically cattle, refers to the impacts from feedlots on the surrounding environment, hence where the feedlot is seen as the source of pollution. This mainly pertains to odours and dust generation. The US.EPA has recently started to focus on the control of air pollution from feed yards and dairies, primarily regulating coarse particulate matter (http://www.vetcite.org/publish/items/000944/index.html). The National Cattle Beef Association in the USA in response has disputed this decision based on the lack of evidence on health impacts associated with coarse dust (TSP) concentrations (http://hill.beef.org/newview.asp?).

A study was conducted by the State University of IOWA on the effects of air contaminants and emissions on animal health in swine facilities. Air pollutants included gases, particulates, bioaerosols, and toxic microbial by-products. The main findings were that ammonia is associated with lowered average number of pigs weaned, arthritis, porcine stress syndrome, muscle lesions, abscesses, and liver ascarid scars. Particulates are associated with the reduction in growth and turbine pathology, and bioaerosols could lower feed efficiency, decrease growth, and increase morbidity and mortality. The study highlighted the lack of information on the health effects and productivity problems of air contaminants on cattle and other livestock. Ammonia and hydrogen sulphide are regarded the two most important inorganic gases affecting the respiratory system of cattle raised in confinement facilities, affecting the mucociliary transport and alveolar macrophage functions. With regard to particulates, it was found that it is the fine inhalable fraction is mainly deriving from dried faecal dust (Holland et al., 2002). Another study conducted by DSM Nutritional Products North America indicated that calves exposed to a dust-stress environment continued to have lower serum vitamin E concentrations (http://www.dsm.com/en_US/html/dnpus/an_texas_study.htm).

Inhalation of confinement house dust and gases produces a complex set of respiratory responses. An individual’s response depends on characteristics of the inhaled components (such as composition, particle size and antigenicity) and of the individual’s susceptibility, which is tempered by extant respiratory conditions (http://www.cdc.gov/nasd/docs). Most of the studies concurred that the main implication of dusty environments are causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels these are having a negative effect. In this light it was decided to use the same screening criteria applied to human health, i.e. the South African Standards and SANS limit values (Section 3).

9 Appendix B – Impact Significance Methodology

Table 9-1: Extent or spatial influence of impact

Extent or Spatial Influence of Impact		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
National	Within Namibia	Not applicable
Regional	Within the Erongo Region	Outside the Mining Licence Area but within the Erongo Region
Local	On-site or within 100 m of the Impact Site	On- or near site, not at any human sensitive receptors

Table 9-2: Magnitude of impact at the indicated special scale

Magnitude of Impact at the Indicated Special Scale		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
High	Social and/or natural functions and/ or processes are severely altered	Exceedances of the Air Quality Limits, where this project causes cumulative impacts to exceed
Medium	Social and/or natural functions and/ or processes are notably altered	Exceedances of the Air Quality Limits, where this project does not cause cumulative impacts to exceed (baseline already in exceedance)
Low	Social and/or natural functions and/ or processes are slightly altered	Slightly below the Air Quality Limits, cumulatively
Very Low	Social and/or natural functions and/ or processes are negligibly altered	Well below the Air Quality Limits, cumulatively
Zero	Social and/or natural functions and/ or processes remain unaltered	Not applicable

Table 9-3: Duration of impact

Duration of Impact		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
Short Term	Up to 3 years	Construction Phase
Medium Term	4 to 10 years after construction	Not applicable
Long Term	More than 10 years after construction	Operational Phase

The SIGNIFICANCE of an impact is derived by taking into account the temporal and spatial scales as well as magnitude. The means of arriving at the different significance ratings is explained in the following table, developed by Ninham Shand in 1995 as a means of minimising subjectivity in such evaluations, i.e. to allow for standardisation in the determination of significance.

Table 9-4: Significance rating

Significance Rating	
Category	**Description**
High	High magnitude with a regional extent and long term duration High magnitude with either a regional extent and medium term duration or a local extent and long term duration Medium magnitude with a regional extent and long term duration
Medium	High magnitude with a local extent and medium term duration High magnitude with a regional extent and construction period or a site specific extent and long term duration High magnitude with either a local extent and construction period duration or a site specific extent and medium term duration Medium magnitude with any combination of extent and duration except site specific and construction period or regional and long term Low magnitude with a regional extent and long term duration
Low	High magnitude with a site specific extent and construction period duration

Significance Rating	
	Medium magnitude with a site specific extent and construction period duration Low magnitude with any combination of extent and duration except site specific and construction period or regional and long term Very low magnitude with a regional extent and long term duration
Very Low	Low magnitude with a site specific extent and construction period duration Very low magnitude with any combination of extent and duration except regional and long term
Medium	Zero magnitude with any combination of extent and duration

Once the significance of an impact has been determined, the PROBABILITY of this impact occurring as well as the CONFIDENCE in the assessment of the impact is determined using the rating systems outlined in the following two tables. It is important to note that the significance of an impact should always be considered in concert with the probability of that impact occurring.

Table 9-5: Probability rating

Probability of Impact		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
Definite	Estimated greater than 95% chance of the impact occurring	Not applicable
Probable	Estimated 5 to 95% chance of the impact occurring	Considered the appropriate probability rating for predicted air quality impacts
Unlikely	Estimated less than 5% chance of the impact occurring	Not applicable

Table 9-6: Confidence rating

Confidence Rating		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
Certain	Wealth of information on and sound understanding of the environmental factors potentially influencing the impact.	Not applicable
Sure	Reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact.	Considered the appropriate confidence rating for predicted operational phase air quality impacts
Unsure	Limited useful information on and understanding of the environmental factors potentially influencing this impact.	Considered the appropriate confidence rating for predicted construction phase air quality impacts

Lastly, the REVERSIBILITY of the impact is estimated using the rating system outlined in the following table.

Table 9-7: Reversibility rating

Reversibility Rating		
Category	**Description**	**Interpretation from an Environmental Air Quality Perspective**
Irreversible	The activity will lead to an impact that is permanent	Only consider impacts on human health where the annual air quality limits is exceeded
Reversible	The impact is reversible, within a period of 10 years	Only consider impacts on vegetation where the dust fallout rate is above the limit

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