Project done on behalf of:
Digby Wells and Associates (Pty) Ltd

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED VALENCIA URANIUM MINE IN NAMIBIA

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REPORT DETAILS

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EXECUTIVE SUMMARY

1. INTRODUCTION

Valencia Uranium Mine, located approximately 75 km southwest of the town of Usakos in central-west Namibia, will comprise of open pit mining operations including a crushing and screening plant, haul roads, materials transfer points, storage piles, waste rock dumps and a Tailings dump. A processing plant where the uranium will be reclaimed will also form part of the operations.

An air quality impact assessment was conducted for the proposed Valencia Uranium Mine and Processing Plant as part of an Environmental Impact Assessment. The main objective of this study was to determine the significance of the predicted impacts from the proposed mining and processing operations on the surrounding environment and on human health.

To achieve this objective, the local climate was characterised and existing ambient air quality data and dust fallout information evaluated. Particulates were identified to be the main pollutant of concern resulting from the proposed mining operations and all potential sources of fugitive dust have been identified and quantified. Gaseous emissions as a result from processing plant were omitted from the assessment due to limited information available. Dispersion simulations were undertaken to reflect both incremental (separate sources) and cumulative (all sources combined) impacts.

The terms of reference were as follows:

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

- The regional climate and site-specific atmospheric dispersion potential.
- Preparation of hourly average meteorological data for input to the dispersion model;
    - Preparation of five year of raw meteorological data, however, a normal requirement is for a five-year database. Meteorological data will be obtained from the nearest weather station to site through the Namibian Weather Services or international meteorological databases. The required meteorological data includes hourly average wind speed, wind direction and temperature data.
    - Formatting of meteorological data for input to the dispersion model (both surface data and upper air data is required).
    - Simulation of wind field, mixing depth and atmospheric stability.
- Obtain and process topographical data for input into the dispersion model.
- Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data recorded to date (if available).
- Collate and analyse all monitoring data available from existing mining operations in the region and recorded data from site (if available).
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and standards, and dustfall classifications with specific reference to the Namibian legislation. Reference will also be made to applicable international requirements such as the World Bank Group.

An ***air quality impact study**,* including the assessment of*:*

- Quantification of all proposed sources of atmospheric emissions including the following sources:
  - Opencast mining operations;
  - Haul roads from the mine to the processing plant,
  - Primary, secondary and tertiary crushing and screening operations;
  - Vehicle entrainment on paved and unpaved roads;
  - Materials handling operations (i.e. tipping, conveyor transfer points, loading and off-loading); and,
  - Wind erosion from exposed areas such as the waste rock dump, topsoil piles and tailings dump.
- Dispersion simulations of ground level PM10 concentrations and dust fallout for the proposed operations reflecting highest daily and annual average PM10 concentrations and total daily dust deposition due to *routine* and *upset* emissions from the opencast mining operations. The US.EPA approved AERMOD model will be used.
- Analysis of dispersion modelling results, including:
  - Determine zones of maximum incremental ground level impacts (concentrations and dust fallout from each source); and,
  - Determine zone of maximum predicted cumulative ground level impacts (concentrations and dust fallout from all sources at the mine).
- Evaluation of potential for human health and environmental impacts.
- Provide dispersion plots for uranium (if the metal content is known) to be used in the assessment of radioactivity of dust impacts (Airshed does not specialises in radioactivity but will be able to provide plots in the required format for the radioactive specialist).

A ***dust management plan*** for the mine*,* including the assessment of*:*

- Develop a dust management plan for the mine, including:
  - Estimation of emission control efficiencies required for each significant source;
  - Identification of suitable pollution abatement measures able to realise the required dust control efficiencies, and possible contingency measures;
  - Specification of source-based performance indicators, targets, and monitoring methods applicable for each source;
  - Recommendation of receptor-based performance indicators comprising of a monitoring network and targets;
  - Recommendations pertaining to record keeping, environmental reporting and community liaison.

2. EVALUATION CRITERIA

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods.

Namibia doesn't have ambient air quality standards that could be used in assessing the acceptability of the predicted impacts. Reference was therefore made to the proposed South African standards, the World Bank Group (WBG) guidelines and the latest (2005) World Health Organisation (WHO) guidelines. These ambient standards and guidelines are primarily for human health protection. In order to assess the dust fallout levels, reference was made to the proposed South African residential and industrial action levels.

3. BASELINE CHARACTERISATION

3.1 Site Description

Valencia Uranium Mine (~75 km southwest of Usakos) has the Rössing/Khan formations to the northwest of the mining site and the Chuos and Geiseb Mountains to the southeast. The relief ranges from 630 mamsl (meters above mean sea level) in the west (near Rössing Mine) to 1257 mamsl in the east at the Chuos Mountains. The Khan River runs to the northwest of the proposed mine through the Rössing/Khan formations. The only sensitive receptor identified within proximity to the mine site is the Valencia farm house located 3.4 km directly south-southeast of the proposed open pit.

3.2 Dispersion Modelling Methodology

Particulate and gaseous concentrations due to the current operations were simulated using the US-EPA approved AERMOD model. AERMOD is a steady state Gaussian Plume model, which is applicable to multiple point, area and volume sources. Ambient PM10 concentrations were simulated to ascertain highest daily and annual averaging levels occurring as a result of the proposed operations. Gaseous emissions were modelled for highest hourly, highest daily and annual averages.

The AERMOD model is able to model point, area, line and volume. The sources at Valencia Mine were grouped and modelled as follows:

- Mining operations (including drilling and blasting, excavation etc.) – modelled as open pit sources;
- Vehicle entrainment on unpaved roads – modelled as area sources;
- Wind blown dust sources – modelled as area sources;
- Crushing and screening – modelled as volume sources; and,

- Materials transfer points – modelled as volume sources.
- Sulphuric Acid Plant – modelled as point source.

A modelling domain of 20 km by 20 km was used with a grid interval of 200 m. Discrete receptor points were included for all sensitive receptors with a receiving height of 1.5 m above ground level.

3.3 Dispersion Potential of the Site

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. 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.

Meteorological data were obtained from the Valencia Weather Station located at the base camp and from the Rössing Weather Station. The Valencia weather data had a period where no data was logged which resulted in 64% data availability. Since a minimum of 80% data is required for analysis, use was made of the Rössing Weather data in the dispersion modelling.

The dominant wind directions are from the northeast (25% of the time), the east-northeast (14%) and the southwest (13%). On average the wind speed are between 2 m/s and 10 m/s. Over the 1 year period assessed calm conditions (wind speeds < 1 m/s) occurred for 18.8% of the time.

For the completion of a baseline investigation, the data must include both air quality and meteorological data. Air quality data typically include dust fallout and ambient air concentration data. No ambient PM10 concentrations are measured in the region and Valencia has only recently (end of August 2007) implemented a dust fallout monitoring network.

3.4 Existing sources of Emissions

There are not many sources of emissions located near the proposed Valencia Uranium Mine. Rössing Uranium Mine is located 23 km southwest of the Valencia with the proposed Trekkopje mine approximately 15 km to the northwest. Rössing mine comprises of a large open pit and is one of the largest uranium mines in the world. Both these mines are considered too far away to have a significant influence on the ambient air quality in the vicinity of Valencia Mine.

Other sources in the region include mainly farming activities and natural fugitive dust sources.

4. IMPACT ASSESSMENT

4.1 Emissions Inventory

An emissions inventory is a comprehensive, accurate and current account of air pollutant emissions and associated source configuration data from specific sources over a specific time period. An emissions inventory was established for the proposed operations at Valencia Mine.

Emissions resulting from the mine and related processes were quantified using emission factors as published by the United States Environmental Protection Agency's and the Australian National Pollution Inventory (NPi). Single valued emission factors are typically applied to the production or throughput amounts, whereas the emission equations require more site specific information such as moisture content, clay content, source dimensions, release heights, vehicle speed and weight, etc. Since Valencia Mine is a greenfields site and limited site specific information was available reference was made to information used in the Trekkopje EIA.

A synopsis of the emissions is provided in Table 1 and Figure 1 for TSP and Figure 2 for PM10.

Table 1: Total TSP and PM10 emissions estimated due to the proposed operations at Valencia Mine.

Source Group	Emissions					
	TSP (tpa)	PM10 (tpa)	TSP (%)	PM10 (%)	TSP rank	PM10 rank
Excavation	475	228	9.2	14.1	4	3
Tipping	31.3	8.1	0.6	0.5	6	5
Crushing& Screening	492	197	9.6	12.2	3	4
Wind Erosion	1,563	463	30.3	28.6	2	2
Drilling & Blasting	38.1	4.1	0.7	0.3	5	6
Vehicle Entrainment	2,551	720	49.5	44.4	1	1
TOTAL	**5150**	**1620**	**100**	**100**	-	-

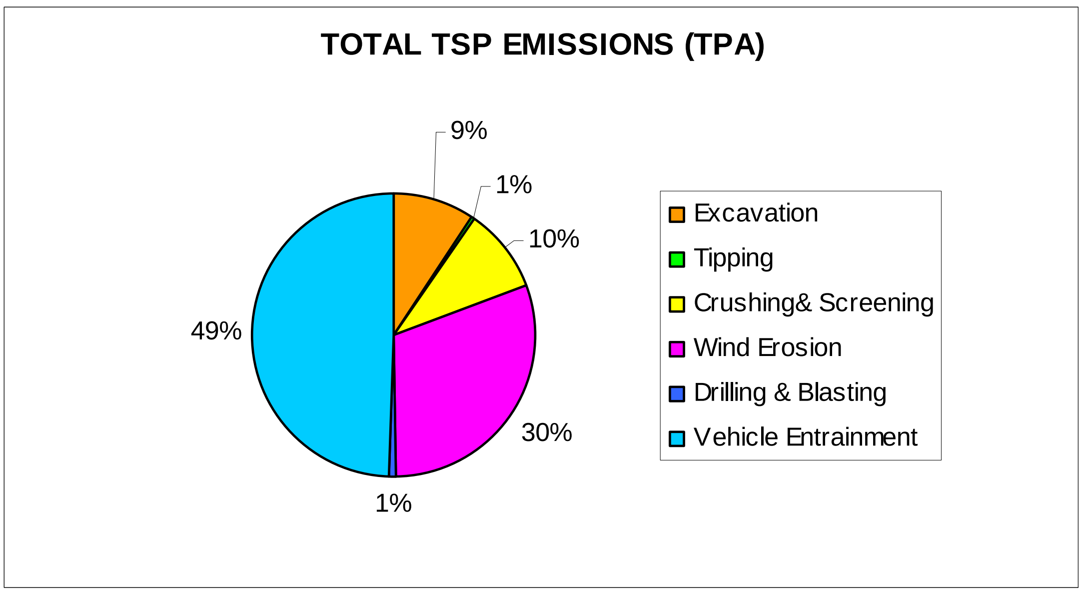

Figure 1: TSP Emissions contribution for all sources at Valencia Mine.

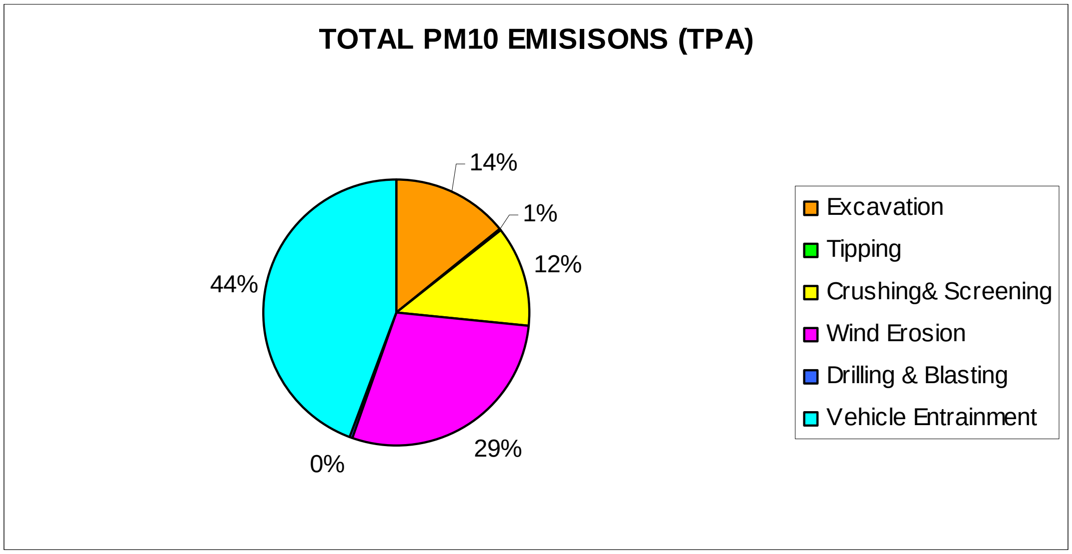

Figure 2: PM10 Emissions contribution for all sources at Valencia Mine.

A Sulphuric Acid Plant is proposed as part of the Valencia Uranium Mine operations. The main pollutants of concern associated with the sulphuric acid production are sulphur dioxide (SO_2), acid mist (H_2SO_4 & SO_3) and carbon dioxide (CO_2). Nearly all the SO_2 emissions are found in the exit stack gasses and are directly a function of the sulphur conversion efficiency (SO_2 oxidised to SO_3). Thus the main pollutants deriving from the stack includes SO_2 and SO_3.

4.2 Dispersion Simulation Results

Simulations were undertaken to determine inhalable particulate (PM10) and gaseous (SO_2 and SO_3) concentrations and dust fallout levels from mining and process related activities. Ambient air quality guidelines and standards are applicable to the assessment of off-site, community exposures (rather than occupational exposures). The comparison of predicted pollutant concentrations to ambient air quality guidelines and standards facilitated a preliminary screening of the potential, which exists for human and animal health impacts.

Maximum PM10 concentrations predicted to occur within the immediate vicinity of the mine (off-site and at sensitive receptors) due proposed operational activities are summarised in Table 2. Table 3 provides the information on the dust fallout levels. Simulations were done assuming no mitigation in place and as an additional scenario dust controls on the unpaved roads were assumed. The Waste Rock Dumps and Tailings Dam were modelled assuming the final height thus reflecting the worst case scenario. The farm house was included as a sensitive receptor.

The Sulphuric Acid Plant was included in the dispersion model as a single stack. Various design p[parameters were provided resulting in 6 Scenarios that were modelled. The scenario resulting in the highest ground level concentrations (Scenario 1) were included to reflect the worst case.

Table 2: Predicted PM10 concentrations due to all operations at the proposed Valencia Uranium Mine (exceedances of air quality guidelines are highlighted).

Pollutant	Averaging Period	Standard/ Guideline	UNMITIGATED				MITIGATED			
			MAX AT MINE BOUNDARY		FARM HOUSE		MAX AT MINE BOUNDARY		FARM HOUSE	
			Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction
PM10	Highest daily	75(a)	26.9	0.4	49.8	0.7	19.3	0.3 0.3 0.4	31.9	0.4
		70(b)		0.4		0.7				0.5
		50(c)		0.5		**1.0**				0.6
	Annual average	40(a)	3.0	0.1	5.83	0.1	1.8	0.05 0.04 0.09	3.2	0.1
		50(b)		0.1		0.1				0.1
		20(c)		0.2		0.3				0.2

Notes:
(a) The proposed South African standards for highest daily averages of 75µg/m³.
(b) World Bank (WB) general environmental guideline of 70µg/m³ utilised.
(c) The World Health Organisation (WHO) air quality guideline (AQG) of 50µg/m³.
(a) The proposed South African standard for annual averages of 40µg/m³.
(b) World Bank (WB) general environmental guideline of 50µg/m³ utilised.
(c) The World Health Organisation (WHO) air quality guideline (AQG) of 20µg/m³.

Table 3: Predicted dust fallout (TSP) due to all operations at the proposed Valencia Uranium Mine (exceedances of air quality guidelines are highlighted).

Pollutant	Averaging Period	Standard/ Guideline	UNMITIGATED				MITIGATED			
			MAX AT MINE BOUNDARY		FARM HOUSE		MAX AT MINE BOUNDARY		FARM HOUSE	
			Max Dep	Fraction	Max Dep	Fraction	Max Dep	Fraction	Max Dep	Fraction
TSP (mg/m²/day)	Daily Average	600(a)	13.2	0.02	22.1	0.04	12.5	0.02	20.9	0.03
		1,200(b)		0.01		0.02		0.01		0.02

Notes:
(a) The proposed South African residential action level.
(b) The proposed South African industrial action level.

5. CONCLUSIONS

5.1 Project Assumptions and Limitations

- The on-site meteorological data only had 62% availability and could not be used in the dispersion modelling for the site. Instead the meteorological data recorded at Rössing Uranium Mine were used. The prevailing wind fields from the two sites differ slightly and therefore the maximum zone of impact might not be reflected correctly.

- No site specific particle size fraction data, moisture content or clay content information was available and use was made of information measured at Trekkopje Mine (Burger and Le Roux, 2006).

- No baseline ambient monitored concentration data was available for the area. A dust fallout monitoring campaign was initiated at the end of August 2007 with 3 months of recorded information provided for inclusion into the report. The dust fallout is reported by Digby Wells & Associates (DWA).

- The impact assessment was limited to airborne particulates (including TSP and PM10). Although the proposed activities would also emit other gaseous pollutants, primarily by haul trucks and mining vehicles, the impact of these compounds was regarded to be low and was omitted from this study.

- The dispersion model (AERMOD) cannot compute real time mining processes, therefore average mining process throughputs were utilised. Thus even though the nature of the open pit mining operations (pit utilisation and roads) change over the life of mine, the open pit mining area of Valencia was modelled to reflect the worst case condition (i.e. resulting in the highest impacts). Similarly, the final design dimensions of the waste rock dumps and Tailings dump were assumed.

- Routine emissions for the proposed operations were simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for. Blasting is seen as an intermittent source of emissions (non-routine) and will occur once a day for a limited period of time (less than an hour). Blasting was modelled to reflect highest hourly impacts but since no hourly ambient air quality standards or guidelines exists for particulates (limited to 24-hour averages) the significance of these impacts could not be determined.

- Mining operations were assumed to be twenty-four hours over a 365 day year.

- One of the main limitations of the study was the lack of site specific information. This included the dimensions of the crusher plant and what control equipment would be implemented, the exact route from the mine to the main road, and the layout of on-site haul roads.

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

- Limited information was supplied on the sulphuric acid plant. Where no source-specific information was provided, reference was made to similar acid plant designs.

5.2 Main Findings from the Impact Assessment

Baseline Assessment

- The main pollutant of concern associated with the uranium mining operations and processing is particulate matter (TSP, PM10 and PM2.5). The processing operations could result in sulphur dioxide (SO_2), Volatile Organic Compounds (VOCs) and ammonia (NH_3) emissions. In addition heavy metals are associated with particulate emissions but the main concern is the radioactive nature of the uranium. Information was only available for particulates (TSP and PM10).

- The prevailing wind field for the area is from the northeast (25% of the time), the east-northeast 11%) and the southwest (14%). The Rössing/Khan formations to the west and north of the proposed mine and the Chuos and Geiseb mountains to the southeast forms a natural wind channel (northeast / southwest).

- No ambient monitored data was available for the area. A dust monitoring network comprising three multi-directional and eight single buckets has been implemented at the end of August 2007. Two months of data were available for inclusion into the report as reported by DWA. The main findings indicated that the dust fallout in the area is within the SLIGHT (<250 $mg/m^2/day$) category as defined by the South African Department of Environmental Affairs and Tourism (DEAT).

Impact Assessment

For the operational phase, the predicted ground level concentrations included only concentrations from the proposed Valencia Uranium Mine operations. No other sources of particulate or gaseous emissions in the area that are expected to have an influence on the background concentrations within the area other than the contribution from the natural dry environment.

- Predicted highest daily PM10 ground level concentrations resulted in concentrations matching the highest daily WHO guideline at the Valencia farmhouse, but complied with both the proposed SA Standard and WBG guideline.

- Over an annual average the predicted PM10 concentrations were low near the mine boundary and at the farm house with no exceedances of the relevant standards and guidelines for either scenario.

- The main sources of PM10 emission contributions were wind blown dust, vehicle entrainment on unpaved roads, and mining (excavating) operations. Wind blown dust, vehicle entrainment and crushing and screening resulted in the highest ground level concentrations. From the wind blown dust sources, the Tailings dump was the main source of emissions and impacts.

- Wind blown dust typically impacts down wind from the direction where the highest velocity winds occur, with vehicle entrained dust bounded near the road where it is generated from. Wind blown dust is a significant source of emissions for the duration of the high wind speed occurrence and with the significance underestimated over a daily average.

- Predicted ground level concentrations from blasting operations were included for highest hourly averages since blasting would occur once a day and last for a few minutes. The significance of the blasting impacts could not be quantified since no hourly guidelines exist for PM10. It is however regarded as a source of nuisance.

- Mitigation measures were assumed for the unpaved access road and the resulting PM10 concentrations were lower than for unmitigated scenarios. The predicted impacts at the farm house reduced to be below the WHO guideline.

- The significance rating for the predicted PM10 concentrations due to the operational phase at the Valencia Uranium Mine was regarded MODERATE,.

- With mitigation measures considered for the unpaved roads, the significance rating reduced to the upper range of the LOW significance category. The significance ratings matrix does however not provide an accurate reflection of the significance to health impacts from the proposed operations.

- Predicted dust fallout levels were very high (>2,400 $mg/m^2/day$) near the sources of emissions. The dustfall levels depleted rapidly away from the source of emissions to levels below the proposed SA action level for residential areas (of 600 $mg/m^2/day$). Dust fallout levels reached 600 $mg/m^2/day$ between 500m and 800m from the source of emission.

- The main sources of TSP emissions were estimated to be vehicle entrainment on unpaved roads, wind blown dust and crushing and screening. The main sources of impact were primarily wind blown dust and mining (excavation) operations.

- Mitigation was only considered for the proposed unpaved access road and this resulted in little reduction in the predicted dust fallout levels.

- The significance from dust fallout is primarily a nuisance issue. The significance rating matrix however provided the same significance for dust fallout as for health impacts, i.e. MODERATE for unmitigated sources, and MODERATE to LOW for mitigated sources.

- Predicted SO_2 emissions resulting from the proposed Sulphuric Acid Plant resulted in ground level concentrations well within the EC standards and WHO Air Quality Guidelines. Similarly, the predicted SO_3 concentrations only equalled the TARA acute ESL at the plant with all predicted impacts outside the plant area well within the TARA ESLs. These predicted results were based on Scenario 1 which can be regarded the worst-case scenario with all the other design options resulting in lower ground level concentrations.

6. DUST MANAGEMENT PLAN FOR VALENCIA URANIUM MINE

6.2 Site Specific Management Objectives

The main pollutant of concern from an air quality management perspective is particulates, both inhalable (PM10) and nuisance (TSP) fractions. Sulphur dioxide (SO_2) and sulphur trioxide (SO_3) will only result from the Acid Plant operations

6.2.1 Source ranking based on emissions

The main sources of emissions were as follows:

- PM10 emissions – (i) wind blown dust (39%), (ii) unpaved roads (38%), (iii) excavation (12%) and (iv) crushing and screening (10%).
- TSP emissions – (i) unpaved roads (44%), (ii) wind blown dust (38%), (iii) crushing and screening (9%), and (iv) excavation (8%).
- The Acid Plant is the only source of SO_2 and SO_3 emissions at the proposed Valencia Uranium Mine

6.2.2 Source ranking based on impacts

- Wind blown dust, vehicle entrainment and crushing and screening resulted in the highest PM10 ground level concentrations. From the wind blown dust sources, the Tailings dump was the main source of emissions and impacts.
- The main sources of dust fallout were primarily wind blown dust and mining (excavation) operations.

6.2.3 Target Control efficiencies

Based on the impact assessment and significance rankings the following target control efficiencies for all main sources of emissions were determined:

Operational Phase

- Vehicle entrainment on the unpaved access road – 85% to 90% control efficiency (CE).
- Vehicle entrainment on the unpaved haul roads – 60% to 75% CE.
- Wind erosion from Tailings dump – 80% CE.
- Wind erosion from the waste rock dump – 40% CE.
- Material handling operations – 98%.
- Sulphur dioxide conversion at Acid Plant – 99.8% as per proposed design.
- Sulphuric Acid mist to be as a minimum 50 mg/m³ but preferably 30 mg/m³.

Closure Phase

- Wind erosion from tailings dump – 100% CE
- Wind erosion from waste rock dumps – 100% CE

6.3 Project-Specific Management Measures

It is recommended that the project proponent commits to air quality management planning throughout the various operations of the mine. It was recommended that an Air Pollution Control System (APCS) be developed for Valencia Uranium Mine and Processing Plant to reduce and control all main contributing sources. This APCS can be incorporated into the EMS (Environmental Management System) of the mine.

6.3.1 Vehicle Entrainment on Unpaved Roads

Vehicle entrained dust from unpaved road surfaces resulted in high impacts near the source and off-site during the operational phase predictions. It is therefore recommended that mitigation measures be considered on the unpaved access road to the mine and the haul roads from the open pit to the crusher plant.

The shortage of water in the region was taken into account when mitigation options were investigated. It was recommended that the access road be treated with a chemical suppressant to ensure >85% control efficiency. The haul roads (since these are not permanent and change over time) should be treated with a chemical water solution. The main difference is that the proposed chemicals for the access road last longer but required more preparation before hand, with the option for the haul roads requiring more frequent application but no road preparation.

6.3.2 Wind Erosion

The main source of concern for wind blown dust is the Tailings dump. The following recommendations regarding wind blown dust sources are made:

- It is recommended that the walls of the Tailings dump be covered (rock gladded) up to 1 m from the top throughout the life of mine. Rock cladding has the potential for effective dust suppression and will result in the reduction of wind blown dust.

- In addition screens should be installed on the crest of the Tailings dump walls mainly to act as wind breaks and to reduce the potential for dust deposition on the natural vegetation that might form on the side walls, hence curbing the growth of the grass.

6.3.3 Other Sources

Materials handling operations including primary crushing and screening of ore and materials transfer point (mainly form the excavator) were identified as potentially significant sources of emissions at the proposed mine.

Water sprays mixed with chemicals (as recommend for the haul roads) is one option at material handling operations, specifically crushing and screening. Emissions deriving from all materials handling operations will reduce by 62% by merely doubling the moisture content of the material handled. A second more costly option is the enclosure of the crushers and screens with dust extraction systems and bag filters attached. Emissions from material handling operation in the open pit will reduce as the pit grows deeper. Literature indicates a 50% reduction of TSP emissions due to pit retention, and 5% for PM10 emissions.

6.4 Monitoring Programme for Valencia Uranium Mine

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators careful attention is usually paid to ensure that progress towards their achievement is measurable, and that the targets set are achievable given available technology and experience.

6.4.1 Specifications of Source Based Performance Indicators

- Source based performance indicators for the Tailings dump would include cover density to be 80% on the entire slope up to 1 m from crest, and dustfall immediately downwind to be <1,200 mg/m^2/day.
- For the unpaved access road it is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 600 mg/m^2/day and for unpaved haul roads associated with on-site activities it should be less than 1,200 mg/m^2/day.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be less than 1,200 mg/m^2/day.
- From all activities associated with Valencia Uranium Mine and Processing Plant, dustfall in close proximity to sensitive receptors (i.e. Farm House) should not exceed 600 mg/m^2/day.
- From the proposed Sulphuric Acid Plant the SO_2 emissions should not exceed 284 mg/Nm^3 and all ground level impacts should be less than 500 µg/m^3 for 10-minute averages and < 50 µg/m^3 (based on WHO IT1) for highest daily averages.
- Sulphur trioxide mist should be less than 50 mg/Nm^3 and ground level concentrations should be less than 1 µg/m^3 over an annual average.

6.4.2 Receptor Based Performance Indicators

It is recommended that the dust fallout network currently comprising of 3 directional dust fallout buckets and 8 single dust fallout buckets remain but that the positions of the single buckets change as soon as operations commence. The proposed locations of the dust buckets are indicated in Figure 3 and discussed as follows:

- The 3 directional buckets have been placed in a triangular formation covering the outskirts of the mining area. One was placed to the north of the open pit and waste rock dump, one to the northeast of the open pit and waste rock dump 2, and one to the south of the mining operations. It is proposed that these buckets remain as is.
- Single buckets are useful in determining the impacts from single sources and tracking improvements made by mitigation measures. The 8 single buckets are proposed to be placed as follows:

- o Single buckets 2, 3 and 4 to remain as is;
- o Two single buckets to be placed to the northeast, southwest, and northwest of the Tailings dump;
- o One single bucket to be placed near the crusher plant; and,
- o One single bucket to be placed next to the access road.

It isn't regarded necessary to implement a PM10 monitor due to the low population density in the area. This should however be reconsidered should the mining personnel stay at the mine. It is further recommended that the existing meteorological station on-site be continued throughout the life of mine.

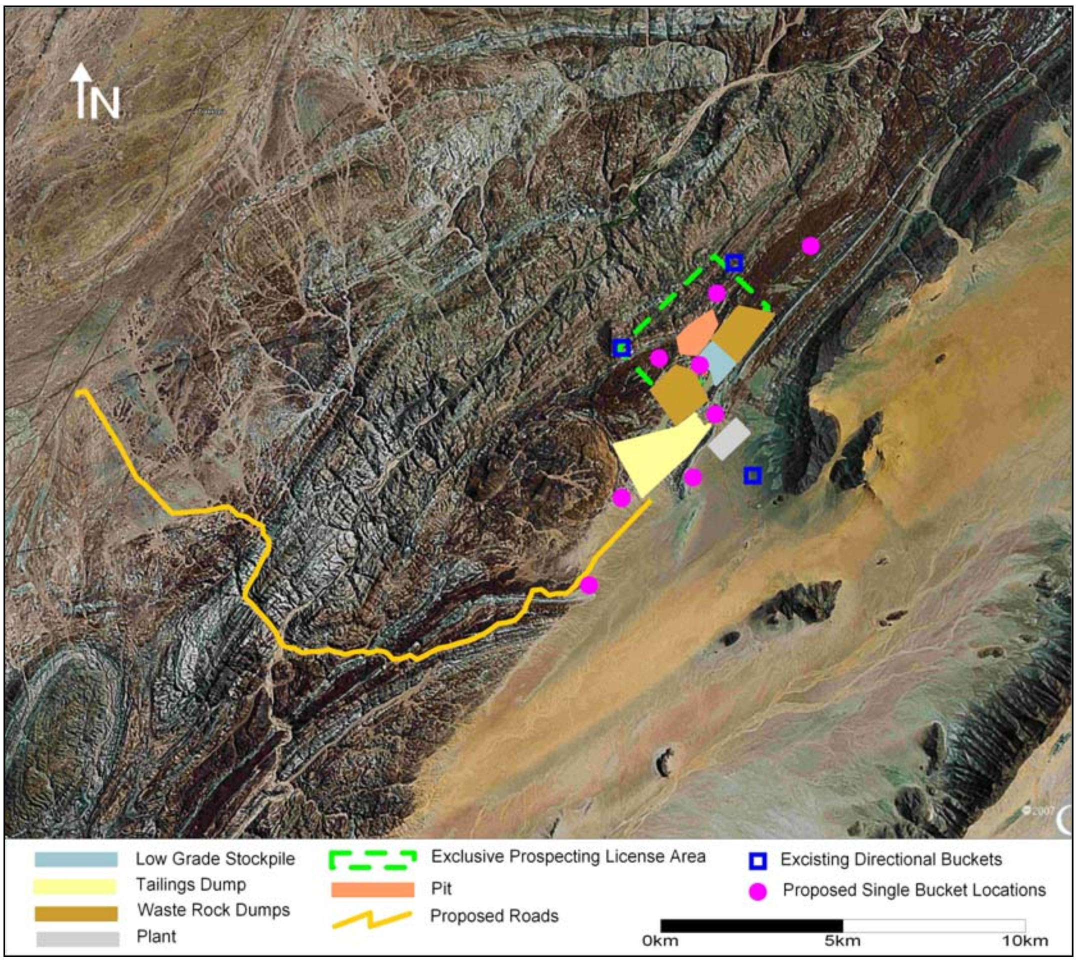

Figure 3: Proposed dust fallout monitoring network for Valencia Uranium Mine and Processing Plant.

6.4.3 Record-keeping, Environmental Reporting and Community Liaison

- It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Annual environmental audits forms part of an APCS and should be initiated at the proposed mine.

- Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. It is recommended that specific intervals at which forum meetings will be held should be stipulated.

- The mine budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. This should be audited by an independent consultant, with reviews conducted on an annual basis

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LIST OF ACRONYMS AND SYMBOLS

Airshed	Airshed Planning Professionals (Pty) Ltd
ANPi	Australian National Pollution Inventory
APCS	Air Pollution Control System
APIA	Air Pollution Impact Assessment
APPA	The Atmospheric Pollution Prevention Act (No.45 of 1965)
CO	Carbon Monoxide
DEAT	South African Department of Environmental Affairs and Tourism
DME	South African Department of Minerals and Energy
DWA	Digby Wells and Associates
EC	European Community
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EU	European Union
IAP	Interested and Affected Parties
IFC	International Finance Corporation (World Bank Group)
m^3	Cubic metre
PM10	Particulate Matter with an aerodynamic diameter of less than 10μ
PM2.5	Particulate Matter with an aerodynamic diameter of less than 2.5μ
ppb	Parts per Billion
ppm	Parts per Million
ROM	Run Off Mine
SAWS	South African Weather Services
tpa	Tonnes per annum
tpd	Tonnes per day
tpm	Tons per month
TSP	Total Suspended Particles
μ	Microns
μg	Micrograms
$\mu g/m^3$	Micrograms per cubic metres
US-EPA	United States Environmental Protection Agency
WBG	The World Bank Group
WHO	The World Health Organisation

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED VALENCIA URANIUM MINE PROJECT IN NAMIBIA

1 INTRODUCTION

Valencia Uranium Mine is a proposed mine to be located approximately 75 km southwest of the town of Usakos in central-west Namibia. The Valencia Mine project will be an opencast mine and cover an area of 735.6 ha. Figure 1-1 provides the location of the proposed mine. The proposed Valencia Uranium Mine will be an opencast mine (~700 ha) with associated mining operations including haul roads, crushing and screening operations, materials handling, drilling and blasting, etc. These mining activities give rise to air pollutants that might have a negative impact on the environment and human health. It is therefore required to determine the possible ground level concentrations and dust fallout levels from the proposed mine as part of an environmental impact assessment and management plan to be developed for the mine.

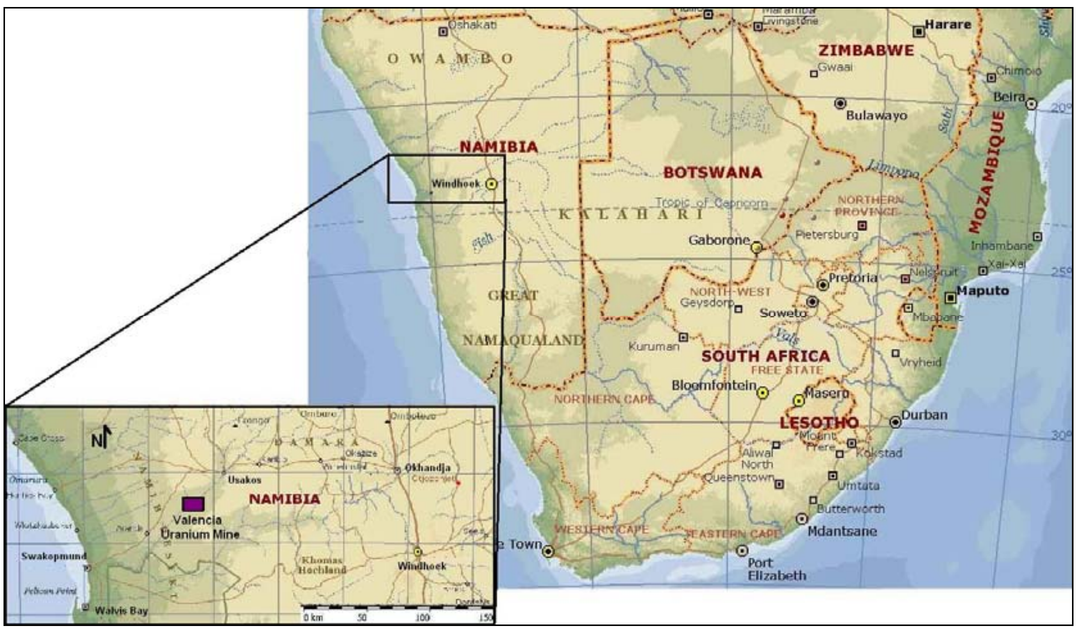

Figure 1-1: Location of the proposed Valencia Uranium Mine in Namibia.

Airshed Planning Professionals (Pty) Ltd was appointed by Digby Wells and Associates (Pty) Ltd (DWA) to undertake the specialist air quality study as part of the Environmental Impact Assessment (EIA). Valencia Uranium (Pty) Limited is the proponent for the project, with Snowden Mining Industry Consultants responsible for the mine design and plan.

1.1 Terms of Reference

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

- The regional climate and site-specific atmospheric dispersion potential.
- Preparation of hourly average meteorological data for input to the dispersion model;
  - o Preparation of five year of raw meteorological data, however, a normal requirement is for a five-year database. Meteorological data will be obtained from the nearest weather station to site through the Namibian Weather Services or international meteorological databases. The required meteorological data includes hourly average wind speed, wind direction and temperature data.
  - o Formatting of meteorological data for input to the dispersion model (both surface data and upper air data are required).
  - o Simulation of wind field, mixing depth and atmospheric stability.
- Obtain and process topographical data for input into the dispersion model.
- Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data recorded to date (if available).
- Collate and analyse all monitoring data available from existing mining operations in the region and recorded data from site (if available).
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and standards, and dustfall classifications with specific reference to the Namibian legislation. Reference will also be made to applicable international requirements such as the World Bank Group.

An ***air quality impact study**,* including the assessment of*:*

- Quantification of all proposed sources of atmospheric emissions including the following sources:
  - o Opencast mining operations;
  - o Haul roads from the mine to the processing plant,
  - o Primary, secondary and tertiary crushing and screening operations;
  - o Vehicle entrainment on paved and unpaved roads;
  - o Materials handling operations (i.e. tipping, conveyor transfer points, loading and off-loading);
  - o Wind erosion from exposed areas such as the waste rock dump, topsoil piles and tailings/slimes dam; and
  - o Sulphuric acid plant operation.
- Dispersion simulations of ground level PM10 concentrations and dust fallout for the proposed operations reflecting highest daily and annual average PM10 concentrations and total daily dust deposition due to *routine* and *upset* emissions from the opencast mining operations. Further dispersion simulation of ground level SO_2 and SO_3 concentrations for the proposed sulphuric acid plant reflecting highest hourly, daily and annual average concentrations. The US.EPA approved AERMOD model will be used.
- Analysis of dispersion modelling results, including:
  - o Determine zones of maximum incremental ground level impacts (concentrations and dust fallout from each source); and,
  - o Determine zone of maximum predicted cumulative ground level impacts (concentrations and dust fallout from all sources at the mine).

- Evaluation of potential for human health and environmental impacts.
- Provide dispersion plots for uranium (if the metal content is known) to be used in the assessment of radioactivity of dust impacts (Airshed does not specialise in radioactivity but will be able to provide plots in the required format for the Radiation Specialist).

A ***dust management plan*** for the mine*,* including the assessment of*:*

- Develop a dust management plan for the mine, including:
    - Estimation of emission control efficiencies required for each significant source;
    - Identification of suitable pollution abatement measures able to realise the required dust control efficiencies, and possible contingency measures;
    - Specification of source-based performance indicators, targets, and monitoring methods applicable for each source;
    - Recommendation of receptor-based performance indicators comprising of a monitoring network and targets;
    - Recommendations pertaining to record keeping, environmental reporting and community liaison.

1.2 Project Description (After Snowden, June 2007)

Valencia Uranium (Pty) Limited plans on exploring the uranium deposit at Valencia, located ~35 km along geological strike to the Rössing Uranium Mine and 40 km from Paladin's Langer Heinrich uranium deposit.

1.2.1 Mining Operations

The proposed mining operations will comprise an open pit producing about 1 Mt monthly of ore per month with a grade of 0.15 kg U_3O_8/tonne. The mine will have a life of at least 10 years. It was calculated that a total waste movement of 122.4 Mt will be mined over the life of mine. The final pit will be 1,400 m long and 700 m wide with a depth of up to 350 m.

The mining operations will include drilling and blasting for the ore bearing material with excavators used to load the ore and waste material into haul trucks. The ROM (run of mine) ore will be hauled out of the pit and transported to the primary crusher with haul trucks. The waste material from the pit will be hauled to one of two waste rock dumps to be established.

The primary crusher will reduce the material to less than 260 mm. The ore will be screened and the large size fraction sent to a radiometric ore sorter. The fine fractions (minus 25 mm) will bypass the sorting circuit and report directly to the milling circuit. Approximately a third of the ore sorted by the radiometric ore sorter will be rejected as waste with the remaining ore joining the finer material into the milling circuit. The mill product (-1.5 mm) will then report to the leach circuit. The crushers will operate on a two shift basis.

Haul roads from the open pit to the waste rock dumps and primary crusher plant will be constructed. The material from the crusher plant will be transported to the processing plant via conveyor. The final routes to the mine from the main road have not been finalised. The primary access route will be across the Khan River linking the mine with the B2 highway about 10 km west of Rössing Mine, a route of approximately 27 km.

1.2.2 Processing Plant

At the processing plant, the crushed ore will undergo milling before entering the leaching process. The grinding circuit will comprise of two open circuit rod or SAG mills also operating in two shifts.

At least six mechanically agitated leach tanks will be implemented. Sulphuric acid and manganese dioxide will be applied at a rate of at least 18 kg/tonne and 4 kg/tonne, respectively. The acid requirements can vary significantly and could be as high at 40 kg/tonne during certain periods. A sulphur-burning acid plant will be constructed on site for the production of acid. The leaching process is expected to last for 10 hours at a time.

Sand and slime separation is the first stage of pregnant solution recovery with counter current decantation (CCD) comprising of the second and final stage. Barren solution will be used as washing medium at the sand/slime separation stage. The solution from the CCD will be passed through a clarifier prior to storing for the CIX. Loaded resin from the CIX will be treated to liberate the uranium ions with the uranium bearing solution passed to the solvent extraction circuit. A multi-hearth furnace will be used to dry the ADU precipitate. Ammonia will be released and the remaining uranium oxide product will be loaded into drums to be exported.

The residue disposal facility will include a tailings reject dump consisting of co-disposed coarse and fine waste products.

The proposed process is indicated in the process flow diagram provided in Figure 1-2.

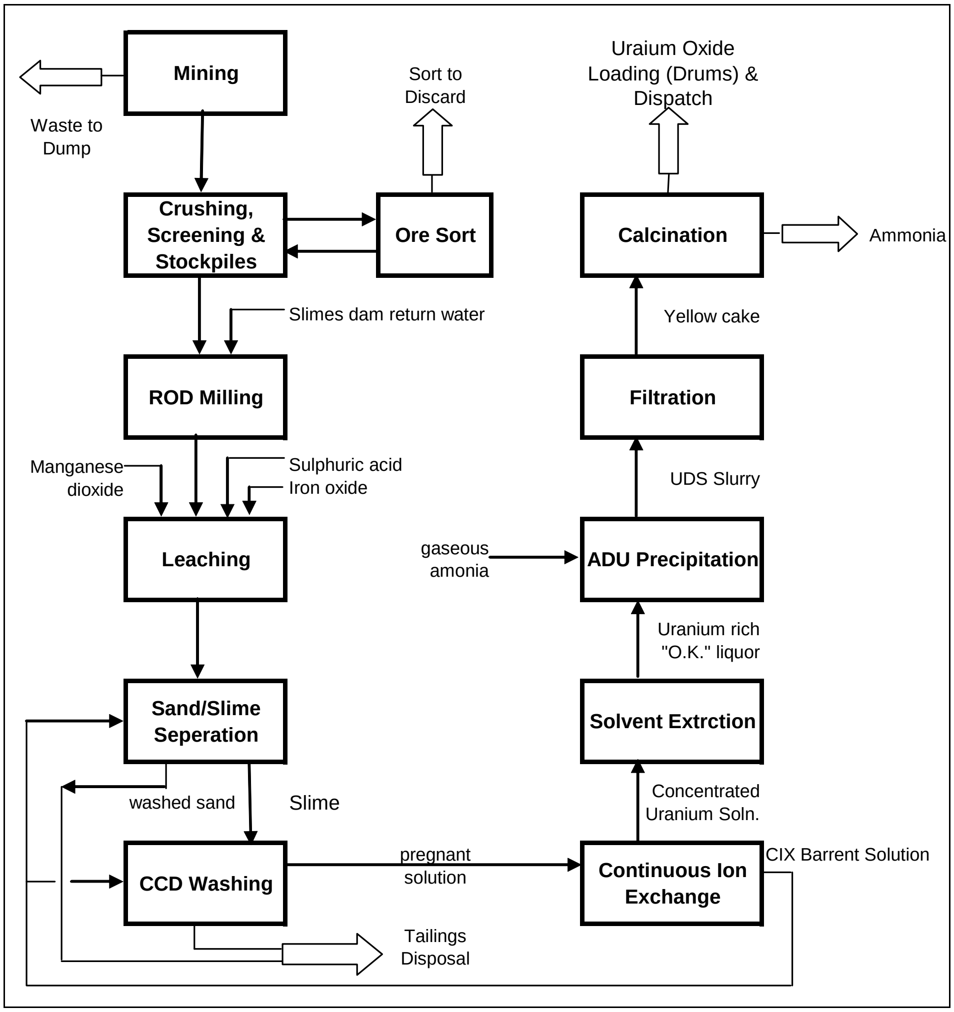

Figure 1-2: Process flow diagram for Valencia Uranium Mine.

1.3 Site Description

Valencia Uranium Mine is located on the farm Valencia 122, approximately 75 km southwest of the town of Usakos in central-west Namibia. The proposed mine area has a prospect mine license (Exclusive Prospecting License). The remainder of the Valencia farm is privately owned with a single standing farmhouse located approximately 3.4km south-southeast of the proposed open pit. To the south of the farm Valencia and to the west are private landowners with the property to the east belonging to the Namibian Government. Vegetation in the region is sparse, with rocky outcrops and gravel plains.

On a regional scale the Rössing/Khan formations starts about 40 km directly east of Swakopmund and stretch northeast for approximately 70 km. Rössing Uranium Mine is located within the Rössing formations 23 km southwest of the proposed Valencia Uranium Mine. Valencia is situated on the eastern side of the Rössing/Khan formations on the outskirts of a valley running parallel to the Chuos Mountains. This mountain range is located ~11 km to the southeast of Valencia Mine and stretches for ~ 40 km in a northeasterly to southwesterly direction. The Geiseb Mountains are located 14 km to the south of the mine site. The relief ranges from 630 mamsl (meters above mean sea level) in the west (near Rössing Mine) to 1257 mamsl in the east at the Chuos Mountains. The Khan River runs through the Rössing/Khan formations. Figure 1-3 clearly indicates the topography around the proposed Valencia Uranium Mine.

Sensitive receptors to be impacted on by air pollution generated from the proposed mining operations primarily comprise of the Valencia farmhouse, located 3.4 km directly south-southeast of the proposed open pit.

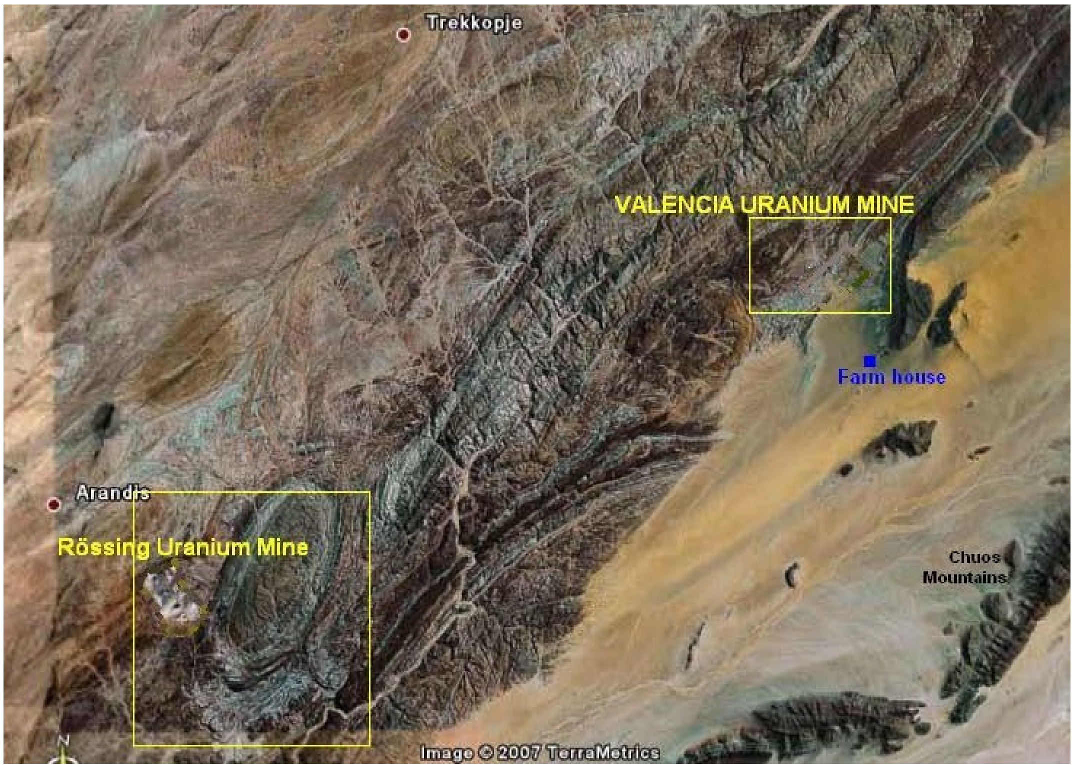

Figure 1-3: Topography of the area surrounding the proposed Valencia Uranium Mine (from Google Earth, 2007).

1.4 Limitations and Assumptions

The following limitations and assumptions need to be taken in cognisance for this study:

- The on-site meteorological data only had 62% availability and could not be used in the dispersion modelling for the site. Instead the meteorological data recorded at Rössing Uranium Mine were used. The prevailing wind fields from the two sites differ slightly and therefore the maximum zone of impact might not be reflected correctly.
- No site specific particle size fraction data, moisture content or clay content information was available and use was made of information measured at Trekkopje Mine (Burger and Le Roux, 2006).

- No baseline ambient monitored concentration data was available for the area. A dust fallout monitoring campaign was initiated at the end of August 2007 with 3 months of recorded information provided for inclusion into the report. The dust fallout is reported by Digby Wells & Associates (DWA).

- The impact assessment was limited to airborne particulates (including TSP and PM10), SO_2 and SO_3. Although the proposed activities would also emit other gaseous pollutants, primarily by haul trucks and mining vehicles, the impact of these compounds was regarded to be low and was omitted from this study.

- The dispersion model (AERMOD) cannot compute real time mining processes, therefore average mining process throughputs were utilised. Thus even though the nature of the open pit mining operations (pit utilisation and roads) change over the life of mine, the open pit mining area of Valencia was modelled to reflect the worst case condition (i.e. resulting in the highest impacts). Similarly, the final design dimensions of the waste rock dumps and Tailings dump were assumed.

- Routine emissions for the proposed operations were simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for. Blasting is seen as an intermittent source of emissions (non-routine) and will occur once a day for a limited period of time (less than an hour). Blasting was modelled to reflect highest hourly impacts but since no hourly ambient air quality standards or guidelines exists for particulates (limited to 24-hour averages) the significance of these impacts could not be determined.

- Mining operations were assumed to be twenty-four hours over a 365 day year.

- One of the main limitations of the study was the lack of site specific information. This included the dimensions of the crusher plant and what control equipment would be implemented, the exact route from the mine to the main road, and the layout of on-site haul roads.

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

- Limited information was supplied on the sulphuric acid plant. Where no source-specific information was provided, reference was made to similar acid plant designs.

1.5 Outline of the Report

The report is outlined as follows:

Section 2	-	Legal requirements, including the specifications of the Namibian Legislation, the World Bank Requirements and the World Health Organisation specifications. The proposed South African Legislation is also included.
Section 3	-	The selection of an appropriate dispersion model and the modelling methodology are discussed in this section.
Section 4	-	Description of the climate and dispersion potential of the site. Baseline characterisation, including all measured ambient air quality data to date and predicted background concentrations.
Section 5	-	This section comprises of source identification and emissions quantification.
Section 6	-	This section discusses the dispersion modelling results and impact assessment of the proposed Valencia Uranium Mine operations.
Section 7	-	Qualitative assessment of the closure and post-closure phases.
Section 8	-	The main conclusions are summarised in this section. Management measures identified for the Valencia Uranium Mine Project are provided including a proposed monitoring network.

2 OVERARCHING LEGISLATION AND AMBIENT AIR QUALITY CRITERIA

In addressing the impact of air pollution emanating from proposed mine and associated process plant, some background on the health effects of the various pollutants need to be provided. Since the terms of reference exclude a detailed toxicological study, this discussion is limited to the most important health impact aspects of each pollutant.

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

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.

This Act 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. These air pollution guidelines have been provided for a number of criteria pollutants namely, sulphur dioxide, oxides of nitrogen, carbon monoxide, ozone, lead and particulate matter. The adoption of a revised guideline for sulphur dioxide was promulgated on 21 December 2001 in terms of the Act. The second schedule to the Act has 72 Scheduled Processes listed. Given the preliminary nature of the proposed plant, it does not appear to fall within any of these scheduled processes.

The South African air pollution act has been revised and recently commenced with. The new act, the National Environmental Management: Air Quality Act (AQA), 2004 (Act No. 39 of 2004) took effect on 11 September 2005, with the exclusion of sections 21, 22, 36 to 49, 51(1)(e), 51(1)(f), 51(3) and 61. Schedule 2 of the AQA provides ambient air quality standards that were based on the previously adopted Department of Environmental Affairs and Tourism (DEAT) guidelines. These are currently being revised with the publication of the new ambient air quality standards (*Government Gazette No.*

28899, 9 June 2006) for public comment. These standards are based on those issued by the South African National Standards (SANS) during 2004[1].

It is not clear how the legal developments in South Africa have affected the Namibian legislation. Compliance of the operation would therefore be measured against the old DEAT guidelines (as used in the original APPA of 1965) and the newly proposed AQA standards, which have been based on the SANS limit values (SANS 1929), which are more in line with international trends.

2.2 World Bank Requirements

The World Bank Group (WBG) has no sector specific guidelines for Uranium mining and/or production but has guidelines for Coal Mining and Production, and General Environmental Guidelines. These are provided in the Pollution Prevention and Abatement Handbook of 1999. The conditions for coal mining are fairly general and consist primarily of good practice and Best Available Technology (BAT) to be applied.

The WBG stipulates that a mining plan and a mine closure plan must be prepared and approved before mining commences. The development plan describes in detail the mining methods and sequence and nature of extraction. This plan must include for instance (both are not limited to) the removal and storage of topsoil, early restoration of worked-out areas, reduction of dust by early re-vegetation and by good maintenance of roads and work areas, control of the release of chemicals, and control of methane gas (a greenhouse gas) to less than 1% of volume. The mine closure plan should include the reclamation of open pits, waste piles, beneficiation tailings, sedimentation basins, and abandoned mine, mills, and camp sites. These plans should include (but not limited) use of overburden for backfill, contour slopes, and plant indigenous vegetation. All mine shafts should be closed and sealed on mine closure.

Emission guidelines should be developed as part of the Environmental Assessment process, hence based on pollution impacts. However the WBG has established emission guidelines which can consistently be achieved by well-designed, well-operated and well-maintained pollution control systems. It should be noted that dilution of air emissions in order to achieve these guidelines are unacceptable. All of the maximum levels should be achieved for at least 95% of the time on an annual basis.

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[1] The South African Bureau of Standards (SABS) was initially engaged to assist the Department of Environmental Affairs and Tourism (DEAT) in the facilitation of the development of ambient air quality standards. This process resulted in the publication of: (a) SANS 69 - South African National Standard - Framework for setting & implementing national ambient air quality standards, and (b) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. The latter document includes air quality limits for particulate matter less than 10 µm in aerodynamic diameter (PM10), dust fall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene. The SANS documents were approved by the technical committee for gazetting for public comment. They were made available for public comment during the May/June 2004 period and were finalised and published during the last quarter of 2004. In the first publication of the AQA, DEAT did not adopt these targets, but rather decided to include the previous CAPCO guidelines as standards in the second schedule, with a view of replacing these with alternative thresholds in the future. The new ambient air quality standards have been published (Government Gazette No. 28899, 9 June 2006) for public comment. The proposed standards adapted the SANS 1929 limit values for sulphur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, ozone, lead and benzene.

Controls may be required on individual sources. For coal crushing operations fabric filters or other systems should be used ensuring particulate emission concentrations of less than 50 mg/Nm³.

2.3 Ambient Air Quality Standards and Guidelines

In this section, the guidelines and standards as stipulated by the World Bank Group (WBG) and the Namibian Government are discussed. To ensure the guidelines and standards used in the current study are in line with the most current international best practice, these guidelines and standards are compared to the World Health Organisation (WHO) guidelines which have recently been revised (October 2005). The newly updated Environmental Health and Safety (EHS) guidelines published by the WB's International Finance Corporation (IFC) in April 2007 reference the WHO guidelines in the absence of national legislate standards. Since the Namibian legislation pertaining to air quality management is based on the South African APPA, the guidelines as was stipulated under the APPA will be referenced as well as the new proposed South African ambient air quality standards.

The main pollutant of concern from the proposed mine and processing plant is particulates. Other pollutants associated with the production of Uranium Oxide include sulphur dioxide (SO_2), sulphur trioxide (SO_3), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and carbon dioxide (CO_2). Due to the limited information regarding the process operations and that no emission factor data exit to quantify these emissions, the focus of the current study was on particulates and SO_2 and SO_3 from the acid plant. Thus, the guidelines and standards provided are for particulates and sulphuric pollutants. Appendix A provides the background to the establishment of ambient air quality guidelines and standards for particulates.

2.3.1 Suspended particulate matter

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

The focus of suspended particulate matter is mainly on the size fractions less than 10 µm due to the health effects associated with the fine dust fractions. The ambient air quality guidelines and standards for PM10 are given in Table 2-1.

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

WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-2 and 2-3.

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

Authority	Maximum 24-hour Concentration (µg/m³)	Annual Average Concentration (µg/m³)
SA standards (Air Quality Act)	180(a)	60
RSA SANS limits (SANS:1929,2004)	75(b)(n) 50(c)	40(b)(n) 30(c)
Australian standards	50(d)	-
European Community (EC)	50(e)	30(f) 20(g)
World Bank (General Environmental Guidelines)	70(h)	50(h)
United Kingdom	50(i)	40(j)
United States EPA	150(k)	50(l)
World Health Organisation	(m)	(m)

Notes:
(a) Not to be exceeded more than three times in one year.
(b) Limit value. Permissible frequencies of exceedance, margin of tolerance and date by which limit value should be complied with not yet set.
(c) Target value. Permissible frequencies of exceedance and date by which limit value should be complied with not yet set.
(d) Australian ambient air quality standards. (http://www.deh.gov.au/atmosphere/airquality/standards.html). Not to be exceeded more than 5 days per year. Compliance by 2008.
(e) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005. Not to be exceeded more than 25 times per calendar year. (By 1 January 2010, no violations of more than 7 times per year will be permitted.)
(f) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2005.
(g) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Compliance by 1 January 2010.
(h) World Bank, 1998. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(i) UK Air Quality Objectives (www.airquality.co.uk/archive/standards/php). Not to be exceeded more than 35 times per year. Compliance by 31 December 2004.
(j) UK Air Quality Objectives (www.airquality.co.uk/archive/standards/php). Compliance by 31 December 2004.
(k) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(l) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). To attain this standard, the 3-year average of the weighted annual mean PM10 concentration at each monitor within an area must not exceed 50 µg/m³.
(m) WHO (2000) issued linear dose-response relationships for PM10 concentrations and various health endpoints with no specific guideline provided. WHO (2005) made available during early 2006 proposes several interim target levels (see Tables 2-2 and 2-3).
(n) New SA standards proposed under Government Notice No. 528, 9 June 2006.

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

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target -1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG.
WHO interim target -2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1.
WHO interim target – 3 (IT -3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use

			of the PM2.5 guideline is preferred.

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

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

Notes:
* 99th percentile (3 days/year)
** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

2.3.2 Dust Fallout

Dust deposition (fallout / nuisance dust) may be gauged according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT) (Table 2-4). The South African Department of Minerals and Energy (DME) has accepted these values as the reference rates for dust deposition for the purposes of an Environmental Management Programme (EMP). The DME further uses the 1200mg/m^2/day threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

Slight dustfall is barely visible to the naked eye. *Heavy* dustfall indicates a fine layer of dust on a surface, with v*ery heavy* dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of >200mg/m^2/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

Table 2-4: **South African DEAT guidelines for dust deposition.**

Classification	Dustfall – monthly average (mg/m^2/day)
SLIGHT	< 250
MODERATE	250 – 500
HEAVY	500 –1200
VERY HEAVY	>1200

A perceived weakness to these current dust-fall guidelines is that they are purely descriptive without giving any guidance for action or remediation. On the basis of the cumulative South African experience of dustfall measurements, Standards South Africa have published two important new standards in terms of air quality underlying limits for dustfall rates

In terms of dust deposition standards, a four-band scale evaluation is used (Table 2-5) as well as target, action and alert thresholds (Table 2-6). Results pertaining to dustfall monitors that are located within the boundaries of the mine as defined by the legal, fenced boundaries of the enterprise cannot be evaluated against the criteria as set out by Table 2-5 in general environmental reports. On-site monitors can thus be evaluated for industrial control purposes and occupational health guidelines or standards.

An enterprise may submit a request to the authorities to operate within band 3 (action band – as outlined in Table 2-5) for a limited period, provided that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings disposal) and provided that an appropriate control technology is applied for this duration. No margin of tolerance will be granted for operations that result in dustfall rates, which fall within Band 4 (alert band) as specified in Table 2-5. Exceptions pertaining to these standards include the following:

- Dustfall that exceeds the specified rates but that can be shown to be the result as some extreme weather or geological event shall be discounted for the purpose of enforcement and control. Such event might typically result in excessive dustfall rates across an entire metropolitan region, and not be localised to a particular operation.
- Natural seasonal variations, for example the naturally windy months each year, will not be considered extreme events for this definition.

No criteria for the evaluation of dustfall levels are available for the United States Environmental Protection Agency (US-EPA), the European Union (EU), the World Health Organisation (WHO) or the World Bank Group (WB).

Table 2-5: Four-band scale evaluation criteria for dust deposition (After SANS 1929: 2004).

Band Number	Band Description Level	Dustfall rate (D) (mg.m^2.day, 30 day average)	Comment
1	Residential	D < 600	Permissible for residential and light commercial.
2	Industrial	600 < D <1200	Permissible for heavy commercial and industrial.
3	Action	1200 < D <2400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	2440 < D	Immediate action and remediation required following the first incidence of dustfall rate being exceeded. Incident report to be submitted to the relevant authority.

Table 2-6: Target, action and alert thresholds for dust deposition (After SANS 1929: 2004).

Level	Dustfall rate (D) (mg.m^2.day, 30 day average)	Averaging Period	Comment
Target	300	Annual	
Action Residential	600	30 days	Three within any year, no two sequential months.
Action Industrial	1200	30 days	Three within any year, not sequential months.
Alert Threshold	2400	30 days	None. First incidence of dustfall rate being exceeded requires remediation and compulsory report to the authorities.

2.3.3 Sulphur Dioxide

Sulphur dioxide is damaging to the human respiratory function. Exposure to sulphur dioxide concentrations above certain threshold levels increases the prevalence of chronic respiratory disease and the risk of acute respiratory illness. Due to it being highly soluble, sulphur dioxide is more likely to be adsorbed in the upper airways rather than penetrate to the pulmonary region.

Ambient air quality guidelines and standards referenced for purposes of this study are given in Table 2-7. The WHO and general environment WBG guidelines are not linked to allowable frequencies of exceedences, with the EC standards indicating allowable incidence exceedances for hourly and daily averages. Even though the ambient air quality at the Valencia site is not regarded to fall into this category (see Section 6), these requirements were referenced to provide a more informed understanding of potential impacts. In the formulation of the WHO goals, the lowest observed level at which adverse health effects are observed to occur as a result of a particular pollutant is identified *and a margin of safety added*. Margins of safety are included to account for uncertainties in, for example, extrapolating health effects from animals to humans or from small human sample group to entire populations.

Table 0-1: Ambient air quality guidelines and standards for sulphur dioxide for various countries and organisations

Authority	Maximum 1-hourly Average (µg/m³)	Maximum 24-hour Average (µg/m³)	Annual Average Concentration (µg/m³)
World Bank (General Environmental Guidelines)	-	125(a)	50(a)
Proposed South African Standards (based on the SANS:1929,2004)	350(b)	125(c)	50(c)
World Health Organisation	-	125(d) 50(e) 20(f)	10-30(g)
European Community (EC)	350(h)	125(i)	20(j)

Notes:
(a) World Bank, 1999. Pollution Prevention and Abatement Handbook. (www.worldbank.org). Ambient air conditions at property boundary.
(b) Proposed South African Standards as published in the Government Gazette of 9th June 2006
(c) SANS 1929 - South African National Standard - Ambient Air Quality - Limits for common pollutants. Also proposed South African Standards as published in the Government Gazette of 9th June 2006
(d) WHO interim target-1 (IT-1). World Health Organisation air quality guidelines global update 2005.
operations.
(e) WHO interim target-2 (IT-2). World Health Organisation air quality guidelines global update 2005.
(f) WHO guideline (AQG). World Health Organisation air quality guidelines global update 2005
(g) Represents the critical level of ecotoxic effects (issued by the WHO for Europe); a range is given to account for different sensitivities of vegetation types (WHO, 2000).
(h) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).
(i) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).
(j) EC First Daughter Directive, 1999/30/EC (http://europa.eu.int/comm/environment/air/ambient.htm). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.

It is important to note that the WHO air quality guidelines (AQGs) published in 2000 for sulphur dioxide have recently been revised (WHO, 2005). Although the 10-minute AQG of 500 µg/m³ has remained unchanged, the previously published daily guideline has been significantly reduced from 125 µg/m³ to 20 µg/m³. The previous daily guideline was based on epidemiological studies. WHO (2005) makes reference to more recent evidence which suggests the occurrence of health risks at lower concentrations. Although WHO (2005) acknowledges the considerable uncertainty as to whether sulphur dioxide is the pollutant responsible for the observed adverse effects (may be due to ultra-fine particles or other correlated substances), it took the decision to publish a stringent daily guideline in line with the precautionary principle. The WHO (2005) stipulates an annual guideline is not needed for the protection of human health, since compliance with the 24-hour level will assure sufficiently lower levels for the annual average. Given that the 24-hour WHO AQG of 20 µg/m³ is anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommends a stepped approach using interim goals as shown in Table 2-8.

Table 0-2: WHO air quality guidelines and interim guidelines for sulphur dioxide (WHO, 2005)

	24-hour Average Sulphur Dioxide (µg/m³)	10-minute Average Sulphur Dioxide (µg/m³)
WHO interim target-1 (IT-1) (2000 AQG level)	125	-
WHO interim target-2 (IT-2)	50(a)	-
WHO Air Quality Guideline (AQG)	20	500

Notes:
(a) Intermediate goal based on controlling either (i) motor vehicle (ii) industrial emissions and/or (iii) 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 improvements that would justify further improvements (such as aiming for the guideline).

2.3.4 Sulphur Trioxide

Sulphur Trioxide is not a criteria pollutant with no associated ambient air quality guidelines or standards. In the current study reference will be made to effects screening and health risk criteria to ensure that the potential for risks due to SO_3 could be gauged. (Effect screening levels are generally published for a much wider range of pollutants compared to health risk criteria.) Where various effect screening and health risk thresholds are available for one pollutant, the most stringent threshold is used in the screening of predicted pollutant concentrations.

Reference will be made to following health effect screening criteria in order to assess the potential for impacts associated with the proposed project:

- Effects Screening Levels (ESLs) recommended by the Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division (TARA) for a vast number of compounds.
- Reference Exposure Levels (RELs) adopted by the California Officer of Environmental Health Hazard Assessment (OEHHA) in September 2002.
- WHO guideline values (GVs) and tolerable concentrations (TCs) given for non-carcinogenic effects.

Sulphur trioxide reacts rapidly with water within the respiratory tract to form sulphuric acid. Therefore the adverse health effects of SO_3 are expected to be the same as for sulphuric acid (ATSDR, 1998).

TARA Effects Screening Levels (ESLs) represents criteria, which may be used in the preliminary assessment of the potential for health risks associated with concentrations of the various of the gaseous constituents under investigation. "Long-term" ESLs are applicable to annual averaging periods or longer durations with "short-term ESLs being applicable to hourly average exposures. TARA ESLs are based on data concerning health effects, odour nuisance potential, vegetation effects, or corrosion effects. ESLs are not ambient air quality standards! If predicted or measured airborne levels of a constituent do not exceed the screening level, it is not expected that any adverse health or welfare effects would results. If ambient levels of constituents in air exceed the screening levels it does not, however, necessarily indicate a problem, but should be viewed as a trigger for a more in-depth review.

Acute and chronic reference exposure limits were recently adopted by California. The chronic limits are given for annual or longer exposure periods, whereas the exact averaging period applicable for the acute exposure limits is stipulated together with the limit value given.

For SO_3 only TARA ESL's have health effect screening criteria (see Table 2-9). No such criteria for SO_3 are stipulated by the WHO guidelines, US.EPA or California OEHHA RELs. According to the Agency for Toxic Substances and Disease Registry (ATSDR), the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH) limit the amount of sulphuric acid in workroom air to 1 milligram per cubic meter of air (1 mg/m^3). There is however no ambient concentration guidelines stipulated (ATSDR, 1998).

Table 2-9: Effects screening levels and health risk criteria.

Constituent	TARA ESLs (1997)	
	Short –term ESL (1 hr) (ug/m_3)	Long –term ESL (year+) ug/m_3)
Sulphur trioxide (SO_3)	10	1

2.3.5 Thresholds related to Vegetation and Ecosystems

Although the main concern when assessing pollution impacts are based initially on thresholds able to protect human health, the need to protect the broader environment is also a legal requirement. Since no guidelines for vegetation suited to local ecosystems have been identified by national government, reference is made to internationally defined air quality criteria given for the protection of vegetation for information purposes. Reference to certain criteria issued by the EC, UK and US for this purpose is given in Table 2-10.

Table 2-10: Thresholds specified by other countries specifically for vegetation and ecosystems

Pollutant	Averaging Period	Threshold (ppb/ppm)	Threshold ($\mu g/m^3$ or mg/m^3)
sulphur dioxide	annual average	3.7 - 11.1 ppb[(a)] 7.4 ppb[(b)]	10 - 30 $\mu g/m^3$[(a)] 20 $\mu g/m^3$ [(b)]
	8-hour		800 – 1000 $\mu g/m^3$[(c)]

(a) Represents the critical level for ecotoxic effects issued by the WHO for Europe; a range is given to account for different sensitivities of vegetation types
(b) EC and UK limit value to protect ecosystems
(c) Threshold limits for pine trees (Peavy, Rowe & Tchobanoglous, 1998)

3 METHODOLOGY

In assessing atmospheric impacts from the proposed mining activities and processing plant an emissions inventory was undertaken (Section 5), atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated (Section 6).

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

3.1 Baseline Assessment

The baseline assessment served to give a detailed description of the state of the environment and existing levels of pollution within the region.

3.1.1 Dispersion Potential of the Site

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. For the purposes of establishing the local climatology, it was necessary to analyse at least one year's data, however, a normal requirement is for a five-year database. An analysis of the data served to provide a general description of the local climate and to calculate fugitive airborne dust emissions to be used in the dispersion simulations.

A general description of the climate for the greater region was based on historical records (e.g. Weather Bureau Reports). Local meteorological data were obtained, both from on-site (Valencia Uranium Mine) and from the Rössing Uranium Mine meteorological station approximately 23 km away. The meteorological data from Valencia was available for 1 year (30 September 2006 to 17 October 2007) with the Rössing data provided for a period of almost 2 years (October 2005 to August 2007). Information was provided for both stations for hourly average wind speed, wind direction and temperature. Mixing heights were estimated for each hour, based on prognostic equations, while night-time boundary layers were calculated from various diagnostic approaches. Wind speed and solar radiation was used to calculate hourly stability classes. The analysis of the meteorological data included diurnal temperature profiles, wind roses, atmospheric stability classifications and inversion height estimations. Precipitation and evaporation data were also included along with solar radiation data.

3.1.2 Ambient Concentrations and Dust Fallout levels

For the completion of a baseline investigation, a good understanding of the existing ambient air quality in the region is required. No such data are available for the region. A dust fallout monitoring network for Valencia Uranium Mine has been established by DWA and was initiated at the end of August 2007. Three months of dust fallout data were available to date and was reported by DWA.

3.2 Emissions Inventory

An emissions inventory was established and comprised emissions for the proposed operational activities at Valencia Uranium Mine. The establishment of an emissions inventory is necessary to provide the source and emissions data required as input to the dispersion simulations. The release of particulates (as stated in preceding sections) represents the most significant emission and is the focus of the current study.

In the quantification of emissions (refer to Section 5) use was made of predictive emissions factor equations published by the US-EPA (EPA, 1996). An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Detailed information pertaining to these quantifications is provided in Appendix B.

3.3 Dispersion Simulation Methodology

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

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The surrounding topography is fairly flat comprising of undulating hills. The most widely used Gaussian plume model is the US-EPA Industrial Source Complex Short Term model (ISCST3). However this model is scheduled to be replaced by the new generation AERMOD model and since this model is also stipulated in the Registration Certificate as the regulatory model, it 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). The AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

- AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources (EPA, 2005). 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).
- The AERMET is a meteorological pre-processor 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 pre-processor designed to simplify and standardise 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. Output includes, for each receptor, location and height scale, which are elevations used for the computation of air flow around hills.

Similar to the ISCST3 a disadvantage of the model 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.

3.3.1 Model Accuracy

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

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

AERMOD has a range of uncertainty of the model predictions between -50% and 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions

3.4 Dispersion Model Data Requirements

3.4.1 Receptor Locations and Modelling Domain

The modelling domain selected for the proposed Valencia Mine included an area of 23 km (north-south) by 40 km (east-west). The area was divided into a grid matrix with a resolution of 585 m by 456 m, with the mine located approximately in the centre of the receptor area. To account for a more accurate modelling scenario the plant boundary was included as a discrete receptor to record the maximum off-site concentrations. In addition, the nearby sensitive receptors identified were included as discrete receptor points. This primarily included the Valencia farmhouse. AERMOD simulates ground-level concentrations for each of the receptor grid points. The height of each receptor point was set to 1.5 m above ground level to account for the breathing zone.

3.4.2 Meteorological Data Input

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 Weather Services data). Due to the fact that certain site-specific parameters are not available these had to be sourced from neighbouring meteorological stations (i.e. Rössing Uranium Mine). Identification of these parameters further serves as a gap identification of meteorological data for the on-site Valencia Uranium Mine station (discussed further in Section 7).

Upper air is not measured in the vicinity of Valencia Uranium Mine and use was made of the South African Weather Services ETA data. The ETA model simulates upper air wind meteorological conditions based on surface measurements and other upper air measurements.

3.4.3 Model Input and Execution

Input into the dispersion model includes prepared meteorological data (AERMET), source data, information on the nature of the receptor grid and emissions input data. The model inputs were verified before the model was executed.

The AERMOD model is able to model point, area, volume and line sources. The waste dumps, Tailings dump and stockpiles were simulated as area sources, the unpaved roads as line sources, materials handling (tipping and crushing operations) as volume sources, and all mining operations (including blasting) as open pit sources. Hourly files incorporating meteorological data were prepared for the area sources.

3.4.4 Plotting of Dispersion Results

Simulated outputs for PM10 (daily and annual), and TSP (average and maximum daily) for the cumulative as well as the individual sources were plotted. Outputs for SO_2 and SO_3 (hourly, daily and annual) for the acid plant were also plotted. All isopleth plots for the individual sources of PM10 and TSP are attached in Appendix C, while the incremental plots are illustrated in the main body of this document.

The predicted air pollution concentrations and dustfall rates were compared to air quality guidelines and standards (as discussed in Chapter 2) to facilitate compliance and impact assessments. These concentrations were summarised and form the basis of the compliance assessment for the combined sources.

Input data types required for the AERMOD model include: source data, meteorological data (pre-processed by the AERMET model), terrain data and information on the nature of the receptor grid.

3.5 Prescribed impact evaluation (After DWA, 2007)

Impacts were evaluated according to the definitions and terminology as outlined in Tables 3-1 to 3-2. The impact evaluation tables are completed at the end of each phase of the project.

Table 3-1: Impact assessment terminology.

TERM	DEFINITION
Grouping of impact	
Routine/Planned Impact	Occur as a result of expected common or regular project activities.
Cumulative impact	Impacts that act together with other impacts (including those from concurrent or planned future third party activities) to affect the same resources and/or receptors as the project.

TERM	DEFINITION
Non-routine/unplanned impact	Occur as a result of exceptional events not expected to occur.
Impact type	
Direct type	Impacts that result from a direct interaction between a planned project activity and the receiving environment (e.g. between occupation of a site and the pre-existing habitats or between an effluent discharge and receiving water quality).
Indirect Impact	Impacts that result from other activities that are encouraged to happen as a consequence of the project (e.g. in-migration for employment placing a demand on natural resources).
Induced impact	Third level impacts caused by a change in the project environment (e.g. employment opportunities created by the increased disposable income of workers hired by the project or its suppliers).
Impact magnitude	
Nature	*Negative*: an impact that is considered to represent an adverse change from the baseline, or introduces a new undesirable factor.
	Positive: an impact that is considered to represent an improvement on the baseline or introduces a positive change.
Duration	*Temporary:* impacts are predicted to occur to be of a short duration and intermittent/occasional in nature.
	Short-term: impacts that are predicted to last only for a limited period (e.g. during construction) but will cease on completion of the activity, or as a result of mitigation/reinstatement measures and natural recovery (e.g. sediment suspension by capital dredging, construction workforce-local community interactions).
	Long-term: impacts that will continue over an extended period, but cease when the project stops operating. These will include impacts that may be intermittent or repeated rather than continuous if they occur over an extended period of time (e.g. repeated seasonal disturbance of species as a result of maintenance dredging, operational employment).
	Permanent: impacts that occur during the development of the project and cause a permanent change in the affected receptor or resource (e.g. alteration of coastal morphology) that endures substantially beyond the project lifetime.
Scale	*Local:* impacts that affect locally important environmental resources or are restricted to a single habitat/biotope, a single (local) administrative area, a single community.
	Regional: impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystem.
	National: impacts that affect nationally important environmental resources, affect an area that is nationally important/protected or have macro-economic consequences.
	International: impacts that affect internationally important resources such as areas protected by International Conventions.
	Trans-boundary: impacts that are experienced in one country as a result of activities in another.
Value/sensitivity of receptor (for environmental receptor)	Specific to receptors to the project – rated according to the ability to adapt.
Ability to adapt (for social receptors)	Low (-): Affected people can easily adapt.
	Low (+): Potential beneficiaries have difficulty adapting.
	High (-): Affect people have difficulty adapting.
	High (+): Potential beneficiaries can easily adapt.
Impact Likelihood	
Low	The impact has not occurred in extractives industry.

TERM	DEFINITION
Medium	Impact has occurred in extractives projects.
High	Impact has occurred in southern Africa.

For purposes of this study, which is to be incorporated into the Environmental Impact Assessment (EIA), the following definition of significance has been adopted:

"An impact is significant if, in isolation or in combination with other impacts, it should, in the judgement of the EIA team, be taken into account in the decision-making process, including the identification of mitigation measures (by the project) and consenting conditions (from regulators and stakeholders)."

Table 3-2: Significance definitions.

SIGNIFICANCE DEFINITIONS	
Positive impact	Positive impacts provide resources or receptors, most often to people, with positive benefits. It is noted that concepts of equity need to be considered in assessing the overall positive nature of some impacts such as economic benefits, or opportunities for employment. Positive impacts can vary in magnitude.
Negligible impact	Negligible impact (or insignificant impact) is where a resource or receptor (including people) will not be affected in any way by a particular activity or the predicted effect is deemed to be 'negligible' or 'imperceptible' or is indistinguishable from natural background variations.
Minor impact	An impact of minor significance is one where an effect will be experienced, but the impact magnitude is sufficiently small (with or without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity/value.
Moderate impact	An impact of moderate significance is one within ticketed limits and standards. Moderate impacts may cover a broad range, from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. Clearly to design an activity so that its effects only just avoid breaking a law and/or cause a major impact is not best practice. The emphasis for moderate impacts is therefore demonstrating that the impact has been reduced to a level that is as low as reasonably practicable (ALARP). This does not necessarily mean that 'moderate' impacts have to be reduced to 'minor' impacts, but that moderate impacts are being managed effectively and efficiently.
Major impact	An impact of major significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resources/receptors. An aim of EIA is to get a position where the project does not have any major residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be major residual impacts after all the practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a facility. It is then the function of regulators and stakeholders to weigh such negative factors against the positive ones such as employment, in coming to a decision on the project.

4 CLIMATOLOGY AND ATMOSPHERIC DISPERSION POTENTIAL

4.1 Atmospheric Dispersion Potential of the Region

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 stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field and atmospheric stability. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

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

4.1.1 Meso-Scale Atmospheric Dispersion Potential

The analysis of meteorological data observed for the site provides the basis for the parameterisation of the meso-scale ventilation potential of the site, and to provide the input requirements for the dispersion simulations. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. A comprehensive data set for at least one year of detailed hourly average wind speed, wind direction and temperature data are needed for the dispersion simulations.

A meteorological station was recently installed at the project site (beginning of September 2006) with data available from 30 September through to 17 October 2007. Due to various technical problems experienced with the on-site weather station only 62% data were captured over the 1-year period. In general a minimum of 80% data capture is required to achieve minimum data quality assurance for data manipulation and summary. Thus, meteorological data for a period of 2 years were obtained from Rössing Uranium Mine located approximately 23 km to the southwest. In order to provide a general description of the dispersion potential of the site, and since mountains separate Valencia and Rössing, the wind profile for both meteorological stations were assessed.

4.1.1.1 Surface Wind Field

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

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

The period, daytime and nighttime wind roses for Rössing Mine are provided in Figure 4-1 with the seasonal wind roses provided in Figure 4-2.

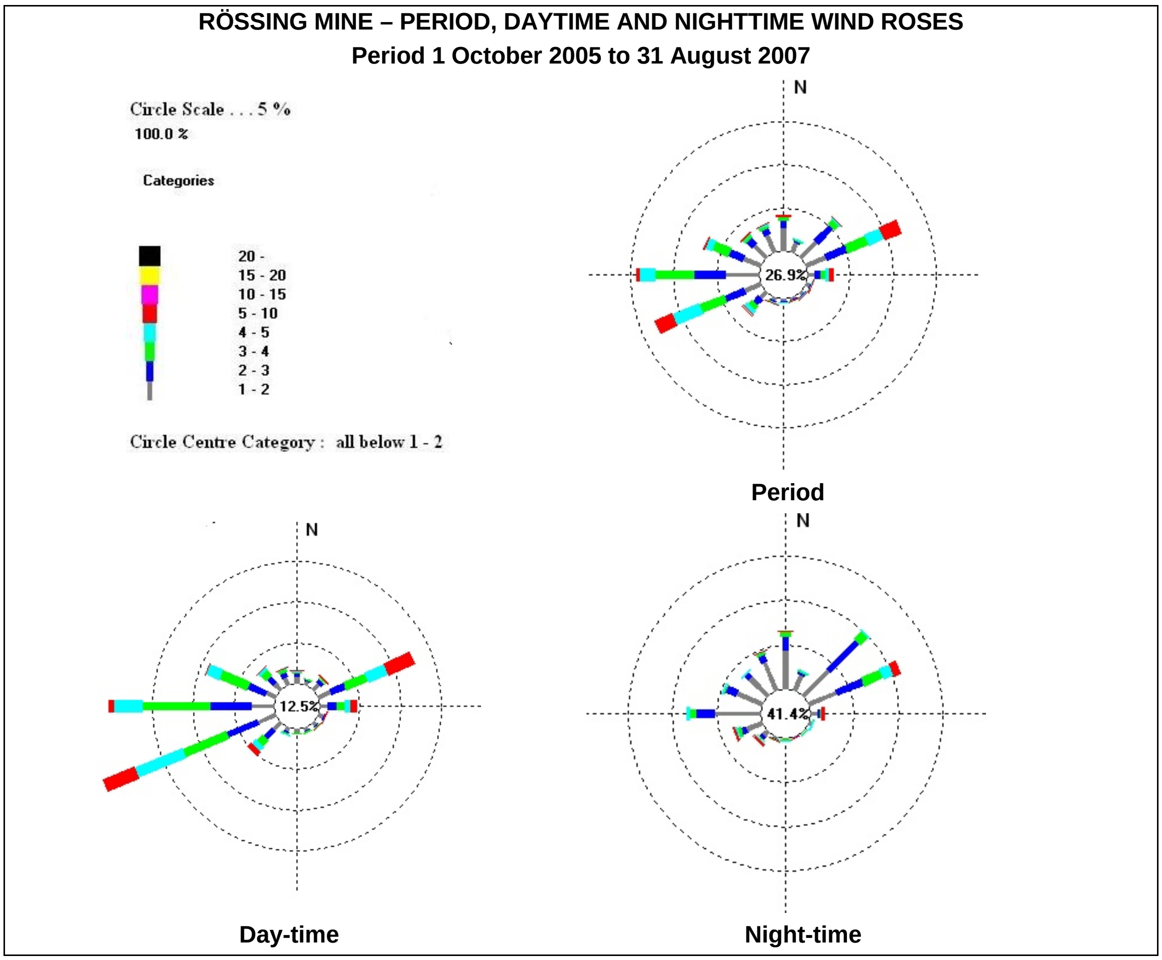

Figure 4-1: Period, daytime and nighttime wind roses for Rössing Mine (1 October 2005 to 31 August 2007).

The prevailing wind direction at Rössing for the 2 year period is from the west (14% of the time), the west-southwest (13%) and the east-northeast (13%). This wind direction also dominates daytime and nighttime wind patterns. These wind components are characterised by low to moderate strong wind speeds. Wind speeds exceeding 5 m/s occurred for 5.4% of the time with the maximum recorded at 8.5 m/s. During the day the westerly and west-southwesterly winds were more dominant with a distinct decrease during nighttime from this direction. Nocturnal flow reflected increases from the northeasterly sector and the north and associated lower wind speeds. As is typical of nighttime conditions an increase in calm conditions from 13% (during daytime) to 41% was noted.

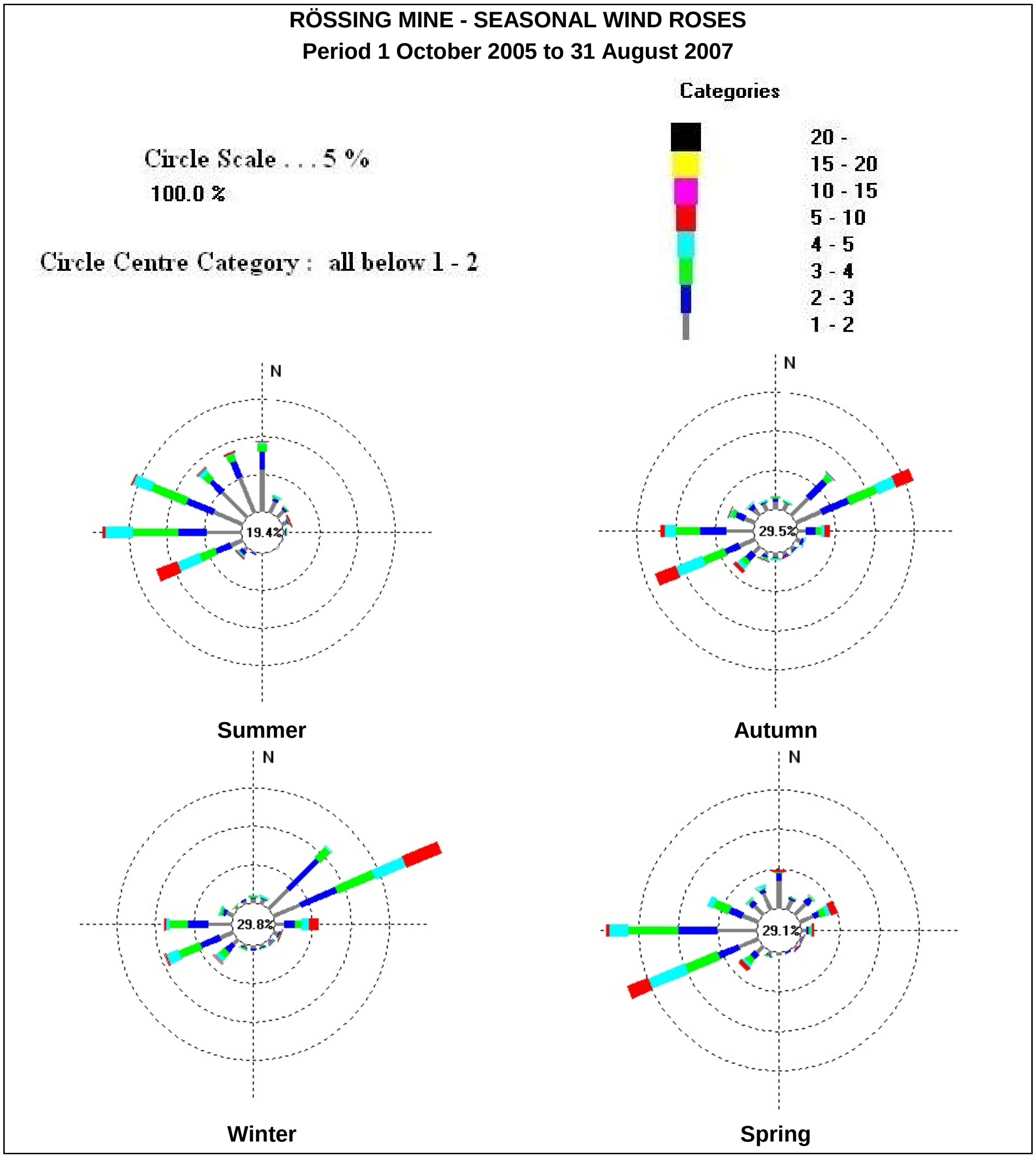

Figure 4-2: Seasonal-average wind roses for Rössing Mine (1 October 2005 to 31 August 2007).

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 west-southwest to the north with almost no flow from the southeast. A shift from the northerly to northeasterly flow was evident during the autumn months with an increase in the west-southwesterly flow. Similar wind field patterns are presented for the winter months with more frequent flow from the northeast. Springtime indicate a reduction of inland windflow with frequent winds from the westerly sector. The frequencies of calms are given as 19.4%, 29.5%, 29.8% and 29.1% for summer, autumn, winter and spring, respectively.

Period, daytime and nighttime wind roses are provided in Figure 4-3 for the Valencia Mine site. Frequent winds were recorded on average to occur from the northeast (25% of the time), the east-northeast (11%) and the southwest (14%). Calm conditions were recorded for 18.8% of the time. Wind speeds in general were low to moderate with winds exceeding 10 m/s recorded only for 1.4% of the time and stronger than 5 m/s for 23.9% with the highest wind speed recorded at 16.5 m/s.

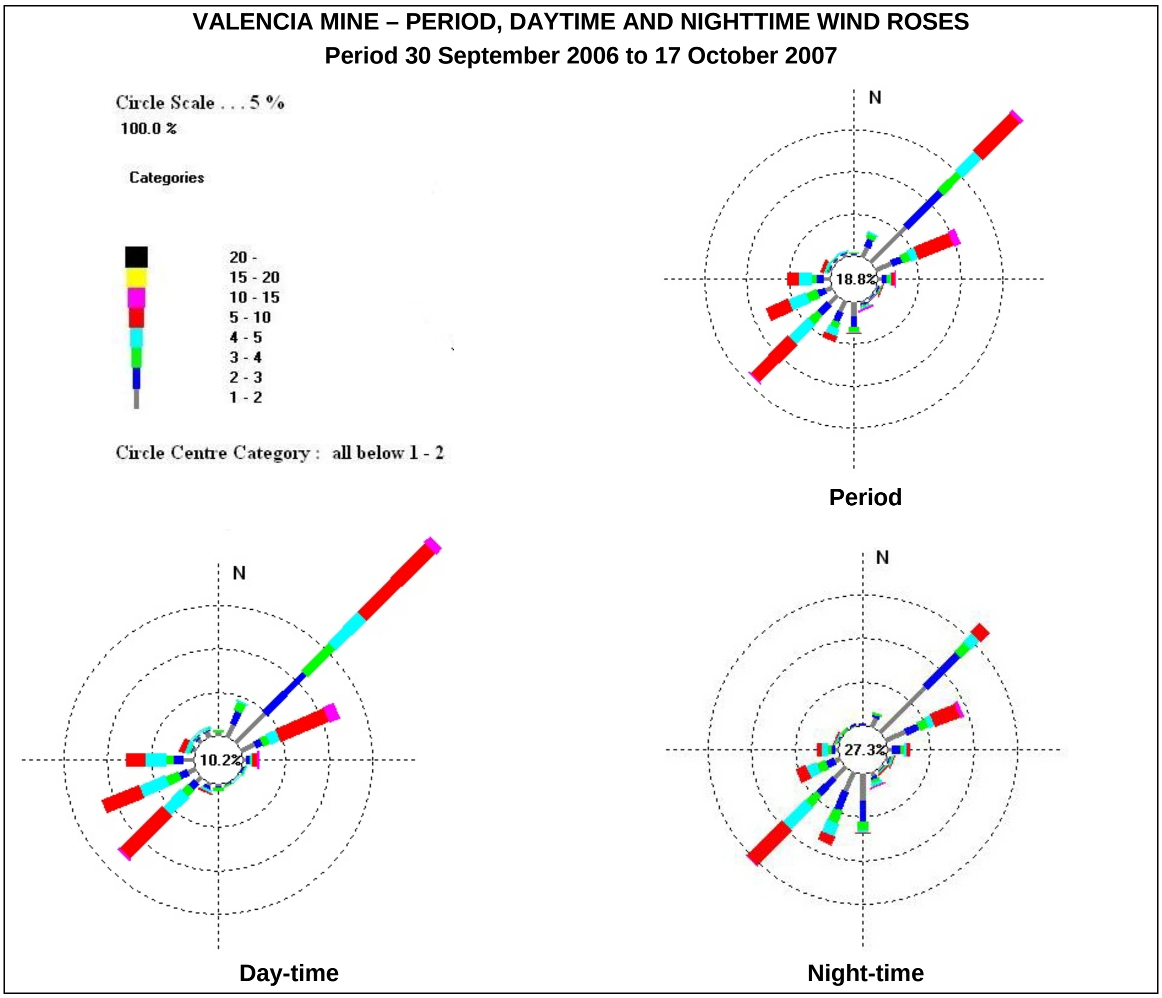

Figure 4-3: Period, daytime and nighttime wind roses for Valencia Mine (30 September 2006 to 17 October 2007).

The daytime and nighttime airflow reflected similar prevailing directions as for the period. Nighttime conditions reflected however lower wind speeds on average with increasing calm conditions (27.3%). During the daytime the prevailing wind direction was from the northeast with frequent strong winds also recorded from the west and west-southwest. The nighttime conditions indicated limited airflow from the westerly sector with an increase in winds from the south.

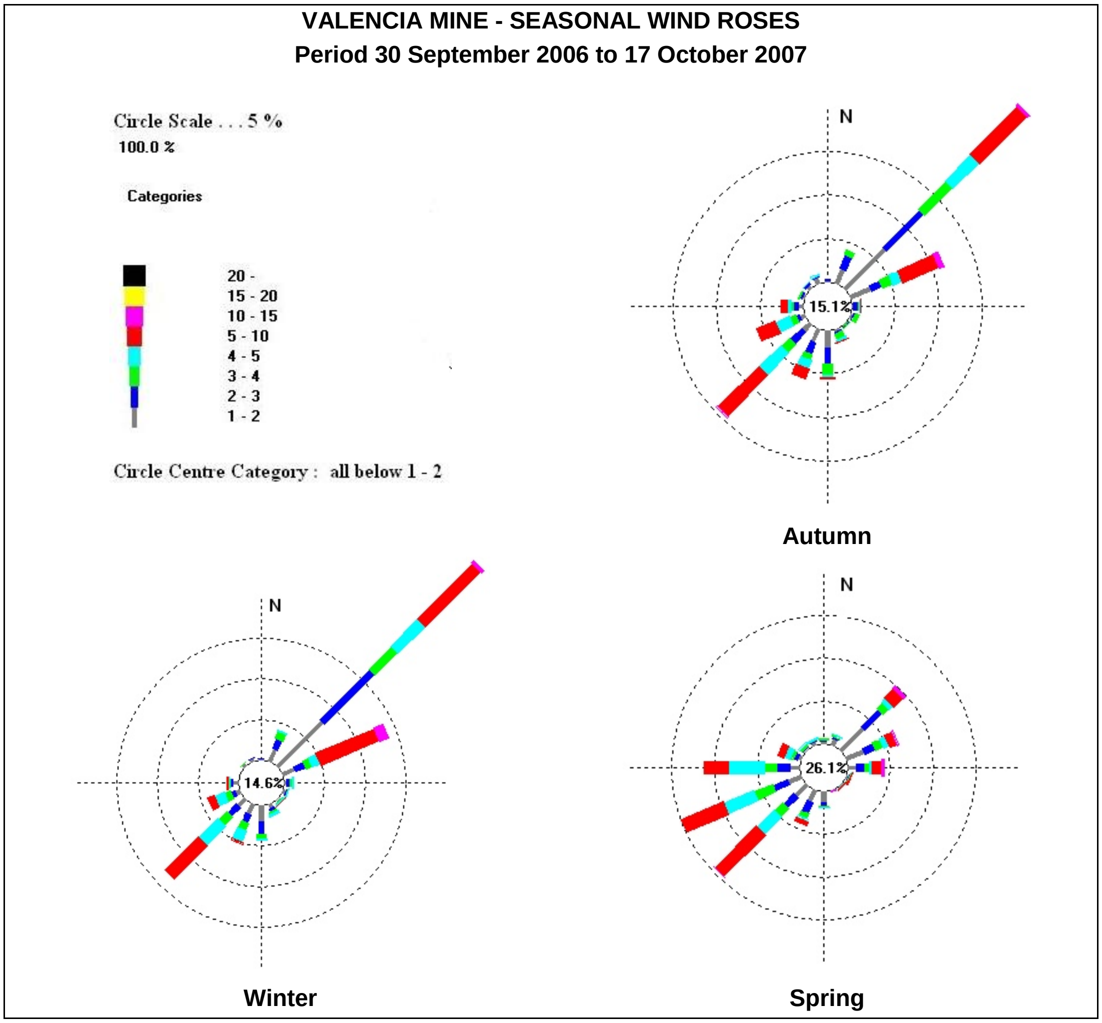

Figure 4-4: Seasonal-average wind roses for Valencia Mine (30 September 2006 to 17 October 2007).

Data were missing during the Summer months with Figure 4-4 only reflecting the remaining three seasons. Autumn reflected the dominant northeasterly and southwesterly directions. During the Winter months winds from the northeast increased slightly whilst during Spring time the northeasterly winds becomes weaker with increasing flow from the southwest to west.

What is interesting about the airflow at Rössing and Valencia Mines are the diurnal variations typical to the influence of land-sea breeze circulation on the airflow. Land-sea breeze circulation arises due to the differential heating and cooling of land and water surfaces. During the day, the land is heated more rapidly than the sea surface; a horizontal pressure gradient develops with surface convergence and ascent over the land and decent and surface divergence over the sea (Atkinson, 1981). Sea breezes therefore characterise the daytime surface circulation resulting in the prevalence of on-shore airflow, with return currents dominating the upper airflow. Thus, the prevailing westerly and west-southwesterly winds recorded at both Rössing and Valencia during daytime. By night, the land cools more quickly than the sea surface resulting in a reversal of the daytime sea breeze and upper air return currents and the onset of land breezes (off-shore) at the surface. Sea breezes are characterised by a marked increase in wind speed, and a reduction in the number of calms. Nighttime conditions reflected by the data recorded at Rössing and Valencia indicated a shift of the windfield from the east-northeast and northeast and a distinct decrease in westerly winds.

4.1.1.2 Temperature Profile

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 nighttime the air in direct contact with the earth's surface are forced to cool accordingly. This is clearly evident from Figures 4-5 and 4-6, reflecting the diurnal temperature profiles at Rössing and Valencia, respectively. The coldest time of the day appears to be between 06h00 and 08h00, 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 15h00 in the afternoon.

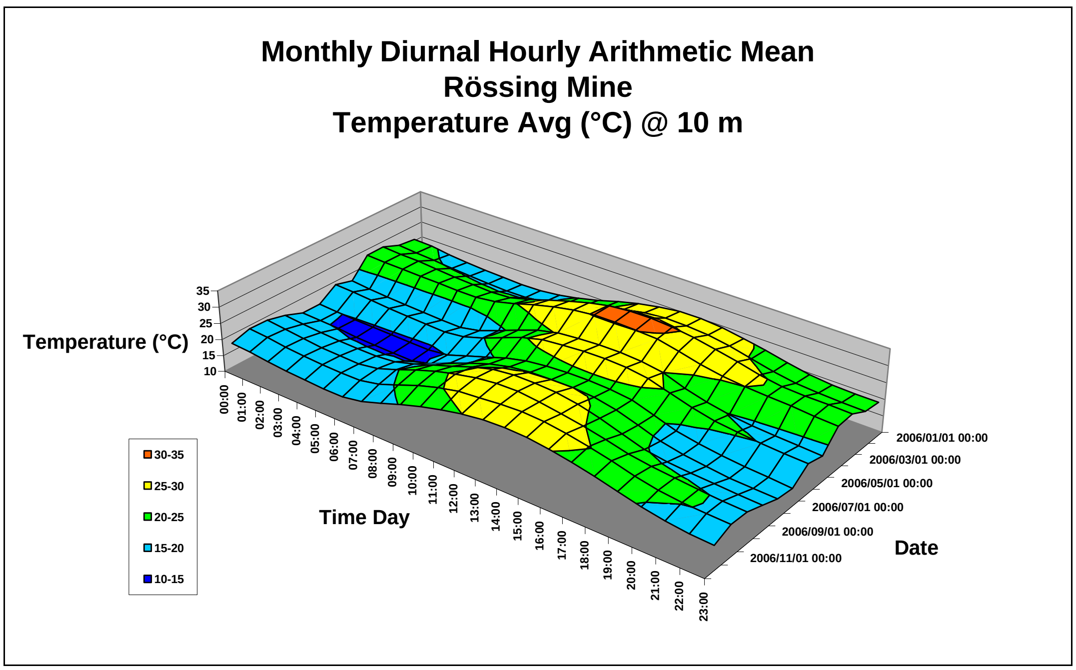

Figure 4-5: Diurnal and monthly variation of ambient air temperatures at Rössing Mine.

The annual monthly maximum, minimum and mean temperatures are given as 38°C, 5°C and 22°C respectively (Table 4-1). The maximum hourly temperature of 38.3°C at Rössing Mine was recorded during the months of October and November with the lowest hourly temperature of 5.3°C recorded in July.

Table 4-1: Maximum, minimum and mean monthly temperatures at Rössing Mine (January to November 2006).

°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly max (°C)	34.6	38.3	35.5	36.6	33.6	33.0	32.0	33.7	36.8	38.3	38.3	33.5
Monthly min (°C)	14.3	14.7	11.4	12.0	10.5	10.1	5.3	7.3	8.0	8.6	11.2	12.0
Monthly mean (°C)	21.9	22.6	25.4	25.5	20.4	21.6	18.3	18.7	20.5	21.8	21.8	20.1

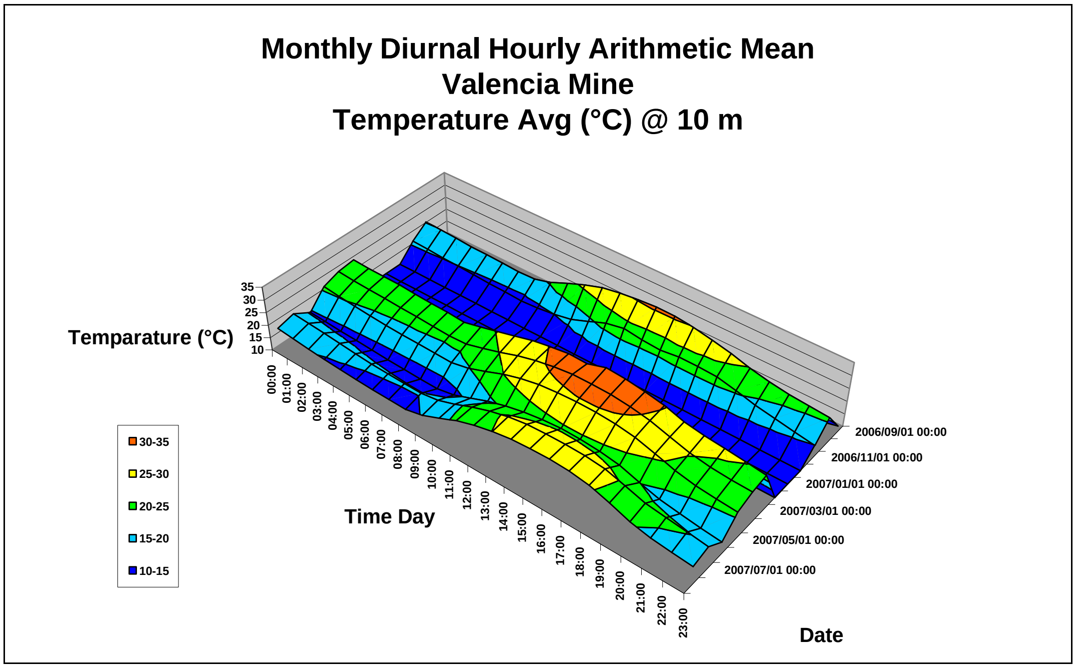

Figure 4-6: Diurnal and monthly variation of ambient air temperatures at Valencia Mine.

Table 4-2 includes the maximum, minimum and mean temperatures as recorded at Valencia Mine. The months of November 2006 to March 2007 were missing from the database. The period average temperatures ranged from 5.9°C (recorded in June and August) to 38.7°C (recorded in September).

Table 4-2: Maximum, minimum and mean monthly temperatures at Valencia Mine (October 2006 to September 2007).

°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly max (°C)	-	-	-	36.2	34.6	30.8	31.7	33.9	38.7	35.7	-	-
Monthly min (°C)	-	-	-	10.7	10.2	5.9	8.3	5.9	8.2	6.8	-	-
Monthly mean (°C)	-	-	-	20.22	23.12	17.35	20.67	19.23	21.11	19.43	-	-

4.1.1.3 Atmospheric Stability

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

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 4-3. The hourly standard deviation of wind direction, wind speed and predicted solar radiation were used to determine hourly-average stability classes.

Table 4-3: Atmospheric Stability Classes.

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

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

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

4.2 Baseline Characterisation

4.2.1 Existing sources

The identification of existing sources of emission in the region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the proposed operation and its associated emissions.

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory was not within the scope of the current study. Instead source types present in the area and the pollutants associated with such source types were noted with the aim of identifying pollutants which may be of importance in terms of cumulative impact potentials. Sources identified as possibly impacting on air quality in the region include, but are not limited to:

- Fugitive emissions from mining operations
- Vehicle tailpipe emissions from national and main roads
- Biomass burning (veld fires in agricultural areas within the region)
- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

4.2.2 Mining Operations in the Region

Mining operations represent potentially significant sources of fugitive dust emissions (PM2.5, PM10 and TSP) with small amounts of oxides of nitrogen (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), methane, and carbon dioxide (CO_2) being released during blasting operations. 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.

Experience has shown that fugitive dust emissions due to on-site operations are typically only of concern within 3 km of the mine boundary. This is the reason for the current manner in which atmospheric emissions are treated for mining operations. Dust suppression methods that are most frequently used in local mining operations include the wet suppression and the chemical stabilisation of haul roads and storage piles, and the vegetation or rock cladding of tailings impoundments.

Rössing Uranium Mine is located 23 km southwest of the proposed Valencia Uranium Mine. Rössing Mine comprises of a large open pit and is one of the largest uranium mines in the world. Trekkopje mine is another proposed uranium mine in the region and also plans to be opencast. Trekkopje is located approximately 15 km to the northwest of Valencia Mine. Both these mines are considered too far away to have a significant influence on the ambient air quality in the vicinity of Valencia Mine.

4.2.3 Vehicle Tailpipe Emissions

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by motor vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulates and lead. Secondary pollutants include: nitrogen dioxide (NO_2), photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

Vehicle tailpipe emissions are also localised sources and unlikely to impact far-field. The roads in the vicinity of the proposed Valencia Mine are located some distance away with the national road between Swakopmund and Windhoek approximately 14 km away to the northwest. Other roads in close proximity to the mine will only be used by mine vehicles.

4.2.4 Agricultural Activities

During the site visit conducted in August 2007 it seemed that the main activity in the region is farming. The region is too arid for crop farming and the main activity seems to be cattle, sheep, goat and game.

Cattle farms (primarily when operated on large scale) are significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. Pollutants associated with dairy production for instance include ammonia (NH_3), hydrogen sulphide (H_2S), Methane (CH_4), Carbon dioxide (CO_2), Oxides of Nitrogen (NO_x) and odour related trace gasses. According to the U.S.EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation.

Organic dust includes dandruff, dried manure, urine, feed, mold, fungi, bacteria and endotoxins (produced by bacteria, and viruses). Inorganic dust is composed of numerous aerosols from building, materials and the environment. Since the dust is biological it may react with the defence system of the respiratory tract. Dust and gas levels are higher in winter, or when ever animals are fed, handled or moved (http://www.cdc.gov/nasd/docs).

4.2.5 Biomass Burning

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. The quantity of dry, combustible matter per unit area is on average 4.5 ton per hectare for savanna areas.

Biomass burning is an incomplete combustion process with carbon monoxide, methane and nitrogen dioxide being emitted during the process. About 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. The visibility of smoke plumes from vegetation fires is due to their aerosol content.

4.2.6 Fugitive Dust Sources

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils are required to be known in order to quantify fugitive emissions from this source. The quantity of wind blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: NO_2, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphur acid, sulphates, nitric acid and nitrate aerosols.

4.3 Measured air quality

No ambient air quality measurements are conducted at Valencia Mine or anywhere else in the region. A dust fallout monitoring network was established at the end of August 2007 and is managed by DWA. The dust fallout monitoring network comprises of three multi-directional dust buckets placed at the mine property borders and one near the existing farmhouse, forming a triangle. A total of eight single dust fallout buckets have also been installed (Figure 4-7).

Dust fallout has been reported by DWA for a three month period, from the 28^{th} of August to the 4^{th} of December 2007. The main findings indicated dust fallout within the South African DEAT MODERATE (250 to 500 mg/m²/day) category for the three multi-directional buckets (summed results from each sampler). The results from the single buckets were all within the SLIGHT (<250 mg/m²/day) dust fallout categories. Single bucket 6 recorded the highest dust fallout (108 mg/m²/day). The three multi-directional buckets indicated different contributing sources with MD1 reflecting higher dust fallout from the south, MG2 had higher dustfall from the west and MG3 reflected highest dust fallout from the east (DWA, 2007).

The dust fallout monitoring will continue for at least 1 year.

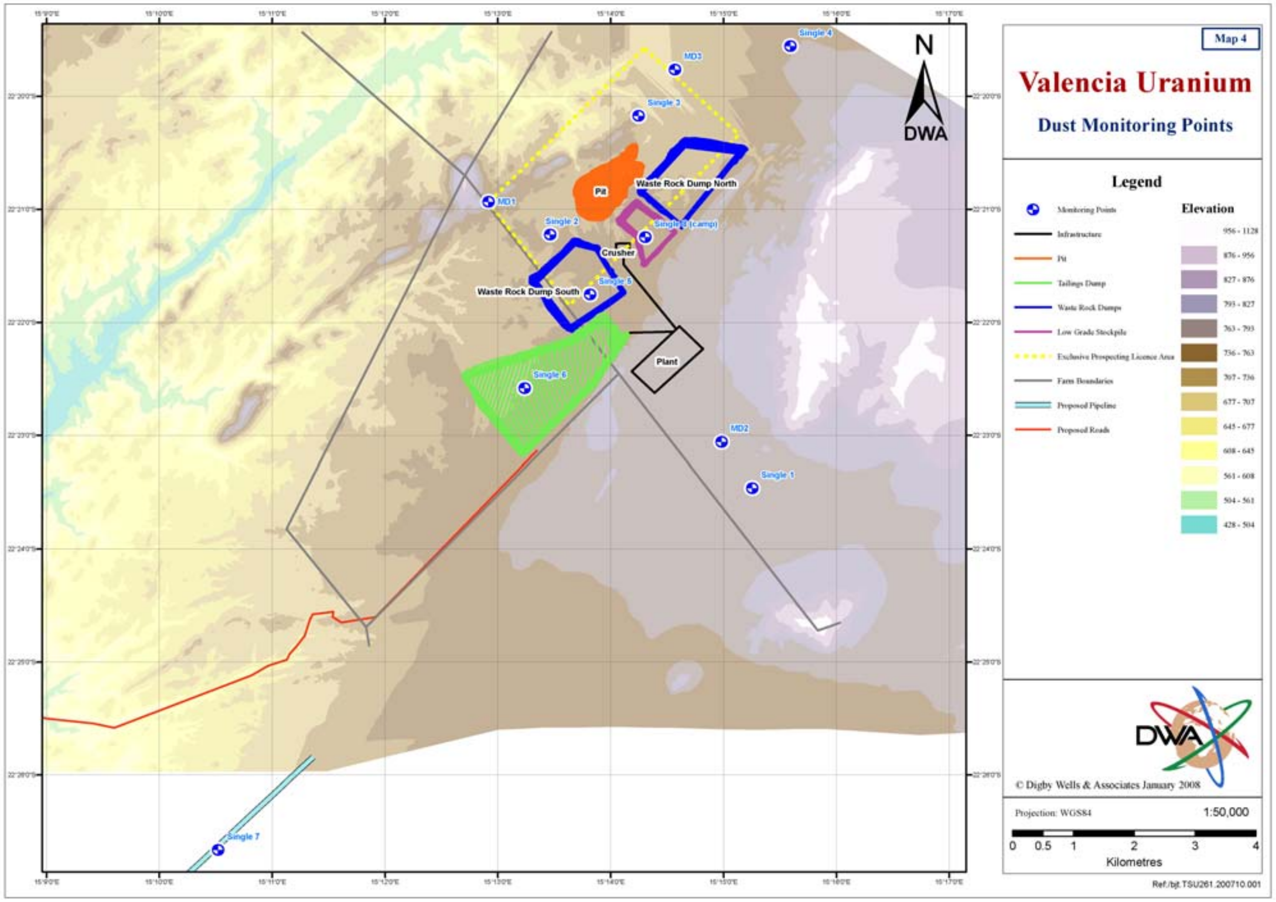

Figure 4-7: Valencia Mine current Dust fallout monitoring network (DWA, 2008).

5 VALENCIA URANIUM MINE EMISSIONS INVENTORY

An emissions inventory for all primary and secondary sources of emissions for the proposed Valencia Uranium Mine was established. The emissions inventory forms the basis for assessing the impact of gaseous and particulate emissions from the processes on the receiving environment. The establishment of an emissions inventory comprises the identification of emission sources, and the quantification of each source's contribution to ambient air pollution concentrations.

The nature and significance of air quality impacts associated with the proposed operations at Valencia Mine forms the focus of the current section. The approach adopted in this section includes the identification of sources of emissions and types of pollutants released, determination of pertinent source parameters, establishment of particle size distributions and chemical compositions of particle emissions, and quantification of each source’s emissions.

5.1 Identification of Environmental Aspects and Impact Criteria

The Valencia Uranium Mine is a proposed mine, with no infrastructure developed for the mine to date. The mining operations were based on design information obtained from the Snowden Pre-feasibility Report (Snowden, 2007). The proposed layout of the mine site was provided by Valencia Uranium (Pty) Limited. The proposed production of the mine is estimated at 1 Mtonnes per month.

The mine will comprise of an open pit utilising truck and shovel mining methods. Primary, secondary and tertiary crushing will form part of the ROM processing. Milling will reduce the material sizes even further before entering the leach and oxidation process at the processing plant where the uranium is extracted. Two waste rock dumps will be generated throughout the life of mine with a low-grade storage pile located southeast of the open pit. One tailings dump will be required to handle the waste stream from the processing plant, and two only one optional locations are currently explored for placing the Tailings dump. An access road will be constructed to link the mine with the main road between Swakopmund and Windhoek. Table 5-1 provides the environmental aspects identified to have an influence on air quality with Figure 5-1 providing the proposed layout of the mining processes.

In assessing atmospheric impacts from the above activities an emissions inventory was compiled. The main pollutant of concern generated as a result of proposed Valencia mining and process operations is fugitive dust. As illustrated in Table 5-1 the Valencia Mine operations will generate TSP, PM10 and various gaseous emissions, including SO_2 and SO_3 from the acid plant. In the quantification of these releases use is made of the predictive emission factors published by the US-EPA (EPA, 1996), since no local emission factors are available.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors and emission inventories are fundamental tools for air quality management. The emission factors are frequently the best or only method available for estimating emissions produced by varying sources. Emission estimates are important, amongst others, for:

- Developing emission control strategies;
- Determining applicability of permitting and control programmes; and
- Ascertaining the effects of sources and appropriate mitigation measures.

Table 5-1: Activities and aspects identified for the operational phase of the Valencia Uranium Mine.

Impact	Source	Activity
Generation of TSP and PM10	Mining operations within open pit area	Waste rock removal by excavator
		Ore removal by excavator
		Drilling and blasting
	Materials handling operations	Loading of waste rock onto trucks and tipping onto discard stockpiles
		Loading ore onto trucks and tipping at crusher / ROM storage piles
		Tipping of ore to storage piles
	Vehicle activity on unpaved roads	Haul trucks transporting waste from open pit to discard stockpiles
		Haul trucks transporting ore from open pit to the primary crusher
	Wind erosion	Tailings dump
		Waste rock dumps
		ROM storage piles
		Product storage piles
	Crushing and screening	Primary crusher
		Secondary crusher
		Tertiary crusher
	Milling	Rod or SAG mills
SO_2 , SO_3, H_2SO_4 & CO_2	Acid Plant	SO_2 to H_2SO_4
SO_2 & VOCs	Leaching & Oxidation	Leach tanks
NH_3		Multi-hearth furnace

It is important to note that revision of these factors is undertaken by the relevant regulating bodies. It is recommended that in maintaining an up-to-date database and emissions inventory, the responsible person/s (air quality), subscribe to the CHIEF Listserv (used by the US-EPA's emission factor and inventory group) to receive information pertaining to:

- New, final or draft sections to AP-42 – compilation of air pollutant emission factors;
- New emission inventory documents;
- New editions of the CHIEF newsletter;
- New releases of software tools; and
- Updates to the emission inventory improvement program reports.

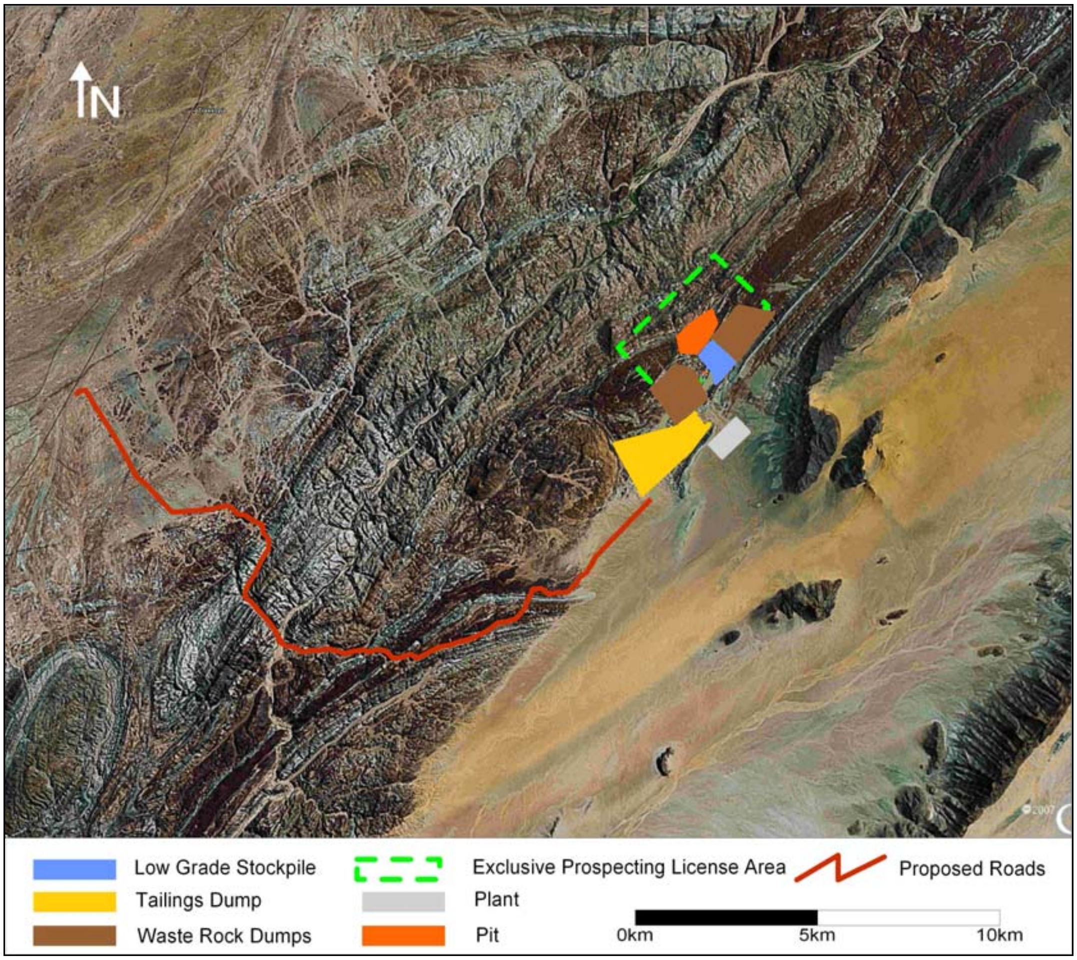

Figure 5-1: Site layout plan for the proposed operations at Valencia Uranium Mine.

5.2 Quantification of Environmental Impacts

Fugitive dust, generated from materials handling operations, wind erosion, crushing/screening and vehicle-entrainment from unpaved roads, is classified as *routine* emissions and is fairly constant throughout the year. Upset conditions may, for example, arise due to drilling and blasting operations.

In the quantification of fugitive dust releases use was made of the predictive emission factor equations published by the US-EPA (EPA, 1996). In addition, use was made of the National Pollutant Inventory (NPi) compiled by the Australian Government (ANPI, 2001). The emission factors used in the current study, and assumptions made in their application, are described below. No local emission factors are available. Fugitive dust emission rates will be estimated for PM10 (i.e. particles <10 µm) and total suspended particulate (TSP).

All the operations were assumed to be continuous for 365 days per year for 24 hours of the day.

5.2.1 Materials Handling Operations

Materials handling operations will result in fugitive dust releases from the various mining operations, the crushing plant and at the processing plant. These activities mainly include the transfer of material by means of tipping, loading and off-loading of trucks and conveyor transfer points. The quantity of dust generated from such loading and off-loading operations depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emissions, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

Equation 1 as depicted and discussed in Appendix B was used to calculate the emission rates from tipping. The emission factors for conveyor transfer points were applied to determine emission rates from these activities and are discussed under section B.1.2 (Equation 2).

The equation for tipping (Equation 1) takes into account the influence of wind speeds on the material being tipped, whereas the emission factors applied to loading and off-loading are single valued emission factors merely accounting for the amount of material handled (i.e. kg of dust per tonne of material handled). The Australian NPi recommends the same equation as for tipping to be applied to excavators, shovels and front-end loaders. The tipping equation was applied to all material transfer actions. The quantity of dust generated from the materials handling operations identified was based on the amount of material stored and retrieved each month. Where no site-specific information was available use was made of the US.EPA AP42 documentation on similar processes.

Material transfer for each type of operation from the mine and processing plant is given in Table 5-2. Most of the material transfer points are at the crusher plant. For the open cast mining limited information was available and use was made of the EIA information from Trekkopje Mine (~14 km to the northwest), assuming that the ore and waste properties would be similar. All tipping points and conveyor transfer points were taken to be open with no mitigation in place.

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations.

Table 5-2: Material transfer for each type of operation.

Location	Activity	Throughput (tonnes / day)
In-pit	ROM ore from excavator to haul truck	35,625.00
	Waste rock to haul truck	35,625.00
Crusher plant	ROM ore from in-pit to ROM pad	35,625.00
	ROM ore form ROM pad to primary crusher	35,625.00
	Primary Crusher to secondary crusher	33,848.68
	Secondary crusher to tertiary crusher	21,973.68
Waste Dump(s)	Waste rock to waste rock dump	11,875.00
Processing Plant	Conveyor tipper to rod mills	23,750.00

5.2.2 Excavation Operations

Emission equation 3 was applied to excavation of ore and waste rock as explained in Appendix B. The parameters taken into account for this equation are the material silt content and moisture content, the mean wind speed and the material throughput. Table 5-3 includes the throughput for the open pit sources at the Valencia Mine.

Table 5-3: Open pit mining sources.

Mining Area	Area (m²)	Tonnes/month	Moisture (%)	Mean Wind Speed (m/s)
Ore	250,000.00	1,033,333.33	2	3.36
Waste rock	250,000.00	716,666.67	2	3.36

5.2.3 Drilling and Blasting

The opencast operations at the mine will consist of drilling and blasting of waste rock and ore bearing rock, and removal thereof by means of an excavator. Almost no topsoil is present at the Valencia Mine site and the proposed operations will primarily entail the removal of ore and waste rock by means of excavators and trucks. The waste material will be removed to the waste rock dumps located near the proposed open pit.

Drilling at opencast mines is typically a continuous process and drilling operations were assumed to be for 24 hours per day. In the quantification of emissions from drilling, the single valued emission factor published by the US.EPA is used (see Equation 4, Appendix B). The units of this emission factor are kg of particulates per drill hole. Information on the number of drill holes and the area affected and these are listed in Table 5-4. Information on drilling and blasting was provided by Valencia Uranium (Pty) Limited.

Table 5-4: Information provided on drilling and blasting activities.

Activity	Units	Waste Material & Ore
Time of day when drilling will occur	hours	24
Time of day when blasting will occur	hours	11h00 - 16h00
Tonnes to be blasted at a time (multiple blasts at a time)	(t)	250,000
Equivalent area blasted at a time	(m²)	9,500
Number of drill holes	per month	5,000
Moisture content	(%)	2
Depth of holes	(m)	12 to 17

Blasting is typically done once a day (or once every several days) and usually occurs in the early afternoons between 11h00 and 16h00. The emission factors for the estimation of fugitive dust emissions from blasting, published by the Australian NPi (ANPi, 2001), were applied and are discussed in Appendix B (Equation 5). The equation requires the area (m²) to be blasted, the moisture content of the material and the depth. The area to be blasted in a year was taken from the Snowden Pre-feasibility Report (Snowden, 2007) and provided in Table 5-4.

Gaseous emissions deriving from blasting operations are directly related to the type of explosives used. The US.EPA has a single value emission factors for ANFO explosives. The same emission factors were adopted by the Australian NPi. Pollutants expected to derive from the explosives include SO_2, NO_x, and CO. No information on the types and quantities of explosives used was available for use in the current study.

5.2.4 Wind Erosion from Exposed Areas

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger *et al*., 1997).

ROM ore will be stockpiled at the crusher plant with a low grade storage pile located near the open pit. Two waste rock dumps will be constructed to accommodate the waste material produced by the open pit operations. A tailings dump will be developed to handle the fine waste material produced by the processing plant. An hourly emissions file was created for each of these source groups. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995) references cited. The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface.

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are discussed in Appendix B (Equations 6 and 7).

Information regarding the nature of the source, the percentage of exposed surface area and the type of material was provided by Valencia Uranium (Pty) Limited. The waste dump and tailings dump dimensions were based on the footprint from the maps provided by Valencia Uranium (Pty) Limited for the project layout. Additional information required for the estimation of emission rates from wind erosion is particle density and bulk density. No particle size distribution information was available and use was made of the particle size analysis done for Trekkopje Mine (Burger and Le Roux, 2006). Ore and waste densities were obtained from the Snowden Pre-feasibility Report. The information on the different storage piles and dumps is listed in Table 5-5 and includes the size, height and volume of each source.

Table 5-5: Parameters for wind erodable sources at the proposed Valencia Uranium Mine.

Source	Height (m)	Length (m)	Width (m)	Volume (m^3)	Moisture (%)	Bulk Density (kg/m^3)	Control Efficiency (%)(a)
Waste rock dump-North	53	1,292	891	61,064,329	2	1,900	0
Waste rock dump-South	50	1,035	932	48,220,850	2	1,900	0
ROM Storage Pile (from opencast mine)	1.2	100	100	12,000	2	1,645	0
Low-grade Storage Pile	30	800	450	10,800,000	2	1,645	0
Tailings Dump	40	3,000	1,000	120,000,000	2	1,645	0
Notes: **(a)** None known - assumed no controls.							

5.2.5 Crushing and Screening Operations

Primary screening operations represent significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of screens also give rise to the potential for the re-entrained of dust emitted by vehicles or by the wind at a latter date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne.

Dry crushing and screening will take place at the crusher plant. Primary, secondary and tertiary screening operations will take place. Dust extraction at the screening is not included in the design and uncontrolled crushing and screening was assumed. Single valued emission factors were applied in the quantification of possible emissions due to crushing and screening as depicted in Appendix B (Equation 8). The US-EPA only supplies emission factors for stone crushing processes and metallic mineral processes. The emission factor for controlled screening was applied to the material being screened. The feed rate to the primary, secondary and tertiary crushers are provided in Table 5-6.

Table 5-6: Emission parameters for crushing and screening operations.

Process	Throughput (tpd)	Moisture Content (%)	Control Efficiency (%)(a)
Primary Crushing	35,625.00	2	0
Secondary Crushing & Screening	33,848.68	2	0
Tertiary Crushing & Screening	21,973.68	2	0
Notes: **(a)** None known - assumed no controls.			

5.2.5.1 Vehicle Entrainment on Unpaved Roads

Vehicle-entrained dust emissions from unpaved haul roads could be a significant source of fugitive dust. Haul roads will run from the opencast mine at Valencia to the waste rock dumps, low-grade ore storage pile and crushing plant. Haul roads are typically unpaved and will remain so due to the changing nature of the roads. An unpaved access road, linking the processing plant at Valencia and the main road (Windhoek/Swakopmund) will be established. The definite route of this road has not yet been established and two options were proposed and were included into the current study. Due to the water scarcity in the region it was taken that water prays will not be a feasible option for dust suppression. A more likely mitigation measure would be chemical suppressants. As a conservative approach however, no controls were assumed for the haul roads and the unpaved access road.

The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions for the current study, is given in Appendix B, Equation 9. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic. Such parameters include average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1996). For the Valencia operations, the amount of ore and waste to be hauled from the open pit area was applied.

The haul road lengths and total vehicle kilometres travelled per day for all proposed truck activities are provided in Table 5-7.

Table 5-7: Parameters used to calculate emissions from vehicle-entrained dust.

Vehicle	Length road (a) (m)	Width of road (m)	Area (m^2)	Silt (%)(b)	Vehicle Capacity (tonne)	VKT per day
Open pit to Waste Rock Dump	1,835	20	36,700	8.4	140	890.57
Open pit to Low-grade Storage Pile	491	20	9,820	8.4	140	40.36
Open pit to ROM Storage Pile	514	20	10,280	8.4	140	130.76
Plant to Drop-off point	33,222	7	664,440	8.4	10	31.89

Notes: VKT/day is vehicle kilometres travelled per day for all the trucks on the roads.
(a) Road lengths assumed to be the shortest sensible route to destination.
(b) Taken from Table 13.2.2-1 – haul road silt content (US.EPA, 2003).

5.3 Synopsis of Particulate Emissions from all Valencia Mining Sources

Total TSP and PM10 emissions calculated for various sources at Valencia Mine are given in Table 5-8. Figures 5-2 and 5-3 provide the same information in graph form for TSP and PM10, respectively. The Table depicts total emission rates from all activities associated with the mining and process activities. Vehicle entrainment on all roads was also taken into account and the wind erosion from storage piles, tailings dump and the waste dumps were accounted for.

From this assessment, it is evident that vehicle entrained dust from all the unpaved roads are the main contributing source to fugitive dust emissions contributing 50% of total TSP emissions and 44% for PM10 emissions. The second largest source is emissions due to wind blown dust from the open and exposed surfaces (storage piles, waste dumps and tailings dump) with a 29% contribution for PM10 and 30% for TSP. Crushing and screening operations ranked the third largest source of TSP emissions (10%) with excavation activities ranking third for PM10 emissions (14%).

Table 5-8: Total TSP and PM10 emissions estimated due to the proposed operations at Valencia Mine.

Source Group	Emissions					
	TSP (tpa)	PM10 (tpa)	TSP (%)	PM10 (%)	TSP rank	PM10 rank
Excavation	475	228	9.2	14.1	4	3
Tipping	31.3	8.1	0.6	0.5	6	5
Crushing& Screening	492	197	9.6	12.2	3	4
Wind Erosion	1,563	463	30.3	28.6	2	2
Drilling & Blasting	38.1	4.1	0.7	0.3	5	6
Vehicle Entrainment	2,551	720	49.5	44.4	1	1
TOTAL	**5150**	**1620**	**100**	**100**	-	-

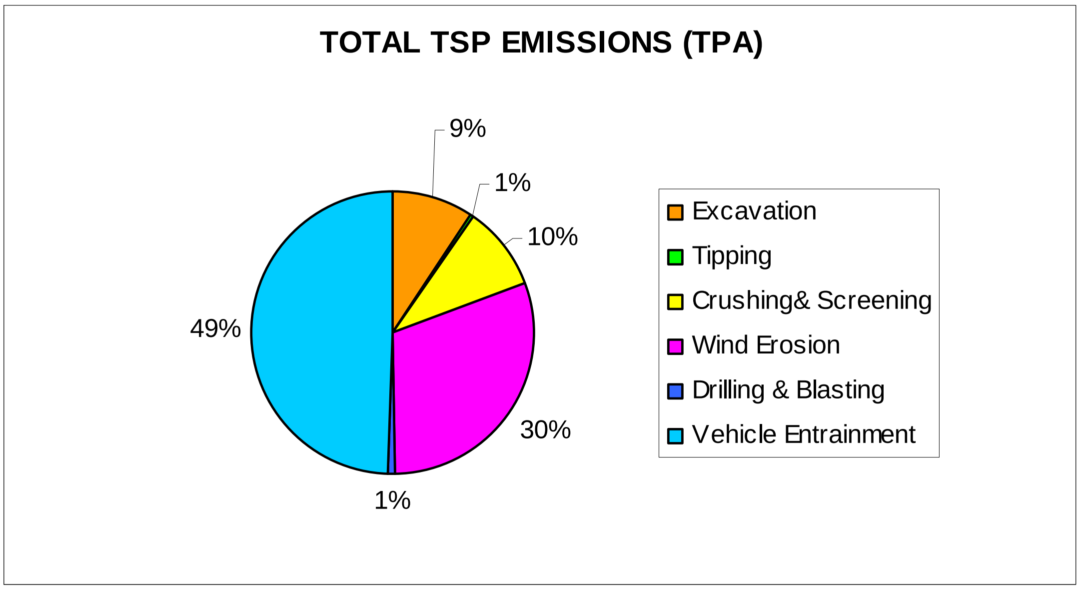

Figure 5-2: TSP Emissions contribution for all sources at Valencia Mine.

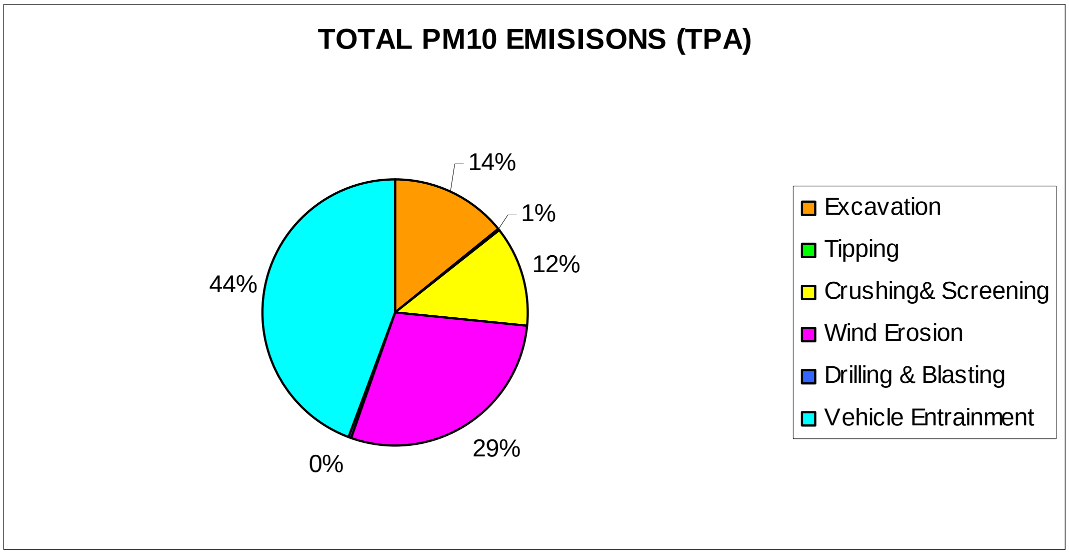

Figure 5-3: PM10 Emissions contribution for all sources at Valencia Mine.

5.4 Acid plant emissions

The manufacturing of Sulphuric Acid uses the contact process. This process is classified according to the raw materials charged, which can include elemental sulphur burning, spent sulphuric acid and hydrogen sulphide burning, and metal sulphide ores and smelter gas burning (EPA, 1995b). No specific design for the proposed acid plant was specified. A brief process description is based on that of the contact process.

The process incorporates three basic operations, each with a distinct chemical reaction. The first step is the oxidisation of the feedstock to sulphur dioxide (SO_2) by means of burning (roasting):

$$S + O_2 \rightarrow SO_2 \quad (1)$$

Step two of the process is the conversion process where the SO2 gas is catalytically oxidised to form sulphur trioxide (SO3):

$$2SO_2 + O_2 \rightarrow 2SO_3 \quad (2)$$

The final step is to absorb the SO_3 in a strong 98% sulphuric acid solution:

$$SO_3 + H_2O \rightarrow H_2SO_4 \quad (3)$$

In the case of sulphide ores and smelter gas plants, the concentrate/feed is passed through a roaster where it is heated to drive the sulphur off in the form of sulphur dioxide (SO_2). The SO_2 in the off-gas is contaminated with dust, acid mist and gaseous impurities. In order to remove the gas must be cooled and passed through purification equipment consisting of electrostatic dust and mist precipitators, and scrubbing and gas cooling towers. After the gases are cleaned and excess water vapour is removed, it is scrubbed with 98% acid in the drying tower (EPA, 1995b). The converter process will comprise 4 stages of conversion resulting in a 99.84% conversion rate from SO_2 to sulphuric acid.

The main pollutants of concern associated with the sulphuric acid production are sulphur dioxide (SO_2), acid mist (H_2SO_4 & SO_3) and carbon dioxide (CO_2). Nearly all the SO_2 emissions are found in the exit stack gasses and are directly a function of the sulphur conversion efficiency (SO_2 oxidised to SO_3). Conversion is always incomplete and is affected by the number of stages in the catalytic converter, the amount of catalysts used, temperature and pressure, and the concentrations of the reactants. Dual absorption has been considered best available control technology with conversion efficiencies of 99.7% and higher (EPA, 1995b).

Sulphuric acid mist forms when SO_3 combines with water vapour at a temperature below the dew point of SO_3. Once formed it is stable with very little being removed in the absorber. The operating temperature of the absorption column directly effect SO_3 absorption depends and subsequently the amount of acid mist that forms in the exit gas. One way of controlling acid mist in the exit gas is by means of a fibre mist eliminator control device. According to the US.EPA only small amounts of carbon dioxide (CO_2) will be emitted from sulphuric acid plants (EPA, 1995b).

Six scenarios will be modelled to reflect the change in ground level impacts according to six different acid plant designs, with stack parameters summarised in Table 5-9 and emission rate provided in Table 5-10.

Table 5-9: Stack parameters for the proposed Acid Plant.

Parameters	Units	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Stack height	m	30	50	75	30	50	75
Stack inner diameter [(a)]	m	1.12	1.12	1.12	1.12	1.12	1.12
Stack exit temperature	°C	80	80	80	80	80	80
Exit gas velocity	m/s	16	16	16	20	20	20
Volumetric flow rate	Am^3/hr	15.7633	15.7633	15.7633	19.7041	19.7041	19.7041
Notes: [(a)] Stack diameter was calculated based on the exit gas velocity and volumetric flow rate.							

Table 5-10: Emissions rates as quantified for the acid plant stack.

Pollutant	Emission rate (g/s)					
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
SO_2 [(1)]	3.47	3.47	3.47	-	-	-
SO_3 [(2)]	0.61	0.61	0.61	0.762	0.762	0.762
Notes: [(1)] Assumed SO_2 = 150 tpd at a conversion of 99.8% [(2)] Assumed SO_3 = not to exceed 50 µg/Nm³.						

Upset conditions will occur during plant start-up and during shut down for maintenance, usually occurring once a year. However, the changes in ground level impacts due to upset conditions are not believed to be significant and therefore, these impacts were not modelled.

6 IMPACT ASSESSMENT OF THE PROPOSED VALENCIA URANIUM MINE

6.1 Dispersion Simulation Results

Dispersion simulations were conducted for all sources associated with the proposed Valencia Uranium Mine Project (viz. mining, materials handling, vehicle entrainment, processing, etc.). Since ambient air quality guidelines and standards are applicable to the assessment of off-site, community exposures (rather than occupational exposures), the predicted concentrations were assessed at the mine boundary and at the farm house. PM10 concentrations, dust fallout, SO_2 and SO_3 data predicted to occur were therefore calculated as a percentage of the relevant guidelines and standards for the purpose of compliance assessment. Reference was made to the guidelines issued by South Africa and the World Bank (WB) and World Health Organisation (WHO).

As discussed in Section 3, AERMOD was used to reflect the impacts from the proposed mining operations. Since no ambient monitoring data for PM10 or SO_x in the region exist, no cumulative assessment could be undertaken. The impact assessment therefore only includes the contribution to ambient air quality in the region from the proposed Valencia Mine sources.

Isopleth plots were generated for PM10 concentrations and dust fallout reflecting all relevant averaging periods for which ambient air quality guidelines and standards exist. It should be noted that the isopleth plots reflects the highest predicted ground level concentrations/depositions for that averaging period, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period of operation. For SO_2 and SO_3 concentrations, isopleth plots were generated, reflecting only the worst-case scenario (highest predicted ground level concentrations) for all relevant averaging periods.

For the dispersion simulations, two control options were simulated namely (i) unmitigated and (ii) mitigated. For the unmitigated option, no controls on any of the sources of emissions were assumed. This can be regarded the worst-case scenario for the proposed mining operations. Based on the emissions inventory (Section 5.3) the main sources of fugitive emissions were identified to be vehicle entrainment on unpaved roads, wind erosion and crushing and screening. It should be noted that the waste rock dumps and Tailings dump were taken at the final design heights and therefore reflected the worst case scenario. Given the water scarcity in the region, mitigation options requiring water suppression methods were regarded unfeasible. Thus, for the mitigated option the following controls were assumed:

- Access road (from main road to Valencia mining site) – 95% Control Efficiency (CE) due to the application of chemical suppressants.
- Open pit operations – between 5% and 50% CE due to pit retention

A detailed description of mitigation options for various sources is included in Section 6.

6.1.1 Inhalable Particulates (PM10)

The concentrations simulated at the referenced receptor points are depicted in Table 6-1. These concentrations reflect emissions from all sources, including the mine, truck activity, crushing and screening and processing operations. Impacts were assessed at a location to the southwest of the open pit near the mine boundary (downwind from most of the activities) and at the existing farm house. Concentrations were referenced against the proposed South African standards, the WBG and WHO guidelines as a fraction. Thus where this value is greater than one an exceedance of the relevant guideline in indicated. The spatial representation of PM10 highest daily and annual average concentrations due to unmitigated sources are illustrated in Figures 6-1 and 6-3, respectively. These plots represent the predicted impacts from all sources at the mine. Figures 6-2 and 6-4 reflect the predicted concentrations due to the selected mitigation options applied. The plots reflecting the incremental contributions from the various sources (including predicted impacts from blasting) are provided in Appendix C.

- The PM10 concentrations predicted near the mine boundary fell within the selected referenced guidelines (i.e. proposed South African, WBG and WHO) for both highest daily and annual averages. The highest concentrations were predicted to occur at the farm house with the highest daily average concentration matching the WHO air quality guideline of 50 $\mu g/m^3$. The annual average concentrations were however well within the respective standards and guidelines. The predicted maximum ground level concentrations both for daily and annual averaging periods occurred on-site near the sources of emissions.
- With mitigation measures in place (i.e. treatment of access road and in pit emission reduction), the predicted maximum daily concentrations reduced by approximately 37% at both locations. Over an annual average the reductions were even higher, ranging between 44% and 69%.

Table 6-1: Predicted PM10 concentrations due to all operations at the proposed Valencia Uranium Mine (exceedances of air quality guidelines are highlighted).

Pollutant	Averaging Period	Standard/ Guideline	UNMITIGATED				MITIGATED			
			MAX AT MINE BOUNDARY		FARM HOUSE		MAX AT MINE BOUNDARY		FARM HOUSE	
			Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction	Max Conc	Fraction
PM10	Highest daily	75(a)	26.9	0.4	49.8	0.7	19.3	0.3	31.9	0.4
		70(b)		0.4		0.7		0.3		0.5
		50(c)		0.5		**1.0**		0.4		0.6
	Annual average	40(a)	3.0	0.1	5.83	0.1	1.8	0.05	3.2	0.1
		50(b)		0.1		0.1		0.04		0.1
		20(c)		0.2		0.3		0.09		0.2

Notes:

(a) The proposed South African standards for highest daily averages of 75µg/m³.
(b) World Bank (WB) general environmental guideline of 70µg/m³ utilised.
(c) The World Health Organisation (WHO) air quality guideline (AQG) of 50µg/m³.
(a) The proposed South African standard for annual averages of 40µg/m³.
(b) World Bank (WB) general environmental guideline of 50µg/m³ utilised.
(c) The World Health Organisation (WHO) air quality guideline (AQG) of 20µg/m³.

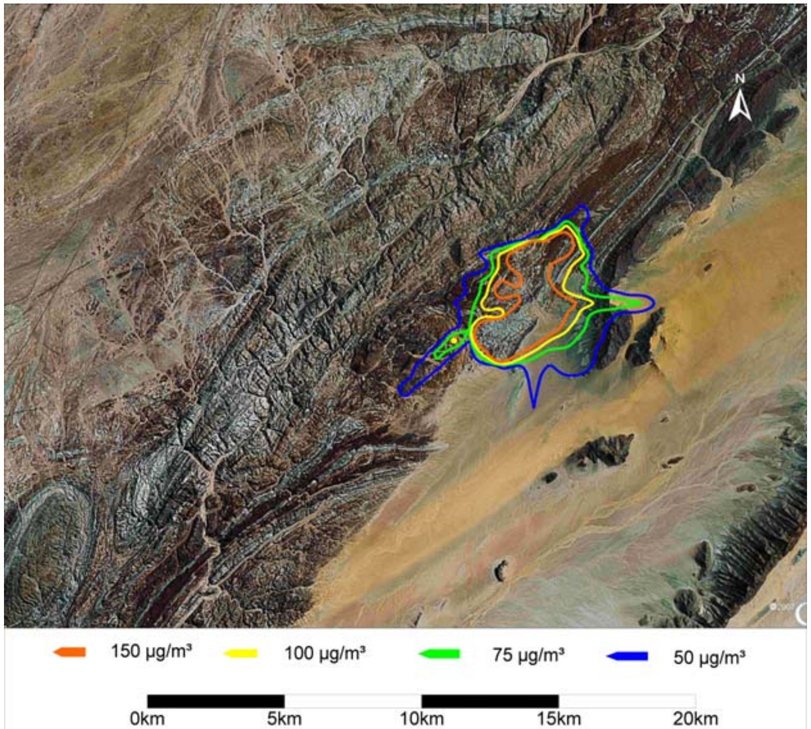

Figure 6-1: Daily predicted PM10 concentrations (µg/m³) for all sources at Valencia Uranium Mine – unmitigated

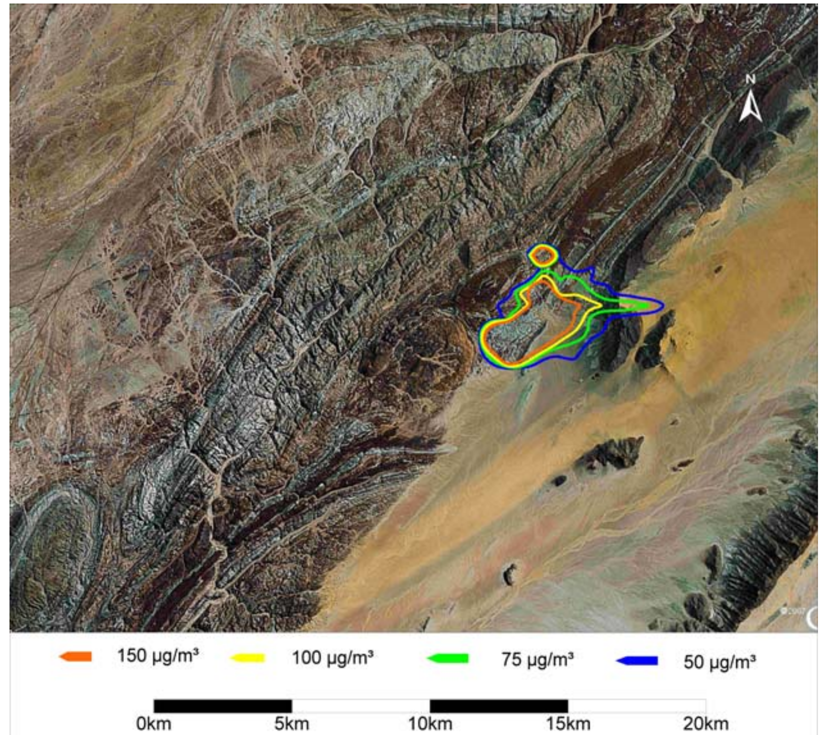

Figure 6-2: Daily predicted PM10 concentrations (µg/m³) for all sources at Valencia Uranium Mine – mitigated

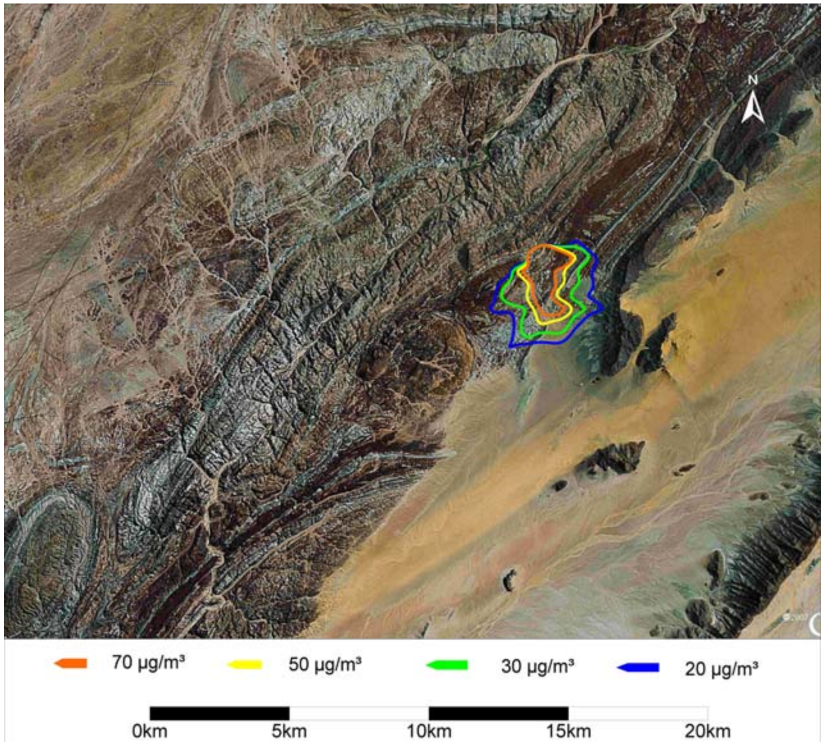

Figure 6-3: Annual predicted PM10 concentrations (µg/m³) for all sources at Valencia Uranium Mine – unmitigated

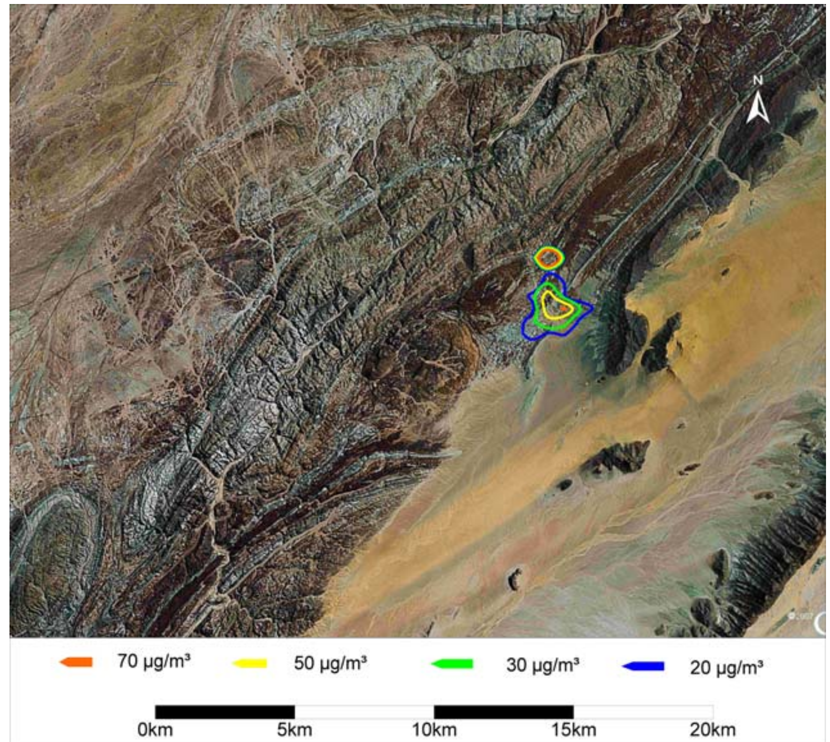

Figure 6-4: Annual predicted PM10 concentrations (µg/m³) for all sources at Valencia Uranium Mine – mitigated

6.1.2 Dust Deposition Levels

Dustfall impacts are generally confined to the near-field of sources. This is due to the fact that larger particles, which contribute most to dustfall rates given their mass, are likely to settle out in close proximity to the source (assuming a ground-based source). The US-EPA (1992) estimates that for a typical mean wind speed of 16km/hr (~4.4m/s), particles larger than about 100µm are likely to settle out within 6 to 9 metres from the edge of the source. Particles that are between 30µm and 100µm are subject to impeded settling, and are likely to settle out within 100 metres from the source.

Dust fallout levels were simulated for highest daily averages to reflect the same averaging periods used when measuring dust fallout. Figure 6-5 provides the predicted dust fallout levels considering no mitigation measures. Figure 6-6 depicts the same sources but assuming chemical suppressants on the haul roads and access road and open pit reductions. Table 6-2 provides the highest average daily dust fallout levels at the two areas identified and compared it against the South African proposed standards for dust fallout also as a fraction.

- The predicted dust fallout was low both at the point nearest the boundary and at the farm house with the highest levels predicted to be 22 mg/m²/day (at the farm house). This is with no mitigation measures in place.
- By adding dust suppression on the roads and open pit, the predicted dust fallout levels are reduced by approximately 5%.

Radiation associated with wind blown dust has not been considered as part of the air quality impact assessment and is seen to be covered by the Radiation Specialist. The predicted PM10 concentrations and dust fallout levels can however be used to determine the potential impacts from radiation within the modelling domain.

Table 6-2: Predicted dust fallout (TSP) due to all operations at the proposed Valencia Uranium Mine (exceedances of air quality guidelines are highlighted).

			UNMITIGATED				MITIGATED			
Pollutant	Averaging Period	Standard/ Guideline	MAX AT MINE BOUNDARY		FARM HOUSE		MAX AT MINE BOUNDARY		FARM HOUSE	
			Max Dep	Fraction	Max Dep	Fraction	Max Dep	Fraction	Max Dep	Fraction
TSP (mg/m²/day)	Daily Average	600(a)	13.2	0.02	22.1	0.04	12.5	0.02	20.9	0.03
		1,200(b)		0.01		0.02		0.01		0.02

Notes:
(a) The proposed South African residential action level.
(b) The proposed South African industrial action level.

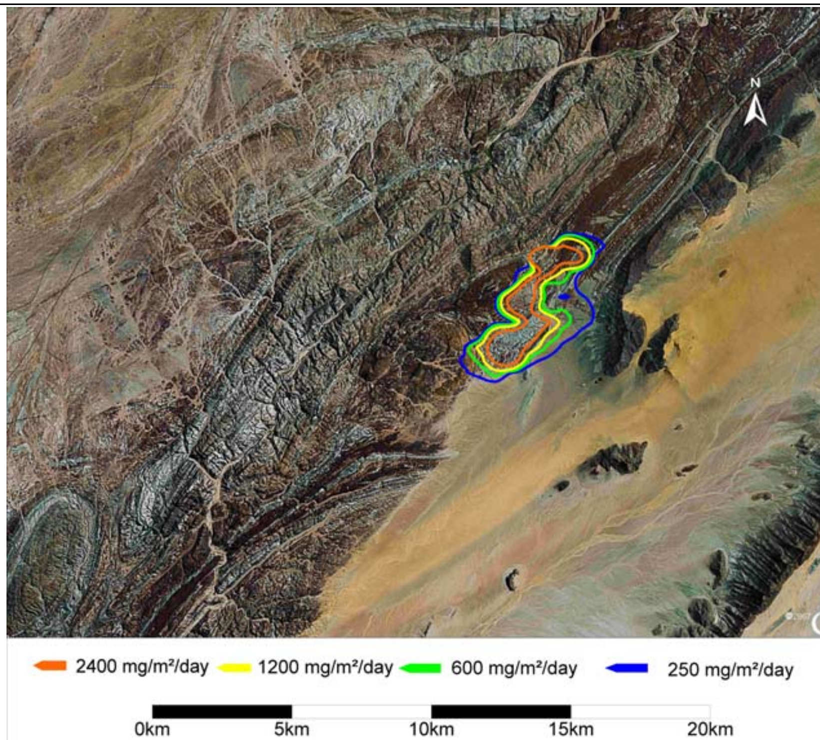

Figure 6-5: Total daily average dust fallout (mg/m²/day) for all sources at Valencia Uranium Mine – unmitigated

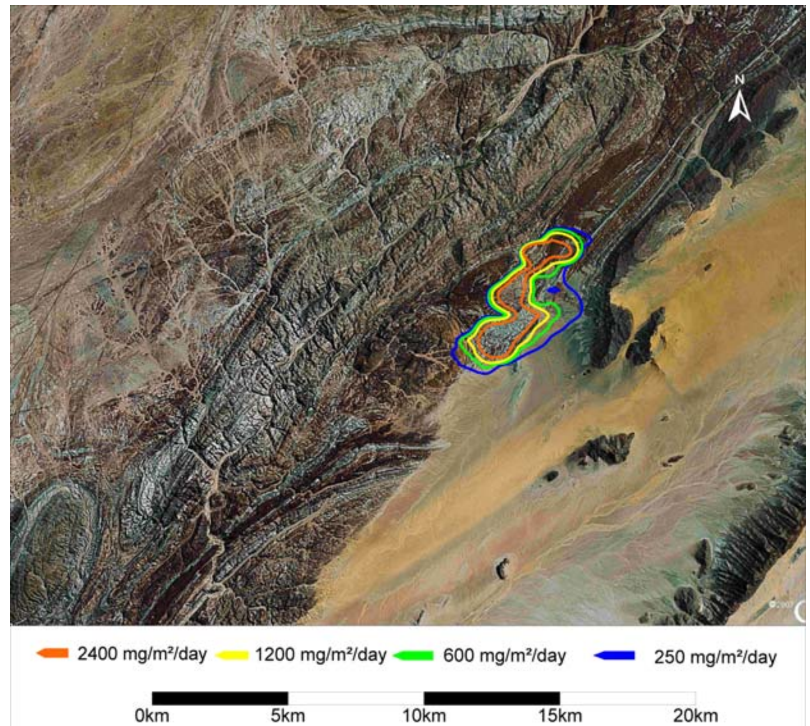

Figure 6-6: Total daily average dust fallout (mg/m²/day) for all sources at Valencia Uranium Mine – mitigated

6.2 Predicted Impacts from the proposed Acid Plant

The proposed acid plan will be located within the plant boundary. As discussed in Section 5.4, six different scenarios were assessed since the plant design has not been finalised. All 6 scenarios were simulated and the "worst-case" scenario was included in this section.

The predicted SO_2 ground level concentrations are provided in Figures 6-7 to 6-9 for highest hourly, highest daily and annual averages, respectively. The highest hourly and annual average plots for SO3 are provided in Figures 6-10 and 6-11, respectively.

- Scenario 1 resulted in the highest predicted ground level concentrations for both SO_2 and SO_3, with Scenario 6 resulting in the lowest.
- Predicted ground level concentrations of SO_2 (Scenario 1) were low and well within the EC Standard for highest hourly averages of 350 µg/m³. Even when compared to the stringent WHO Air Quality Guideline of 20 µg/m³ over a daily average, the predicted concentrations are below. Annual average predictions indicated insignificantly low concentrations.
- No ambient air quality guidelines exist for SO_3 and use was made of various screening criteria as discussed under Section 2.3.4. The highest hourly predicted ground level concentrations were below the TARA acute ESL of 10 µg/m³ for highest hourly averages except at the plant. The annual average concentrations were well below the 1 µg/m³ TARA chronic ESL.

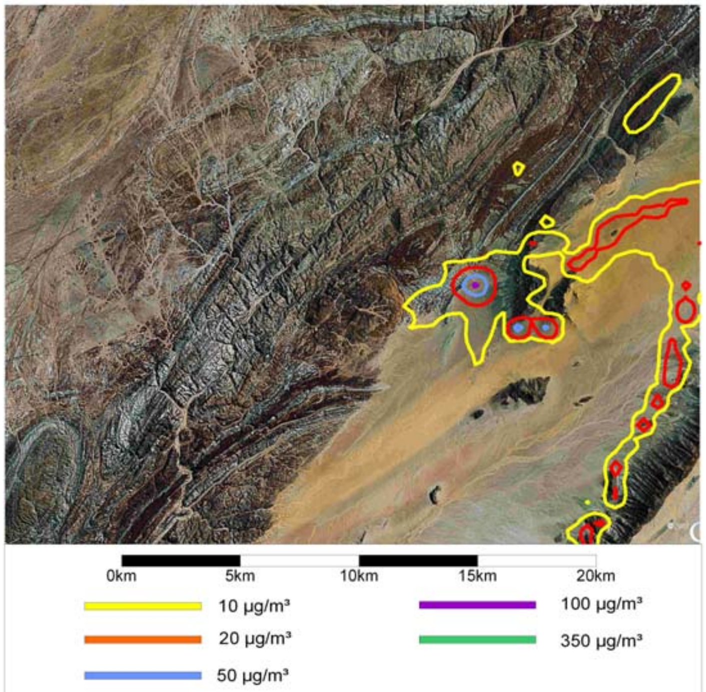

Figure 6-7: Hourly predicted SO_2 concentrations (µg/m³) for the acid plant at Valencia Uranium Mine – Scenario 1

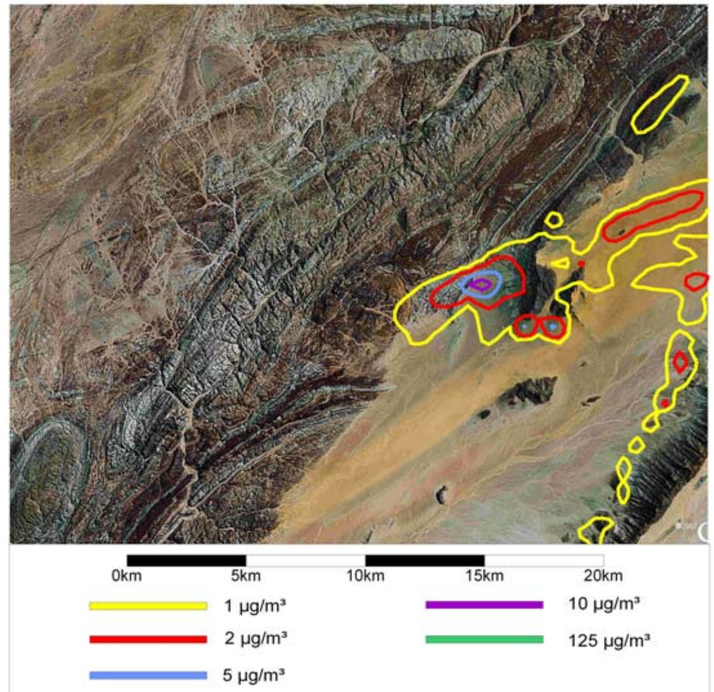

Figure 6-8: Daily predicted SO_2 concentrations (µg/m³) for the acid plant at Valencia Uranium Mine – Scenario 1

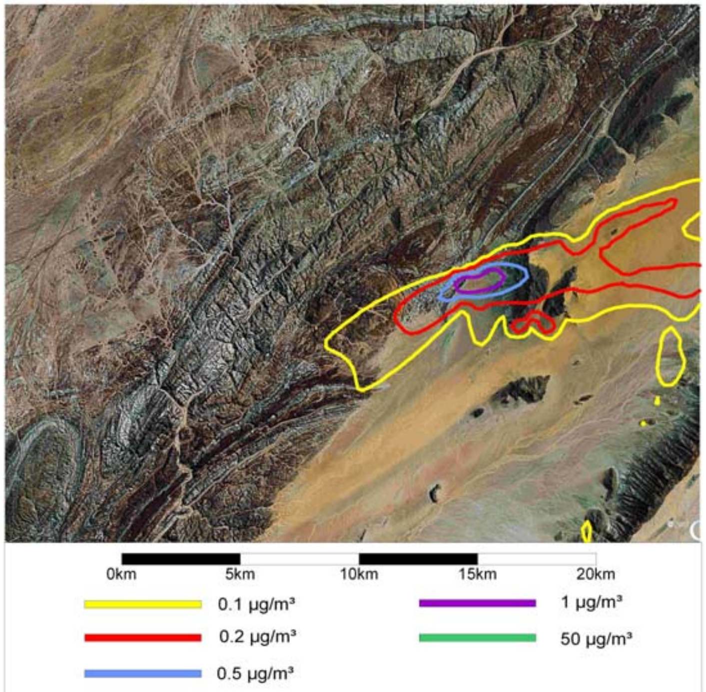

Figure 6-9: Annual average predicted SO_2 concentrations (µg/m³) for the acid plant at Valencia Uranium Mine – Scenario 1

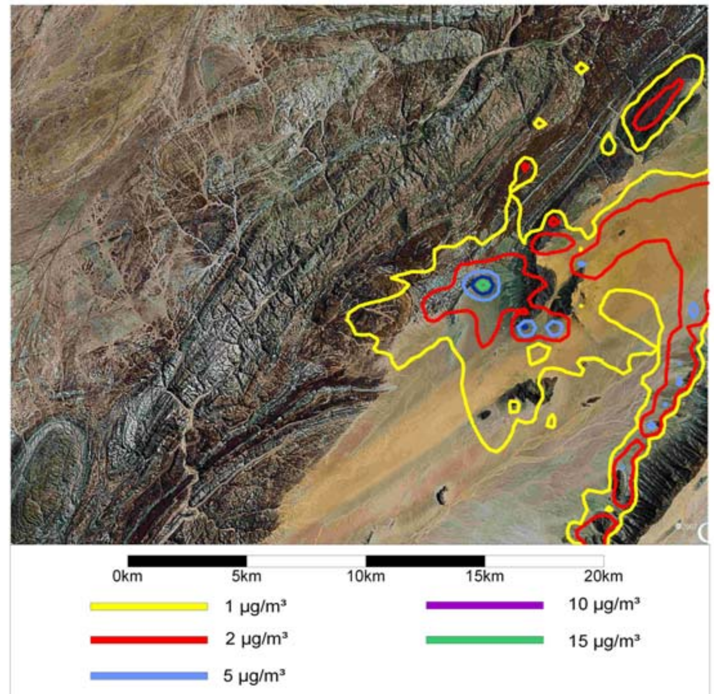

Figure 6-10: Hourly predicted SO_3 concentrations (µg/m³) for the acid plant at Valencia Uranium Mine – Scenario 1

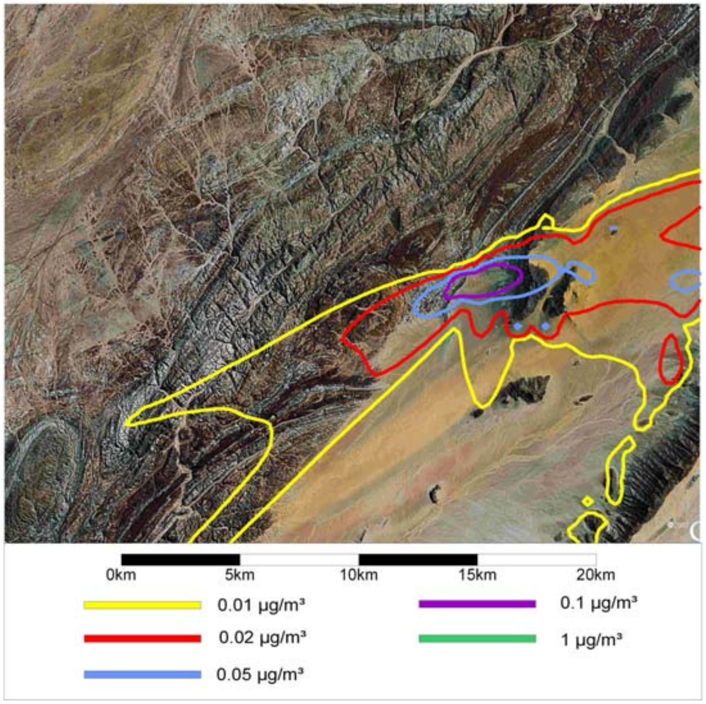

Figure 6-11: Annual average predicted SO_3 concentrations (µg/m³) for the acid plant at Valencia Uranium Mine – Scenario 1

6.3 Significance Rating of Operational Activities

The significance of atmospheric emissions estimated to emanate from activities during the operational phase may be determined based on the impact assessment matrices provided by DWA. Results from the significance rating are illustrated in Table 6-3.

The individual sources of emissions as stipulated in the emissions inventory section (Section 5.3) have been used for the significance rating. The main focus of air quality impacts are however on the contribution from all sources of emissions on the receiving environment and human health. The likelihood of implementing the possible mitigation measures were also taken into account during the significance rating. The mitigation options recommended are provided in Section 8 of this report.

The significance rating for the individual sources (i.e. excavation, drilling and blasting, crushing and screening, and materials transfer points) resulted in a significance of less than 35%, both considering human health impacts and nuisance impacts due to dust fallout. No thresholds for particulates exist to determine the significance of the impacts on vegetation. Wind blown dust from the Tailings dump resulted in a higher significance rating of 48% with wind blown dust from the waste rock dumps and low grade storage pile resulting in a significance rating of 28%. .

With mitigation measures taken into account, the significance rating for the individual sources reduced between 0% and 14%. For unpaved roads, should chemicals be applied to the road surface to curb dust emissions, the significance would reduce by 57%. The overall significance from all the sources would reduce by 33% considering the same mitigation measures.

The significance rating for the proposed Sulphuric Acid Plant was rated to be low (less than 16%). Since the design is on a 99.8% conversion this was regarded as part of the mitigation. Thus there is no unmitigated option for the Acid Plant.

It should be noted that the significance rating matrix has been designed primarily for environmental impact assessments and not for human health risks. The significance rating therefore does not provide an accurate representation of the potential risk associated with the inhalable dust impacts due to the proposed operations.

Table 6-3: Assessment of the significance of impacts during the operational phase for the Valencia Uranium Mine Project.

Unmitigated				Impact significance before mitigation							Mitigation	Impact significance after mitigation						
Activity	Impacted Environment	Impact	Positeve or Negative Impact	EIA Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)	Management/Mitigation Measure	EMP Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)
Excavation in open pit	Air quality	Inhalable (PM10) concentrations impacting on human health	N		2	1	3	6	3	24	With increase in pit depth reduction in emissions will occur		2	1	3	6	3	24
Dilling in open pit	Air quality		N		2	1	3	6	3	24	With increase in pit depth reduction in emissions will occur		2	1	3	6	3	24
Blasting in open pit	Air quality		N		2	1	3	6	3	24	Intermittent source of emissions - blast only during certain times of the day		2	1	3	6	3	24
Vehicle entrainment on haul roads	Air quality		N		3	1	3	7	3	28	Chemical sprays on roads (water soluble - not permanent)		2	1	3	6	3	24
Materials transfer points	Air quality		N		2	1	3	6	3	24	water sprays - limited water available		2	1	3	6	3	24
Crushing and Screening	Air quality		N		3	1	3	7	3	28	water sprays - limited water available / enclose with dust extraction system attached		2	1		3	3	12
Processing plant operations	Air quality		N		1	1	3	5	3	20	No mitigation options identified		1	1	3	5	3	20
Vehicle entrainment on access road	Air quality		N		3	2	3	8	3	32	Chemical treatment of roads (permanent)		2	2	3	7	3	28
Wind blown dust from Tailings dump	Air quality		N		3	2	4	9	4	48	Wind breaks & rock cladding		2	2	4	8	3	32

Unmitigated				Impact significance before mitigation							Mitigation	Impact significance after mitigation						
Activity	Impacted Environment	Impact	Positeve or Negative Impact	EIA Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)	Management/Mitigation Measure	EMP Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)
Wind blown dust from waste dumps	Air quality	Dust deposition levels - nuisance	N		2	1	4	7	3	28	Wind breaks & rock cladding		2	1	4	7	3	28
Wind blown dust from low-grade storage pile	Air quality		N		2	1	4	7	3	28	Wind breaks & rock cladding		2	1	4	7	3	28
Combined impacts from all activities	Air quality		N		3	2	4	9	4	48	Combination of above		2	2	4	8	3	32
Excavation in open pit	Air quality		N		1	1	3	5	3	20	With increase in pit depth reduction in emissions will occur		1	1	3	5	3	20
Dilling in open pit	Air quality		N		1	1	3	5	3	20	With increase in pit depth reduction in emissions will occur		1	1	3	5	3	20
Blasting in open pit	Air quality		N		1	1	3	5	3	20	Intermittent source of emissions - blast only during certain times of the day		1	1	3	5	3	20
Vehicle entrainment on haul roads	Air quality		N		1	1	3	5	3	20	Chemical sprays on roads (water soluble - not permanent)		1	1	3	5	3	20
Materials transfer points	Air quality		N		1	1	3	5	3	20	water sprays - limited water available		1	1	3	5	3	20
Crushing and Screening	Air quality		N		1	1	3	5	3	20	water sprays - limited water available / enclose with dust extraction system attached		1	1		2	3	8
Processing plant operations	Air quality		N		1	1	3	5	3	20	No mitigation options identified		1	1	3	5	3	20
Vehicle entrainment on access road	Air quality		N		2	2	3	7	3	28	Chemical treatment of roads (permanent)		2	2	3	7	3	28
Wind blown dust from Tailings dump	Air quality		N		2	1	4	7	3	28	Wind breaks & rock cladding		1	1	4	6	3	24

Unmitigated				Impact significance before mitigation							Mitigation	Impact significance after mitigation						
Activity	Impacted Environment	Impact	Positeve or Negative Impact	EIA Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)	Management/Mitigation Measure	EMP Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)
Wind blown dust from waste dumps	Air quality		N		1	1	4	6	3	24	Wind breaks & rock cladding		1	1	4	6	2	16
Wind blown dust from low-grade storage pile	Air quality		N		1	1	4	6	3	24	Wind breaks & rock cladding		1	1	4	6	2	16
Combined impacts from all activities	Air quality		N		2	2	4	8	3	32	Combination of above		1	2	4	8	3	28
Sulphuric Acid Plant	Air quality	SO_2			1	1	4	6	2	16	Mitigation measures are part of the process (i.e.99.8% conversion)		1	1	4	6	2	16
Sulphuric Acid Plant	Air quality	SO_3			1	1	4	6	2	16	Mitigation measures are part of the process (i.e.99.8% conversion)		1	1	4	6	2	16

7 IMPACT ASSESSMENT: CLOSURE PHASE

All activities will have ceased by the closure phase of the project. This includes the mining operations and the processing plant operation. The main source of air pollutants namely vehicle entrained dust on the unpaved roads would have ceased once closure has been reached. This will obviously result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts of the mining operations and the waste dumps and Tailings dump and thus ultimately the rehabilitation efforts during operation.

7.1 Identification of Environmental Aspects

Aspects and activities associated with the closure phase of the proposed project are listed in Table 7-1.

Table 7-1: Activities and aspects identified for the closure phase.

CLOSURE PHASE	
Aspects	**Activities**
Fugitive dust	Demolition and stripping away of all buildings and facilities.
Fugitive dust	Wind blown dust from Tailings dump.
Fugitive dust	Wind blown dust from waste rock dumps.
Fugitive dust	Degradation of treated road surfaces resulting in unpaved road surfaces.

The significance rating of the closure phase is provided in Table 7-2. Based on the DWA significance matrix the following conclusions were drawn:

- Incremental impacts due to rehabilitation and demolition activities to be undertaken during the closure phase are of low to high significance should no mitigation measures be employed. The demolition of buildings could result in significant fugitive dust emissions but the duration will be short whereas wind blown dust from the Tailings dump and waste rock dumps will have a permanent impact on the environment if not controlled.

- With mitigation measures in place, specifically on the waste dumps and Tailings dump, the significance of the impacts is expected to fall within the low significance category.

- The degradation of the treated roads is inevitable once the mining operations cease. The traffic volumes would however reduce considerably since the main use of the roads are for the purpose of the mine, resulting a low significance.

- No significant aspects should occur during the closure and post-closure phases given the implementation of rehabilitation strategies during the operational phase of the mine. This will include the covering (preferably rock cladding) and vegetation of the waste rock dumps and Tailings dump side walls and surface areas. It is therefore assumed that the potential for fugitive dust impacts will have been rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure being granted for these facilities. The mitigation options recommended are provided in Section 8 of this report.

Table 7-2: Assessment of the significance of impacts during the closure phase for the Valencia Uranium Mine Project.

Unmitigated				Impact significance before mitigation							Mitigation	Impact significance after mitigation						
Activity	Impacted Environment	Impact	Positeve or Negative Impact	EIA Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)	Management/Mitigation Measure	EMP Reference	Severity	Spatial Scale	Duration	CONSEQUENCE	PROBABILITY	Significance (%)
Demolition and stripping away of all buildings and facilities	Air quality	Inhalable (PM10) concentrations impacting on human health	N		3	1	1	5	3	20	No mitigation options identified		3	1	1	5	3	20
Wind blown dust from tailings dump	Air quality		N		4	2	5	11	3	44	Rock cladding – side walls and surface		1	1	5	7	3	28
Wind blown dust from waste rock dumps	Air quality		N		3	1	5	9	3	36	Rock cladding – side walls and surface		1	1	5	7	3	28
Degradation of treated road surfaces resulting in unpaved road surfaces	Air quality		N		2	2	5	9	3	36	No mitigation options identified		3	2	5	10	3	40
Demolition and stripping away of all buildings and facilities	Air quality	Dust fallout - nuisance	N		3	1	1	5	3	20	No mitigation options identified		3	1	1	5	3	20
Wind blown dust from Tailings dump	Air quality		N		4	2	5	11	3	44	Rock cladding – side walls and surface		1	1	5	7	3	28
Wind blown dust from waste rock dumps	Air quality		N		3	1	5	9	3	36	Rock cladding – side walls and surface		1	1	5	7	3	28
Degradation of treated road surfaces resulting in unpaved road surfaces	Air quality		N		2	2	5	9	3	36	No mitigation options identified		3	2	5	10	3	40

8 AIR QUALITY MANAGEMENT MEASURES FOR VALENCIA URANIUM MINE

An air quality impact assessment was conducted for the proposed Valencia Uranium Mine in Namibia. The main objective of this study was to determine the significance of the predicted impacts from the proposed operations on the surrounding environment and on human health.

Dispersion simulations were undertaken to reflect both incremental (separate sources) and cumulative (all sources combined) impacts for all sources of atmospheric emissions.

Mitigation options were only assumed for the unpaved access road.

8.1 Conclusions

The main findings from this investigation may be summarised as follows:

8.1.1 Baseline Assessment

- The main pollutant of concern associated with the uranium mining operations and processing is particulate matter (TSP, PM10 and PM2.5). The processing operations could result in sulphur dioxide (SO_2), Volatile Organic Compounds (VOCs) and ammonia (HN_3) emissions. In addition heavy metals are associated with particulate emissions but the main concern is the radioactive nature of the uranium. Information was only available for particulates (TSP and PM10).

- The prevailing wind field for the area is from the northeast (25% of the time), the east-northeast (11%) and the southwest (14%). The Rössing/Khan formations to the west and north of the proposed mine and the Chuos and Geiseb mountains to the southeast forms a natural wind channel (northeast / southwest).

- No ambient monitored data was available for the area. A dust monitoring network comprising three multi-directional and eight single buckets has been implemented at the end of August 2007. Three months of data were available for inclusion into the report as reported by DWA. The main findings indicated that the dust fallout in the area is within the SLIGHT (<250 mg/m²/day) category as defined by the South African DEAT.

8.1.2 Impact Assessment

For the operational phase, the predicted ground level concentrations included only concentrations from the proposed Valencia Uranium Mine operations. No other sources of particulate or gaseous emissions in the area that are expected to have an influence on the background concentrations within the area other than the contribution from the natural dry environment.

- Predicted highest daily PM10 ground level concentrations resulted in concentrations matching the highest daily WHO guideline at the Valencia farmhouse, but complied with both the proposed SA Standard and WBG guideline.

- Over an annual average the predicted PM10 concentrations were low near the mine boundary and at the farm house with no exceedances of the relevant standards and guidelines for either scenario.

- The main sources of PM10 emission contributions were wind blown dust, vehicle entrainment on unpaved roads, and mining (excavating) operations. Wind blown dust, vehicle entrainment and crushing and screening resulted in the highest ground level concentrations. From the wind blown dust sources, the Tailings dump was the main source of emissions and impacts.

- Wind blown dust typically impacts down wind from the direction where the highest velocity winds occur, with vehicle entrained dust bounded near the road where it is generated from. Wind blown dust is a significant source of emissions for the duration of the high wind speed occurrence and with the significance underestimated over a daily average.

- Predicted ground level concentrations from blasting operations were included for highest hourly averages since blasting would occur once a day and last for a few minutes. The significance of the blasting impacts could not be quantified since no hourly guidelines exist for PM10. It is however regarded as a source of nuisance.

- Mitigation measures were assumed for the unpaved access road and the resulting PM10 concentrations were lower than for unmitigated scenarios. The predicted impacts at the farm house reduced to be below the WHO guideline.

- The significance rating for the predicted PM10 concentrations due to the operational phase at the Valencia Uranium Mine was regarded MODERATE.

- With mitigation measures considered for the unpaved roads, the significance rating reduced to the upper range of the LOW significance category. The significance ratings matrix does however not provide an accurate reflection of the significance to health impacts from the proposed operations.

- Predicted dust fallout levels were very high (>2,400 $mg/m^2/day$) near the sources of emissions. The dustfall levels depleted rapidly away from the source of emissions to levels below the proposed SA action level for residential areas (of 600 $mg/m^2/day$). Dust fallout levels reached 600 $mg/m^2/day$ between 500m and 800m from the source of emission.

- The main sources of TSP emissions were estimated to be vehicle entrainment on unpaved roads, wind blown dust and crushing and screening. The main sources of impact were primarily wind blown dust and mining (excavation) operations.

- Mitigation was only considered for the proposed unpaved access road and this resulted in little reduction in the predicted dust fallout levels.

- The significance from dust fallout is primarily a nuisance issue. The significance rating matrix however provided the same significance for dust fallout as for health impacts, i.e. MODERATE for unmitigated sources, and MODERATE to LOW for mitigated sources.

- Predicted SO_2 emissions resulting from the proposed Sulphuric Acid Plant resulted in ground level concentrations well within the EC standards and WHO Air Quality Guidelines. Similarly, the predicted SO_3 concentrations only equalled the TARA acute ESL at the plant with all predicted impacts outside the plant area well within the TARA ESLs. These predicted results were based on Scenario 1 which can be regarded the worst-case scenario with all the other design options resulting in lower ground level concentrations.

8.2 Site Specific Management Objectives

The main objective of Air Quality Management measures for the proposed Valencia Uranium Mine is to ensure that all operations at the mine and processing plant will be within compliance with the Namibian legal requirements and international best practice (i.e. WBG and WHO stipulations). In order to define site specific management objectives, the main sources of pollution needed to be identified. Sources can be ranked based on 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.

The main pollutants of concern identified during the impact assessment were particulates (PM10 and TSP). Sulphur dioxide (SO_2) and sulphur trioxide (SO_3) will only result from the Acid Plant operations.

8.2.1 Source Ranking by Emissions

The primary sources during operations were identified as vehicle entrainment on the unpaved roads, wind erosion from the Tailings dump and materials handling operations (including crushing and screening and excavation). For TSP emissions, vehicle entrainment contributed 50%, wind erosion 30% and crushing and screening operations 10%. For PM10 the contributions were 44% from vehicle entrainment, 29% from wind erosion, 14% from excavation and 12% from crushing and screening. The processing plant could not be included in the emissions inventory due to insufficient information.

Feasible mitigation measures identified included chemical treatment of the access road with a minimum of 85% control efficiency, and water sprays combined with chemicals on the haul roads to result in 75% control efficiency. Vegetation cover on the Tailings dump and waste rock dumps were also not seen as a practical solution due to the sparse natural vegetation cover of the region.

8.2.2 Source Ranking by Impacts

Predicted impacts were screened using the proposed South African ambient air quality standards, the WBG guidelines and the latest (2005) WHO air quality guidelines. The relevant standards and objectives are provided under Section 2 of this report.

8.2.2.1 Operational Phase

By taking all sources at the mine into account, predicted PM10 daily concentrations complied with the proposed SA standard and the WBG guideline at the Valencia farm house but equalled the WHO guideline.

Dust fallout was also predicted to be high close to the source of emissions but well below the proposed SA residential action level and industrial action level at the farm house and mine boundary.

The main sources of particulates resulting in off-site impacts (both for PM10 and TSP) during the operational phase included vehicle entrainment from unpaved roads and wind erosion. Materials handling operations such as crushing and screening and excavation activities were also significant impacting sources.

The Acid Plant is the only source of SO_2 and SO_3 emissions at the proposed Valencia Uranium Mine.

8.2.2.2 Closure Phase

The potential for impacts during closure phase are dependent on the extent of demolition and rehabilitation efforts during closure and on features which remain (viz. the Tailings dump). It was assumed that the potential for fugitive dust impacts due to these sources could be rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure being granted for these facilities.

8.2.3 Target Control Efficiencies

Based on the impact assessment and significance rankings the following target control efficiencies for all main sources of emissions were determined.

8.2.3.1 Operational Phase

- Vehicle entrainment on the unpaved access road – 85% to 90% control efficiency through chemical treatment of the road surface to result in a semi-permanent capped area.
- Vehicle entrainment on the unpaved haul roads – 60% to 75% control efficiency through effective water sprays combined with chemicals.
- Wind erosion from Tailings dump – 80% control efficiency through rock cladding and wind breaks on the edges of the Tailings dump.
- Wind erosion from the waste rock dump – 40% control efficiency through rock cladding.
- Material handling operations – 98% reduction through enclosure of secondary and tertiary crushing and screening operations with effective dust extraction and associated bag filters.
- Sulphur dioxide conversion at Acid Plant – 99.8% as per proposed design.
- Sulphuric Acid mist to be as a minimum 50 mg/m³ but preferably 30 mg/m³.

8.2.3.2 Closure Phase

- Wind erosion from Tailings dump – 100% control efficiency through rock cladding or chemical capping of side slopes and surface.
- Wind erosion from waste rock dumps – 100% control efficiency through rock cladding or chemical capping of side slopes and surface.

8.3 Project-specific Management Measures

8.3.1 Identification of Suitable Pollution Abatement Measures

8.3.1.1 Vehicle Entrainment on Unpaved Haul Roads

Vehicle entrained dust from unpaved road surfaces resulted in high impacts near the source and off-site during both construction and operational phase predictions. It is therefore recommended that mitigation measures be considered on all unpaved haul roads and the unpaved access road.

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilisation (EPA, 1987; Cowhert *et al.*, 1988; APCD, 1995).

The access road to the mine runs through fairly remote parts. However, given the amount of dust generated by truck movement on the unpaved roads it is recommended that the surface be treated to ensure a reduction in emissions of more than 85%. There are numerous chemicals on the market each with advantages and disadvantages. Some are applied together with water and requires more frequent re-applications with other products having a longer life but also requires more preparation of the road surfaces.

The efficiency of mitigation measures applied depends on the silt loading of he road surface and the evaporation rate (where water is used). With high silt loading and high evaporation rates the control efficiency will be less. It is therefore important that the roads be kept clean to ensure high control efficiency. Furthermore, the maintenance of the roads will strongly influence the effectiveness of the mitigation measure.

The control efficiency of vacuum and broom sweepers is dependent on: sweeper design and maintenance, the frequency of sweeping, the nature of the area being swept, and the particle size distribution of the dust on the roadway. Until recently, the control efficiency of vacuum sweepers was given as being generally in the range of 0% to 60% (Table 8-1). Other options include water flushing which will be dependant on the availability of water at the mine.

Table 8-1: Control efficiencies for control measures for paved and treated roads.

Paved Road Control Measures	Estimated PM10 Control Efficiency	Reference
General road cleaning	35%[(a)]	Cowherd *et al*. 1988
Vacuum sweeping	0% - 58% 30% - 60%[(b)] 46%[(c)] 34%[(d)]	Cowherd and Kinsey 1986 Calvert *et al.* 1984 Eckle and Trozzo 1984 Cowherd *et al.* 1988
'Improved' vacuum sweeping	37%[(d)]	Cowherd *et al.* 1988
Broom sweeping	25% to 30%[(e)]	Cowherd *et al.* 1988, EPA 1992
Water flushing	69-0.231 V [(f)(g)]	Cowherd and Kinsey 1986
Water flushing followed by sweeping	96-0.263V [(f)(g)]	Cowherd and Kinsey 1986

Notes:

a) Represents the upper bound on efficiencies obtained in practice since no redeposition after cleaning was considered in the estimation of the control efficiency.
b) Refers to control efficiency provided by efficiency designed and well maintained vacuum sweepers.
c) Control efficiency for particulates with an aerodynamic diameter of less than 30 µm (PM30).
d) Estimated based on measured initial and residual < 63 µm loadings on urban paved roads.
e) Maximum (initial) instantaneous control efficiencies with the efficiency decreasing after cleanup.
f) Water applied at 2.173 litres per m^2.
g) V = number of vehicle passes since application.

It is standard practice at most mines to utilise water trucks on the unpaved roads. However, with the high evaporation rate for the area it is recommended that water be used in combination with chemical surfactants to reduce the amount of water required to achieve certain control efficiencies. An empirical model, developed by the US-EPA (EPA, 1996), was used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account evaporation rates and traffic. It was estimated that water and chemical sprays resulting in at least 75% control efficiency would be a requirement to result in a significant reduction in ground level concentrations from all on-site haul roads. Should only water be applied, the amount needed to ensure 75% control efficiency on the various haul roads was calculated to be 0.115 litres/m²/hour (no rain) assuming 10 trucks per hour. This was based on the annual average evaporation data for Rössing Uranium Mine (RUL, 2007).

The rate of watering required to ensure various control efficiencies, given site-specific evaporation rates and traffic rates, calculated on the basis of this model are illustrated in Figure 7-1. Average monthly evaporation rates, as averages for the Northern Cape region, were used in the calculation (Schulze, 1997). As an example the watering rates required for 10 trucks per hour was included (return trips included).

The annual average calculated hourly water application rate is illustrated in Figure 8-1.

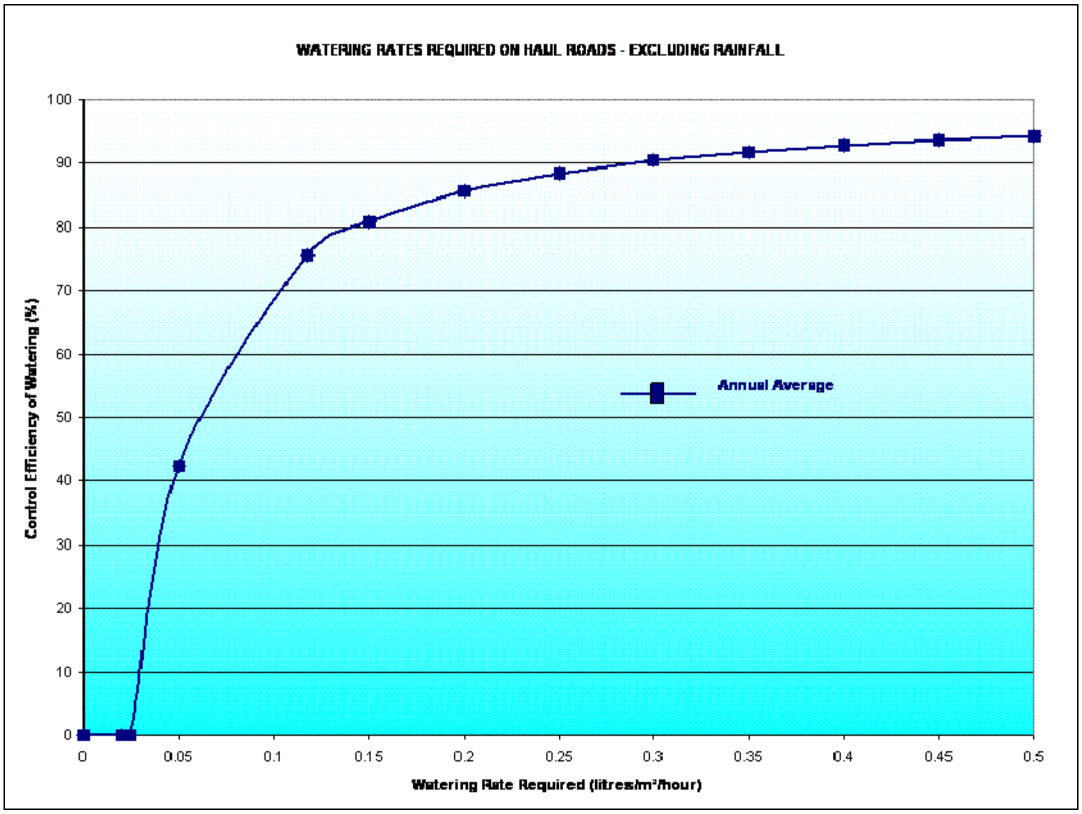

Figure 8-1: Calculated watering rates based on an annual evaporation rate for Rössing Uranium Mine based on 10 trucks per hour. These curves represent the worst-case scenario since they do not take into account rainfall.

8.3.1.2 Wind Erosion

The largest impacting source would be wind erosion from the Tailings dump. These storage areas are engineered to optimise the amount of tailings stored, while avoiding potential environmental impacts. Because many tailings are finely grained, they can easily be eroded when dry and storage areas become dust. With no controls on the slopes and on the surfaces of the Tailings dump, high impacts would be experienced.

Substantial research has been done on erosion from gold mine tailings. Even though the properties differ between gold mine tailings and uranium tailings (the latter comprise of larger particle sizes on average), the physical behaviour of wind blown dust from exposed surfaces are similar. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation (Burger *et.al*., 1997).

Vegetal cover retards erosion by binding the residue with a root network, by sheltering the residue surface and by trapping material already eroded. Vegetation is also considered the most effective control measure in terms of its ability to also control water erosion. The long-term effectiveness of suitable vegetation selected for the site will be dependent on (a) the nature of the cover, and (b) the availability of aftercare. It should be noted that vegetation is defined for this purpose as the "establishment of self sustaining vegetation cover".

Erosion losses from grassed slopes measured for gold tailings dams was found to be in the order of 100 t/ha/year compared to uncontrolled slopes from which losses of up to 500 t/ha/year were recorded (Blight, 1989). Rock cladding or armouring of the sides of tailings dams has been shown in various international studies to be effective in various instances in reducing wind erosion of slopes. Cases in which rock cladding has been found to be effective in this regard generally involve rock covers of greater than 0.5 m in depth (Ritcey, 1989; Jewell and Newson, 1997).

The following recommendations regarding wind blown dust sources are made:

- It is recommended that the walls of the Tailings dump be covered (rock gladded) up to 1 m from the top throughout the life of mine. Rock cladding has the potential for effective dust suppression and will result in the reduction of wind blown dust.

- In addition screens should be installed on the crest of the Tailings dump walls mainly to act as wind breaks and to reduce the potential for dust deposition on the natural vegetation that might form on the side walls, hence curbing the growth of the grass.

It should be noted that the wind erosion equations are very sensitive to clay percentage, moisture content and particle size distribution of the material. Sampled values were used from the proposed Trekkopje Uranium Mine and might not be representative of the proposed tailings dam physical characteristics. It is therefore recommended that samples be taken and analysed for clay and moisture content, and particle size distribution as soon as the mine is in operation. The emissions should then be re-quantified and the simulation redone for inclusion into the Environmental Management Plan.

8.3.1.3 Materials Handling Operations

Materials handling operations including primary crushing and screening of ore and materials transfer point (mainly form the excavator) were identified as potentially significant sources of emissions at the proposed mine.

Enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts. According to the Australian NPi, water sprays can have up to 50% control efficiency, and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed, up to 100% control efficiency can be achieved. With these control measures in place, the impacts would reduce to negligible levels. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

The control efficiency of pure water suppression can be estimated based on the US-EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 8-3. From the relationship between moisture content and dust control efficiency it is apparent that by doubling the moisture content of the material an emission reduction of 62% could be achieved. Thus chemicals mixed into the water will not just save on water consumption but also improve the control efficiency of the application even further.

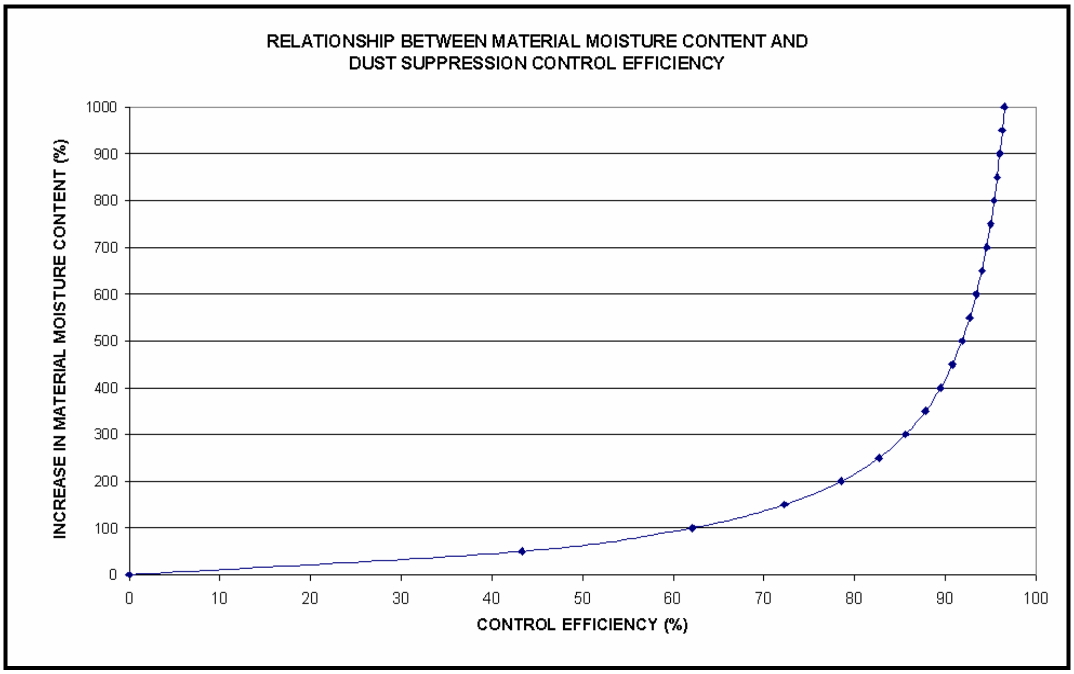

Figure 8-2: Relationship between the moisture content of the material handled and the dust control efficiency (calculated based on the US-EPA predictive emission factor equation for continuous and batch drop operations).

Control efficiencies from the application of liquid spray systems at conveyor transfer points have *in practice* been reported to be in the range of 42% to 75%. General engineering guidelines which have been shown to be effective in improving the control efficiency of liquid spray systems are as follows:

- Of the various nozzle types, the use of hollow cone nozzles tend to afford the greatest control for bulk materials handling applications whilst minimising clogging;

- Optimal droplet size for surface impaction and fine particle agglomeration is about 500μm; finer droplets are affected by drift and surface tension and appear to be less effective; and,
- Application of water sprays to the underside of conveyor belts have been noted by various studies to improve the efficiency of water suppression systems and belt-to-belt transfer points.

8.3.1.4 Open pit operations

All materials handling operations will reduce dust generation by 62% by merely doubling the moisture content of the material handled. In addition, the Australian NPi in their Emission Estimation Technique Manual for Mining stipulates a 50% reduction of TSP emissions due to pit retention, and 5% for PM10 emissions. This is based on the increase in volume (the deeper the pit becomes) and thus resulting in better dispersion potential for specifically PM10 emissions before reaching the surface. Similarly for TSP, the potential for deposition on the surface becomes smaller for more dust would settle within the pit.

8.3.1.5 Sulphuric Acid Plant

Upset conditions should be restricted to the minimum number of maintenance periods per year. The surrounding community should be informed via email or telephone of the planning of such an event and the anticipated duration thereof and when the plant will be started up. Careful record should be kept of the number and duration of *upset* conditions.

Bi-annual emissions monitoring is recommended as soon as the plant is in operation, measuring both *routine* and *upset* emissions. This will serve to verify the quantified emissions used in this study which were based on design specifications.

8.4 Monitoring Requirements

8.4.1 Performance Indicators

Key performance indicators against which progress may be assessed form the basis for all effective environmental management practices. In the definition of key performance indicators, careful attention is usually paid to ensure that progress towards their achievement is measurable and that the targets set are achievable given available technology and experience.

Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of wind erosion exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below a certain threshold represents an impact- or receptor-based performance indicator. Source-based performance indicators have been included in regulations abroad. The Queensland Environmental Management Overview Strategy (QDPI, 1988), for example, states that erosion rates must not be higher than 40 t/hectare/year and that the depths of drills and gullies be limited to less than 30 cm. The ambient air quality guidelines and standards given for respirable and inhalable particulate concentrations by various countries represent receptor-based objectives.

8.4.2 Specification of Source Based Performance Indicators

- Source based performance indicators for the Tailings dump would include cover density to be 80% on the entire slope up to 1 m from crest, and dustfall immediately downwind to be <1,200 mg/m^2/day.
- For the unpaved access road it is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 600 mg/m^2/day and for unpaved haul roads associated with on-site activities it should be less than1,200 mg/m^2/day.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dustfall in the immediate vicinity of various sources should be less than 1,200 mg/m^2/day.
- From all activities associated with Valencia Uranium Mine and Processing Plant, dustfall in close proximity to sensitive receptors (i.e. Farm House) should not exceed 600 mg/m^2/day.
- From the proposed Sulphuric Acid Plant the SO_2 emissions should not exceed 284 mg/Nm^3 and all ground level impacts should be less than 500 µg/m^3 for 10-minute averages and < 50 µg/m^3 (based on WHO IT1) for highest daily averages.
- Sulphur trioxide mist should be less than 50 mg/Nm^3 and ground level concentrations should be less than 1 µg/m^3 over an annual average.

8.4.3 Receptor based Performance Indicators

Based on the impacts predicted from the mining operations on the surrounding environment and the limitations associated with the data used, it is recommended that the current dust fallout monitoring network be continued and expanded.

8.4.3.1 Dust fallout monitoring network

A dust fallout network for Valencia Uranium Mine was initiated at the end of August 2007 in order to determine the baseline dust fallout levels before the mining operations commence. This will provide management with an indication of what the increase in fugitive dust levels are once mining operations commence. In addition, a dust fallout network can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal trend analysis;
- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

It is therefore recommended that the dust fallout network currently comprising of 3 directional dust fallout buckets be expanded to include at least 5 additional single dust fallout buckets. The existing and proposed locations of the dust buckets are indicated in Figure 8-4 and discussed as follows:

- The 3 directional buckets have been placed in a triangular formation covering the outskirts of the mining area. One was placed to the north of the open pit and waste rock dump, one to the northeast of the open pit and waste rock dump 2, and one to the south of the mining operations. It is proposed that these buckets remain as is.

- Single buckets are useful in determining the impacts from single sources and tracking improvements made by mitigation measures. The 8 single buckets are proposed to be placed as follows:
  - Single buckets 2, 3 and 4 to remain as is;
  - Two single buckets to be placed to the northeast, southwest, and northwest of the Tailings dump;
  - One single bucket to be placed near the crusher plant; and,
  - One single bucket to be placed next to the access road.

It wasn't regarded necessary to implement a PM10 monitor due to the low population density in the area. This should however be reconsidered should the mining personnel stay at the mine. It was further recommended that the existing meteorological station on-site be continued throughout the life of mine.

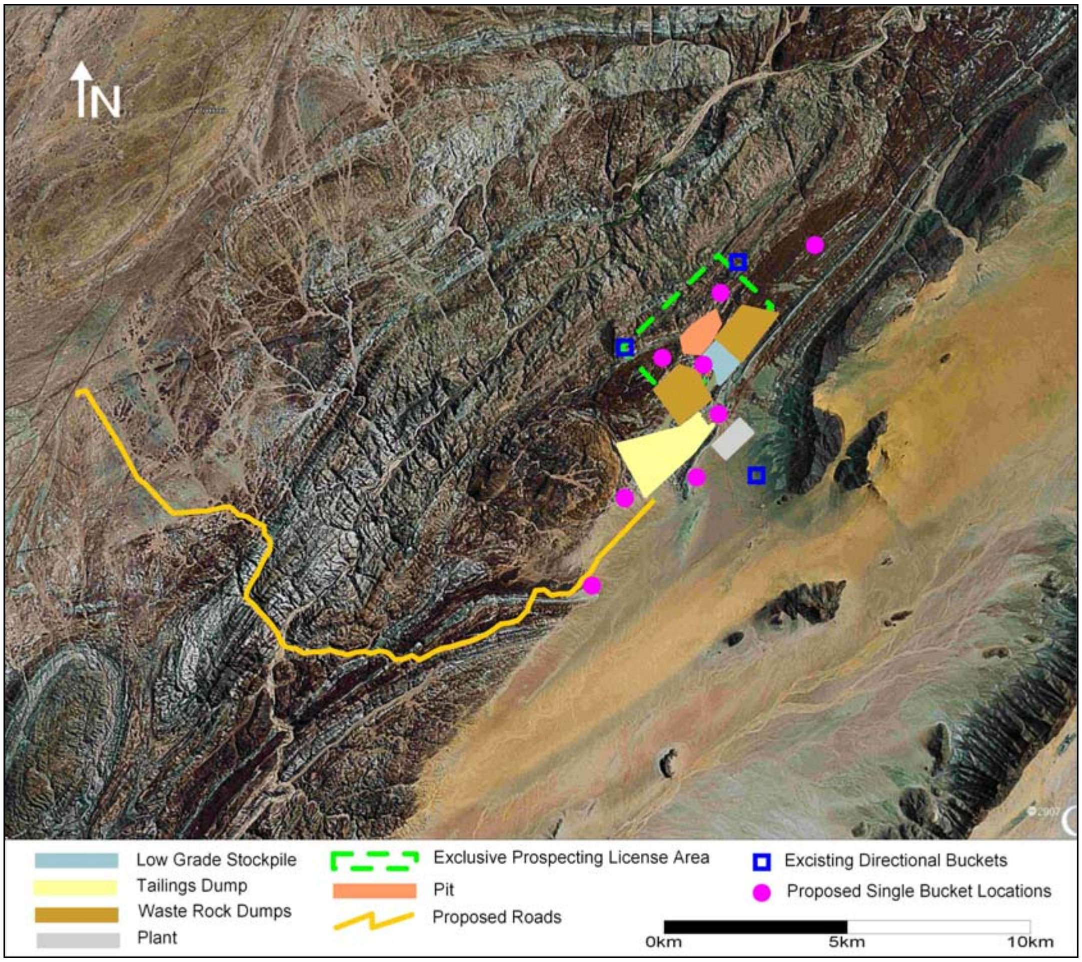

Figure 8-3: Proposed dust fallout monitoring network for Valencia Uranium Mine and Processing Plant.

Table 8-2: Ambient air monitoring, performance assessment and reporting programme.

Monitoring Strategy Criteria	Dustfall Monitoring
Monitoring objectives	- Assessment of compliance with dustfall limits within the main impact zone of the operation. - Facilitate the measurement of progress against environmental targets within the main impact zone of the operation. - Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation. - Tracking of progress due to pollution control measure implementation within the main impact zone of the operation. - Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of the mine operations and the Tailings dump.
Monitoring location(s)	Figure 8-4. Dustfall to be recorded by dustfall monitoring network comprising 5 single bucket and 3 directional bucket monitors.
Sampling techniques	*Single Bucket Dust Fallout Monitors* Dust fallout sampling measures the fallout of windblown settleable dust. Single bucket fallout monitors to be deployed following the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739). This method employs a simple device consisting of a cylindrical container half-filled with de-ionised water exposed for one calendar month (30 days, ±3 days). The water is treated with an inorganic biocide to prevent algae growth in the buckets. The bucket stand comprises a ring that is raised above the rim of the bucket to prevent contamination from perching birds. Once returned to the laboratory, the content of the bucket are filtered and the residue dried before the insoluble dust is weighed. *Four-bucket Wind-Directional Monitors* The monitor comprises four buckets with a rotating lid comprising a gap to permit dust collection in one bucket. The location of the gap is determined by the sector from which the wind is blowing – permitting the collection of dustfall on a wind-directional basis. The buckets are deployed and samples analysed in the same manner as described above for the single buckets.
Accuracy of sampling technique	Margin of accuracy given as ±200 $mg/m^2/day$.
Sampling frequency and duration	On-going, continuous monitoring to be implemented facilitating data collection over 1-month averaging period.
Commitment to QA/QC protocol	Comprehensive QA/QC protocol implemented.
Interim environmental targets (i.e. receptor-based performance indicator)	Maximum total daily dustfall (calculated from total monthly dustfall) of not greater than 600 $mg/m^2/day$ for residential areas. Maximum annual average dustfall to be less than 1,200 $mg/m^2/day$ on-site.
Frequency of reviewing environmental targets	Annually (or may be triggered by changes in air quality regulations).
Action to be taken if targets are not met	(i) Source contribution quantification. (ii) Review of current control measures for significant sources (implementation of contingency measures where applicable).

Monitoring Strategy Criteria	Dustfall Monitoring
Procedure to be followed in reviewing environmental targets and other elements of the monitoring strategy (e.g. sampling technique, duration, procedure)	Procedure to be drafted in liaison with I&APs through the proposed community liaison forum. Points to be taken into account will include, for example: (i) trends in local and international ambient particulate guidelines and standards and/or compliance monitoring requirements, (ii) best practice with regard to monitoring methods, (iii) current trends in local air quality, i.e. is there an improvement or deterioration, (iv) future development plans within the airshed (etc.)
Progress reporting	At least twice annually to the necessary authorities and community forum.

8.4.3.2 PM10 ambient monitor

Given the low population density in the area, the proposed mining operations will primarily have occupational significance rather than ambient health implications. It is therefore not regarded necessary at this stage to have a PM10 monitor in place. It is however proposed that this be considered should the mine personnel with their families reside on the mine property.

8.4.3.3 Meteorological monitor

It is recommended that the meteorological station located at Valencia Uranium Mine be continued throughout the life of the mine. The station must as a minimum measure the following parameters:

- wind speed (m/s or km/hr) and direction (degrees);
- temperature (°C);
- solar radiation (W/m²); and,
- rainfall (mm).

The basic requirements for a weather station would be the recording of hourly average wind speed and wind direction data, as well as temperature. The wind monitor should be a high performance wind sensor to cover a wind speed range of up to 60 m/s, including a gusts survival. A rain gauge would be optional, usually comprising of a tipping bucket for simple and effective rainfall measurements. In addition a solar radiation sensor would measure global radiation for agricultural, meteorological and hydrological applications.

8.5 Record-keeping, Environmental Reporting and Community Liaison

8.5.1 Periodic Inspections and Audits

Periodic inspections and external audits are essential for progress measurement, evaluation and reporting purposes. According to the Guidelines of the Chamber of Mines (1996), every decommissioned residue deposit should be inspected at yearly intervals by a suitably qualified person and any alteration or deterioration of conditions at the deposit reported to the responsible authority.

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Annual environmental audits forms part of an APCS and should be initiated at Valencia Uranium Mine. Results from site inspections and off-site monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all I&APs, including authorities and persons affected by pollution.

Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

8.5.2 Liaison Strategy for Communication with I&APs

Stakeholder forums possibly provide the most effective mechanisms for information dissemination and consultation. Specific intervals at which forum meetings will be held should be stipulated, and information provided on how people will be notified of such meetings.

8.5.3 Financial Provision (Budget)

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and I&AP liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures.

The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

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APPENDIX A: HEALTH ASSESSMENT CRITERIA AND BACKGROUND

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

Previously no ambient air quality standards for South Africa existed. The Department of Environmental Affairs and Tourism (DEAT) have issued ambient air quality guidelines to support receiving environment management practices. These have been adopted as standards in the Air Quality Act but are currently under review. The local ambient air quality standards are only available for such criteria pollutants that are commonly emitted, such as sulphur dioxide (SO_2), lead (Pb), oxides of nitrogen (NO_x), carbon monoxide (CO) and particulates.

In this section, a detailed discussion on the establishment of all relevant guidelines and standards are discussed.

A.1. Ambient Air Quality Criteria for Suspended Particulates

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. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (Figure A-1) (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

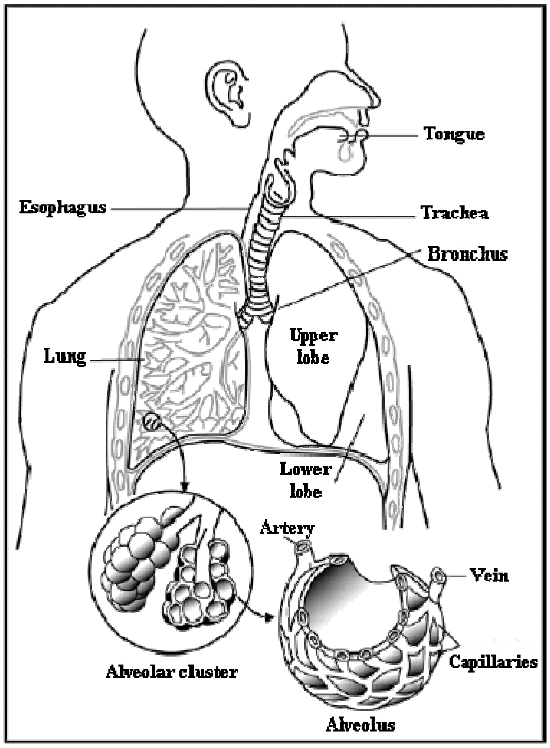

Figure A-1: Schematic diagram indicating the trachea, bronchus and alveolar regions (NCOH, 1992).

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

A.1.1. Dose Response Relationships for Suspended Particulate Exposures

The World Health Organisation (WHO) no longer supports air quality threshold levels for particulates. The WHO stated that the development of a new procedure for the assessment of health impacts occurring due to airborne particulates was necessary since the threshold for the onset of health effects could not be detected (WHO, 2000). The new approach adopted by the WHO is comparable to that for carcinogenic compounds, with linear relationships between PM10 or PM2.5 concentrations and various types of health effects being established. Such linear relationships are presented in Figures B-2 to B-4 for increases in daily mortality rates, hospital admissions and various health endpoints such as bronchodilator use, cough and symptom exacerbation (WHO, 2000).

The WHO recommends that reference be made to the linear relationship of PM10 and PM2.5 with various health effect indicators in determining acceptable levels of risk. In determining 'acceptable' airborne particulate concentrations a decision maker will be faced with the following controversial decisions:

- selection of the curve to be used for deriving an acceptable ambient particulate concentration (i.e. decide from which health effect the population is to be protected);

- determine the population or sensitive groups to be protected from air pollution effects. For example, the use of the bronchodilator application curve would imply that asthmatics are a sensitive group to be protected by the chosen standard; and

- set a fixed value for the acceptable risk in a population so that a single value for a given exposure period may be defined (Junker and Schwela, 1998; Schwela, 1998).

The graphs given in Figures A-2 to A-4 were not intended for use for PM10 concentrations below 20 µg/m^3, or above 200 µg/m^3; or for PM2.5 concentrations below 10 µg/m^3 or above 100 µg/m^3. This caution is required as mean 24-hour concentrations outside of these ranges were not used for the risk assessment and extrapolations beyond these ranges would therefore be invalid.

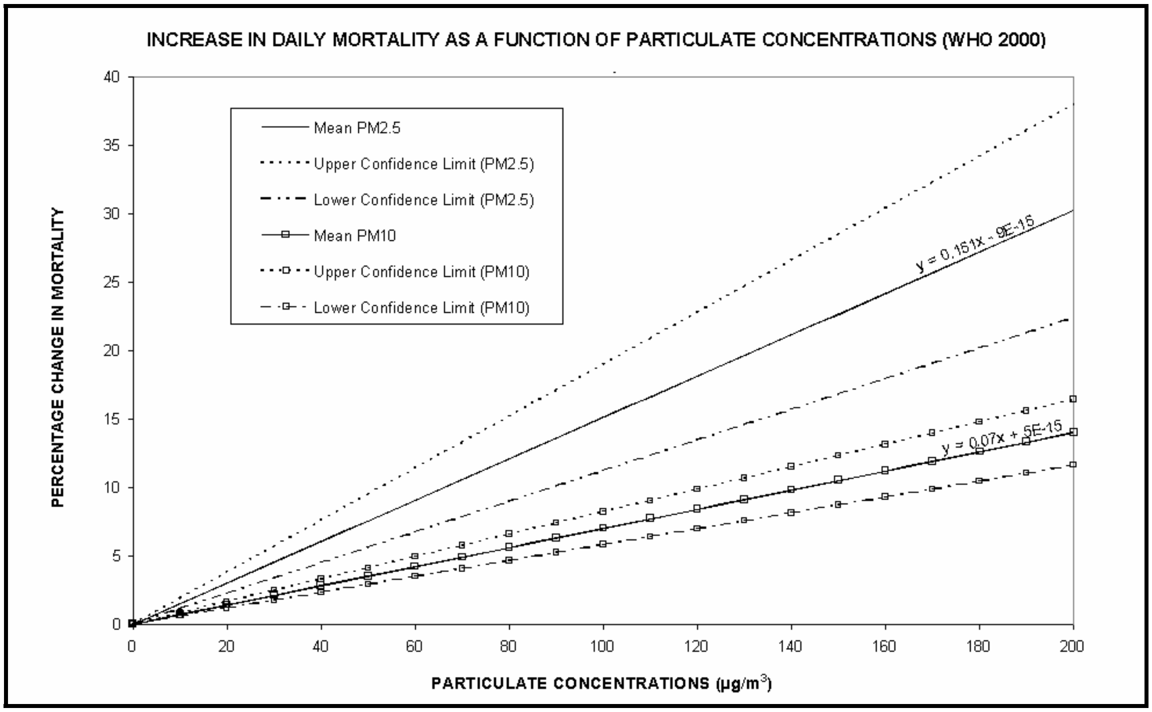

Figure A-2: Increases in daily mortality as a function of increases in PM10 and PM2.5 concentrations (after WHO, 2000).

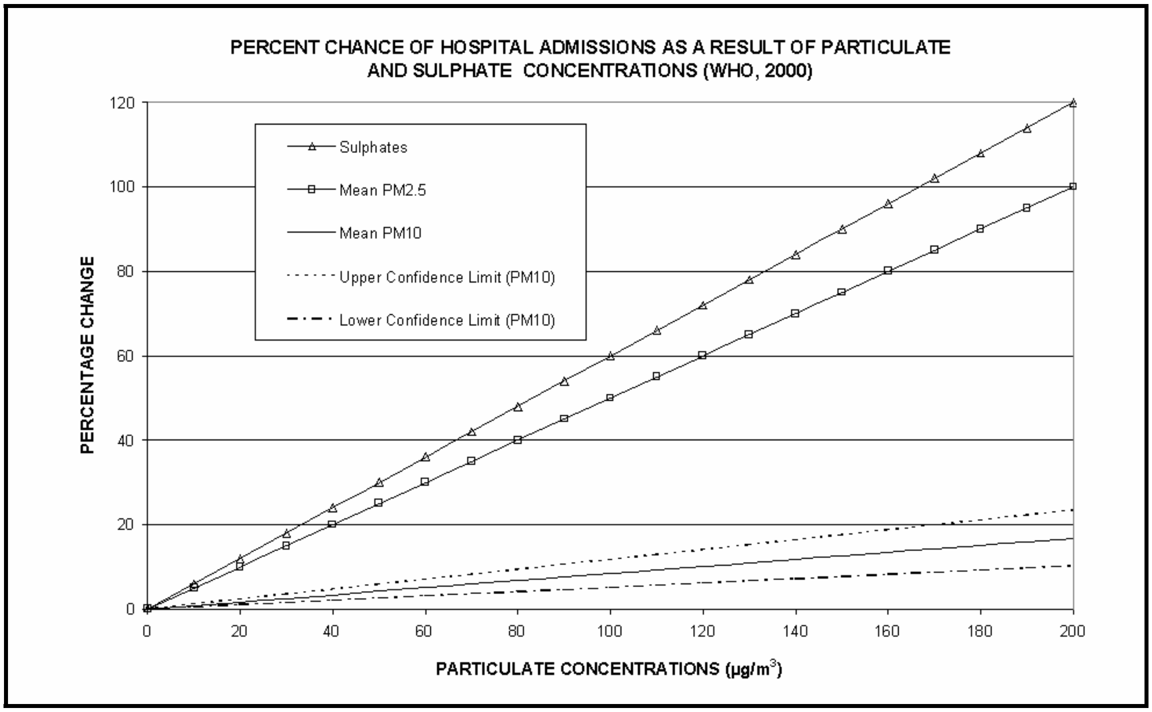

Figure A-3: Increases in hospital admissions as a result of increased PM10, PM2.5 and sulphate concentrations (WHO, 2000).

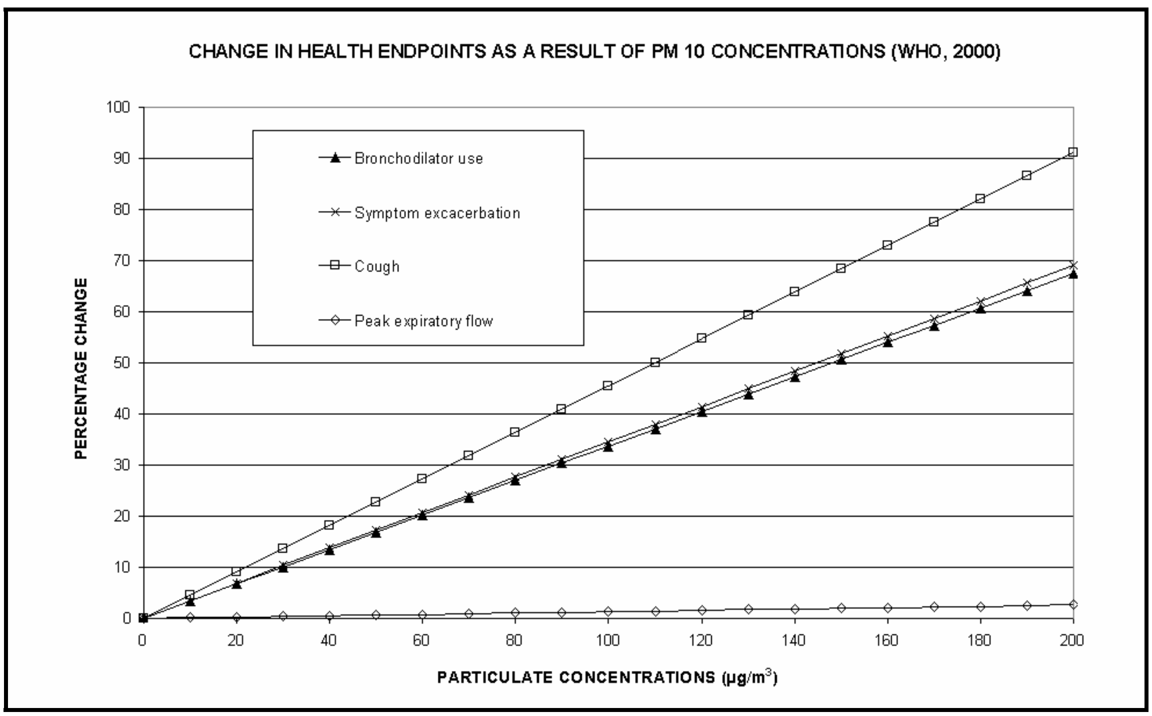

Figure A-4: Percentage change in the occurrence of various health endpoints as a result of changes in ambient PM10 concentrations (WHO, 2000).

The Canadian Environmental Protection Agency (CEPA) has recently undertaken an extensive review of epidemiological studies conducted throughout the world with regard to the relationship between particulate concentrations and human health. The conclusion reached was that daily or short-term variations in particulate matter, as PM10 or PM2.5, were significantly associated with increases in all-cause mortality in 18 studies carried out in 20 cities across North and South America, England, and Europe. The association between particulate concentrations and acute mortality could not be explained by the influence of weather, season, yearly trends, diurnal variations, or the presence of other pollutants such as SO_2, CO, NO_x and O_3 (CEPA/FPAC Working Group, 1998).

In its review the CEPA could find no evidence of a threshold in the relationship between particulate concentrations and adverse human health effects, with estimates of mortality and morbidity increasing with increasing concentrations. As for the relationship expressed by the WHO, the lack of an apparent threshold suggests that it is problematic to select a level at which no adverse effects would be expected to occur as a result of exposure to particulate matter. The relative risk for PM10 was given by the CEPA as varying between 0.4% and 1.7% per 10 μg/m^3 increase, with an unweighted mean of 0.8% and a weighted mean of 0.5% per 10 μg/m^3 increase. In what the CEPA termed the "best-conducted study" which examined PM2.5, a mean increase in mortality of 1.5% per 10 μg/m^3 was observed (CEPA/FPAC Working Group, 1998) (Figure A-5).

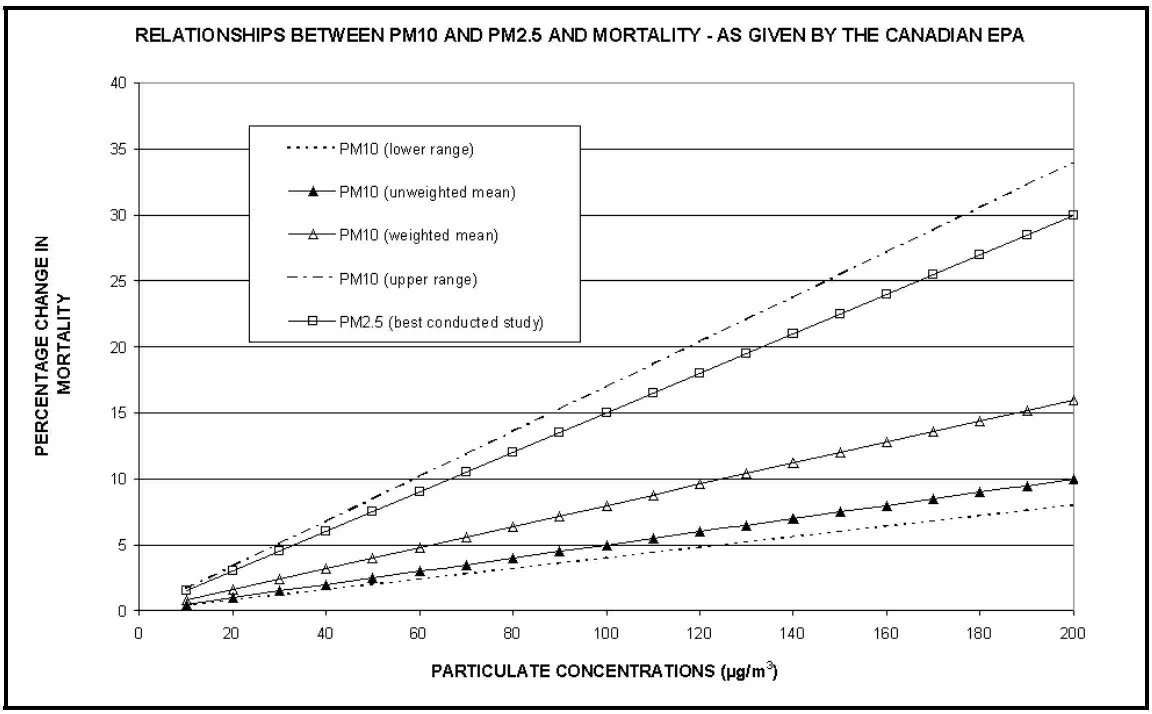

Figure A-5: Relationships between PM10 and PM2.5 and mortality indicated by the Canadian EPA (CEPA/FPAC Working Group, 1998).

The CEPA recommended that the reference levels for PM10 and PM2.5, for a *daily* averaging period, be 25 μg/m^3 and 15 μg/m^3, respectively. These levels are estimates of the lowest ambient particulate concentrations at which statistically significant increases in health responses can be detected based upon available data and current technology. The CEPA emphasises that the reference levels should not be interpreted as thresholds of effects, or levels at which impacts do not occur (CEPA/FPAC Working Group, 1998).

A fairly recent review was prepared by CONCAWE (Hext *et al.* 1999) of the health effects of exposure top PM2.5 particles, including the so-called ultra fine particles with aerodynamic diameter of <0.1 µm. The following conclusions were presented in their report:

- *Dosimetric consideration of inhaled PM2.5 suggests that asymmetric deposition patterns in some individuals with obstructive lung diseases might result in localised doses from near ambient concentrations that might enhance the already existing conditions.*

- *Particles of low solubility pose a limited risk to health but animal experiments imply that trace metals and adsorbed components associated with some particle types may enhance pulmonary responses.*

- *Many of the experimental studies have been conducted at high concentrations and used the rat as experimental species. It is now evident that the rat lung may over-respond to the presence of particles in the lung, especially at high doses, and thus results in this species and their extrapolation to man may need to be interpreted with caution.*

- *Ambient acidic particles probably pose the greatest risk to health and there is a suggestion from epidemiological studies that acidity is an important aspect of air pollution with respect to respiratory symptoms.*

- *There is no effect of concern on pulmonary function in normal healthy individuals at concentrations of acidic aerosols as high as 1000 µg/m^3. Effects that may have biological significance may occur at concentrations below 100 µg/m^3 in the most sensitive asthmatic individuals.*

- *There is evidence to suggest that acidic particles may enhance in a synergistic manner the effects of gaseous components of air pollution such as O_3, adding support to the view that health effects associated with episodic increases in urban airborne pollutants arise from an additive or synergistic combination of exposure to both the particulate phase and the gaseous phase.*

- *Ultra fine particles (particles < 100 nm diameter) may pose a greater health risk due to higher particle numbers and deposition efficiencies in the lung and greater biological reaction potential, but further studies or evidence will be required for a full evaluation to be made.*

- *There is a limited number of epidemiological studies that have specifically addressed PM2.5. These appear to provide limited evidence of an association between PM2.5 levels and acute and chronic mortality available at present. However, this is not convincing for several reasons including study design, lack of robust correlation between environmental data and reported exposed population and inability of identifying or selecting out one individual harmful component (PM2.5) from an ambient mixture of a number of potentially harmful components.*

- *The overall pattern that emerges is that PM2.5, at normal ambient levels or those seen during episodic pollutant increases, poses limited risk, if any, to normal healthy subjects. Individuals suffering already from cardio-respiratory disease or pre-disposed to other respiratory* *diseases such as asthma may be at risk of developing adverse responses to exposure to increased ambient levels of PM2.5 but more robust evidence is required to substantiate this.*

Dose-response coefficients for PM10 used by the UK Department of Environment, Transport and the Regions in a recent study were given as follows (Stedman *et al* 1999):

Health Outcome:		**Dose-Response Coefficient:**
Deaths brought forward (all causes)	-	+0.75% per 10 μg/m^3 (24 hr mean)
Respiratory hospital admissions	-	+0.8% per 10 μg/m^3 (24 hr mean)

The United Kingdom Department of Environment classifies air quality on the basis of concentrations of fine particulates as follows (based on 24-hour average concentrations):

< 50 μg/m^3	=	Low
50 – 74 μg/m^3	=	Moderate
75 – 99 μg/m^3	=	High
> 100 μg/m^3	=	Very high

In estimating the health costs due to road traffic-related air pollution, the WHO Ministerial Conference on Environment and Health used chronic exposure levels (Seethaler 1999) in three countries namely Austria, France and Switzerland to derive increased frequencies of health outcomes. Seven air pollution related health outcomes were considered. These and the Effect Estimate Relative Risk are summarised in Table B-1, below.

It is important to note that the linear relationships depicted by the WHO, CEPA and UK Department of Environment, Transport and the Regions are based on *epidemiological* studies. Causal relationships based on *clinical* studies have not yet been established to support such linear relationships. Clinical studies involve controlled human exposure investigations, whereas epidemiological studies are observational in nature. In epidemiological studies, the investigator has no control over exposure or treatment of subjects, but rather examines the statistical relationship between dose and response.

Table A-1: Additional health cases for exposure to 10 μg/m^3 PM10 increments (Seethaler 1999).

Health Outcome	Age	Effect Estimate Relative Risk [(1)]
Total Mortality	Adults (≥ 30 years)	1.043 (Range: 1.026 –1.061)
Respiratory Hospital Admissions	All Ages	1.0131 (Range: 1.001 –1.025)
Cardiovascular Hospital Admissions	All Ages	1.0125 (Range: 1.007 –1.019)
Chronic Bronchitis Incidence	Adults (≥ 25 years)	1.098 (Range: 1.009 –1.194)
Acute Bronchitis	Children (< 15 years)	1.306 (Range: 1.135 –1.502)
Restricted Activity Days [(2)]	Adults (≥ 30 years)	1.094 (Range: 1.079 –1.109)
Asthmatics: Asthma Attacks [(3)]	Children (< 15 years)	1.044 (Range: 1.027 –1.062)
Asthmatics: Asthma Attacks [(3)]	Adults (≥ 15 years)	1.039 (Range: 1.019 –1.059)

Notes:

(1) Calculated expectancy frequency at the reference level of 7.5 µg/m^3 PM10 (±95% confidence interval)
(2) Restricted activity days: total person-days per year
(3) Asthma attacks: total person days with asthma attacks

A.2. Dust Deposition Limits

Nuisance impacts due to dust are associated with dustfall and soiling impacts and with reductions in visibility. Atmospheric particulates change the spectral transmission, thus diminishing visibility by scattering light. The scattering efficiency of such particulates is dependent upon the mass concentration and size distribution of the particulates. Various costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics. The soiling of building and materials due to dust frequently gives rise to damages and costs related to the increased need for washing, cleaning and repainting. Dustfall may also impact negatively on sensitive industries, e.g. bakeries or textile industries.

No criteria for the evaluation of dust falls levels are available for the US-EPA, EU, WHO, or the WB. Dust deposition may be gauged according to the criteria published by the South African Department of Environmental Affairs and Tourism (DEAT). In terms of these criteria dust deposition is classified as follows:

SLIGHT	-	less than 250 mg/m^2/day
MODERATE	-	250 to 500 mg/m^2/day
HEAVY	-	500 to 1200 mg/m^2/day
VERY HEAVY	-	more than 1200 mg/m^2/day

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

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface, with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 mg/m^2/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers. Local experience, gained from the assessment of impacts due to dust from mine tailings dams in Gauteng, has shown that complaints from the public will be activated by repeated dustfall in excess of ~2000 mg/m^2/day. Dustfall in excess of 5 000 mg/m^2/day impacting on residential or industrial areas generally provoke prompt and angry complaints.

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

Table A-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)	

Starting in ~1984, widespread monitoring of dustfall around gold tailing reclamation sites along the length of the Witwatersrand and around surface coal mines, using the American Standard Test Method (ASTM1739), has been undertaken. Although several other countries have dustfall guidelines, none have monitored dustfall as extensively as in South Africa. The accumulated data from over two hundred sites with continuous records extends as long as 17 years at the oldest sites. Considerable experience has been accumulated within the framework of the DEAT guidelines as to what is acceptable, tolerable and what is intolerable.

A perceived weakness in the current dust-fall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, VERY HEAVY). On the basis of the cumulative South African experience of dustfall measurements, we propose a modified set of dustfall standards, within the overall framework of the new Clean Air Legislation.

A.2.1 Dust-fall Standards Proposed

Measurement Methods

The method of dustfall measurement shall be by capture of particles by gravitational settling across a horizontal surface into a deep container, following the American Standard Test Method (ASTM1739) or any subsequent amendments to that standard. Measurements shall extend over 30 ± 3 days.

The number and location of samplers shall be sufficient to monitor dust-fall at representative locations around the dust source, and will include monitors located at human residences and sensitive business, industrial or agricultural locations within a maximum distance of 2 km from source boundary. At least one monitor shall be placed upwind or at some distance from the source to characterise typical background dustfall beyond the zone of influence of the source. For practical purposes this may be taken as more than 2 km from source. Micro-surroundings of the samplers shall where possible follow the ASTM 1739 prescriptions.

Dustfall monitors may also be located within the boundaries of the industrial plant as defined by the legal, fenced boundaries of the enterprise, for industrial control purposes. Even when included in general environmental reports, these site-internal monitors shall not be evaluated against the standards in terms of the CAA.

Equivalent Methods

Equivalent methods may be accepted by the DEAT (specify responsible officer or Directorate) on submission of a technical report demonstrating equivalence. At a minimum equivalence testing shall consist of three co-located samplers of the reference type and the test type, operated continuously for a period not less than six months. The mean dustfall rates obtained by the test method shall agree with the reference method within one standard deviation as determined by the replicate measurements.

Variations of Method

To establish the contributions to dust-fall rate by two sources located near to each other, directional samplers incorporating two or more dustfall collection containers and some movable lid may be used to monitor dustfall. While these samplers may be used in a qualitative manner to determine relative contributions from the sources, or determine the net difference in dustfall rate of air passing across an industrial boundary, sectorial dustfall rates obtained by such methods shall not be definitive for purposes of complying with the standards. The sum of all dustfalls from all containers averaged over the entire sampling period may be used as equivalent to a single container sampler.

Analytical Procedures

Analytical procedures shall follow the ASTM 1739 prescriptions.

Reporting Conventions

Dustfall rates shall be expressed in units of (mg m^{-2} day^{-1}, 30-day average).

Evaluation of Dustfall

See main report (section 2.3.2).

Margin of Tolerance

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.

Responsible Agency

As sources of dustfall are readily identified and localised, responsibility for monitoring shall be with the owner or operator of the source enterprise(s). Results of monitoring from instruments located in public areas, taken to mean any monitor other than within the defined industrial/mining premises, shall be reported to regulatory authorities on a regular basis (monthly or quarterly). The cost of such monitoring shall be for the account of the operator or owner of the source enterprise.

Exceptions

Dustfalls that exceed the specified levels but that can be shown to be the result of some extreme weather or geological event shall be discounted for the purpose of enforcement and control. Such events might typically result in excessive dustfall rates across an entire metropolitan region, and not be localised to a particular operation. Natural seasonal variations, such as dry windy periods during the Highveld spring will not be considered extreme events for this definition.

APPENDIX B: TECHNICAL DESCRIPTION OF EMISSIONS QUANTIFICATION

B.1 Fugitive Dust Emissions

Emissions from materials handling operations associated with mining will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are most readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increases in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

The four main sources of fugitive particulate emissions associated with most mining operations are: (i) materials handling operations (e.g. loading to trucks/conveyors, stockpiling and reclamation of material); (ii) entrainment of roadway dust by on-site vehicles; (iii) wind erosion of stockpiles and open areas; and (iv) drilling and blasting operations.

B.1.1 Fugitive Dust Emissions from Tipping Operations

The following predictive equation was used to estimate emissions from anticipated material tipping operations are as follows:

$$EF = 0.0016 \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}} \quad (1)$$

where,

EF	=	emission factor (kg dust / tonne transferred)
U	=	mean wind speed (m/s)
M	=	material moisture content (%)
k	=	particle size multiplier (dimensionless)

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for the different types of material were not available and use was made of the typical moisture contents given by US-EPA in the section pertaining aggregate handling and storage piles (EPA, 1998a).

B.1.2 Conveyor Transfer Points

Conveyor transfer of material is given by the US.EPA as a single valued emission factor available to calculate emissions emanating from transfer of material. The US-EPA emission factor was applied, viz.:

$$E_{TSP} = 0.0062 \text{ kg of dust / tonne of material transferred} \quad (2)$$

B.1.3 Fugitive Dust Emissions from Excavating

Excavation results in the release of fugitive dust to atmosphere. The formula given by the US.EPA to calculate emissions emanating from these activities are presented below for TSP and PM10 respectively.

$$EF = k * 0.0016 * (U/2.2)^{1.3} * (M/2)^{-1.4} \quad (3)$$

Where :

EF	=	emission factor (kg dust / tonne transferred)
U	=	mean wind speed (m/s)
M	=	material moisture content (%)
k	=	particle size multiplier (dimensionless)

This is the same emission factor equation as for materials transfer points (see equation 1). A moisture content of 2% was assumed based on data provided. The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations.

C.1.4 Blasting and Drilling Operations

Blasting and drilling operations represent intermittent sources of fugitive dust emissions.

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

$$E_{TSP} = 0.59 \text{ kg of dust / drill hole} \quad (4)$$

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

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

$$E_{TSP} = 344\left(\frac{A^{0.8}}{M^{1.9} \times D^{1.8}}\right) \quad (5)$$

Where,

E_{TSP} = Total Suspended Particulate emissions in kg/blast
A = horizontal area (m²)
M = moisture content of the blasted material (%)
D = depth of blast holes (m)

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

B.1.5 Wind Erosion from Exposed Areas

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

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

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

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

for

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

and

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

where,

$E_{(i)}$ = emission rate (g/m²/s) for particle size class i

P_a = air density (g/cm³)

g	=	gravitational acceleration (cm/s³)
u_*^t	=	threshold friction velocity (m/s) for particle size i
u^*	=	friction velocity (m/s)

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

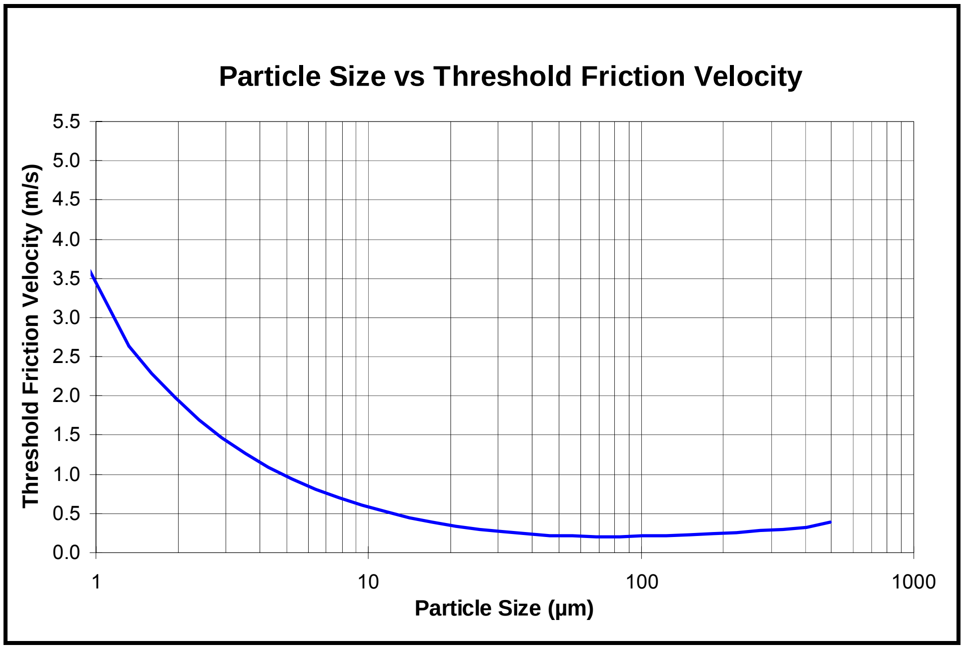

Figure B- 1: Relationship between particle sizes and threshold friction velocities using the calculation method proposed by Marticorena and Bergametti (1995).

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (EPA, 1998c):

$$U^* = 0.053U_{10}^+ \quad (7)$$

(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.)

The wind speed variation over the dump is based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US-EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile.

The ratios of surface wind speed (us) to approach wind speed (ur), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure B-2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope). The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow. (The higher the ratio, the greater the wind exposure potential.)

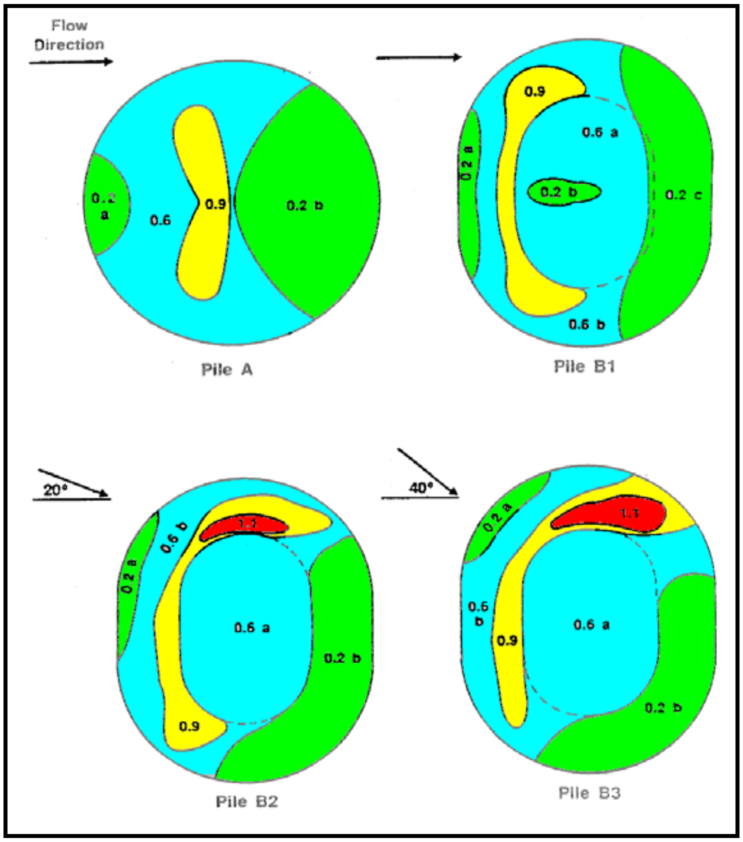

Figure B- 2: Contours of normalised surface wind speeds (i.e. surface wind speed / approach wind speed) (after EPA, 1998c).

B.1.6 Crushing and Screening Operations

Primary crushing represents a significant dust-generating source if uncontrolled. Dust fallout in the vicinity of crushers also gives rise to the potential for the re-entrainment of dust emitted by vehicles or by the wind at a latter date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne.

A single valued US-EPA emission factor was used in the quantification of possible emissions due to uncontrolled screening activities, viz.:

$$E_{TSP} = 0.0152 \text{ kg of dust / tonne of material screened}$$

$$E_{PM10} = 0.0076 \text{ kg of dust / tonne of material screened} \quad (8)$$

A total suspended particulate fraction of 1.3 and 56.4 tonnes per annum due to crushing and screening operations were estimated due to the processing of 10,201.68 tonnes per day of ROM. Similarly 0.5 and 28.2 tonnes per annum of inhalable particulates were estimated due to these processes.

B.1.7 Vehicle-Entrained Emissions from Unpaved Roads

The force of the wheels of vehicles travelling on unpaved roadways causes pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to affect the road surface once the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic, including average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1998b).

The unpaved road size-specific emission factor equation of the US-EPA was revised in their 1998 AP42 document on Unpaved Roads and was used in the quantification of emissions for the current study. It is given as follows:

$$E = k(\frac{s}{12})^a (\frac{W}{3})^b \qquad (9)$$

where,

E = emissions in kg of particulates per vehicle kilometre travelled (lb/VMT)
K,a,b and c = empirical constants (Table B-1)
s = surface material silt content (%)
W = mean vehicle weight (tonnes)

The metric conversion from lb/VMT to grams (g) per vehicle kilometre travelled (VKT) is as follows:
1 lb/VMT = 281.9 g/VKT

Table B- 1: Constants for unpaved road equation (US.EPA, 1998).

Constant	PM2.5	PM10	PM30[1]
K (lb/VMT)	0.38	2.6	10
a	0.8	0.8	0.8
b	0.4	0.4	0.5
c	0.3	0.3	0.4
Notes: [1] PM-30 may be used as a substitute for TSP.			

APPENDIX C: DISPERSION RESULTS FOR INCREMENTAL SOURCES AT VALENCIA URANIUM MINE

Table C-9-1: Concentration Plots – PM10.

Pollutant	Source	Averaging Period	Guideline (µg/m³)	Figure No.
Unmitigated				
PM10	Roads - unpaved	Highest daily	75[1] 70 [2] 50 [3]	C-1
		Annual average	40 [1] 50 [2] 20 [3]	C-2
	Wind Erosion (Scenario 1)	Highest daily	75[1] 70 [2] 50 [3]	C-3
		Annual average	40 [1] 50 [2] 20 [3]	C-4
	Wind Erosion (Scenario 2)	Highest daily	75[1] 70 [2] 50 [3]	C-5
		Annual average	40 [1] 50 [2] 20 [3]	C-6
	Material handling (Tipping)	Highest daily	75[1] 70 [2] 50 [3]	C-7
		Annual average	40 [1] 50 [2] 20 [3]	C-8
	Material handling (Crushing & Screening)	Highest daily	75[1] 70 [2] 50 [3]	C-9
		Annual average	40 [1] 50 [2] 20 [3]	C-10
Mitigated				
PM10	Roads - unpaved	Highest daily	75[1] 70 [2] 50 [3]	C-11
		Annual average	40 [1] 50 [2] 20 [3]	C-12

Notes: [1] Proposed South African standards (SANS).
[2] WBG guidelines
[3] WHO Air Quality Guidelines.

Table C-2: Dust Deposition Plots – TSP.

Pollutant	Source	Averaging Period	Guideline (µg/m³)	Figure No.
Unmitigated				
TSP	Roads - unpaved	Total daily average	600[1] 1,200 [2]	C-13
	Wind Erosion (Scenario 1)	Total daily average		C-14
	Wind Erosion (Scenario 2)	Total daily average		C-15
	Material handling (Tipping)	Total daily average		C-16
	Material handling (Crushing & Screening)	Total daily average		C-17
Mitigated				
TSP	Roads - unpaved	Total daily average	600[1] 1,200 [2]	C-18

Notes: [1] Proposed South African residential action level (SANS).
[2] Proposed South African industrial action level (SANS).

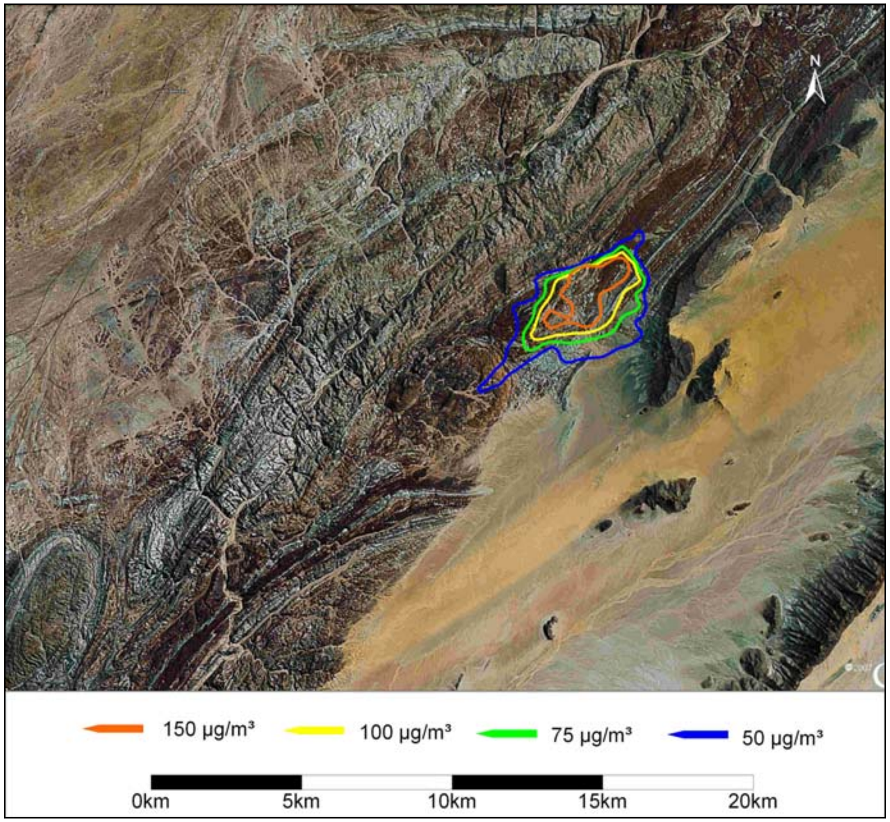

Figure C- 1: Highest daily average PM10 concentration (µg/m³) as a result from vehicle entrainment on unpaved roads

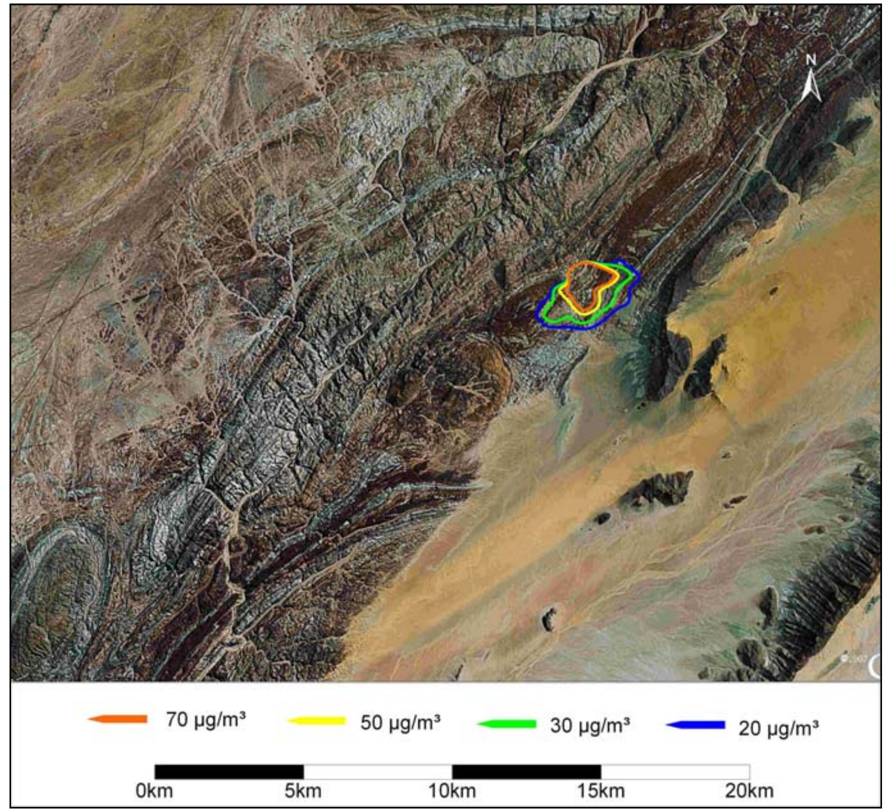

Figure C- 2: Annual average PM10 concentration (µg/m³) as a result from vehicle entrainment on unpaved roads

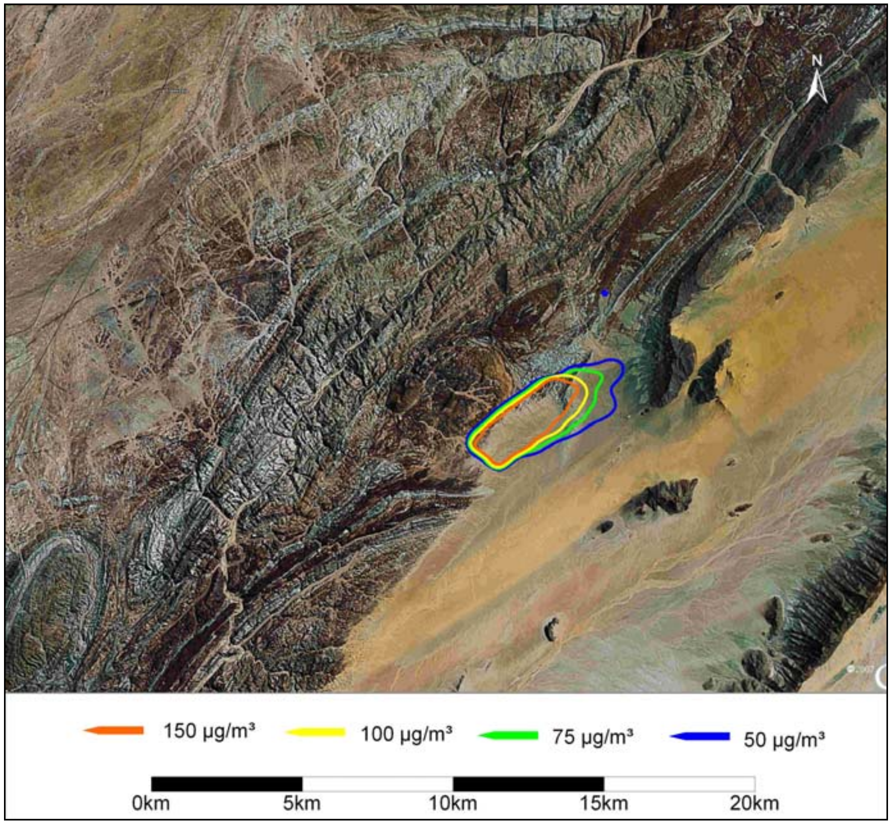

Figure C- 3: Highest daily average PM10 concentration (µg/m³) as a result from wind blown dust (Scenario 1)

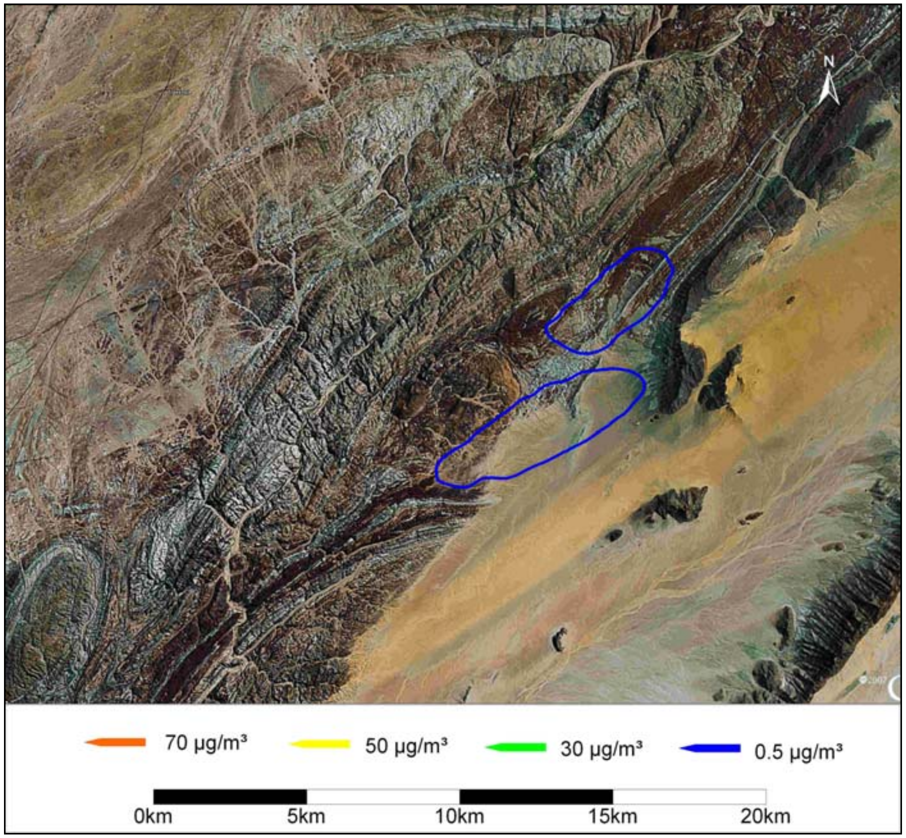

Figure C- 4: Annual average PM10 concentration (µg/m³) as a result from wind blown dust (Scenario 1)

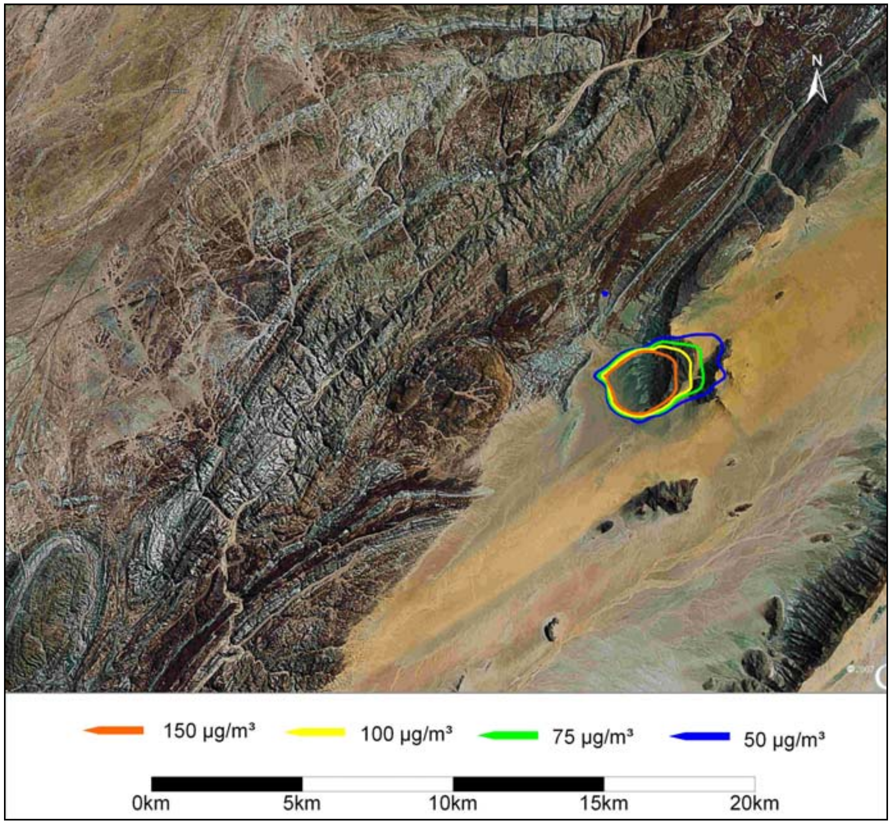

Figure C- 5: Highest daily average PM10 concentration (µg/m³) as a result from wind blown dust (Scenario 2)

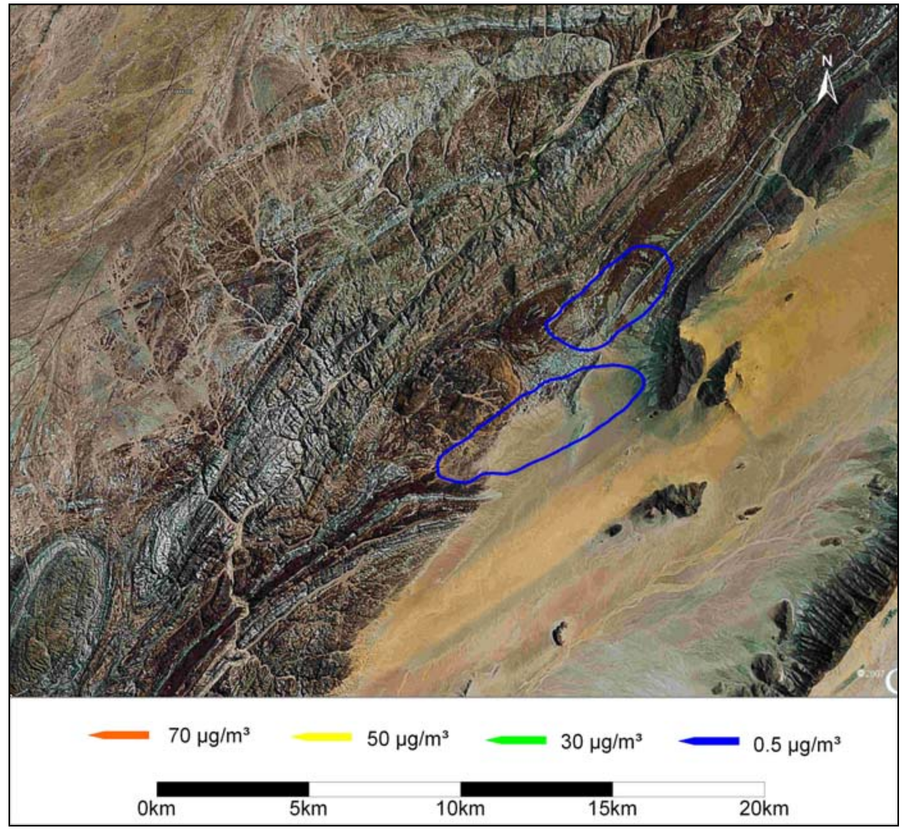

Figure C- 6: Annual average PM10 concentration (µg/m³) as a result from wind blown dust (Scenario 2)

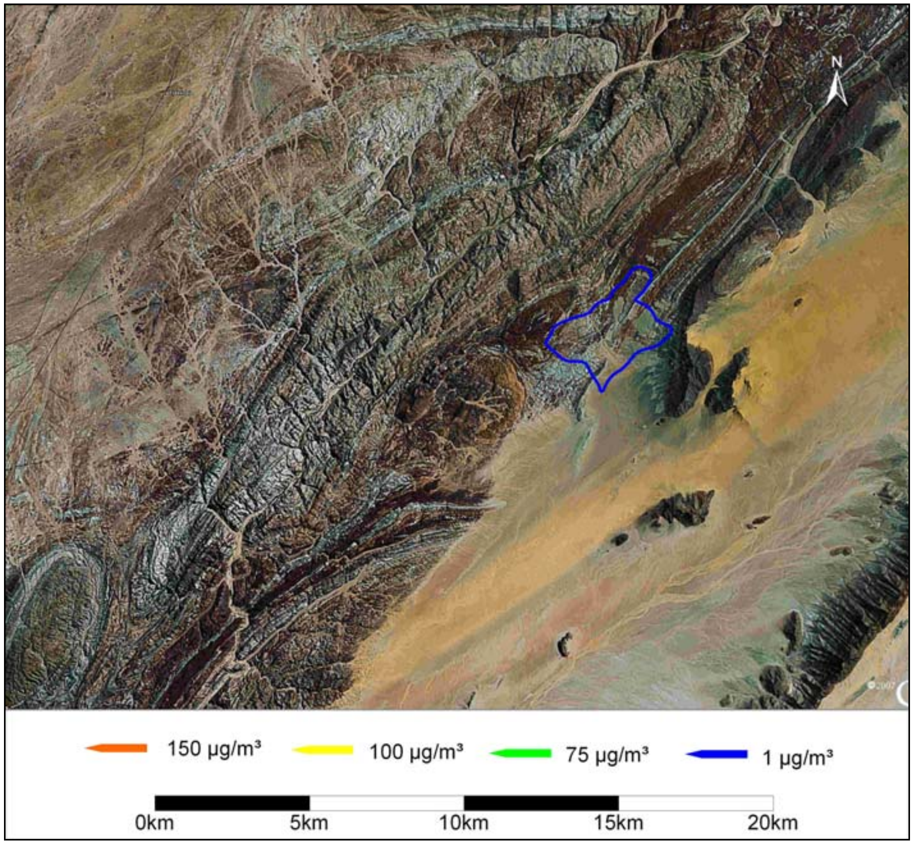

Figure C- 7: Highest daily average PM10 concentration (µg/m³) as a result from materials handling operations (tipping)

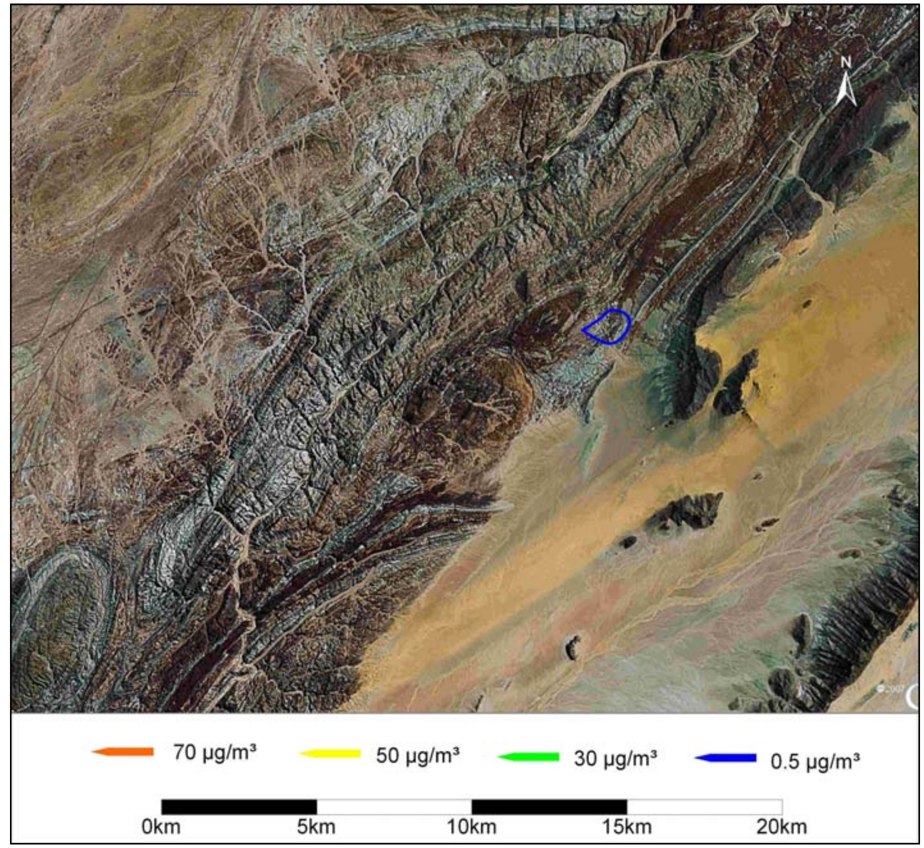

Figure C- 8: Annual average PM10 concentration (µg/m³) as a result from materials handling operations (tipping)

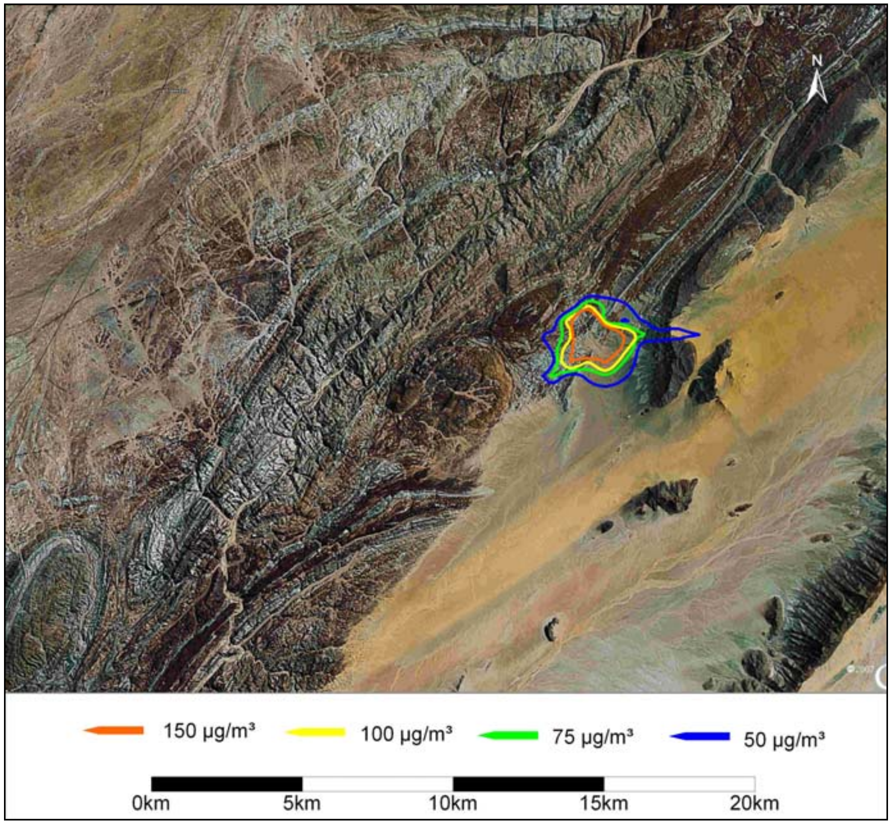

Figure C- 9: Highest daily average PM10 concentration (µg/m³) as a result from crushing and screening operations

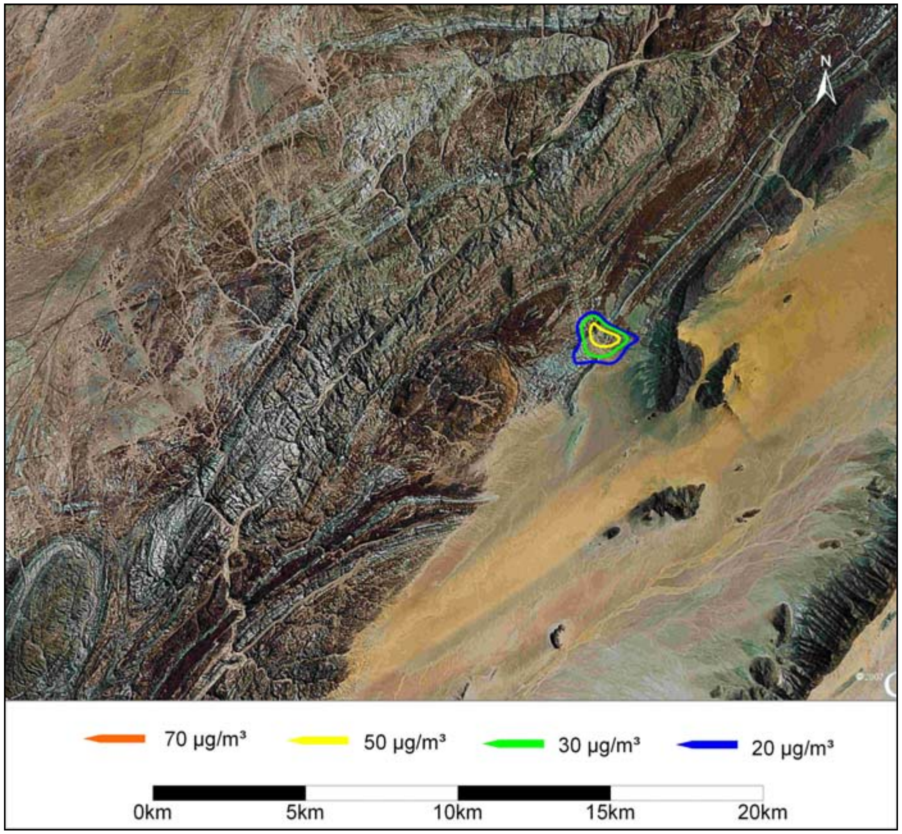

Figure C- 10: Annual average PM10 concentration (µg/m³) as a result from from crushing and screening operations

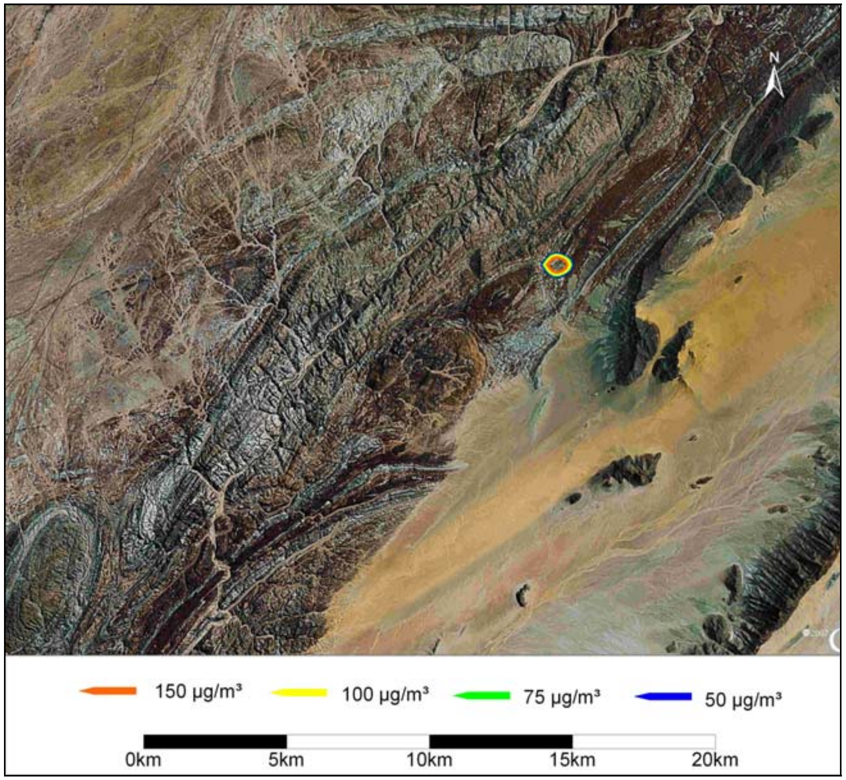

Figure C- 11: Highest daily average PM10 concentration (µg/m³) as a result from vehicle entrainment on unpaved roads - mitigated

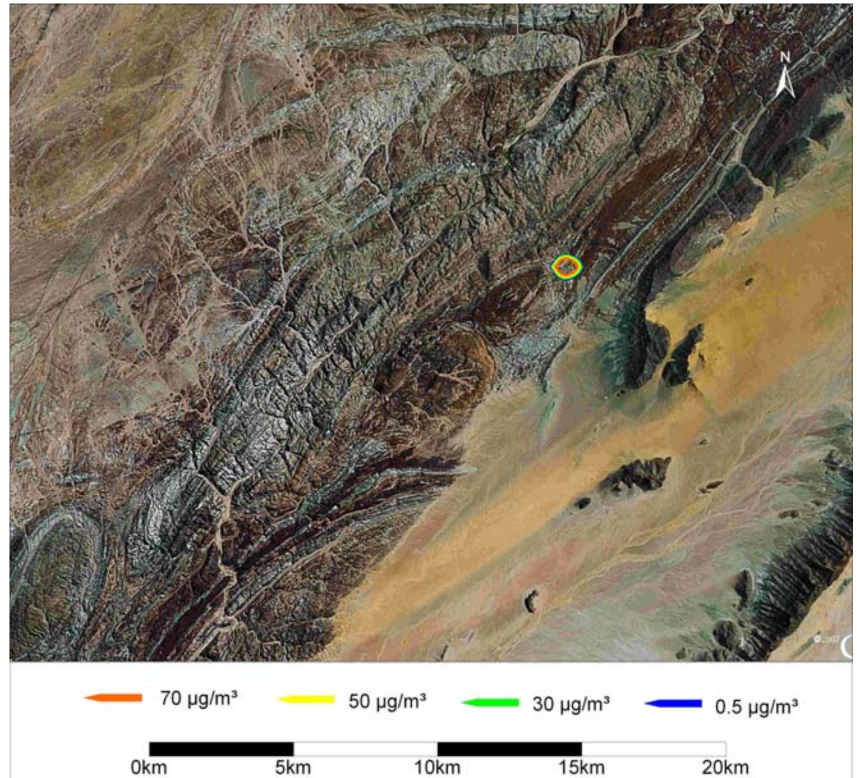

Figure C- 12: Annual average PM10 concentration (µg/m³) as a result from vehicle entrainment on unpaved roads - mitigated

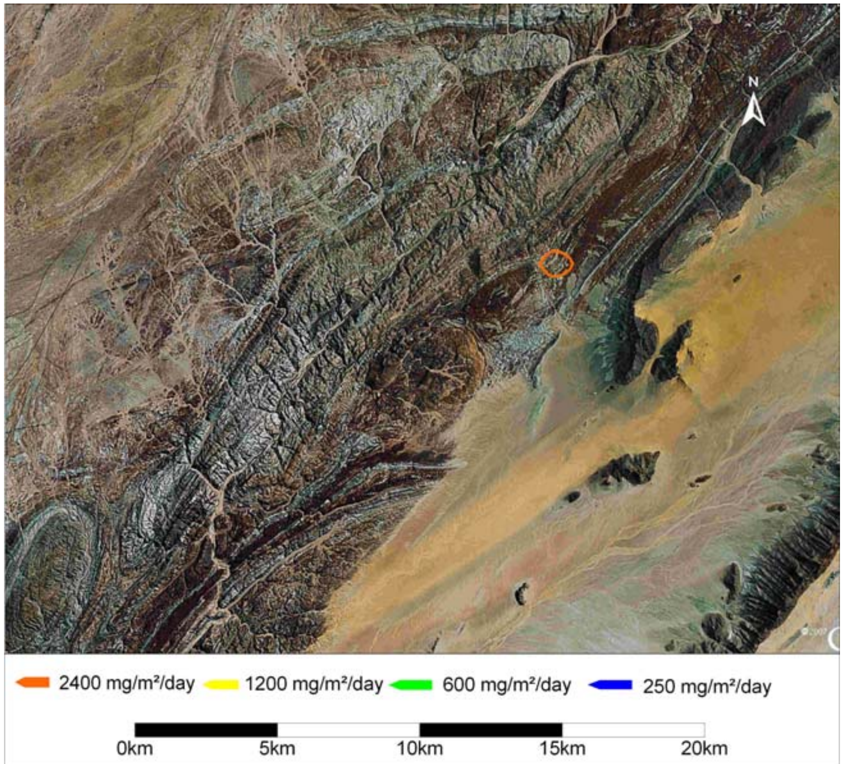

Figure C- 13: Total daily average dust fallout (mg/m^2/day) as a result from vehicle entrainment on unpaved roads

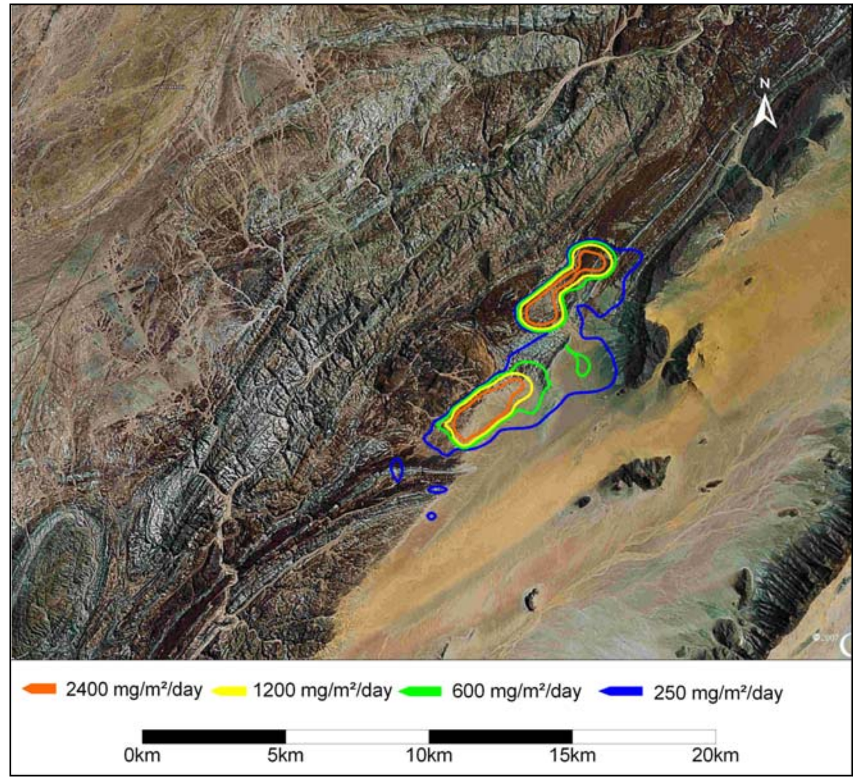

Figure C- 14: Total daily average dust fallout (mg/m^2/day) as a result from wind blown dust (Scenario 1)

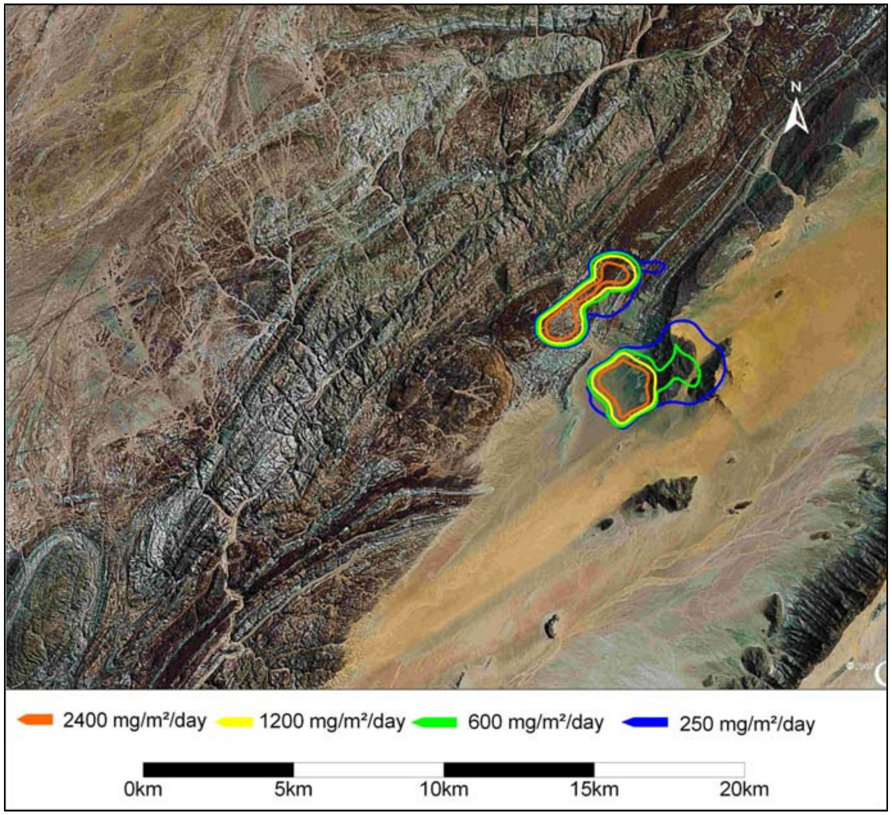

Figure C- 15: Total daily average dust fallout (mg/m^2/day) as a result from wind blown dust (Scenario 2)

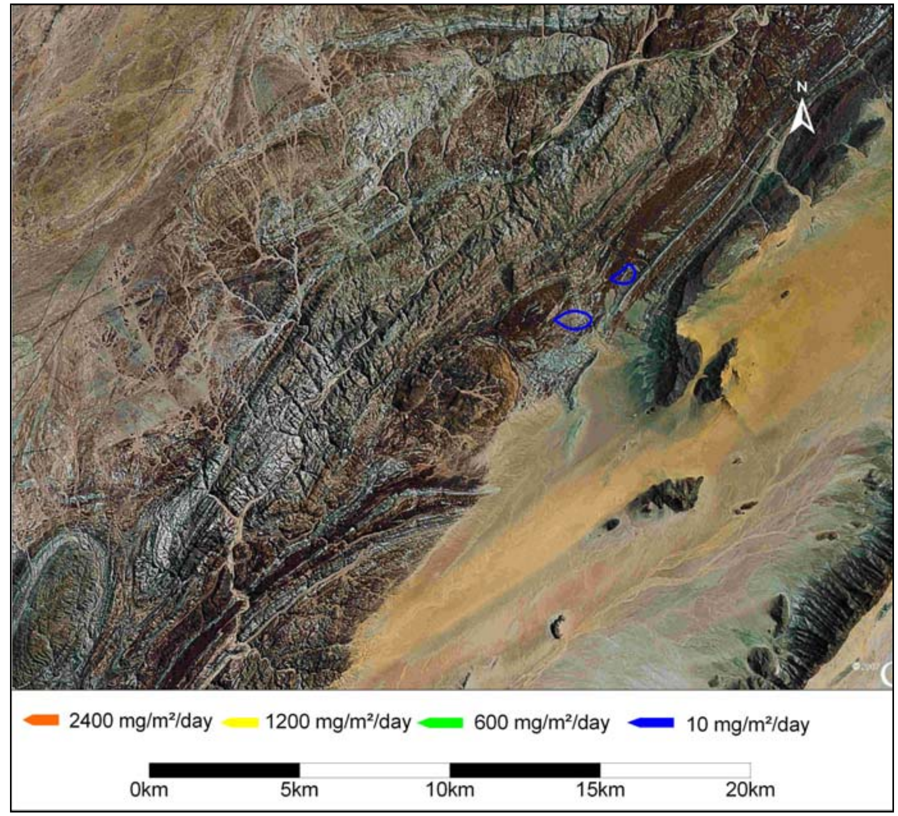

Figure C- 16: Total daily average dust fallout (mg/m^2/day) as a result from materials handling operations (tipping)

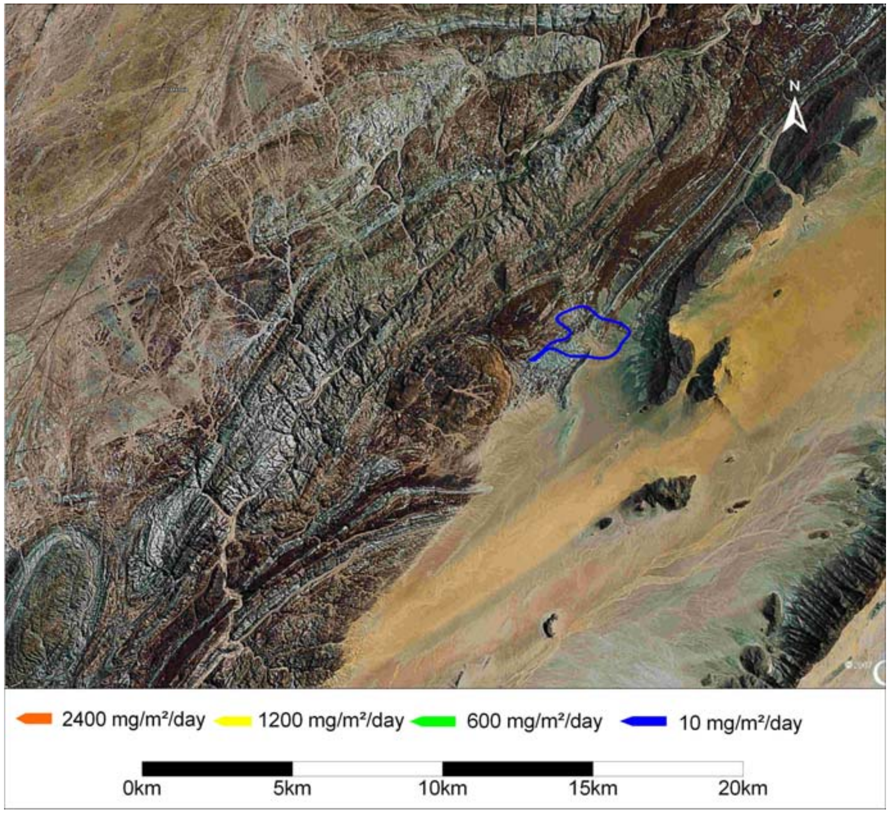

Figure C- 17: Total daily average dust fallout (mg/m^2/day) as a result from crushing and screening operations

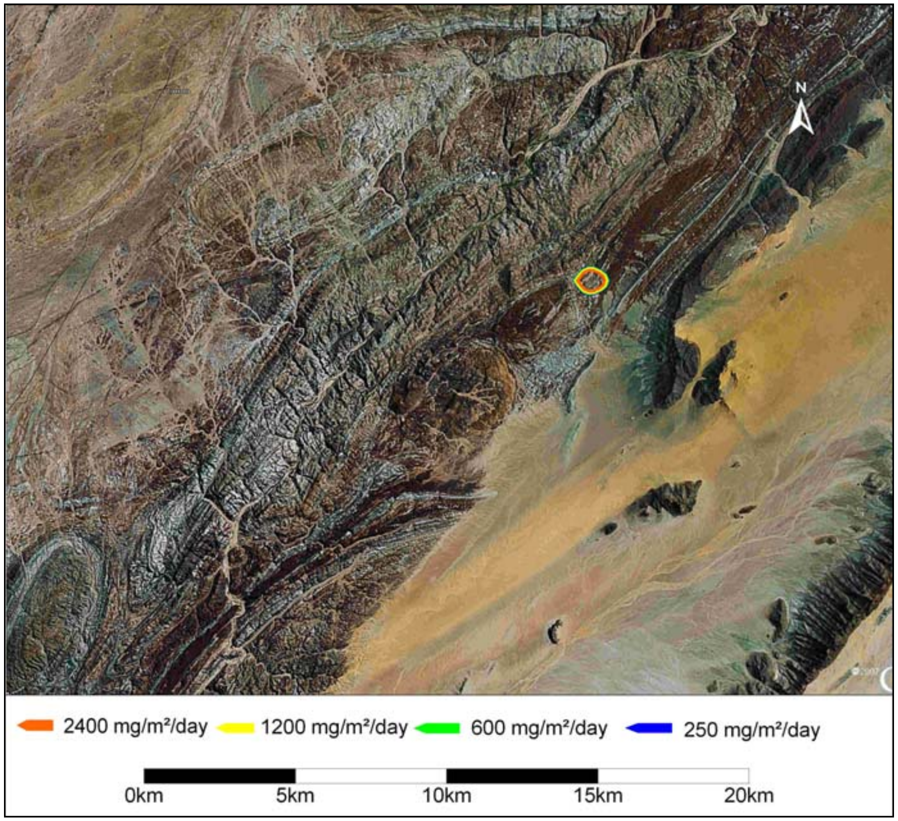

Figure C- 18: Total daily average dust fallout (mg/m^2/day) as a result from vehicle entrainment on unpaved roads - mitigated