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SLR Environmental Consulting (Namibia) (Pty) Ltd

Noise Impact Assessment for Rössing Uranium's Proposed Desalination Plant near Swakopmund
Environmental Noise Impact Assessment

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Report Details

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List of Acronyms

Airshed	Airshed Planning Professionals (Pty) Ltd
EHS	Environment, Health and Safety (IFC)
DAF	Dissolved Air Flotation
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
NSR	Noise Sensitive Receptor
PTS	Permanent Threshold Shift
RO	Reverse Osmosis
RUDP	Rössing Uranium Desalination Plant
SABS	South African Bureau of Standards
SANS	South African National Standards
SEIA	Social and Environmental Impact Assessment
SLM	Sound Level Meter
SLR	SLR Environmental Consulting (Namibia) (Pty) Ltd
S/N	Signal to noise ratio
SWRO	Seawater Reverse Osmosis
TTS	Temporary Threshold Shift
WHO	World Health Organisation

Glossary

A-weighting	The 'A-weighting' filter simulates the human hearing characteristic, which is less sensitive to sounds at low frequencies than at high frequencies. "dBA" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities, that have the same units (in this case sound pressure) that has been A-weighted
dB	Noise is reported in decibels (dB). "dB" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure.
L_{Aeq} (T)	The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured). The International Finance Corporation (IFC) provides guidance with respect to LAeq (1 hour), the A-weighted equivalent sound pressure level, averaged over 1 hour.
L_{AFmax}	The maximum A-weighted noise level measured with fast time weighting. It's the highest level of noise that occurred during the sampling period.
L_{A90}	The A-weighted 90% statistical noise level, i.e. the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the LAeq could have been in the absence of noisy single events and is considered representative of background noise levels.
L_{Zeq} (T)	The un-weighted sound pressure level, where T indicates the time over which the noise is averaged.
$L_{R,dn}$	L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the period of a day and night, i.e. 24 hours, and wherein the $L_{Req,n}$ has been weighted with 10 dB in order to account for the additional disturbance caused by noise during the night.
$L_{Req,d}$	L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the day-time period, i.e. from 06:00 to 22:00
$L_{Req,n}$	The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the night-time period, i.e. from 22:00 to 06:00.
Δ	The increase in noise level above the baseline

Executive Summary

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by SLR Environmental Consulting (Namibia) (Pty) Ltd (SLR) to undertake an environmental noise impact assessment for the proposed Rössing Uranium Desalination Plant (RUDP) near the Swakopmund Salt Works north of Swakopmund, Namibia.

The study included:

1. A short term noise sampling campaign
2. A desktop study of the receiving (baseline) acoustic environment, incl.:
    a. The identification of noise sensitive receptors from available maps.
    b. A study of atmospheric noise attenuation by referring to weather records, land use and topography data sources.
    c. A review of environmental noise guidelines.
    d. Analysis of sampled baseline noise levels.
3. A noise impact assessment, incl.:
    a. A review of available detailed project information.
    b. The establishment of a noise emissions inventory for proposed operations.
    c. Noise propagation modelling to determine environmental noise levels.
    d. The screening of simulated environmental noise levels against noise criteria.
    e. The rating of impact significance.
    f. A specialist noise impact assessment report including management, mitigation and monitoring plans.

In the measurement and assessment of environmental noise levels within the study area, extensive reference was made to procedures prescribed by the International Finance Corporation (IFC) in their General Environment, Health and Safety (EHS) Guidelines (2007) and in South African National Standards (SANS) 10103 (2008). In the absence of guidelines on the assessment of noise impacts on nearby birdlife reference was made to the results of an extensive literature survey. Atmospheric noise attenuation potential was determined from weather data recorded at Wlotzkasbaken between 2001 and 2007 and site observations of local land use and ground cover. Noise sensitive receptors (NSRs) were identified during a visit to site and available maps.

Sound power levels or 'noise emissions' from activities associated with the proposed RUDP were estimated based on source data provided by Royal HaskoningDHV and sound power level predictions for industrial machinery as published in the 'Handbook of Acoustics'. Reference was also made to data published by the European Commission (EC) Working Group Assessment of Exposure to Noise (WG-AEN).

The propagation of noise from proposed activities was calculated according *to 'The Calculation of Sound Propagation by the Concawe method'* (SANS 10357, 2004). Meteorological data obtained from the Wlotzkasbaken weather station were applied in calculations. Reference was also made to data made available for Swakopmund. Noise impacts were calculated both in terms of the ambient noise levels as a result of the RUDP incrementally, as well as the effective increase in ambient noise levels over the baseline i.e. cumulative assessment. The significance of noise impacts was determined in accordance with the procedure prescribed by SLR.

The main findings of the study are summarised below:

- The northern suburbs of Swakopmund and the Mile 4 Caravan Park are the closest residential NSRs at between 3.5 and 4 km south of the proposed desalination plant. The impacts of noise on these receptors were screened against IFC guidelines for residential receptors (day-time 55 dBA, night-time 45 dBA, and increase above baseline 3 dBA).
- Birdlife within the Damara Tern and Guano Platform areas were also included as NSRs. The impacts of noise on these receptors were screened against the interim guideline proposed by Dooling and Popper (2007) of 60 dBA.
- Based on the local wind field day-time noise impacts are expected to be most notable to the south and north-north east, on average. During the night it is expected to be most significant to the south of proposed operations.
- Noise impacts will be most notable at night, firstly because of the effect of temperature and secondly as a result of lower local baseline night time noise levels.
- There are no features (natural or otherwise) within the local study area that may act as acoustic barriers between the proposed desalination plant and local NSRs.
- Ground cover includes sand and gravel plains and is considered acoustically 'hard' i.e. not conducive to noise attenuation.
- Baseline noise levels during the day and notes taken during sampling indicate the Swakopmund Salt Works to be the most notable local noise source. Traffic along the C34 also contributes significantly to local baseline day and night-time noise levels. At night, ocean surf noise becomes more sudible than during the day.
- From the sampling data and site observations, representative day- and night-time baseline noise levels of 49.2 dBA and 44.0 dBA were determined respectively. These levels were applied in the calculation of cumulative noise levels and the expected increase in noise as a result of the expected intruding industrial noise.
- There are no distinguishing elements in significance of impacts associated with the location alternatives considered in the study.
- During the construction phase, impacts on human receptors and birdlife is considered **'Very Low'** with no-, or marginal exceedances of assessment criteria at NSR.
- With the installation of a boundary wall to act as an acoustic barrier, the significance of impacts on human receptors and birdlife during the operational phase will reduce from **'Low'** to **'Very Low'**.
- With mitigation, the proposed RUDP is not expected to affect social or natural functions or processes notably.

It is concluded that, provided that the environmental noise mitigation and management measures recommended in this report are implemented and adhered to, significant noise implications are unlikely and the Project could proceed.

Noise Impact Assessment for Rössing Uranium's Proposed Desalination Plant near Swakopmund
Environmental Noise Impact Assessment

1 INTRODUCTION

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by SLR Environmental Consulting (Namibia) (Pty) Ltd (SLR) to undertake an environmental noise impact assessment for the proposed sea water desalination plant near the salt works north of Swakopmund, Namibia.

2 BACKGROUND

2.1 Project Description

The following basic process description was provided by SLR:

The desalination plant will be located approximately 6 km north of Swakopmund, at the existing Swakopmund Salt Works. The project will comprise the following components that will be assessed as part of the Social and Environmental Impact Assessment (SEIA) process:

- The seawater intake system and associated infrastructure. The water intake will be located in the vicinity of the existing Swakopmund Salt Works intake.
- Infrastructure to transport water to the plant.
- A new seawater buffer pond near the plant.
- The pre-treatment plant that will remove sediments, solids and organic matter. This plant will most likely comprise of a Dissolved Air Flotation (DAF) system.
- A Modular Seawater Reverse Osmosis (SWRO) desalination plant with a capacity of approximately 3 million m^3/year (or average of 8 200 m^3/day with capacity to produce up to 10 000 m^3/day). This will be housed together with the post- and pre-treatment infrastructure in a fenced off plant area.
- The waste water outlet system (discharging into the surf) and associated infrastructure. Two discharge alternatives are being assessed (Outfall 1 in the north and Outfall 5 located near the existing salt works bitterns outlet), both within the Mining Licence area of the Swakopmund Salt Works
- A new 11 kV power line of approximately 6 km would need to be constructed, together with a new substation at the plant.
- A water supply line of roughly 850 m to the existing NamWater pipeline, transporting desalinated water.
- Related services and structures i.e. offices, access road, etc.

The media filters and Reverse Osmosis (RO) plant will be housed in the same building which will be approximately 60 m x 20 m x6 m high, while the post treatment and pre-treatment plants, and the storage tanks would be located adjacent to the plant building. The equipment room, offices, and chemical storage room would also be housed in a 13 m x 20 m x 6 m high building that is connected, or is immediately adjacent, to the main plant building.

2.2 Terms of Reference

The following tasks are included in the noise impact assessment:

1. A baseline study; including;
    a. A short term noise sampling campaign (20 minutes per sample) at 3 locations during the day and night and in accordance with South African National Standards (SANS) 10103 (2008) and International Finance Corporation's (IFC) General Environmental, Health and Safety Guidelines (EHS) of 2007.
    b. A desktop study of the receiving (baseline) acoustic environment, including:
        i. The identification of noise sensitive receptors from available maps.
        ii. A study of atmospheric noise attenuation by referring to weather records, land use and topography data sources.
        iii. A review of environmental noise guidelines.
        iv. Analysis of sampled baseline noise levels.
    c. A baseline environmental noise report.
2. A detailed noise impact assessment, including:
    a. A review of available detailed project information.
    b. The establishment of a noise emissions inventory for proposed operations.
    c. Noise propagation modelling to determine environmental noise levels.
    d. The screening of simulated environmental noise levels against noise criteria.
    e. The rating of impact significance.
    f. A specialist noise impact assessment report including management, mitigation and monitoring plans.

3 METHODOLOGY

Before more details regarding the methodology adopted for the assessment is given, the reader is provided with some background, definitions and conventions used in the measurement and assessment of environmental noise.

3.1 Background to Environmental Noise and the Assessment Thereof

Noise is generally defined as unwanted sound transmitted through a compressible medium such as air. Sound in turn, is defined as any pressure variation that the ear can detect. Human response to noise is complex and highly variable as it is subjective rather than objective.

Noise is reported in decibels (dB). "dB" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure. The relationship between sound pressure and sound pressure level is illustrated in Equation 1.

$$L_p = 20 \cdot \log_{10}\left(\frac{p}{p_{ref}}\right)$$

Equation 1

Where:

L_p is the sound pressure level in dB;
p is the actual sound pressure in Pa; and
p_{ref} is the reference sound pressure (p_{ref} in air is 20 µPa)

3.1.1 Perception of Sound

Sound has already been defined as any pressure variation that can be detected by the human ear. The number of pressure variations per second is referred to as the frequency of sound and is measured in hertz (Hz). The hearing of a young, healthy person ranges between 20 Hz and 20 000 Hz.

In terms of sound pressure level, audible sound ranges from the threshold of hearing at 0 dB to the pain threshold of 130 dB and above. Even though an increase in sound pressure level of 6 dB represents a doubling in sound pressure, an increase of 8 to 10 dB is required before the sound subjectively appears to be significantly louder. Similarly, the smallest perceptible change is about 1 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

3.1.2 Frequency Weighting

As **human hearing** is not equally sensitive to all frequencies, a 'filter' has been developed to simulate human hearing. The 'A-weighting' filter simulates the human hearing characteristic, which is less sensitive to sounds at low frequencies than at high frequencies. "dBA" is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities, that have the same units (in this case sound pressure) that has been A-weighted.

3.1.3 Adding Sound Pressure Levels

Since sound pressure levels are logarithmic values, the sound pressure levels as a result of two or more sources cannot just simply be added together. To obtain the combined sound pressure level of a combination of sources such as those at an industrial plant, individual sound pressure levels must be converted to their linear values and added using Equation 2.

$$L_{p\_combined} = 10 \cdot \log\left(10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} + 10^{\frac{L_{p3}}{10}} + \cdots 10^{\frac{L_{pi}}{10}}\right)$$

Equation 2

This implies that if the difference between the sound pressure levels of two sources is nil the combined sound pressure level is 3 dB more than the sound pressure level of one source alone. Similarly, if the difference between the sound pressure levels of two sources is more than 10 dB, the contribution of the quietest source can be disregarded (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

3.1.4 Environmental Noise Propagation

Many factors affect the propagation of noise from source to receiver. The most important of these are:

- The type of source and its sound power;
- The distance between the source and the receiver;
- The extent of atmospheric absorption (attenuation);
- Wind speed and direction;
- Temperature and temperature gradient;
- Obstacles such as barriers or buildings between the source and receiver;
- Ground absorption;
- Reflections;
- Humidity; and
- Precipitation

To arrive at a representative result from either measurement or calculation, all these factors must be taken into account (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

3.1.5 Environmental Noise Indices

In assessing environmental noise either by measurement or calculation, reference is made to the following indices:

- **L_{Zeq} (T)** – The un-weighted sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured).
- **L_{Aeq} (T)** – The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured). The International Finance Corporation (IFC) provides guidance with respect to L_{Aeq} (1 hour), the A-weighted equivalent sound pressure level, averaged over 1 hour.
- **L_{A90}** – The A-weighted 90% statistical noise level, i.e. the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the L_{Aeq} could have been in the absence of noisy single events and is considered representative of background noise levels.
- **L_{AFmax}** – The maximum A-weighted noise level measured with fast time weighting. It's the highest level of noise that occurred during the sampling period.

3.2 Approach to Study

The assessment included a study of the legal requirements pertaining to noise impacts, a study of the physical environment of the area surrounding the project and the analyses of existing noise levels in the area. The impact assessment focused on the estimation of sound power levels (noise 'emissions') and sound pressure levels (noise impacts) associated with the construction and operational phases. The findings of the assessment components informed recommendations of management measures, including mitigation and monitoring. Individual aspects of the noise impact assessment methodology followed in the study are discussed in more detail below.

3.2.1 *Short Term Environmental Noise Sampling Methodology*

In the measurement of environmental noise levels within the study area, extensive reference was made to procedures prescribed by the IFC in their General EHS Guidelines (2007) and in SANS 10103 (2008). A summary of the procedure is given below:

- Noise monitoring was carried out using a Type 1 sound level meter (SLM) which meets all the appropriate International Electrotechnical Commission (IEC) standards. Equipment details are summarised in Table 1.
- The noise monitoring programs was designed and conducted by a trained specialist.
- Sampling was done at the following three locations (Figure 1):
  - Location 1 was selected for its proximity to the Swakopmund Salt Works, the nearest industrial noise sensitive receptor (NSR) to the proposed desalination plant.
  - Location 2 was selected as being representative of noise levels at the site for the proposed desalination plant.
  - Location 3 was selected for its proximity to Swakopmund and the Mile 4 Caravan Park, the closest residential NSRs to the proposed desalination plant.
- Monitoring periods of 20 minutes per sample were sufficient for statistical analysis of typical day-and night-time noise levels within the project area.
- The sensitivity of the SLM was tested and before and after each sample to confirm calibration status.
- The acoustic indices recorded depend on the type of noise being monitored. L_{Aeq}, L_{Aeq}, L_{A90} and L_{AFmax} were recorded. In addition to these indices, the 3[rd] octave band frequency spectra were also recorded.
- The SLM was located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface (e.g., wall). Pictures taken of SLM placement are provided in Figure 2.
- The following were included in field notes:
  - Coordinates and description of general acoustic climate and audible noise sources;
  - Date, time and duration of samples;
  - General weather conditions (measured with a hand-held anemometer) incl. wind speed, wind direction, temperature, relative humidity and cloud cover; and
  - Time and nature of noise incidents during sampling period.

Table 1: Equipment details

Instrument	Type	Serial Number	Date calibrated
Sound Level Calibrator	Brüel & Kjaer Type 4231	2725297	December 2013
Sound Analyser	Brüel & Kjaer Type 2250 Light	2731851	December 2013
Microphone	Brüel & Kjaer ½" Microphone Type 4950	2709293	December 2013

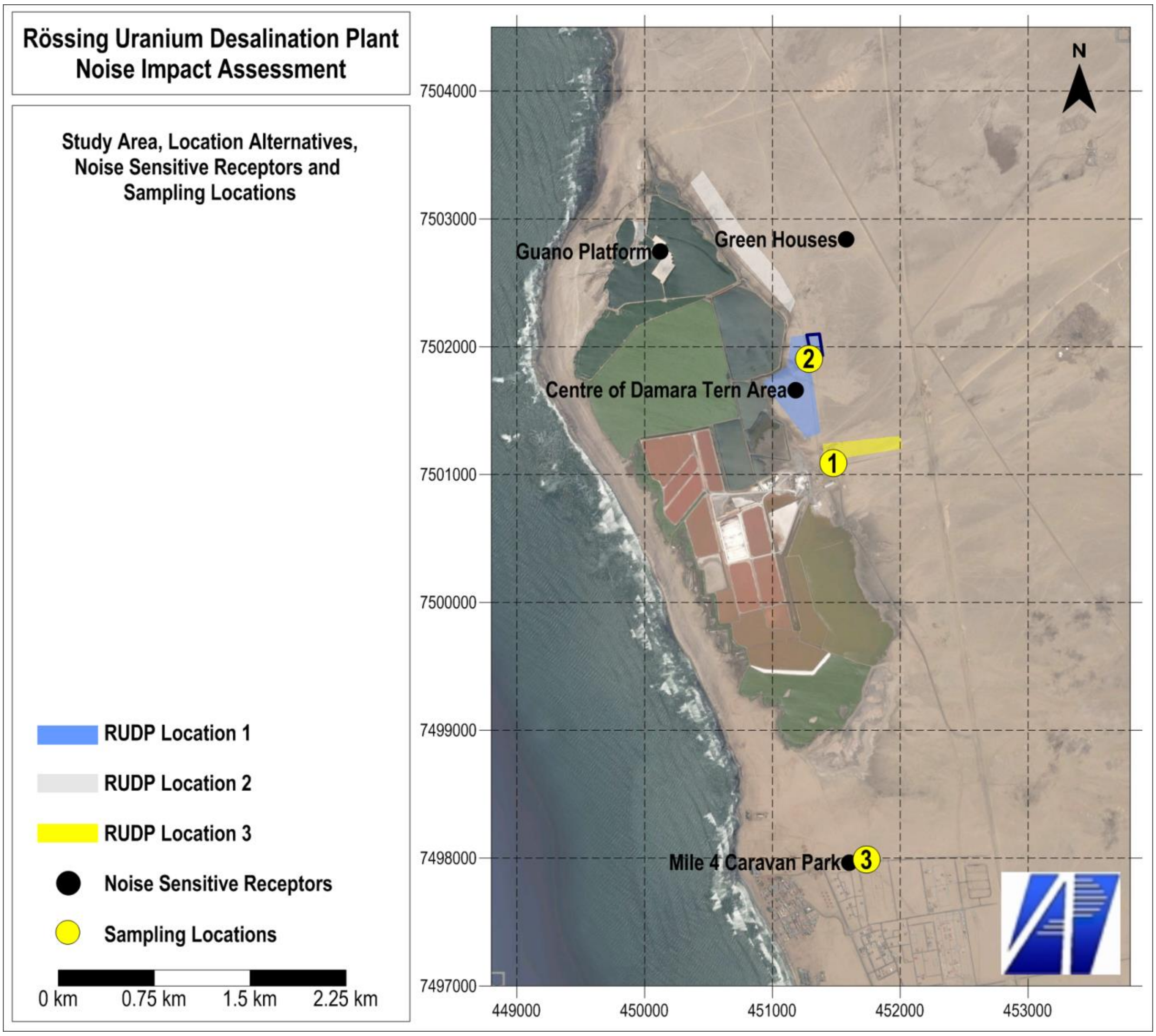


Figure 1: Environmental baseline noise sampling locations

(a) Location 1 from the east

(b) Location 1 from the north

(c) Location 2 from the east

(d) Location 2 from the west

(e) Location 3 from the south

(e) Location 3 from the north

Figure 2: Pictures of sampling locations

3.2.2 Noise Impact Assessment Methodology

Sound power levels (L_W) or 'noise emissions' from activities associated with the proposed RUDP were estimated based on source data provided by Royal HaskoningDHV and sound power level predictions for industrial machinery as published in the 'Handbook of Acoustics' (Crocker, 1998). Reference was also made to data published by the European Commission (EC) Working Group Assessment of Exposure to Noise (WG-AEN) (EC WG-AEN, 2003).

The propagation of noise from proposed activities was calculated according *to 'The Calculation of Sound Propagation by the Concawe method'* (SANS 10357, 2004). The Concawe method makes use of the International Organisation for Standardization's (ISO) air absorption parameters and equations for noise attenuation as well as the factors for barriers and ground effects. In addition to the ISO method, the Concawe method facilitates the calculation of sound propagation under a variety of meteorological conditions. Meteorological data obtained from the Wlotzkasbaken weather station were applied in calculations. Reference was also made to data made available for Swakopmund.

Noise impacts were calculated both in terms of the ambient noise levels as a result of the RUDP incrementally, as well as the effective increase in ambient noise levels over the baseline i.e. cumulative assessment. Impacts were assessed according to guidelines published by the IFC for residential and industrial areas. These guidelines refer to guidelines a by the World Health Organisation (WHO) in their *'Guidelines for Community Noise'*. To assess annoyance at nearby places of residence, reference was made to guidelines published in SANS 10103 (2008).

Note: the IFC and SANS guidelines are specifically for assessing the impact of noise on human communities. It provides no guidance for the assessment of impacts on wildlife.

3.2.3 The Assessment of Location Alternatives

This study investigated the impact of industrial activities at the proposed RUDP during is construction and operational phases within three potential locations (see the shaded areas labelled Locations 1 to 3 in Figure 1). The proposed RUDP will be located within one of these areas. Although a preferred site location has been identified (the north-eastern extent of Location 1) impacts on NSRs with the facility located within each of the Location alternatives were assessed.

4 ASSUMPTIONS AND LIMITATIONS

The following important assumptions and limitations to the study should be noted.

- Although noise measurements are considered sufficient in the determination of baseline noise levels for use during the impact assessment phase to estimate cumulative impacts, the reader is reminded that these measurements do not take into account:
  - Varying weather conditions associated with seasons;
  - Varying ocean conditions, most notably surf generated noise;
  - Varying traffic noise along the C34 over an entire day; and
  - The effect of variability activities at the Swakopmund Salt Works.
- 24 hour average wind speed and wind direction data for Swakopmund was supplied for use in the study. A distinction between the wind field during the day and night can however not be made from 24 hour average data. Hourly data recorded at Wlotzkasbaken were applied in calculations.
- No information on the nature and extent of construction activities were available at the time of the study. A generic approach for determining the impact of the construction phase, as recommended by the EC (EC WG-AEN, 2003), was adopted.

- All construction and operational phase activities were assumed to be continuous that is, 24 hours per day.

5 Legal Requirements and Noise Level Guidelines

In the absence of Namibian environmental noise and impact guidelines reference is made to guidelines published by the IFC (IFC, 2007) and the South African Bureau of Standards (SABS) (SANS 10103, 2008). Both these guidelines are in line with the World Health Organisation (WHO) Guidelines for Community Noise (WHO, 1999). Noise levels guidelines adopted in the assessment of impacts on birdlife (a concern raised by the avian specialists) is also discussed in this section.

5.1 IFC Guidelines on Environmental Noise

The IFC General EHS Guidelines on noise address impacts of noise beyond the property boundary of the facility under consideration and provides noise level guidelines.

The IFC states that noise impacts **should not exceed the levels presented in Table 2**, or result in a maximum **increase above background levels of 3 dBA** at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. Δ = 3 dBA is, therefore, a useful significance indicator for a noise impact.

Table 2: IFC noise level guidelines

Noise Level Guidelines (IFC, 2007)		
Area	**One Hour L_{Aeq} (dBA) 07:00 to 22:00**	**One Hour L_{Aeq} (dBA) 22:00 to 07:00**
Industrial receptors	70	70
Residential, institutional and educational receptors	55	45

5.2 SANS 10103

SANS 10103 (2008) successfully addresses the manner in which environmental noise is to be assessed in South Africa, and is fully aligned with the WHO guidelines of 1999. The values given in Table 3 are typical rating levels that should not be exceeded outdoors in the different districts specified. Outdoor ambient noise exceeding these levels will be considered annoying to the community.

Table 3: Typical rating levels for outdoor noise

Type of district	Equivalent Continuous Rating Level ($L_{Req,T}$) for Outdoor Noise SANS 10103 (2008)[6]		
	Day/night $L_{R,dn}$[(c)] (dBA)	Day-time $L_{Req,d}$[(a)] (dBA)	Night-time $L_{Req,n}$[(b)] (dBA)
Rural districts	45	45	35
Suburban districts with little road traffic	50	50	40
Urban districts	55	55	45
Urban districts with one or more of the following; business premises; and main roads	60	60	50
Central business districts	65	65	55
Industrial districts	70	70	60

Notes

(a) $L_{Req,d}$ =The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the day-time period, i.e. from 06:00 to 22:00.

(b) $L_{Req,n}$ =The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the night-time period, i.e. from 22:00 to 06:00.

(c) $L_{R,dn}$ = The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the period of a day and night, i.e. 24 hours, and wherein the $L_{Req,n}$ has been weighted with 10dB in order to account for the additional disturbance caused by noise during the night.

SANS 10103 (2008) also provides a useful guideline for estimating community response to an increase in the general ambient noise level caused by intruding noise. If Δ is the increase in noise level, the following criteria are of relevance:

- $\Delta \leq 0$ dB: There will be no community reaction;
- 0 dB < $\Delta \leq$ 10 dB: There will be 'little' reaction with 'sporadic complaints';
- 5 dB < $\Delta \leq$ 15 dB: There will be a 'medium' reaction with 'widespread complaints'. Δ = 10 dB is subjectively perceived as a doubling in the loudness of the noise;
- 10 dB < $\Delta \leq$ 20 dB: There will be a 'strong' reaction with 'threats of community action'; and
- 15 dB < Δ: There will be a 'very strong' reaction with 'vigorous community action'.

The categories of community response overlap because the response of a community does not occur as a stepwise function, but rather as a gradual change.

5.3 Birds and Their Response to Noise

The purpose of this section is to briefly summarise findings of a literature study specifically focussed on identifying thresholds against which impacts on birds of interest in this investigation, the Damara Tern and Guano Platform area, can be assessed. It is however import to first gain an understanding of the avian auditory system and how it compares to that of humans.

5.3.1 Avian Hearing

Research into the topic is perhaps best summarised in reports by Dooling (2002) and Dooling & Popper (2007) which considered published research from as far back as 1973. The purpose of these reports was to determine levels at which effects on birdlife would occur as a result of highway and wind turbine noise specifically. Both studies provide substantial information on the auditory response of several bird species as well as birds in general.

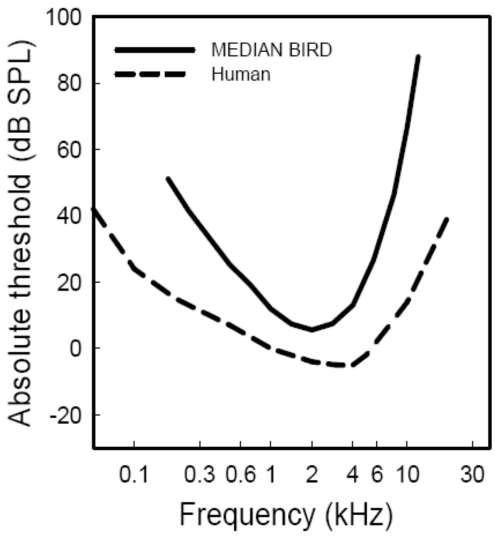
Generally, humans have better auditory sensitivity (lower auditory thresholds[1]) both in quiet and in noise than does the 'typical' bird. This is illustrated in the audiograms presented in Figure 3. Whereas the hearing of a young, healthy person ranges between 20 Hz and 20 kHz, the hearing of a bird (the median of data for 49 bird species) ranges between 100 Hz and 10 kHz. Birds hear best at frequencies between about 1 and 5 kHz, with absolute (best) sensitivity often approaching 0 to 10 dB at the most sensitive frequency, which is usually in the region of 2 to 4 kHz. ***The typical bird therefore hears less well than humans and over a narrower bandwidth***.

According to Dooling (2002), there are some exceptions to the above homogenous picture of avian hearing. Pigeons, for instance, may have an unusual auditory sensitivity to very low frequency sounds. By some estimates they may be almost 50 dB more sensitive than humans in the frequency region of 1 to 10 Hz. The auditory sensitivity of some nocturnal predators, such as barn owls, is another exception (See Figure 3 (b), strigiformes).

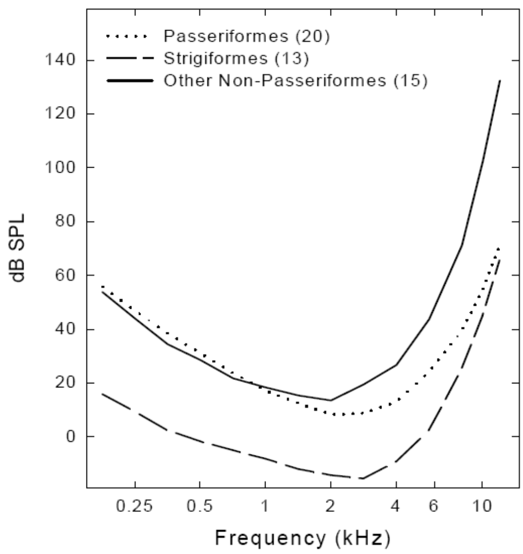
Birds are however unusual among vertebrates in the remarkable consistency of their auditory structures and in their basic hearing capabilities, such as absolute thresholds of hearing. Dooling (2002) reports that the centre frequency (the frequency at which hearing is most sensitive) and high-frequency cutoff are significantly and inversely correlated with a bird's size and weight. It is postulated that body size puts a constraint on the low-frequency sensitivity of small birds. Figure 3 (b) shows that the region of lowest thresholds for birds is between 1 and 5 kHz, at which hearing thresholds range from –10 dB to about 20 dB. Hearing sensitivity falls off at the rate of about 15 dB/octave below 1 kHz and about 35 to 40 dB/octave above about 3 kHz.

Almost all avian species rely heavily on acoustic communication for species and individual recognition, mate selection, territorial defence, and other social activities. Dooling (2002) states that it has long been recognized that there is a strong correlation between the range of hearing in birds and the frequency spectrum of bird vocalizations. That is, with the exception of some nocturnal predators, birds hear best in the spectral region of their species-specific vocalizations. This is an important observation since it highlights the fact that considerations of the masking or hearing damage effects of noise on acoustic communication in birds should focus attention on the critical frequency region of about 1 to 6 kHz.

[1] The hearing threshold is the minimum sound pressure level of a pure tone that an average ear with normal hearing can hear with no other sound present. The threshold relates to the sound that can just be heard by the organism.



(a) Median bird hearing thresholds from 49 bird species measured behaviourally and physiologically in the quiet in a free field (solid line) compared to human hearing threshold (dashed line) (Dooling & Popper, 2007)



(b) Median hearing thresholds for various bird species. (Dooling R. , 2002)

Figure 3: Hearing thresholds of several bird species in comparison with human hearing

5.3.2 Direct Effects of Noise on Hearing in Birds

It is generally accepted that there are three overlapping categories of noise effects on birds as a result of traffic, construction and industrial type noise: hearing damage and temporary threshold shifts, masking, and other physiological and behavioural responses.

Just like humans and other animals, birds show a ***shift in hearing sensitivity*** in response to sounds that are sufficiently long and/or intense. During a literature survey by Dooling & Popper (2007) it was found that birds can tolerate continuous (e.g. up to 72 hours) exposure to 110 dBA without experiencing hearing damage or a Permanent Threshold Shift (PTS). PTS or permanent hearing loss occurs if the intensity and duration of the noise is sufficient to damage the delicate inner ear sensory hair cells. At continuous noise levels below 110 dBA down to about 93 dBA, birds can experience a Temporary Threshold Shift (TTS). A TTS can lasts from seconds to days depending on the intensity and duration of the noise to which the animal was exposed.

Absolute auditory sensitivity is, by definition, the minimum sound pressure level that can be heard in the quiet. However, in normal everyday life (for humans or other animals) hearing takes place against a background of noise. For animals, this background noise is usually environmental noise from a variety of sources, including wind, other animal vocalizations, and anthropogenic sources. Auditory scientists have spent a great deal of effort investigating the effect of noise on hearing a signal not just in humans but in many other animals, including a number of bird species.

Of the potential effects on birds within the context of the current investigation, ***masking***, the interference with the detection one biologically relevant sound by another, is of most significance. It refers to the increase in thresholds for detection or discrimination of sounds in the presence of another sound. Data from two kinds of masking experiments are described below.

Measuring pure tone thresholds in broadband noise is the simplest kind of masking experiment. In such an experiment, the spectrum level (the sound energy contained within a specific frequency) is used when describing the level of noise that masks a signal. This is because it is the noise in the frequency region of a signal that is most important in masking the signal, not noise at more distant frequency regions. In a typical masking experiment, the ratio between the sound pressure level in a pure tone and the spectrum level of the background noise is called the critical ratio.

Critical ratio data, obtained behaviourally, for 14 species of birds, including songbirds, non-songbirds, and nocturnal predators as reported by Dooling (2002) are presented in Figure 4. This figure describes the level in dB above the spectrum level of a background noise that a pure tone must be in order to be heard. For example, for the average bird a pure tone in the region of 3 kHz must be at least 28 dB above the spectrum level of the noise in order to be detected. For the human, the same pure tone need only be about 22 dB above the spectrum level of noise to be heard. This difference in masked thresholds of 6 dB is significant when considered in terms of the decrease in sound pressure with distance. Because of the inverse square law, this difference represents approximately a doubling of distance; a human can still detect a sound in noise at twice the distance the typical bird can. It is noted that the average critical ratio curve follows quite closely the typical pattern of approximately a 2 to 3 dB/octave increase in signal-to-noise (S/N) ratio that is characteristic of these functions in mammals, including humans (the 3 dB/octave slope is shown by a dotted line in Figure 4). Knowing the S/N ratio at threshold for a bird allows predictions about how far away a sound can be heard in a noisy background.

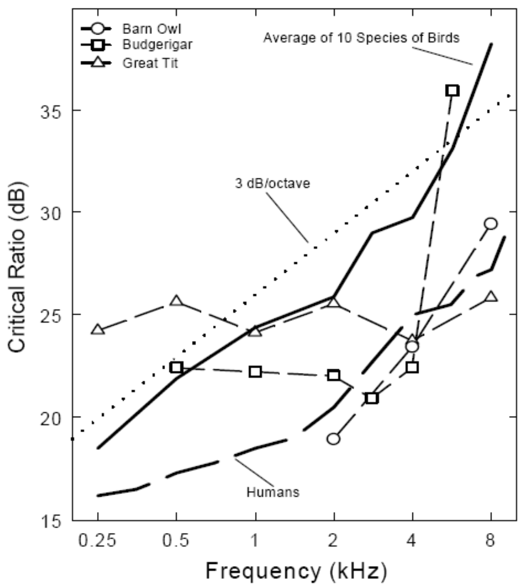


Figure 4: Masking functions (critical ratios) for 14 species of birds (Dooling R. , 2002)

Just as noise can mask a pure tone, it can also mask other noise. It can be determined how much a noise has to be increased in level in order to detect the increase. Another approach determines the level required of a second noise added to an original noise so that the second noise is just detectable. Experiments to determine how much the level of a noise needs to be increased to be detected has been done in humans, and the answer is about 0.5

to 1.0 dB (see Section 3.1.1). Similar data are available in the form of modulation transfer functions for three species of birds: the budgerigar, the starling, and the barn owl. Dooling (2002) reports that all three species can hear about a 1.5 dB change in level of flat, broadband noise. Again it appears that human acoustic discrimination abilities are slightly better than those of birds.

Table 4: Critical ratio (S/N) in dB to be exceeded for the detection of pure tones and broadband noise for an average bird (Dooling R. , 2002)

Signal	1 kHz	2 kHz	3 kHz	4 kHz	Broadband Noise
S/N (dB)	24 dB	27 dB	28.9 dB	30 dB	1.5

5.3.3 Recommended Thresholds

Dooling & Popper (2007) recommends, pending additional research, 'interim' guidelines for the protection of birds against potential effects from different industrial and commercial type noise sources (Table 5).

Table 5: Recommended interim guidelines for the protection of birds against potential effects from different industrial and commercial type noise sources

<table>
<tr><th>Noise Source Type</th><th>Hearing Damage</th><th>TTS</th><th>Masking</th><th>Potential Behavioural/ Physiological Effects</th></tr>
<tr><td>Single impulse (e.g. a blast)</td><td>140 dBA</td><td>not applicable</td><td>not applicable</td><td rowspan="5">Any audible component of highway noise has the potential of causing behavioural and/or physiological effects independent of any direct effects on the auditory system of PTS, TTS, or masking.</td></tr>
<tr><td>Multiple impulse (e.g. jackhammer, pile driver)</td><td>125 dBA</td><td>not applicable</td><td>Ambient
(50 to 60 dBA in areas with noise levels typical of suburban areas)</td></tr>
<tr><td>Non-impulsive continuous (e.g. construction, industrial noise)</td><td>None</td><td>93 dBA</td><td>Ambient
(50 to 60 dBA in areas with noise levels typical of suburban areas)</td></tr>
<tr><td>Highway noise</td><td>None</td><td>93 dBA</td><td>Ambient
(50 to 60 dBA in areas with noise levels typical of suburban areas)</td></tr>
<tr><td>Alarms (97 dB/100 ft)</td><td>None</td><td>not applicable</td><td>not applicable</td></tr>
</table>

As noise levels associated with the facility under study will not likely result in noise levels in excess of 80 dBA off-site, only guidelines for masking and other potential behavioural or physiological effects are considered. According to the research by Dooling & Popper (2007), it is unlikely that a noise level below an overall level of about 50 to 60 dBA would have much of an effect on acoustic communication or the biology of a bird in a quiet suburban area.

In assessment of the baseline (Section 6.3) it was found that noise levels within the vicinity of the proposed RUDP are in the range of 40 to 55 dBA. According to SANS 10103 (2008) this is typical of suburban areas. **Therefore, for the purpose of this assessment, the 60 dBA interim guideline proposed by Dooling & Popper (2006) for the protection of birds against potential masking, behavioural and physiological effects was adopted.**

6 DESCRIPTION OF THE AFFECTED ENVIRONMENT

The extent of noise impacts as a result of an intruding industrial noise depends largely on existing noise levels in the project area. Higher ambient noise levels will result in less noticeable noise impacts and a smaller impact area. The opposite also holds true. Increases in noise will be more noticeable in areas with low ambient noise levels.

Further, if the dimensions of a noise source are small compared with the distance to the listener, it is called a point source. All sources (except traffic) of noise at the proposed desalination plant will be quantified as point sources. The sound energy from a point source spreads out spherically, so that the sound pressure level is the same for all points at the same distance from the source, and decreases by 6 dB per doubling of distance. This holds true until ground and air attenuation noticeably affect the level.

The impact of an intruding industrial noise on the environment will therefore rarely extend over more than 5 km from the source and is therefore always considered "local" in extent.

This chapter provides details of the receiving acoustic environment in terms of:

- Local NSRs;
- The local atmospheric noise propagation and attenuation potential; and
- Locally sampled baseline noise levels.

6.1 Noise Sensitive Receptors

The following NSRs have been identified:

- Employees of the Swakopmund Salt Works (industrial NSRs). The Swakopmund Salt Works plant area is situated within 1 km south of the proposed site for the desalination plant. Since worker noise exposure is regulated under occupational health and safety rules the impact of the proposed RUDP on the salt works is qualitatively discussed but not assessed.
- Residents of the northernmost suburbs of Swakopmund and holiday makers at the Mile 4 Caravan Park (residential NSRs).
- Residents at the green houses to the north-northeast of the desalination plant. It is however currently unclear if people reside or work at this location and will be confirmed at a later stage.
- Birds at the guano platform.
- The Damara Tern breeding area.

The minimum distances between NSRs and considered location alternatives area presented in Table 6 and shown in Figure 5. These distances were used in determining 'worst case' impacts associated with location alternatives under consideration.

Table 6: Minimum distances between NSRs and proposed RUDP location alternatives

	Proposed RUDP Situated Within:	Location 1	Location 2	Location 3
Minimum Direct Distance to NSR	Green Houses	767 m (Figure 5, 1A)	593 m (Figure 5, 2A)	1 593 m (Figure 5, 3A)
	Guano Platform	1 187 m (Figure 5, 1B)	445 m (Figure 5, 2B)	1 849 m (Figure 5, 3B)
	Damara Tern Breeding Area (Centre)	271 m (Figure 5, 1C)	639 m (Figure 5, 2C)	515 m (Figure 5, 3C)
	Mile 4 Caravan Park/Northern Suburbs of Swakopmund	3 327 m (Figure 5, 1D)	4 334 m (Figure 5, 2D)	3 145 m (Figure 5, 3D)

6.2 Noise Propagation and Attenuation Potential

6.2.1 Atmospheric Absorption and Meteorology

Atmospheric absorption and meteorological conditions have already been mentioned with regards to its role in the propagation on noise from a source to receiver (Section 3.1.4). The main meteorological parameters affecting the propagation of noise include wind speed, wind direction and temperature. These along with other parameters such as relative humidity, air pressure, solar radiation and cloud cover affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy. Average day-and night time wind speed, wind direction, temperature, relative humidity, pressure and solar radiation used as input to the selected noise propagation model are provided in Table 7. Wlotzkasbaken data was obtained from a study completed by Airshed in 2011 (Liebenberg-Enslin & Krause, 2011). Wlotzkasbaken is located approximately 20 km north of the project area.

24 hour average wind speed and wind direction data for Swakopmund (2001 to 2006) was also supplied for use in the study. A distinction between the wind field during the day and night can however not be made from 24 hour average data. Hourly data recorded at Wlotzkasbaken were applied in calculations.

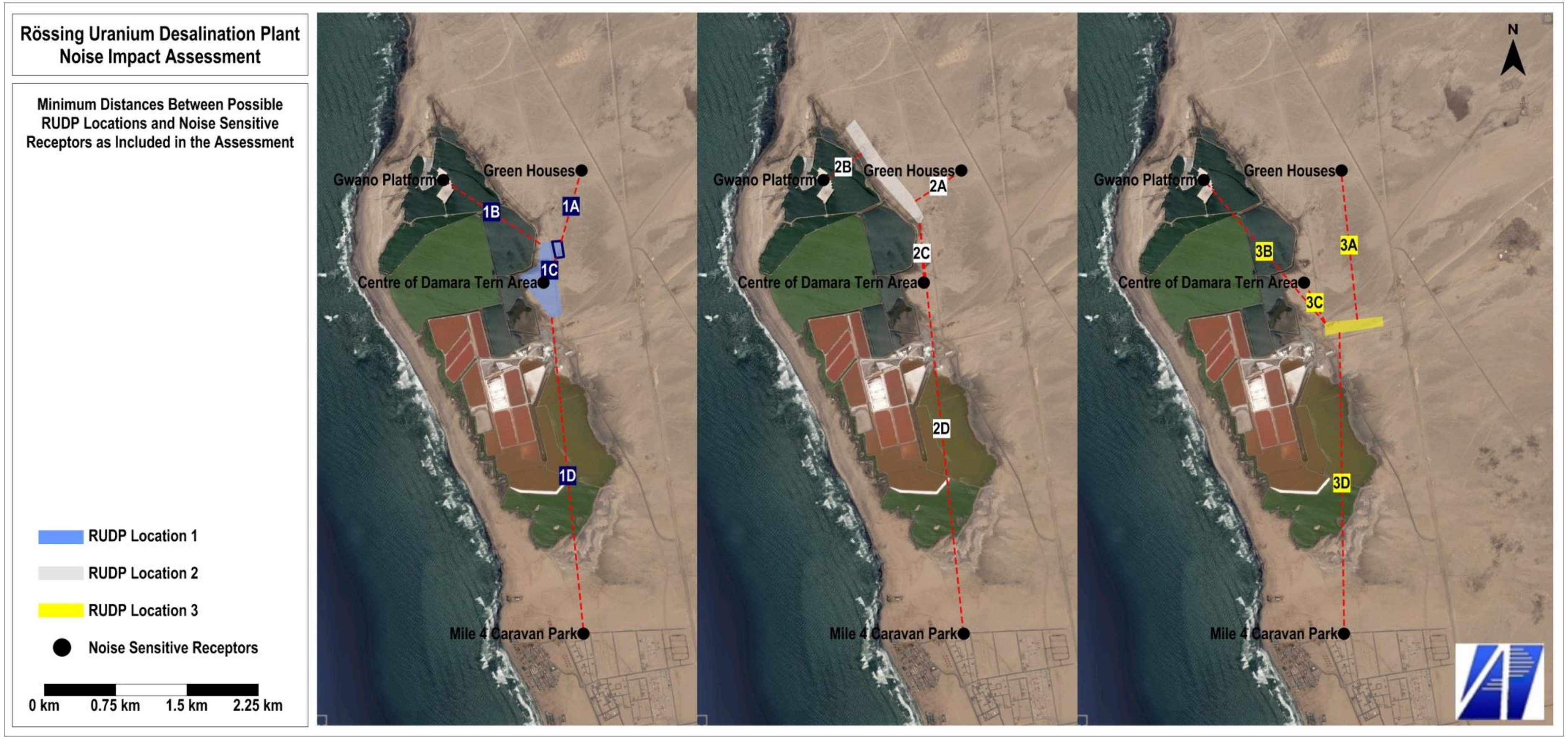
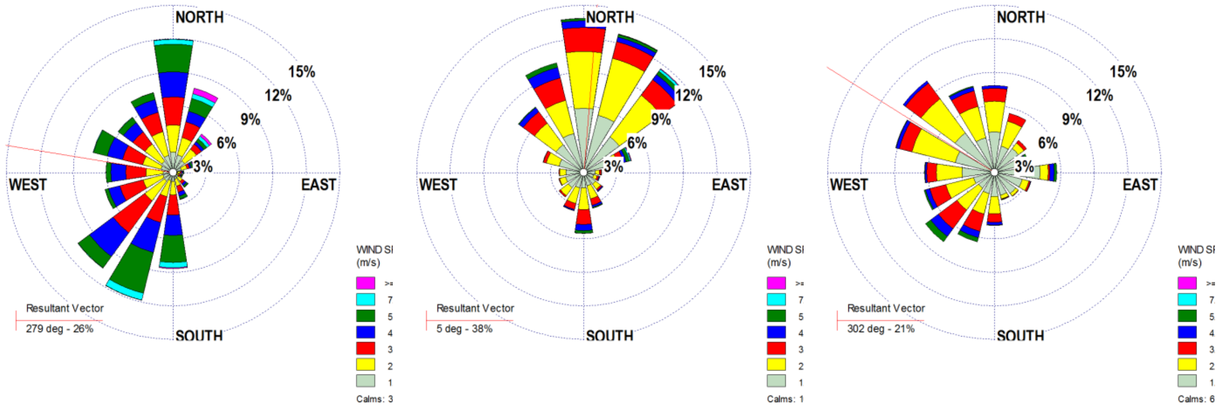


Figure 5: Minimum distances between possible RUDP locations and NSRs as included in the assessment of 'worst case' impacts

It is well known that wind speed increases with altitude. This results in the 'bending' of the path of sound to 'focus' it on the downwind side and creating a 'shadow' on the upwind side of the source. Depending on the wind speed, the downwind level may increase by a few dB but the upwind level can drop by more than 20 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). It should be noted that at wind speeds of more than 5 m/s ambient noise levels are mostly dominated by wind generated noise. The diurnal wind field at Wlotzkasbaken, the nearest representative meteorological station is presented in Figure 6. Wind roses represent wind frequencies for the 16 cardinal wind directions. Frequencies are indicated by the length of the shaft when compared to the circles drawn to represent a frequency of occurrence. Wind speed classes are assigned to illustrate the frequencies with high and low winds occurring for each wind vector. The frequencies of calms, defined as periods for which wind speeds are below 1 m/s, are also indicated.

On average, during the day, noise impacts are expected to be most notable to the south and north-north east. During the night it is expected to be most significant to the south of proposed operations.



(a) Wlotzkasbaken day-time wind rose (07:00 to 22:00)

(b) Wlotzkasbaken night-time wind rose (22:00 to 07:00)

(c) Swakopmund period average wind rose from 24-hour average data

Figure 6: Wind roses

Temperature gradients in the atmosphere create effects that are uniform in all directions from a source. On a sunny day with no wind, temperature decreases with altitude and creates a 'shadowing' effect for sounds. On a clear night, temperatures may increase with altitude thereby 'focusing' sound on the ground surface. Noise impacts are therefore generally more notable during the night.

Table 7: Average diurnal meteorological parameters

Parameter	Average Diurnal Meteorological Parameters (Wlotzkasbaken 2001 to 2009)		Average 24-hour Meteorological Parameters (Swakopmund 2001 to 2006)
	Day-time	Night-time	
Temperature	18 °C	14 °C	15°C
Relative Humidity	100% (106%)[c]	100% (126%)[c]	not available
Wind Speed	3.5 m/s	2.1 m/s	2.2 m/s
Wind Direction (° from)	0°[a]	0°[a]	~45°
Air Pressure	101.3 kPa[b]	101.3 kPa[b]	not available
Solar Radiation	353 W/m^2	not applicable	not available

Notes:

(a) Since NSR are all located to the south of the proposed desalination plant, a wind direction of 0° will be considered in the assessment.
(b) Air pressure at 0 m above sea level.
(c) Relative humidity should not be higher than 100%. Values in brackets are what was reported in Wlotzkasbaken data. The maximum of 100% was applied in calculations.

6.2.2 Terrain, Ground Absorption and Reflection

Noise reduction caused by a barrier (i.e. natural terrain, installed acoustic barrier, building) feature depends on two factors namely the path difference of the sound wave as it travels over the barrier compared with direct transmission to the receiver and the frequency content of the noise (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). There are however no features with the local study area that may act as acoustic barriers between the location alternatives for the proposed RUDP and local NSRs.

Sound reflected by the ground interferes with the directly propagated sound. The effect of the ground is different for acoustically hard (e.g., concrete or water), soft (e.g., grass, trees or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to take into account the frequency content of the noise source and the type of ground between the source and the receiver (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). Ground cover includes sand and gravel plains and is considered acoustically ‘hard' i.e. not conducive to noise attenuation.

6.3 Sampled Baseline Noise Levels

A summary of sampling points, times, weather conditions and observations made during sampling is provided in Table 8.

Table 8: Summary of sampling points, times, weather conditions and general acoustic environment

Sampling Point	Coordinates	Sampling Date and Time	General Description of Environment from a Noise Perspective	Conditions During Sampling
1	14°31.672' E 22°35.792' S	Day-time 20-Aug-14 10:00	Audible noise sources included activities at the Swakopmund Salt Works, traffic towards the Swakopmund Salt Works and along the C34 as well as ocean surf.	Wind speed 1.9 m/s (average) and 2.5 m/s (maximum) Temperature 16°C Relative humidity 75% Thin clouds, 90% cloud cover
		Night-time 20-Aug-14 22:00	Audible noise sources included traffic along the C34 as well as ocean surf and some nocturnal birds.	Wind speed 1.8 m/s (average) and 2 m/s (maximum) Temperature 14°C Relative humidity 82% Clear skies
2	14°31.558' E 22°35.344' S	Day-time 20-Aug-14 10:24	Audible noise sources included birds, distant noise from the Swakopmund Salt Works, and traffic along the C34 as well as ocean surf.	Wind speed 1.9 m/s (average) and 2.5 m/s (maximum) Temperature 17°C Relative humidity 72% Thin clouds, 85% cloud cover
		Night-time 20-Aug-14 22:24	Audible noise sources included occasional traffic along the C34 and ocean surf.	Wind speed 2 m/s (average) and 2.5 m/s (maximum) Temperature 13°C Relative humidity 82% Clear skies
3	14°31.825' E 22°37.460' S	Day-time 20-Aug-14 10:58	Audible noise sources included construction noise to the south, occasional air traffic and road traffic along the C34.	Wind speed 3.8 m/s (average) and 4.9 m/s (maximum) Temperature 16°C Relative humidity 84% Thin clouds, 90% cloud cover
		Night-time 20-Aug-14 22:55	Audible noise sources included occasional traffic along the C34 and ocean surf.	Wind speed 0.8 m/s (average) and 1.9 m/s (maximum) Temperature 15°C Relative humidity 78% Clear skies

Sampled baseline day and night time L_{Aeq} and L_{A90} as well as L_{AFmax} values are given in Table 9. Time series and 3rd octave band frequency spectra are graphically presented in Figure 7 to Figure 15. The following is noted:

- Baseline noise levels during the day and notes taken during sampling indicate the Swakopmund Salt Works to be the most notable local noise source. Traffic along the C34 also contributes significantly to local baseline day and night-time noise levels. At night, ocean surf noise becomes more observable than during the day.
- The IFC day-time guideline of 55 dBA for residential areas was only marginally exceeded at Point 1 near the Swakopmund Salt Works.
- Sampled night-time noise levels exceed the IFC guideline of 45 dBA for residential areas only at Point 3. The exceedance was as a result of a vehicle passing on the C34 at high speed. Without this incidence, the night-time L_{Aeq} (20 min) reduces to 40.6 dBA. This is illustrated in Figure 14.
- The large difference (more than 5 dBA) between sampled L_{Aeq} and L_{A90} at Points 1 and 3 during the day as well as at Point 3 during the night indicate the presence of noisy incidences i.e. passing vehicles and Swakopmund Salt Works activities.
- The large difference between day and night-time noise levels sampled at Point 1 supports the supposition that the Swakopmund Salt Works is currently the most notable noise source in the local study area. The Swakopmund Salt Works was observed not to be operational at night.
- Day and night levels at Point 2 differed by less than 5 dBA indicating the presence of a constant noise source in the area. Frequency spectra also indicate the relative small difference between day and night time noise levels. This is typical of noise levels close to the ocean or in areas with little human activity.
- **From the data and site observations, representative day- and night-time baseline noise levels of 49.2 dBA and 44.0 dBA were determined respectively. These levels were applied in the calculation of cumulative noise levels and the expected increase in noise as a result of the expected intruding industrial noise.**

Table 9: Summary of sampled baseline noise levels

Sampling Point	Day-time			Night-time			Frequency Spectra
	L_{Aeq} (20 min) (dBA)	L_{A90} (dBA)	L_{AFmax} (dBA)	L_{Aeq} (20 min) (dBA)	L_{A90} (dBA)	L_{AFmax} (dBA)	
1	55.4 (Figure 7)	40.9	79.9	39.9 (Figure 8)	38.6	50.1	(Figure 9)
2	37.4 (Figure 10)	35.3	52.1	41.0 (Figure 11)	39.2	53.6	(Figure 12)
3	51.3 (Figure 13)	42.8	47.2	50.5 (Figure 14)	38.5	80.7	(Figure 15)

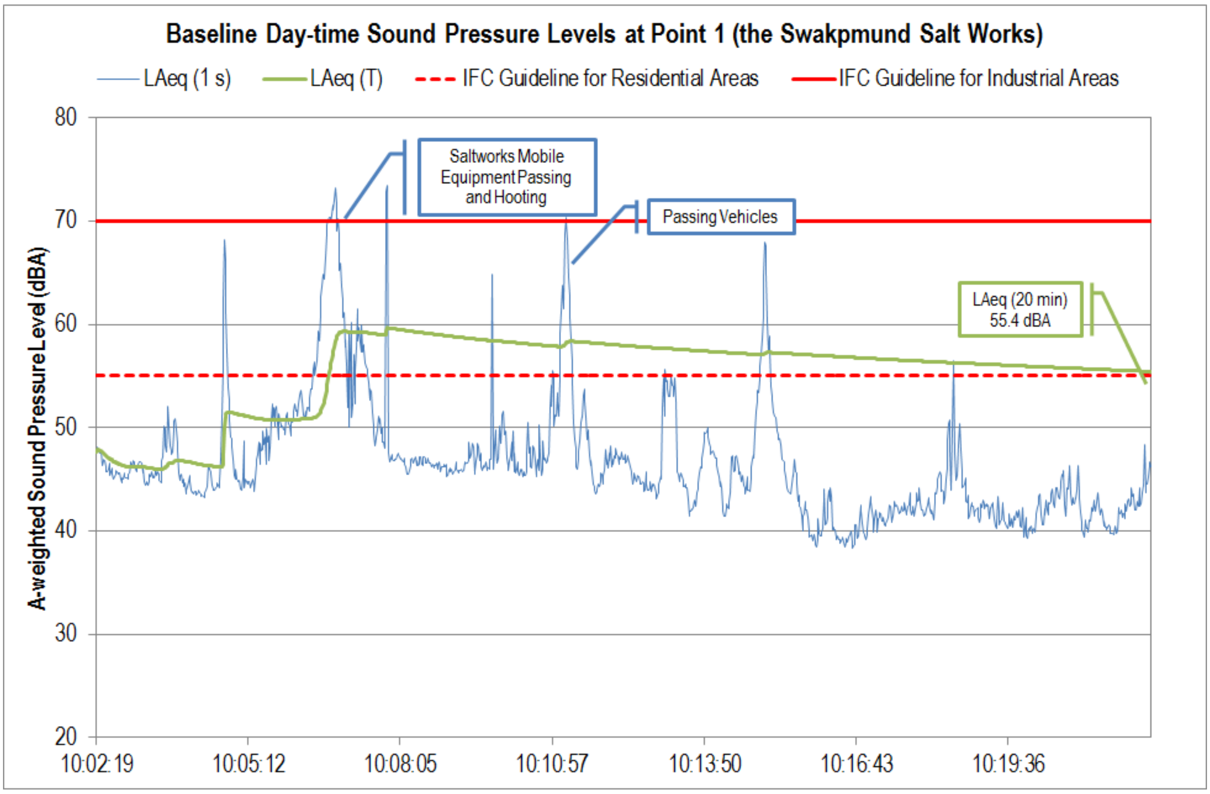


Figure 7: 20-minute day-time sample at Point 1, the Swakopmund Salt Works on 20-Aug-14

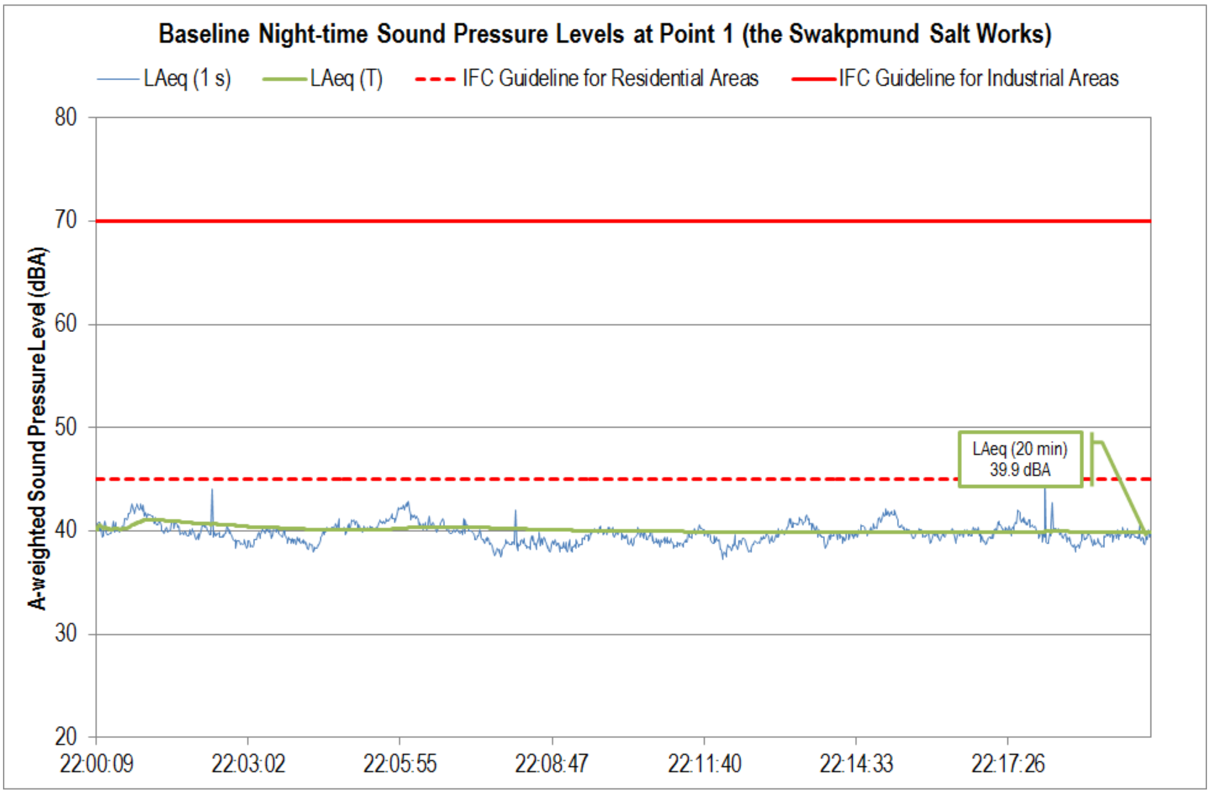


Figure 8: 20-minute night-time sample at Point 1, the Swakopmund Salt Works on 20-Aug-14

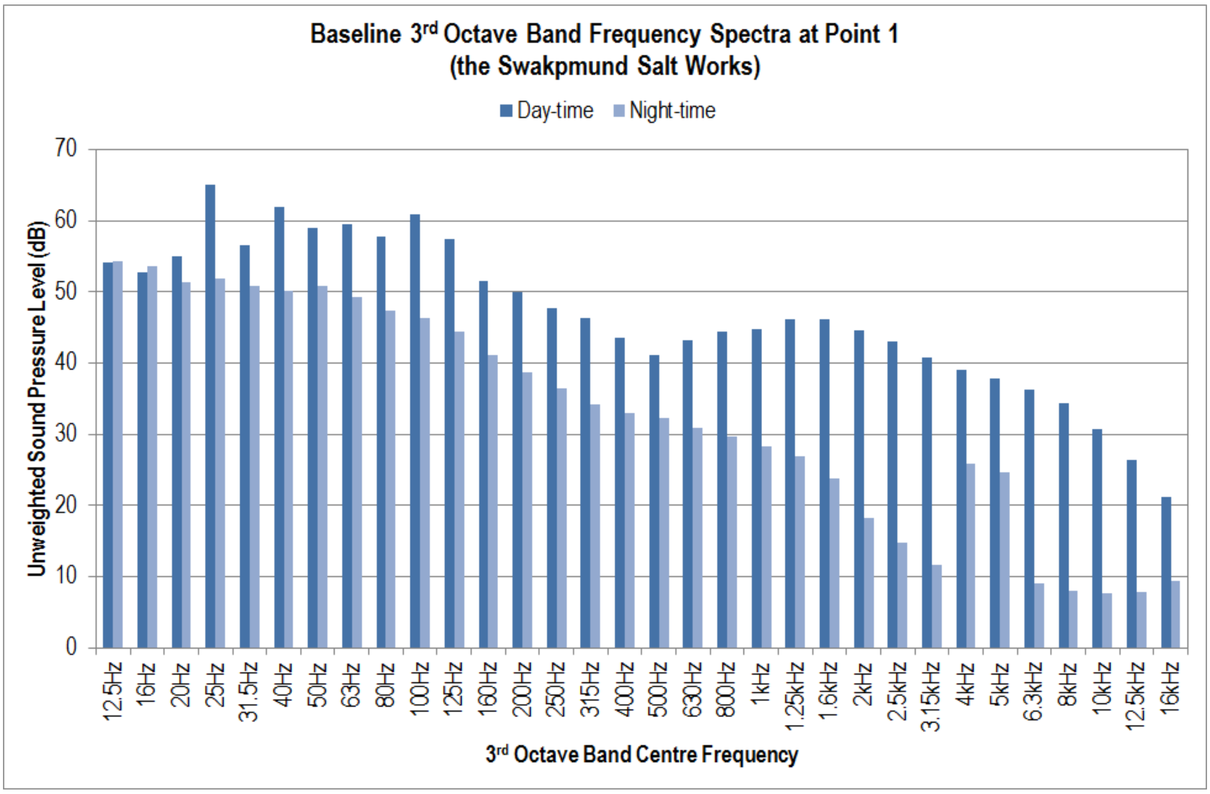


Figure 9: 3rd octave band frequency spectra at Point 1, the Swakopmund Salt Works on 20-Aug-14

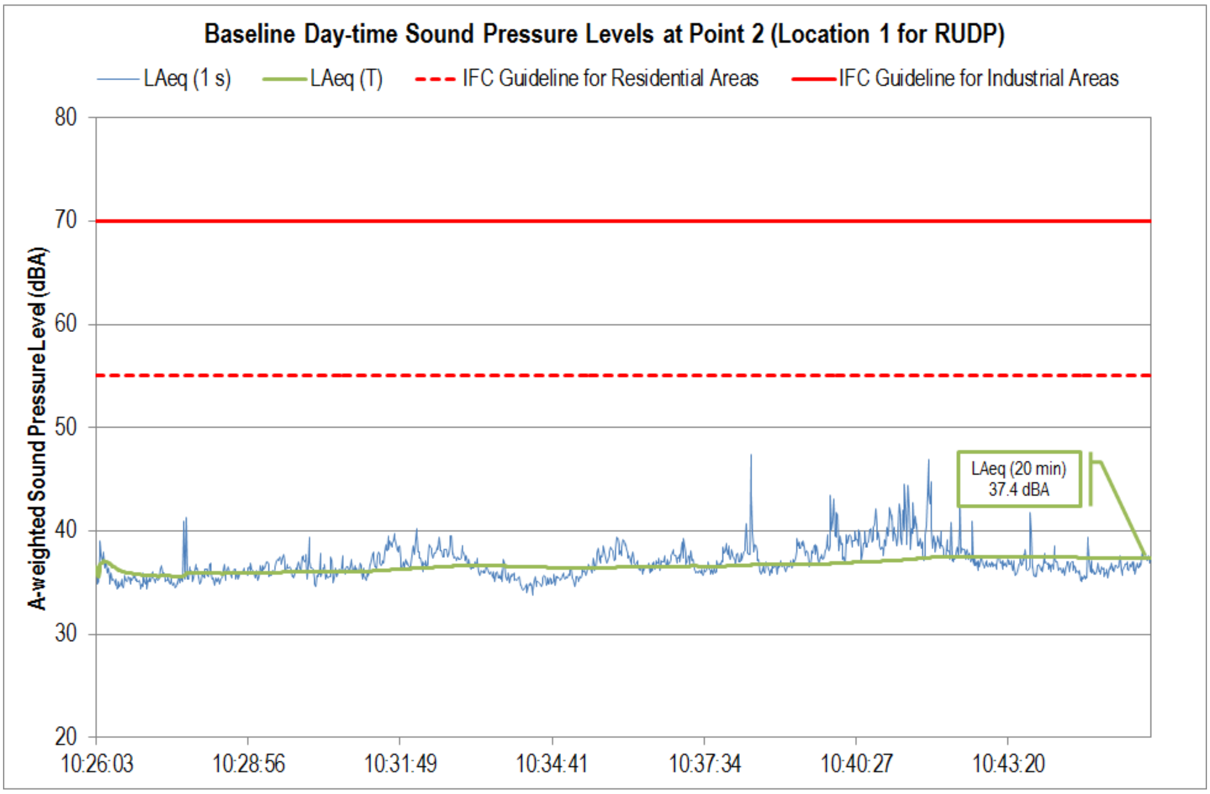


Figure 10: 20-minute day-time sample at Point 2, Location 1 for the RUDP, on 20-Aug-14

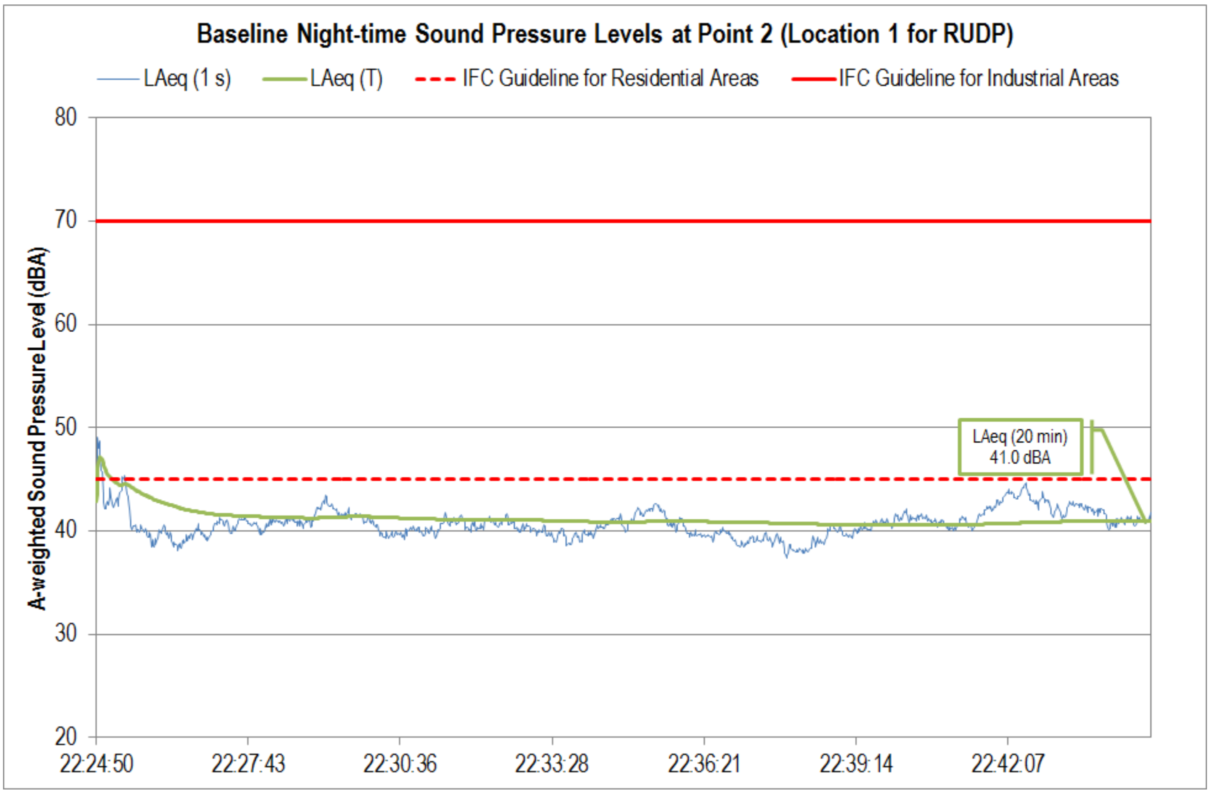


Figure 11: 20-minute night-time sample at Point 2, Location 1 for the RUDP, on 20-Aug-14

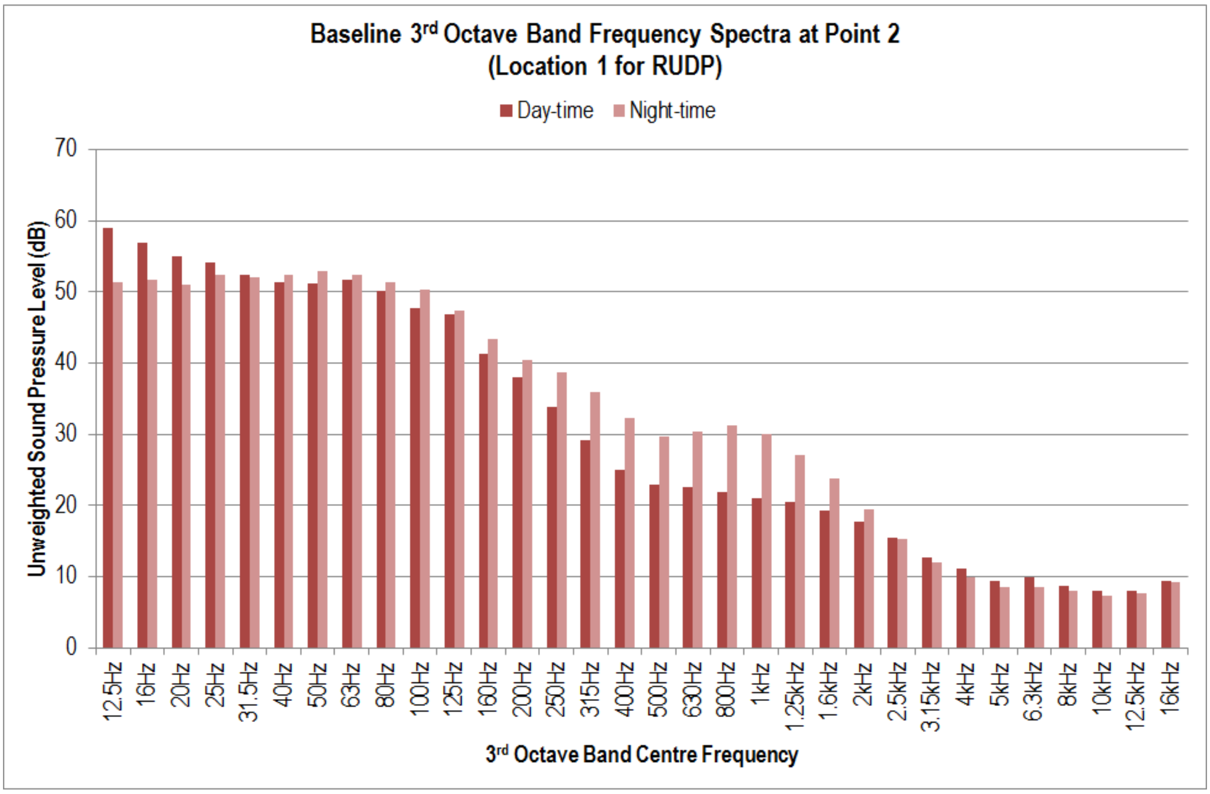


Figure 12: 3rd octave band frequency spectra at Point 2, Location 1 for the RUDP, on 20-Aug-14

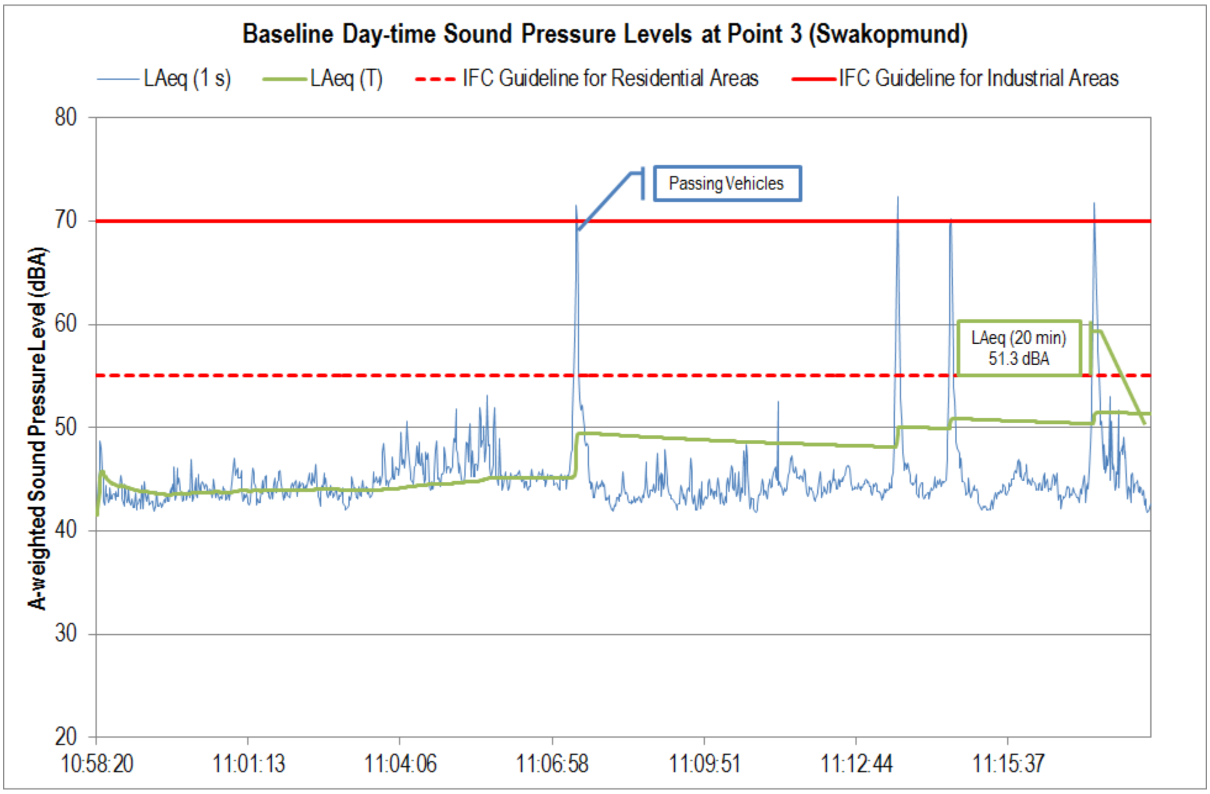


Figure 13: 20-minute day-time sample at Point 3, Swakopmund on 20-Aug-14

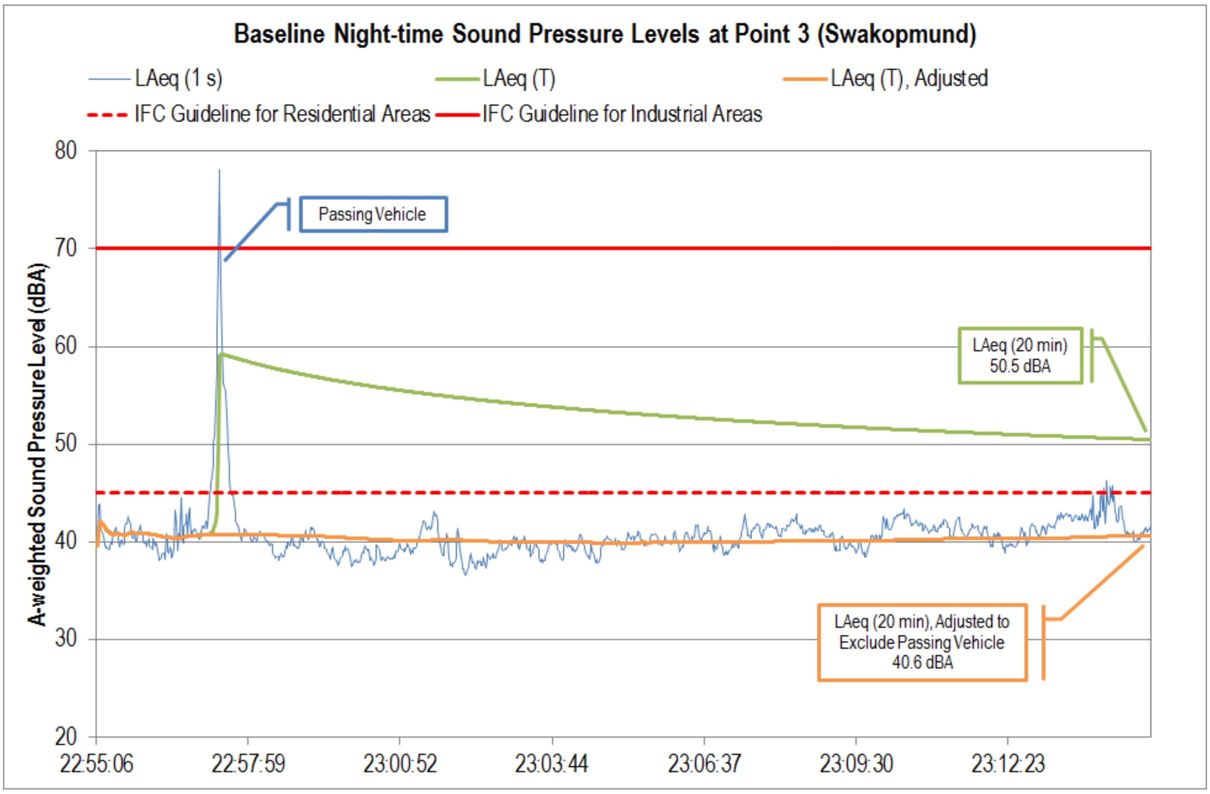


Figure 14: 20-minute night-time sample at Point 3, Swakopmund on 20-Aug-14

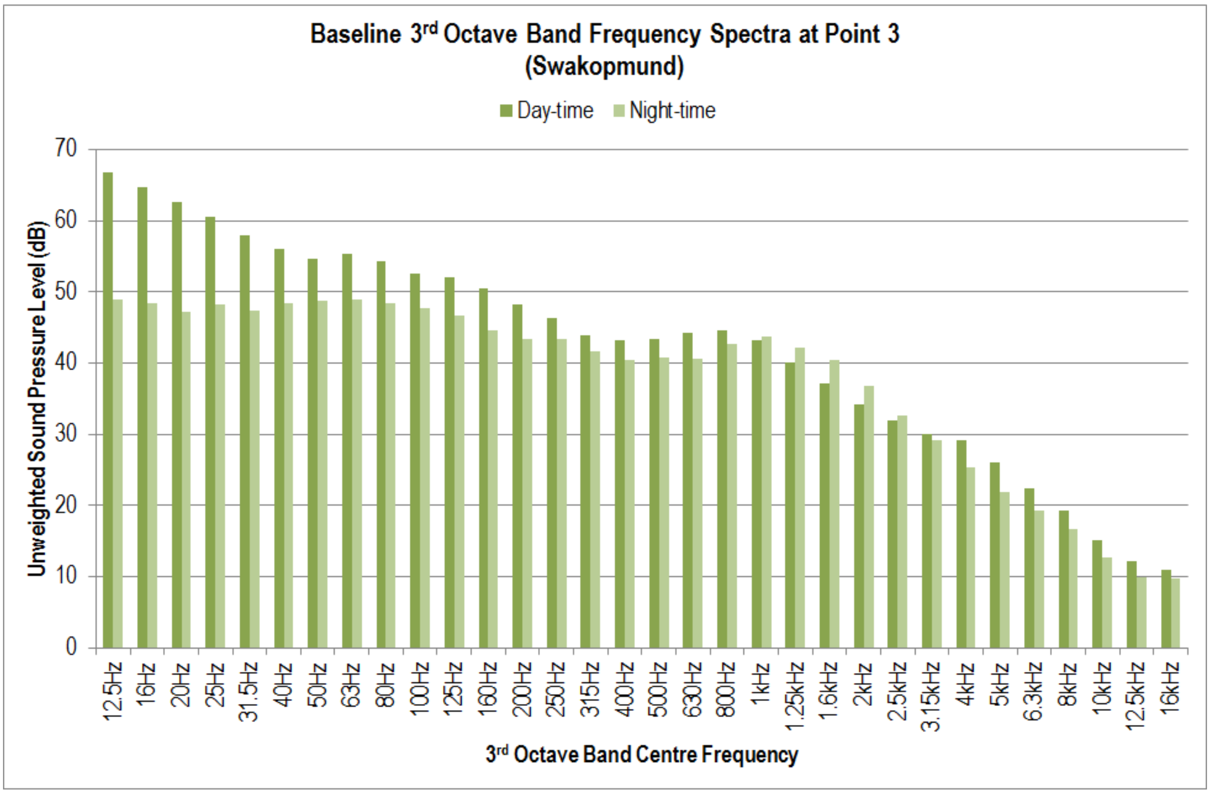


Figure 15: 3rd octave band frequency spectra at Point 3, Swakopmund on 20-Aug-14

7 Impact Assessment

Noise will be generated during the construction and operational phases of the proposed RUDP. Sources of noise were identified from project descriptions and information supplied by SLR and Royal HaskoningDHV. The noise source inventory, noise propagation modelling and results for these phases and location alternatives are discussed in Section 7.1 and Section 7.2.

7.1 Noise Sources and Sound Power Levels

7.1.1 Construction Phase

The extent and character of construction phase noise will be highly variable as different activities with different equipment will take place at different times, over different periods, in different combinations, in different sequences and on different parts of the construction site. The construction phase is however expected to include the following noise generating activities:

- Earthworks, including site excavations and levelling;
- Concrete mixing, casting and levelling; and
- Steelworks (columns, beams, trusses and roof).

In the absence of information related to the extent of construction activities a general approach was adopted. Construction related noise was estimated over an area wide basis by applying the EC WG-AEN L_W rating of 65 dBA/m^2 for heavy industrial activities (EC WG-AEN, 2003). The footprint area of the proposed RUDP was estimated at approximately 7 700 m^2. Octave band L_W's for activities during the construction phase is given in Table 10.

It was assumed that construction activities would occur continually over 24 hours of the day.

Table 10: L_W's of activities during the construction phase

Source	L_{Wi} at Octave Band Centre Frequencies (dB)							L_{WA} (dBA)
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	
Construction	97.9	102.9	105.9	100.9	98.9	95.9	89.9	104.1

7.1.2 Operational Phase

The operational phase will include the following sources of noise:

- Pumps, compressors, fans, mixers and electrical motors associated with the process;
- Road traffic; and
- General commercial and light industrial activities.

It was assumed that operational activities would occur continually over 24 hours of the day.

7.1.2.1 Vehicle Noise

It was given that 15 passenger vehicles may be expected to do daily return trips to site (1 to 2 vehicles per hour). In addition to the passenger vehicles, 10 tonne delivery trucks are expected to complete 9 return trips per day (maximum 1 vehicle per hour). L_W's from these vehicles were estimated through the application of the following equation recommended by Crocker (1998):

$$L_W = 99 + 10 \cdot \log kW$$

Equation 3

In the equation, L_W is the overall sound power level in dB and kW is the power rating of the vehicle's engine. In practice the sound power level will average about 4 dB lower than the calculated level since engines are not always operated in the maximum power condition (Crocker, 1998). Octave band sound power levels were obtained by applying adjustments recommended by Crocker (1998). Calculated L_W's are given in Table 11.

Table 11: L_W's of diesel mobile equipment

Equipment	Power (kW)	L_{Wi} at Octave Band Centre Frequencies (dB)							L_{WA} (dBA)
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	
Passenger Vehicle	50[(a)]	101.0	106.0	109.0	104.0	102.0	99.0	93.0	107.2
10 t Truck	130[(a)]	100.7	105.7	108.7	103.7	101.7	98.7	92.7	106.9

Notes:

(a) Assumed

7.1.2.2 Plant Equipment

A list of plant equipment and sound pressure levels (L_P) at 1 m was supplied by Royal HaskoningDHV (Table 12). The list also indicated which sources would be located within the plant building. The octave band L_W's of plant equipment (estimated from adjustments recommended by Crocker (2008)) is also given in Table 12.

Effective LW's from the facades of the plant building were estimated from L_W's of sources located indoors and the application of the widely used 'room equation' and taking into account absorption coefficients of and transmission losses through the walls of the building. In the absence of detailed information a simplified model of the rectangular main RO building was used in calculations. The building (width 20 m, length 73 m, assumed height 10 m) is expected to be constructed from steel frames with zinc-aluminium cladding or similar. The calculation assumed a totally enclosed space.

To illustrate the effect of building enclosure of some sources of noise reference is made to the result of the calculations discussed above. The combined L_W of noise sources located with the plant building was estimated at 113 dB. The associated total L_W of the building facades was calculated as 105 dB. A reduction of 8 dBA is therefore expected as a result of absorption and transmission losses through the zinc-aluminium clad building walls.

Table 12: L_W's for plant equipment

Operational Area[a]	Item Description[a]	Qty. [a]	Located inside or outside of building? [a]	L_P (dB) at 1 m[a]	Octave Band Sound Power Levels L_{Wi} (dB) [b]							L_{WA} (dBA) [b]
					63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
Sea Water Intakes	Pumps	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Feed Pump to Plant	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Filter Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
Pre-treatment	Aeration system / compressor	2	Out	95 - 100	96.7	99.0	99.5	99.1	101.5	105.2	102.2	109.3
	Recirculation pump	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Mixers and scrapers	2	Out	50	48.8	51.6	52.9	55.0	53.3	50.8	45.0	57.7
Media Filters	Blower	2	In	90 – 95	93.8	96.6	97.9	100.0	98.3	95.8	90.0	102.7
	Backwash Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
RO Trains	RO Units including HP Pump	4	In	85	87.0	88.0	90.0	90.0	93.0	90.0	86.0	96.5
	Energy Recovery Unit	4	In	90 - 95	96.8	99.6	100.9	103.0	101.3	98.8	93.1	105.7
	Compressor and ancillary equipment	2	In	95 - 100	96.7	99.0	99.5	99.1	101.5	105.2	102.2	109.3
RO and Chemical Dosing	CIP Pumps	3	In	65	65.8	66.8	68.8	68.8	71.8	68.8	64.8	75.3
	Dosing Pumps	6	In	65	68.8	69.8	71.8	71.8	74.8	71.8	67.8	78.3
Product Water System	Product Pump	2	In	85	84.0	85.0	87.0	87.0	90.0	87.0	83.0	93.5

Operational Area[a]	Item Description[a]	Qty. [a]	Located inside or outside of building? [a]	L_P (dB) at 1 m[a]	Octave Band Sound Power Levels L_{Wi} (dB) [b]							L_{WA} (dBA) [b]
					63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
Chemical Dosing and Effluent Handling	Dosing Pumps duty and standby	6	In	65	68.8	69.8	71.8	71.8	74.8	71.8	67.8	78.3
	Waste Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Mixers	1	In	50	45.8	48.6	49.9	52.0	50.2	47.8	42.0	54.7
Media Filters	Ventilation Fan	2	In	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Reverse Osmosis Trains	Cartridge Filter	4	no data (n/d)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Product Water System	Remineralisation units (Limestone columns)	3	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Product Water System	Chlorine System	1	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d

Notes:

(a) Supplied by Royal HaskoningDHV

(b) Calculated

7.1.2.3 Other General Light Industrial Noise

Other more general noise sources, not specifically identified or noted, were estimated over an area wide basis by applying the EC WG-AEN L_W rating of 60 dBA/m^2 for light industrial activities (EC WG-AEN, 2003). The footprint area of the proposed RUDP was estimated at approximately 7 700 m^2. Octave band L_W's for general light industrial activities during the operational phase is given in Table 13.

Table 13: L_W's of general light industrial activities during the operational phase

Source	L_{Wi} at Octave Band Centre Frequencies (dB)							L_{WA} (dBA)
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	
General light industrial activities.	92.9	97.9	100.9	95.9	93.9	90.9	84.9	99.1

7.2 Noise Propagation and Simulated Noise Levels

The propagation of noise from the construction and operational phases was calculated in accordance with SANS 10103. Meteorological and site specific acoustic parameters as discussed in Section 6.2.1 along with source data discussed in 7.1, were applied in the model.

The propagation of noise was calculated over a distance of approximately 6 km at 100 m intervals. To facilitate the assessment of impacts associated with the different location alternatives and to facilitate comparison with IFC guidelines and the 60 dBA threshold for birds recommended by Dooling & Popper (2007), results are presented as follows:

- As **transects graphs** indicating:
    - Incremental (proposed RUDP only) and cumulative (proposed RUDP in addition to the baseline) day- and night-time L_{Aeq} (1 hr) as a function of downwind distance from proposed activities.
    - The increase in noise levels over the baseline L_{Aeq} (1 hr) as a function of downwind distance from proposed activities (human NSRs only).
- Bar charts showing **'worst-case' impacts at each sensitive receptor for each location alternative**. The graphs show:
    - Incremental and cumulative day- and night-time L_{Aeq} (1 hr) with the proposed RUDP situated within Location 1, 2 or 3 (see Figure 5 for RUDP locations).
    - The increase in noise levels over the baseline L_{Aeq} (1 hr) with the proposed RUDP situated within Location 1, 2 or 3 (see Figure 5 for RUDP locations) (human NSRs only).
- As isopleths of:
    - L_{Aeq} (1 hr) during the day and night as a result of the proposed RUDP located **at the preferred site within Location 1**. An isopleth is a line on a map connecting points at which a given variable (in this case L_P) has a specified constant value. This is analogous to contour lines on a map showing terrain elevation. In the assessment of environmental noise, isopleths present lines of constant noise level as a function of distance.

- The increase in day- and night-time L_{Aeq} (1 hr) over the baseline as a result of the proposed RUDP located **at the preferred site within Location 1**.

7.2.1 Construction Phase

From simulations for the construction phase the following was found:

- The IFC day-time guideline of 55 dBA is exceeded only within the immediate vicinity (within 200 m) of construction activities (Figure 16) whereas exceedance of the IFC night-time guideline of 45 dBA is expected up to 1 km downwind (Figure 17). The increase in noise levels above the baseline reduces to less than 3 dBA within 300 m during the day and 600 m during the night (Figure 18).
- The Dooling & Popper interim guideline of 60 dBA for birds adopted in this study is only exceeded within 100 m from construction activities (Figure 18).
- From the assessment of 'worst case' impacts at community NSRs at minimum distances from location alternatives considered the following was found:
  - Residents of the Green Houses may be exposed to noise levels in excess of only the night-time IFC guideline should the RUDP be located within Location 1 or 2. The increase above the baseline at these houses is however expected to be slightly notable only when the facility is sited within Location 2. According to SANS 10103 (2008) sporadic complaints with little community reaction can be expected (Figure 19).
  - The proposed RUDP is not expected to have any effect on environmental noise levels at the Mile 4 Caravan Park or northern Suburbs of Swakopmund (Figure 20).
- From the assessment of 'worst case' impacts at the Damara Tern and Guano Platform areas, it was found that the Dooling & Popper interim guideline of 60 dBA will not be exceeded during the day or night irrespective of the location alternative selected for the site of the RUDP (Figure 21 and Figure 22).
- Total day- and night time noise levels associated with the RUDP situated within the preferred area of Location 1 are presented in Figure 23 and Figure 25. The increase over the day- and night-time baseline of 49 dBA and 44 dBA respectively are presented in Figure 24 and Figure 26. It should be noted that these isopleths are representative of an hour during which the wind is from the north (see Table 7 for meteorological parameters applied in simulations). Winds from the north occur 12 to 15 % of the hours within a year.

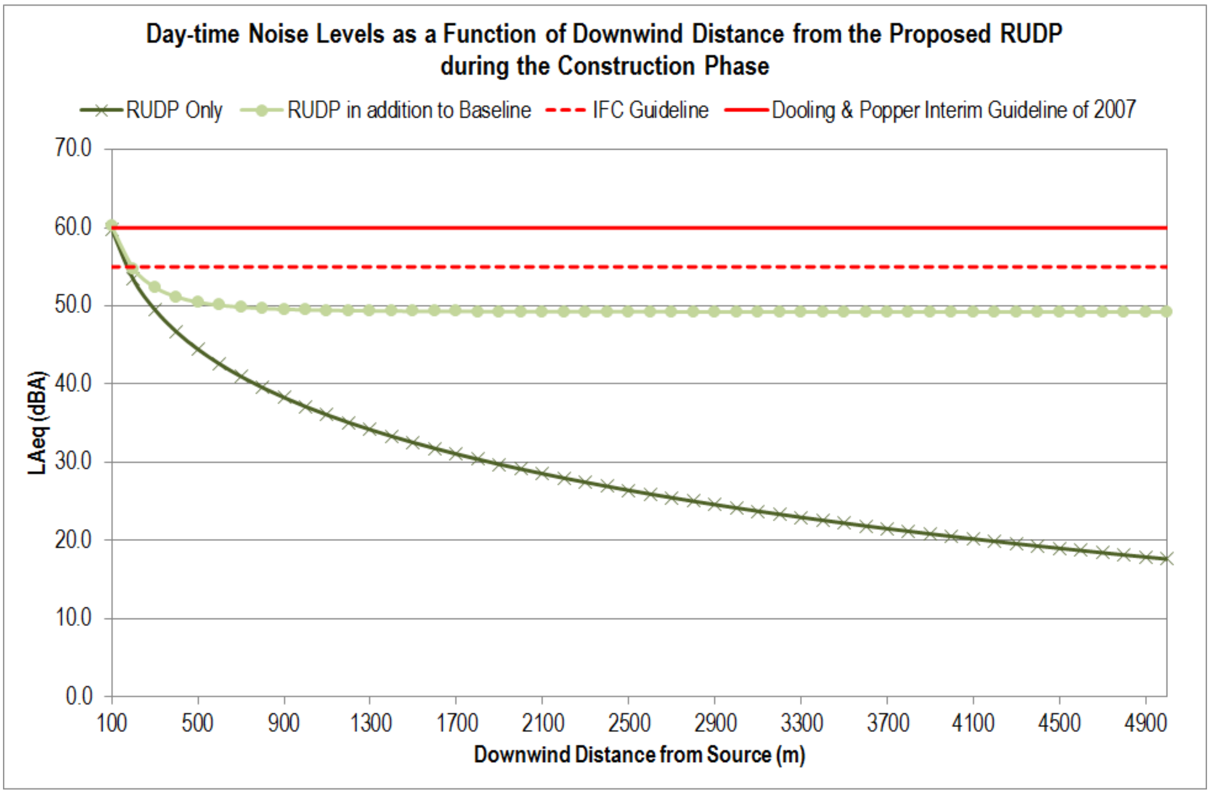


Figure 16: Transect of downwind day-time L_{Aeq} (1 hour) during the construction phase

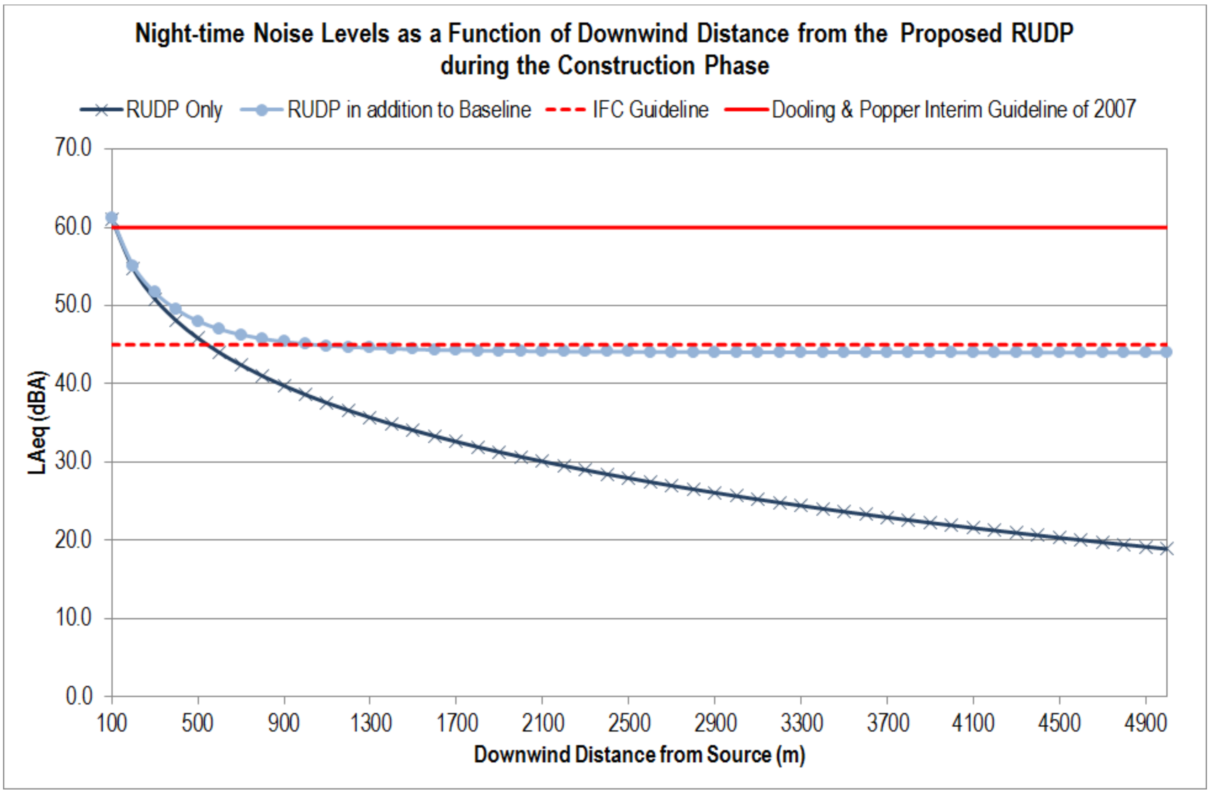


Figure 17: Transect of downwind night-time L_{Aeq} (1 hour) during the construction phase

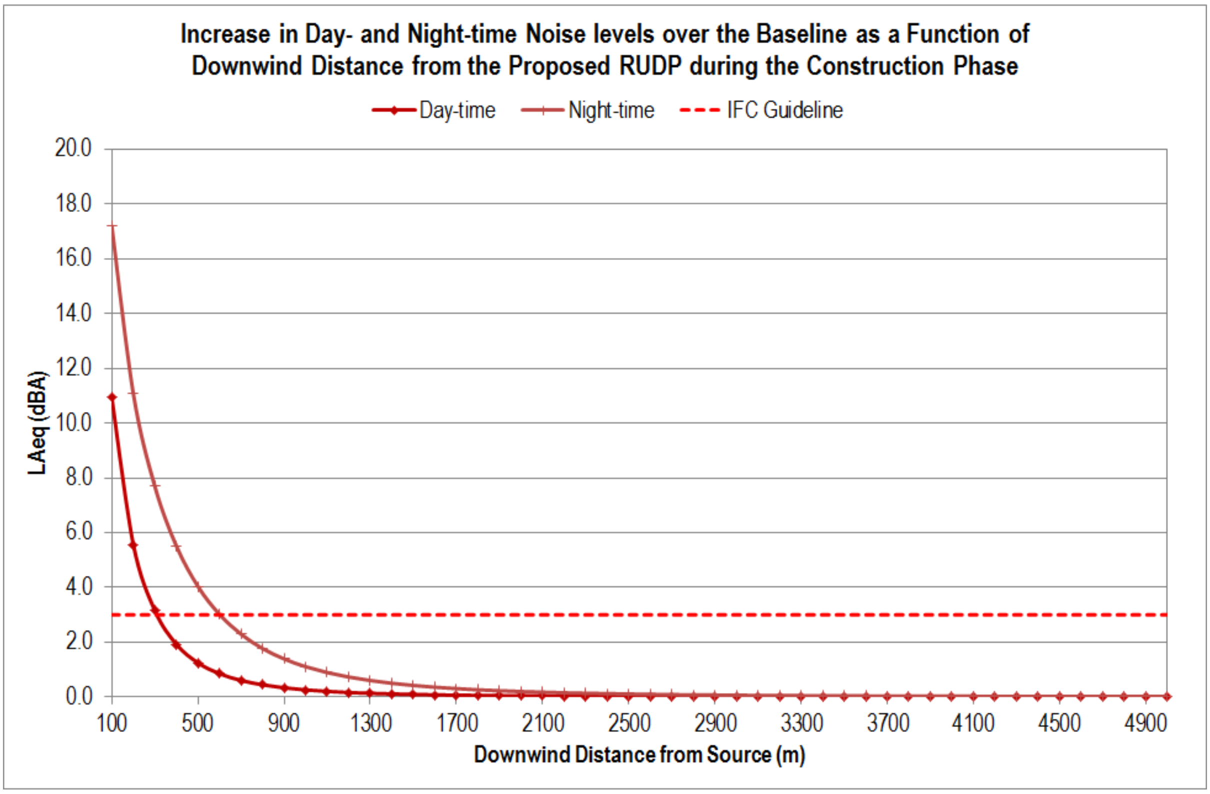


Figure 18: Transect of downwind increase in L_{Aeq} (1 hour) over the baseline during the construction phase

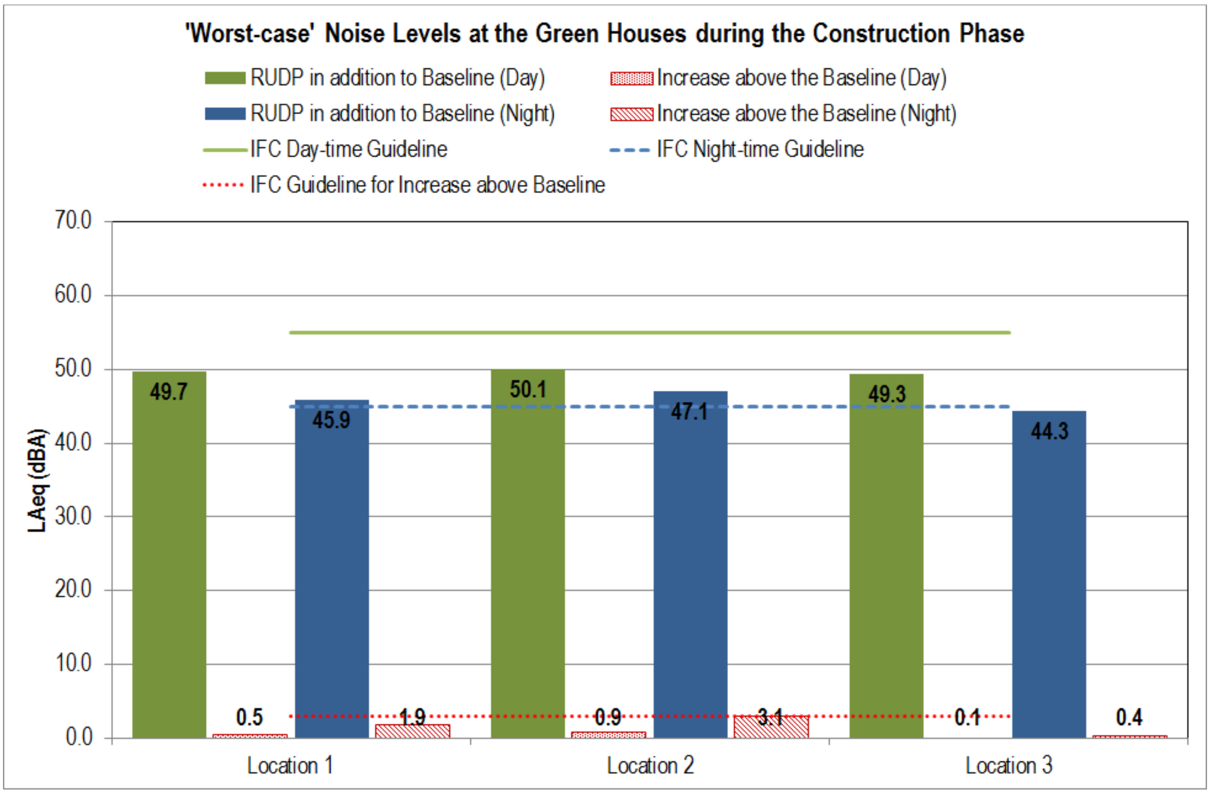


Figure 19: 'Worst-case' noise levels at the Green Houses during the construction phase

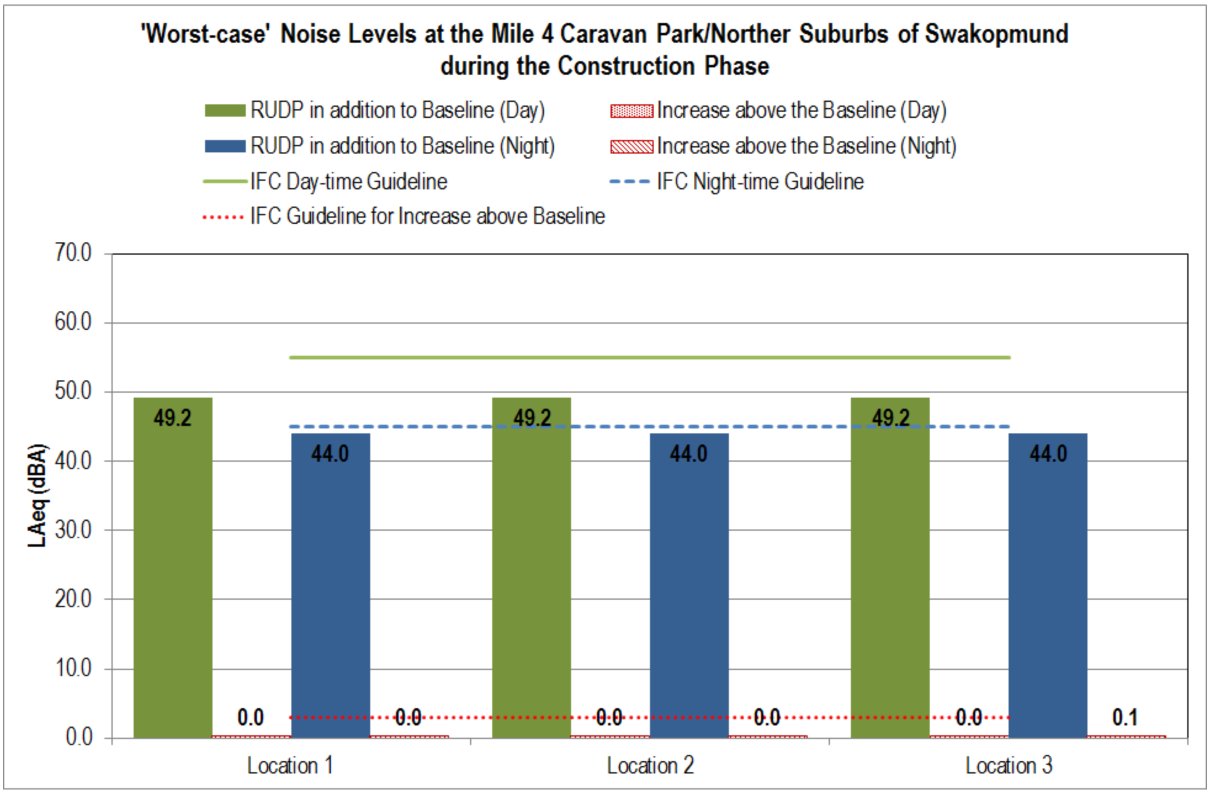


Figure 20: 'Worst-case' noise levels at the Mile 4 Caravan Park during the construction phase

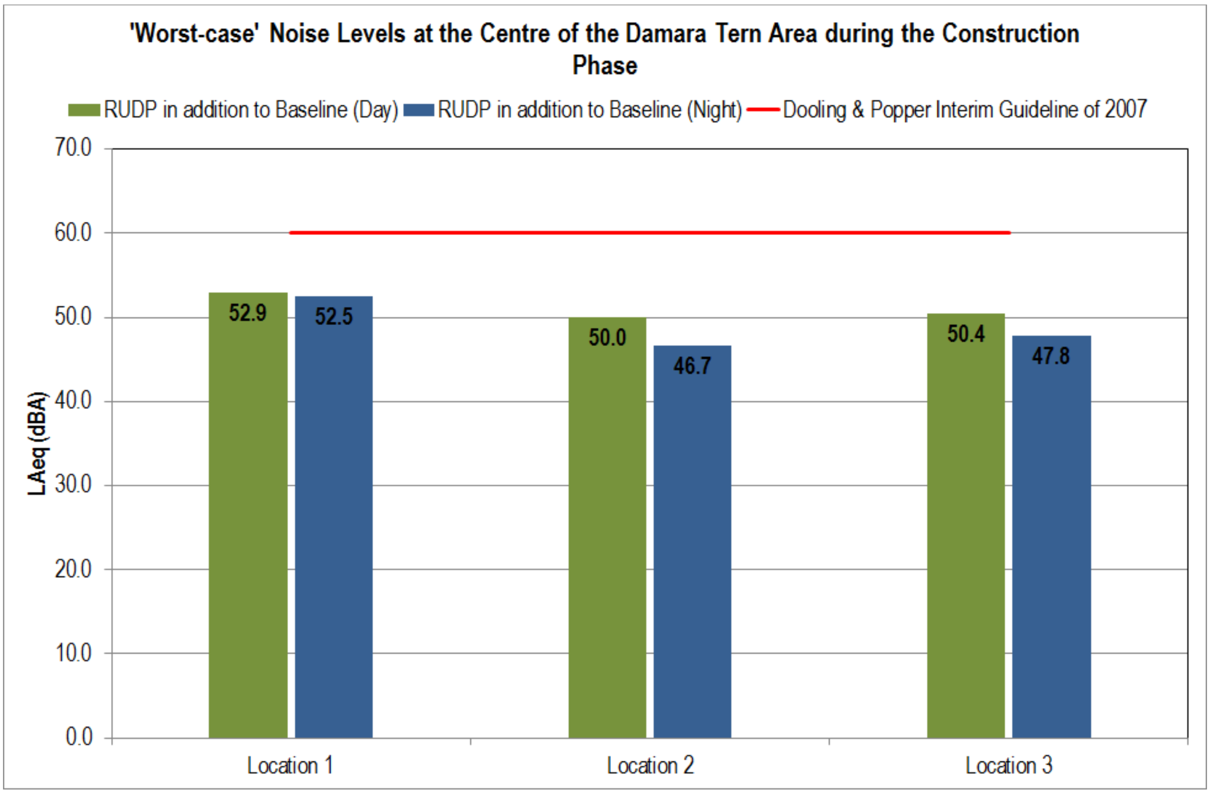


Figure 21: 'Worst-case' noise levels at the centre of the Damara Tern area during the construction phase

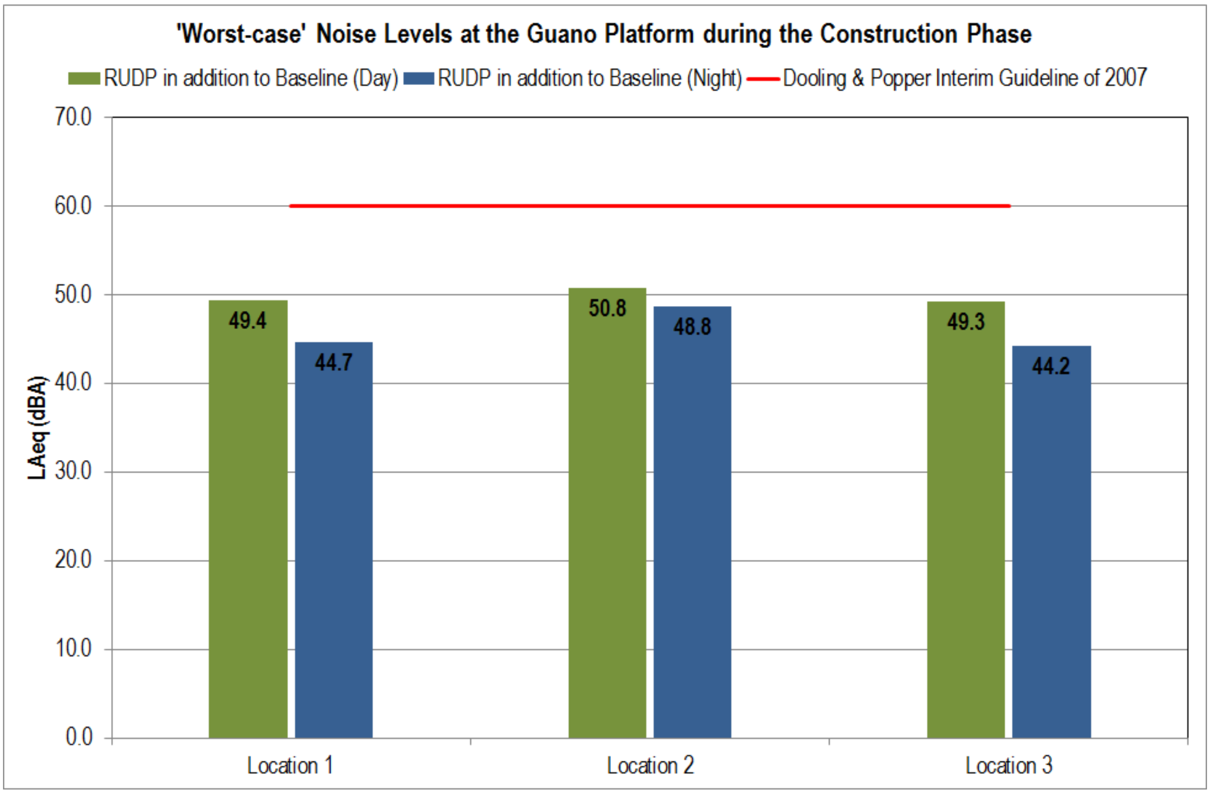


Figure 22: 'Worst-case' noise levels at the Guano Platform during the construction phase

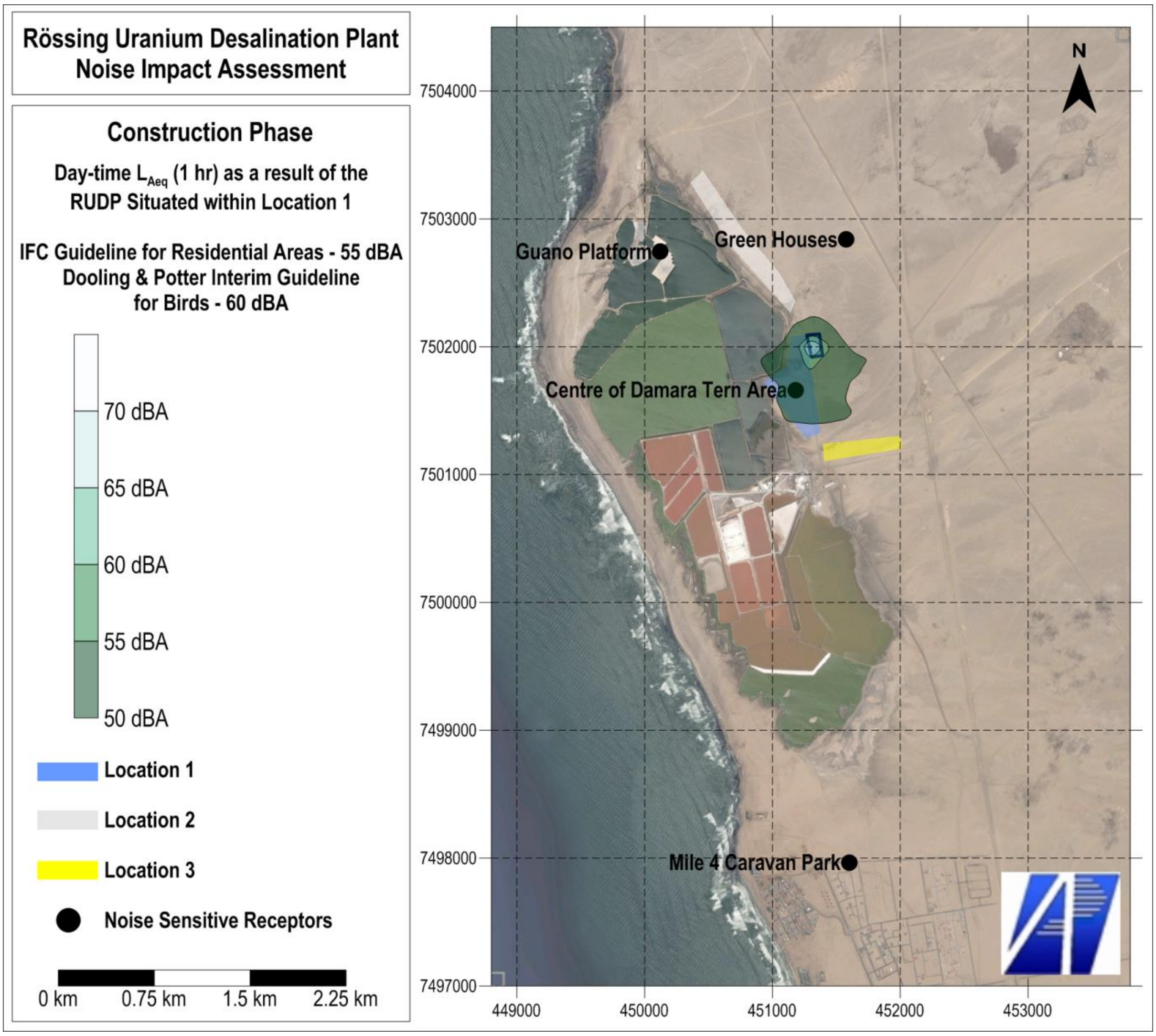


Figure 23: Isopleths of day-time L_{Aeq} (1 hr) during the construction phase with the RUDP at the preferred site within Location 1

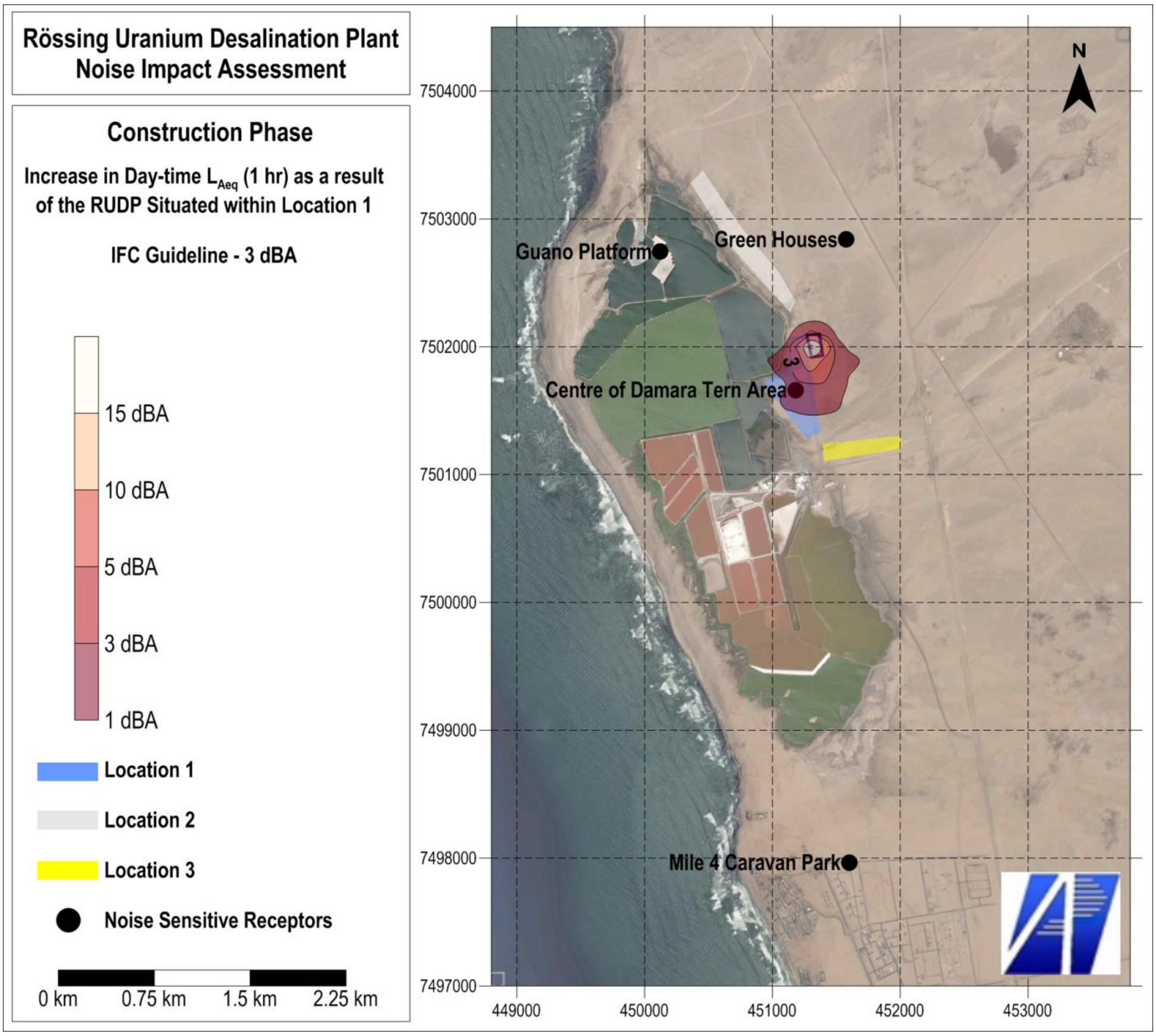


Figure 24: Isopleths of the increase in day-time L_{Aeq} (1 hr) during the construction phase with the RUDP at the preferred site within Location 1

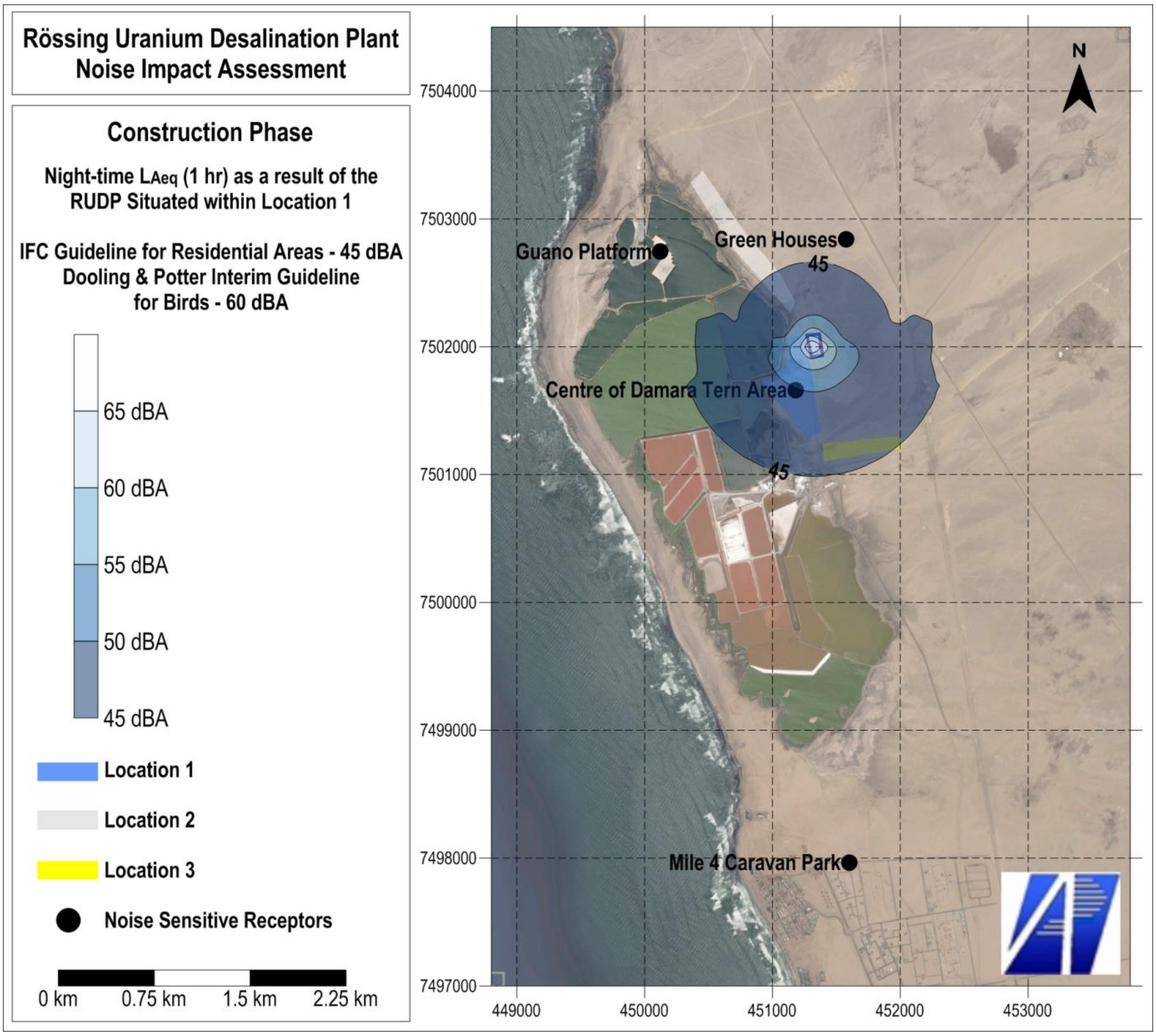


Figure 25: Isopleths of night-time L_{Aeq} (1 hr) during the construction phase with the RUDP at the preferred site within Location 1

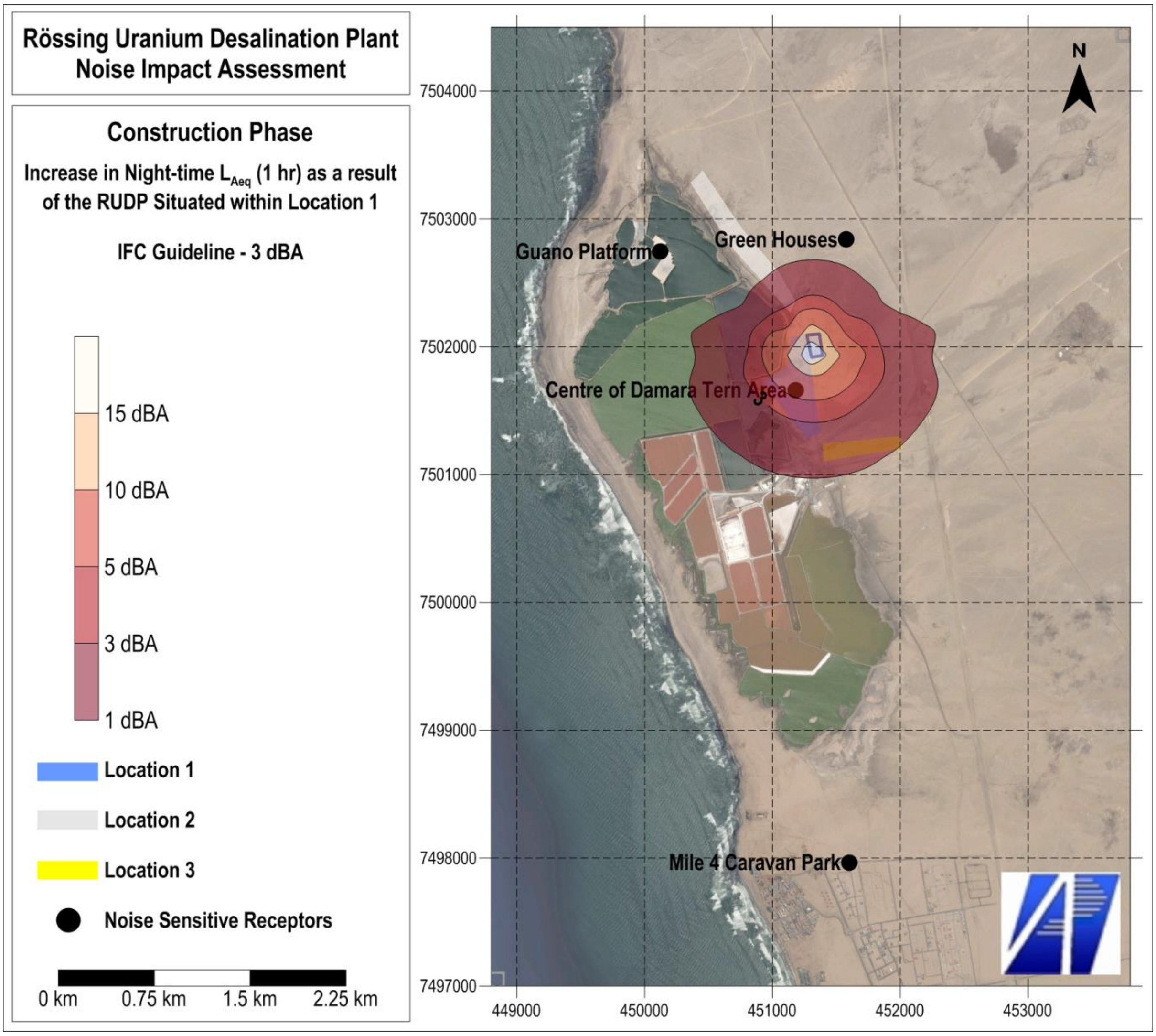


Figure 26: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the construction phase with the RUDP at the preferred site within Location 1

7.2.2 Operational Phase

From simulations for the operational phase the following was found:

- The IFC day-time guideline of 55 dBA is exceeded over 400 m from the RUDP (Figure 27) whereas exceedance of the IFC night-time guideline of 45 dBA is expected up to 1.8 km downwind (Figure 28). The increase in noise levels above the baseline reduces to less than 3 dBA within 700 m during the day and 1.2 km during the night (Figure 29).
- The Dooling & Popper interim guideline of 60 dBA for birds adopted in this study is exceeded 250 m from the RUDP during the day and 300 during the night (Figure 27 and Figure 28).
- From the assessment of 'worst case' impacts at community NSRs at minimum distances from location alternatives considered the following was found:
  - Residents of the Green Houses may be exposed to noise levels in excess of only the night-time IFC guideline should the RUDP be located within Location 1, 2 or 3. The increase above the baseline at these houses is however expected to be notable when the facility is sited within

Location 1 and 2. According to SANS 10103 (2008) sporadic complaints with little community reaction can be expected (Figure 30).

  - The proposed RUDP is not expected to have any effect on environmental noise levels at the Mile 4 Caravan Park or northern Suburbs of Swakopmund (Figure 31).

- From the assessment of 'worst case' impacts at the Damara Tern and Guano Platform areas, it was found that the Dooling & Popper interim guideline of 60 dBA will be exceeded at the Damara Tern area during the night when the RUDP plant is situated within Location 1 (Figure 32 and Figure 33).
- Total day- and night time noise levels associated with the RUDP situated within the preferred area of Location 1 are presented in Figure 34 and Figure 36. The increase over the day- and night-time baseline of 49 dBA and 44 dBA respectively are presented Figure 35 and Figure 37. It should be noted that these isopleths are representative of an hour during which the wind is from the north (see Table 7 for meteorological parameters applied in simulations). Winds from the north occur 12 to 15 % of the hours within a year.

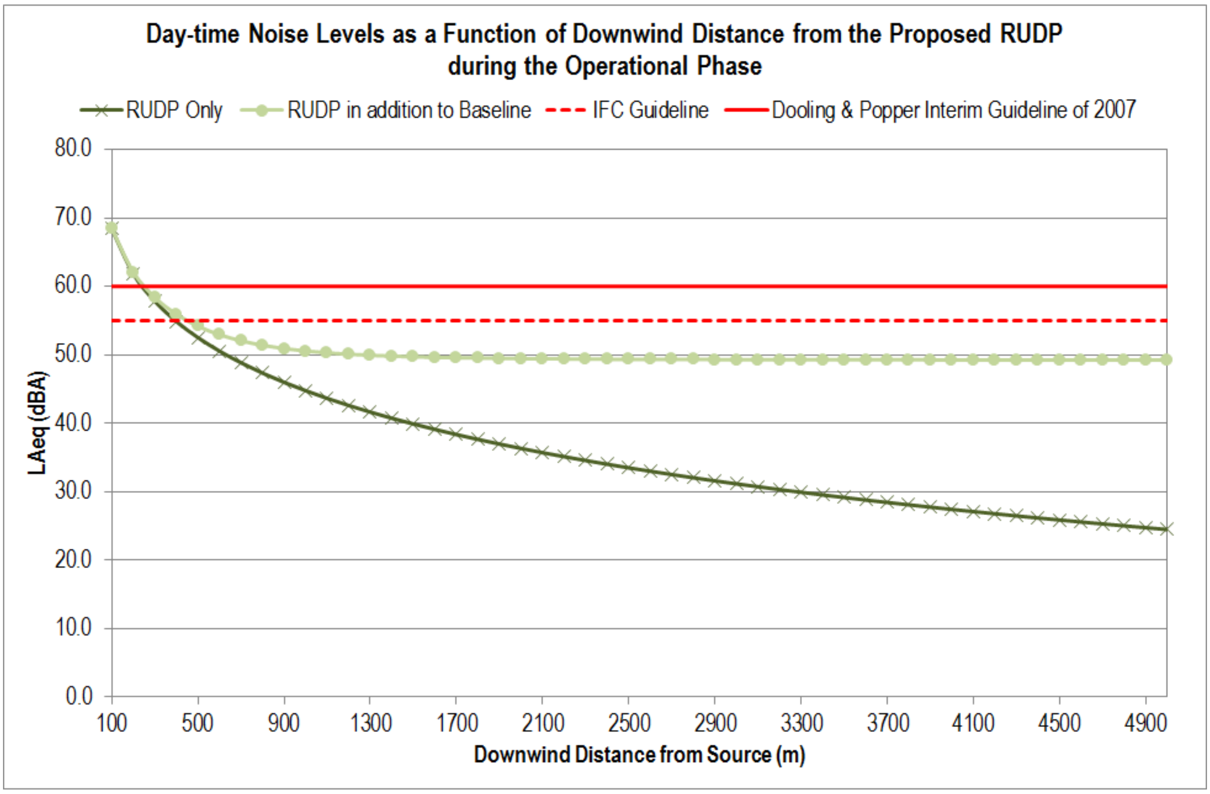


Figure 27: Transect of downwind day-time L_{Aeq} (1 hour) during the operational phase

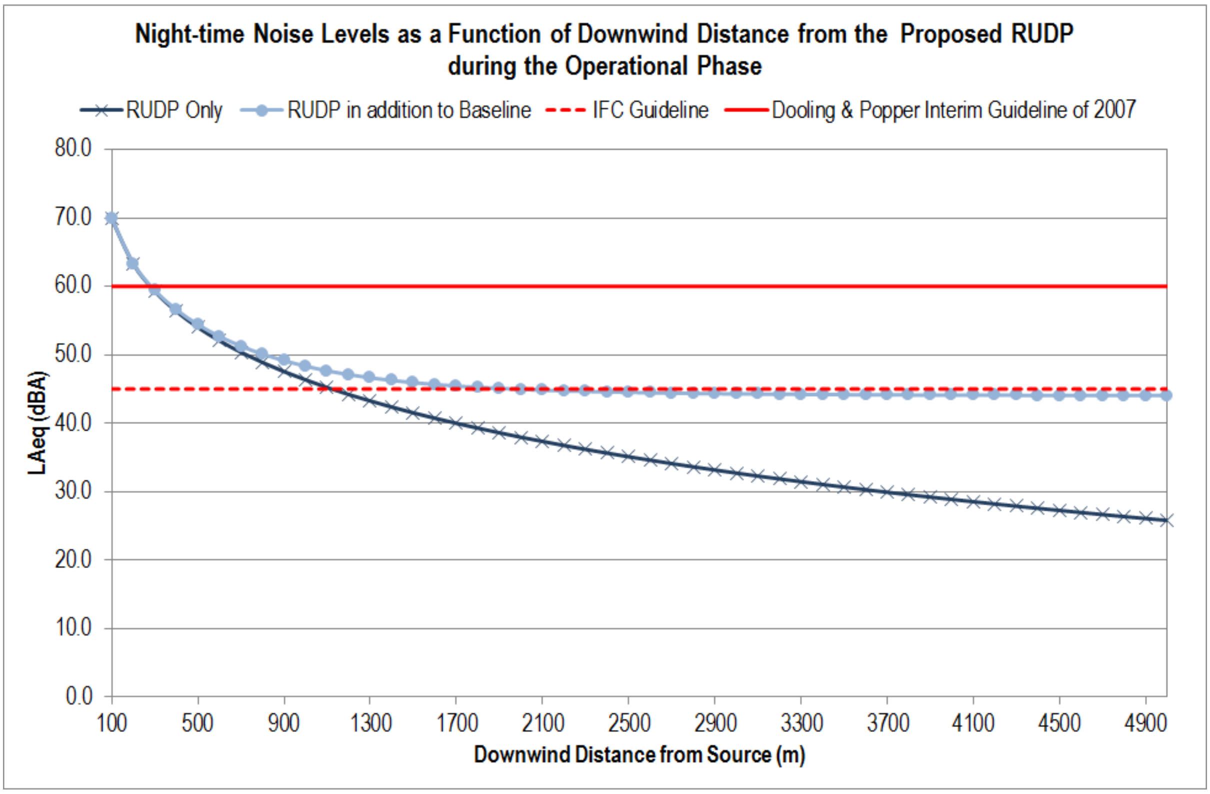


Figure 28: Transect of downwind night-time L_{Aeq} (1 hour) during the operational phase

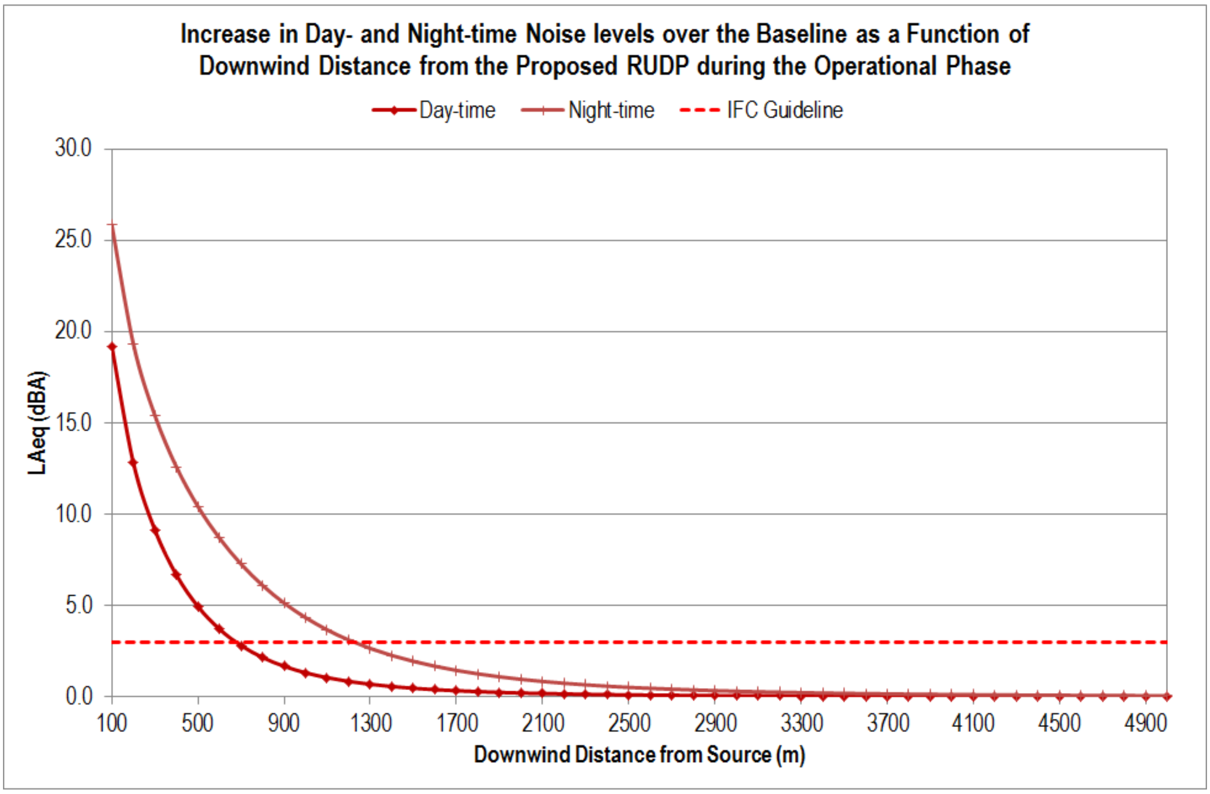


Figure 29: Transect of downwind increase in L_{Aeq} (1 hour) over the baseline during the operational phase

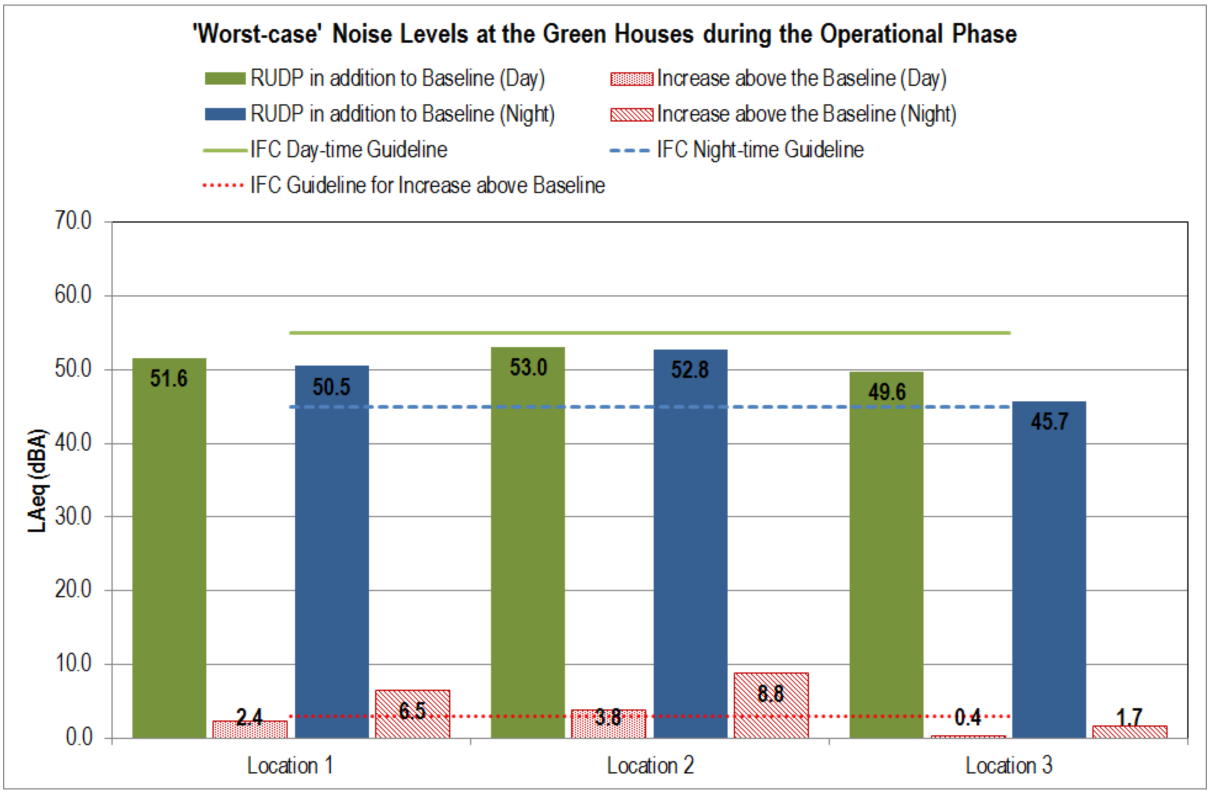


Figure 30: 'Worst-case' noise levels at the Green Houses during the operational phase

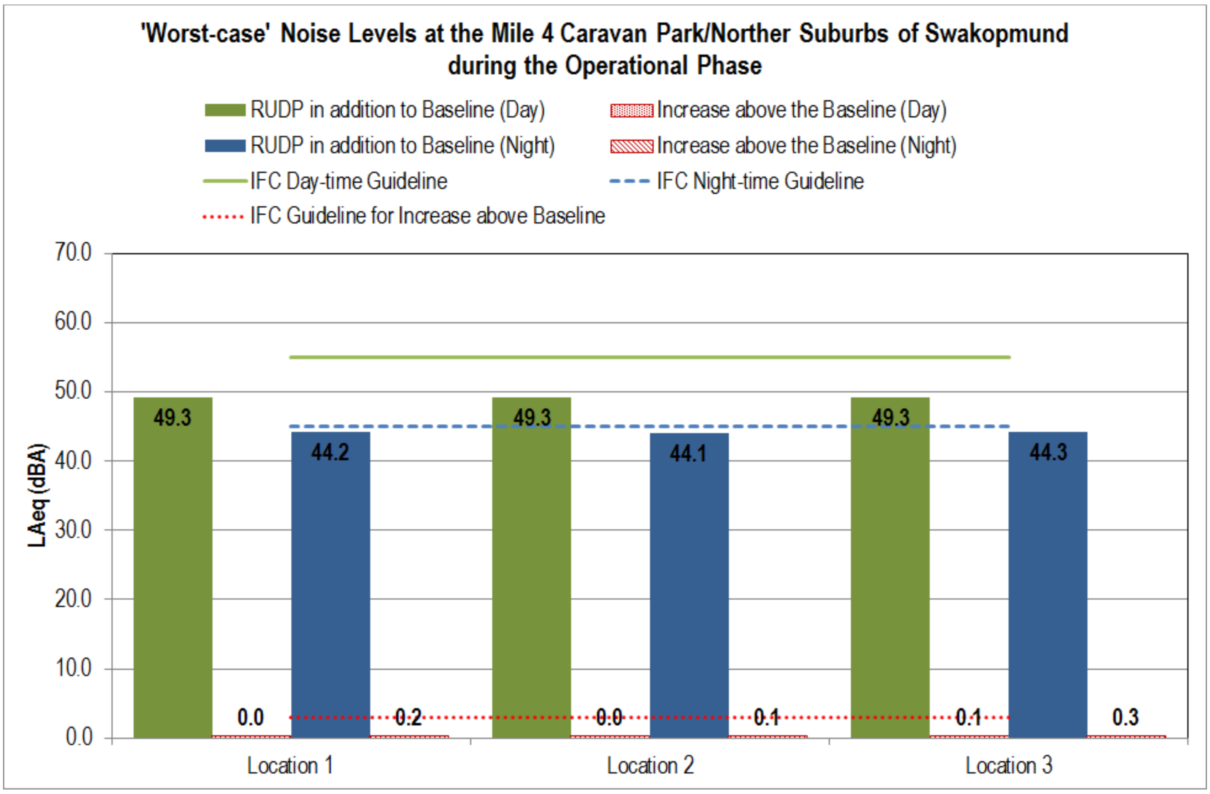


Figure 31: 'Worst-case' noise levels at the Mile 4 Caravan Park/northern suburbs of Swakopmund during the operational phase

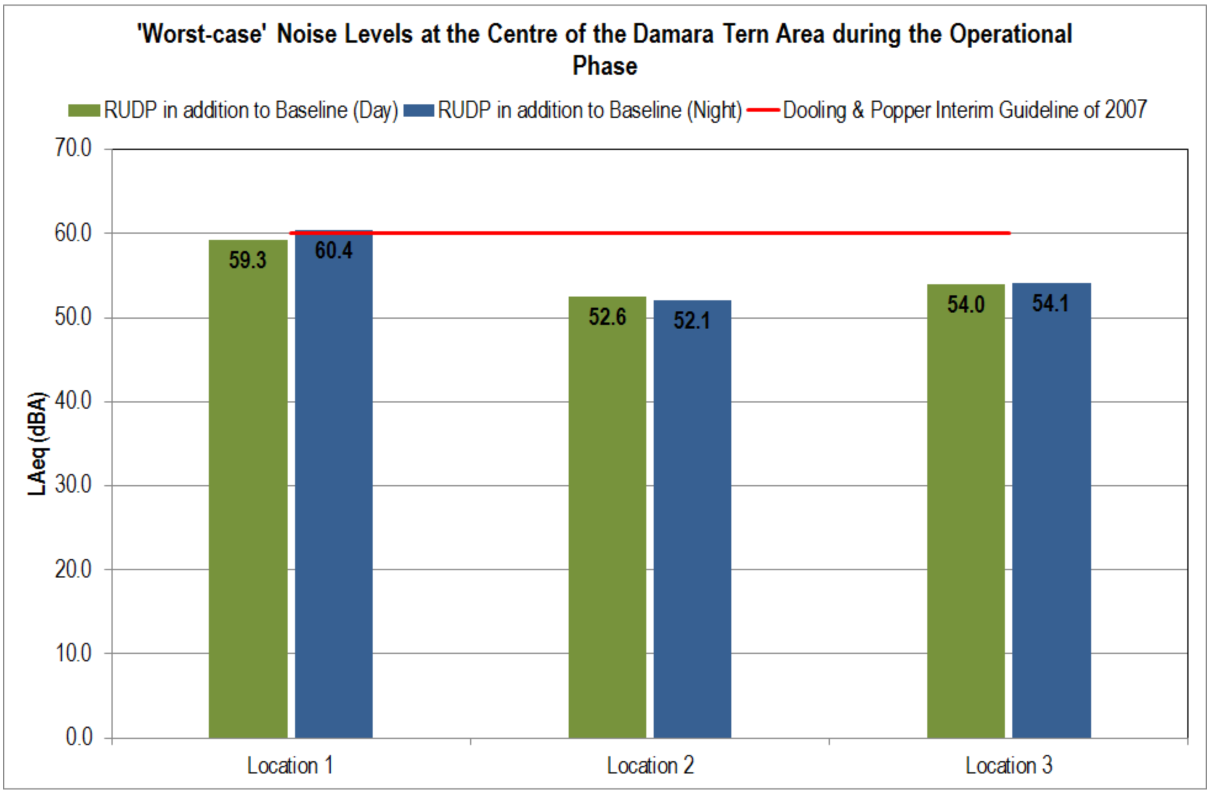


Figure 32: 'Worst-case' noise levels at the Damara Tern area during the operational phase

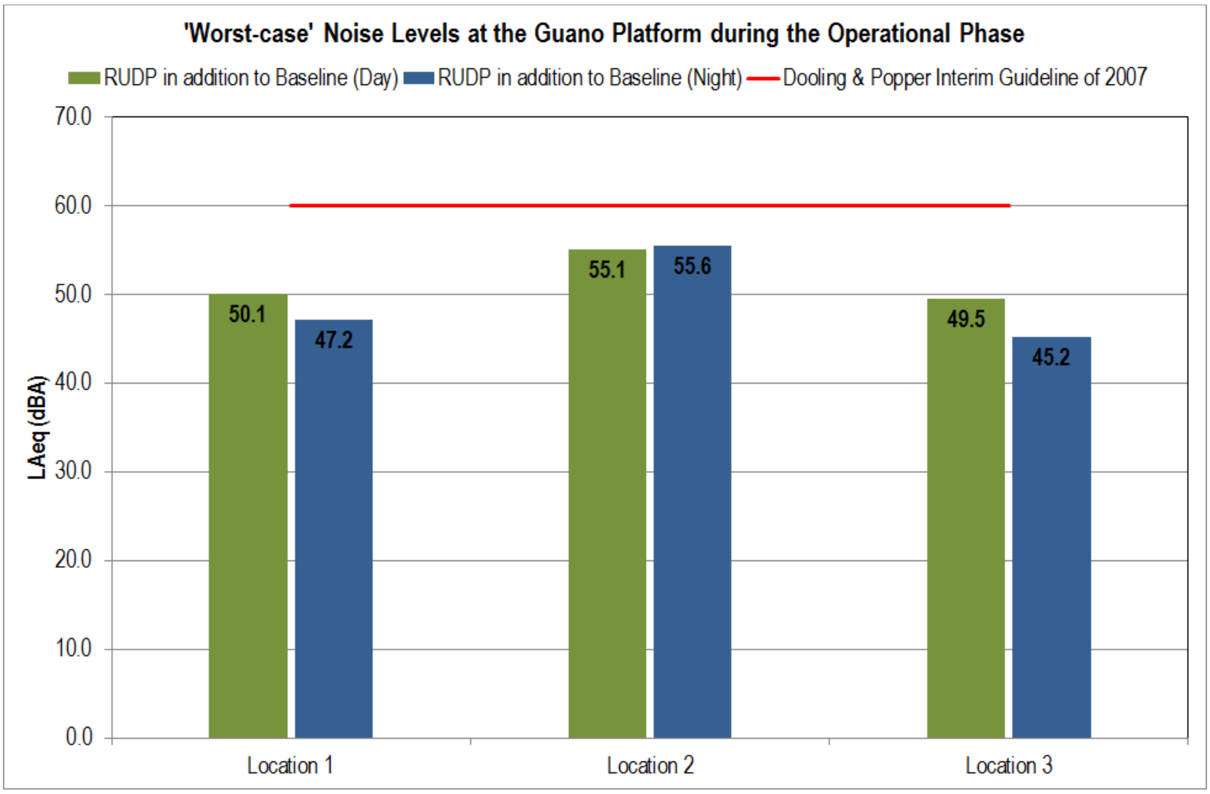


Figure 33: 'Worst-case' noise levels at the Guano Platform during the operational phase

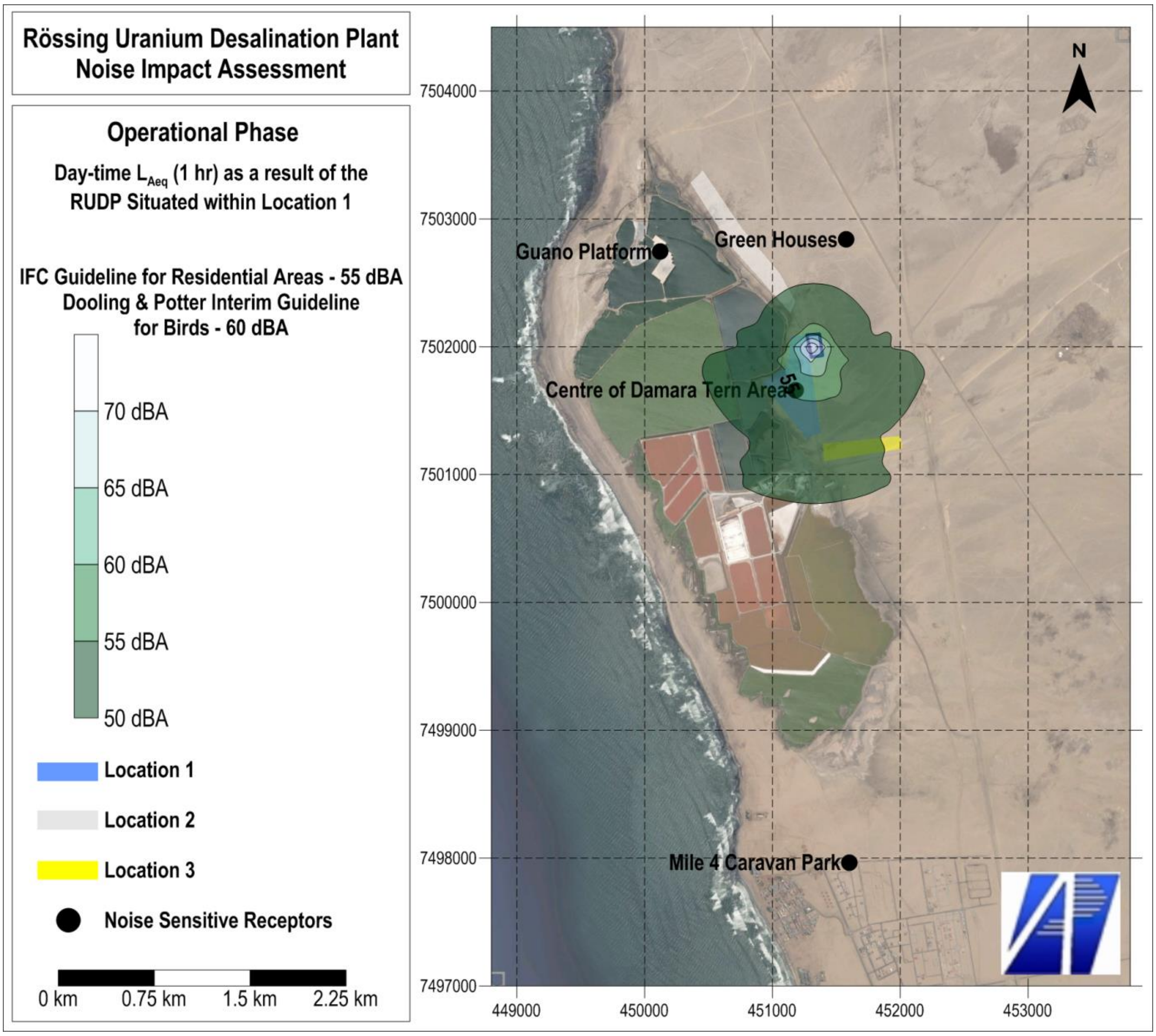


Figure 34: Isopleths of day-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1

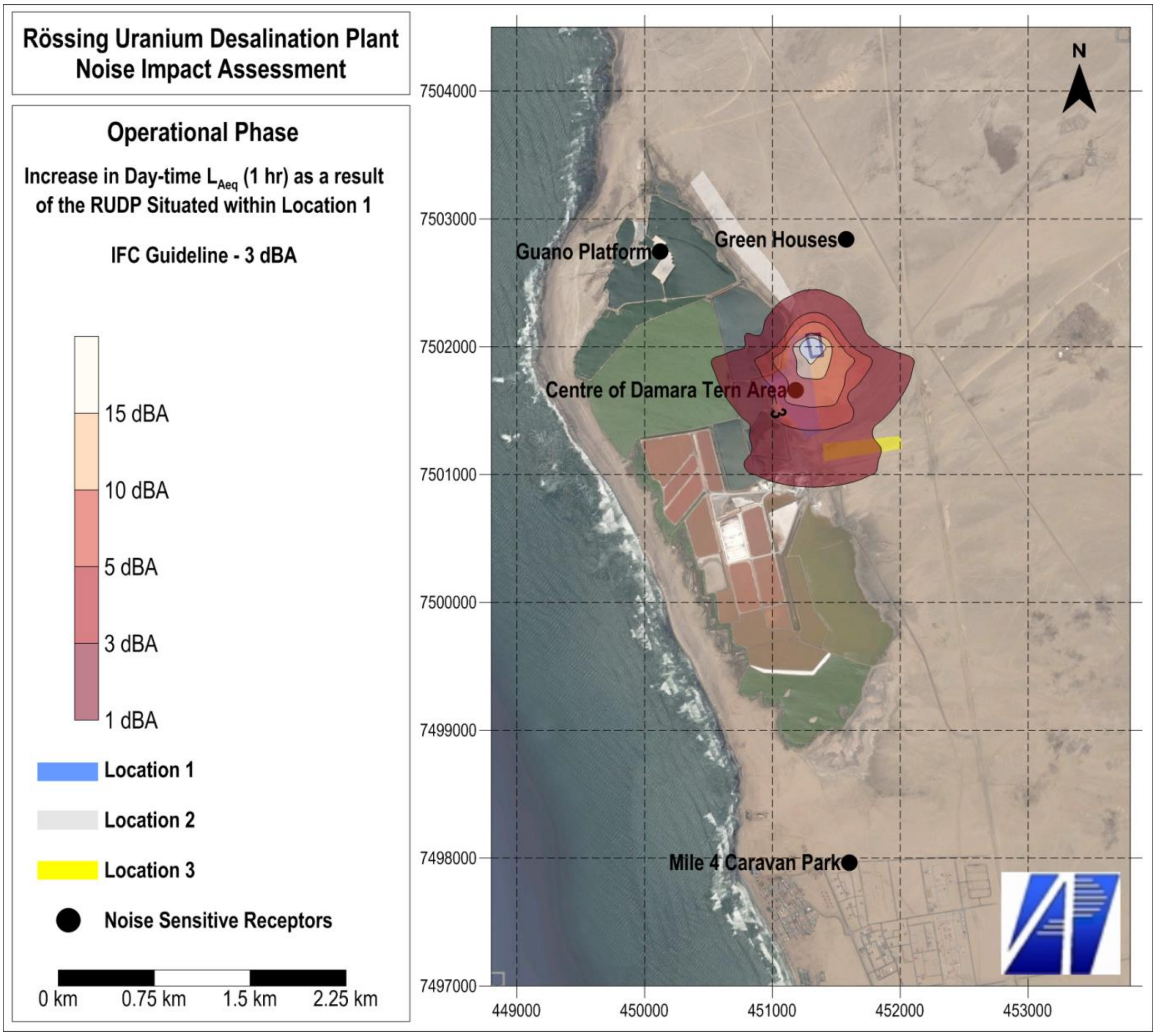


Figure 35: Isopleths of the increase in day-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1

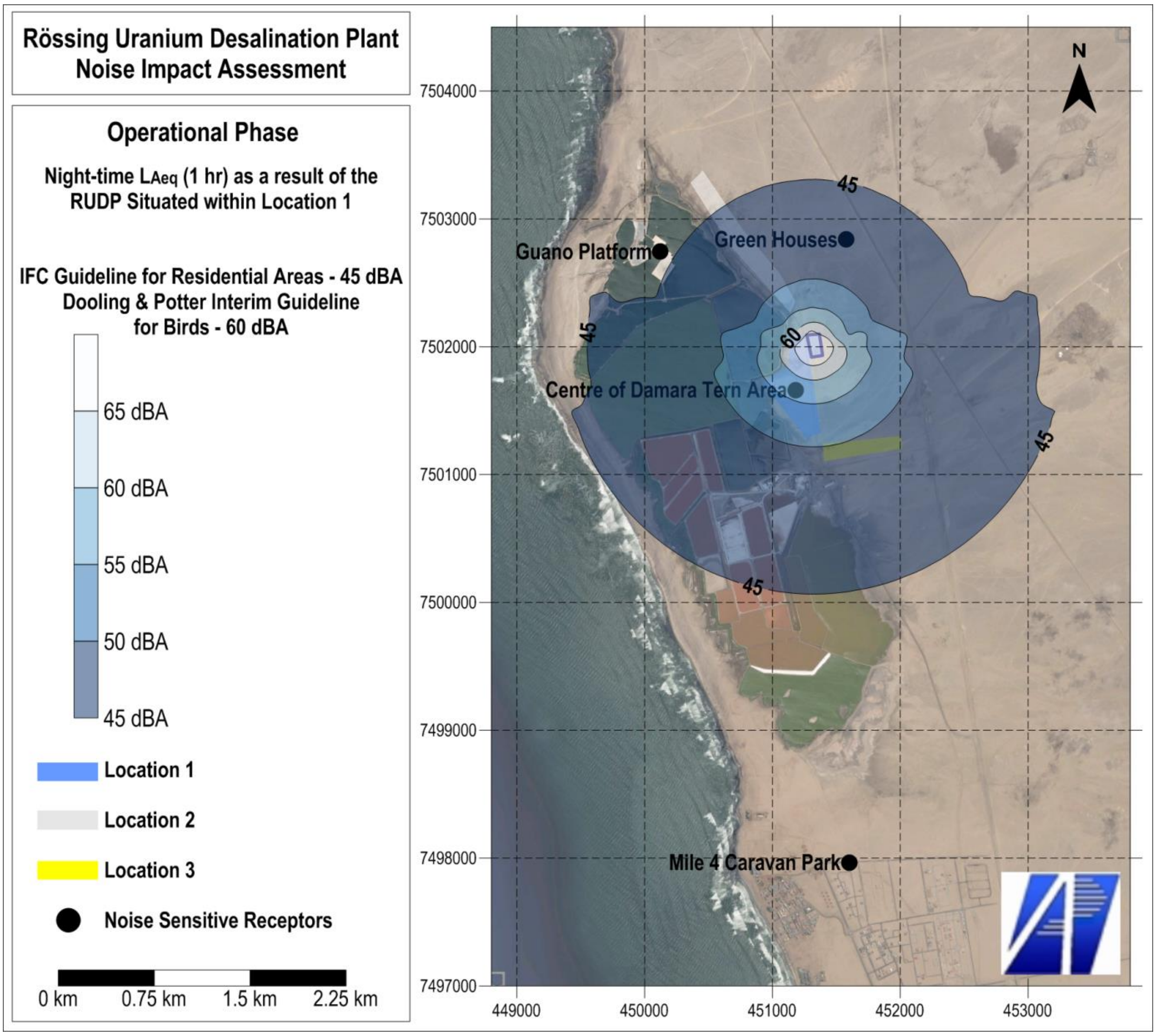


Figure 36: Isopleths of night-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1

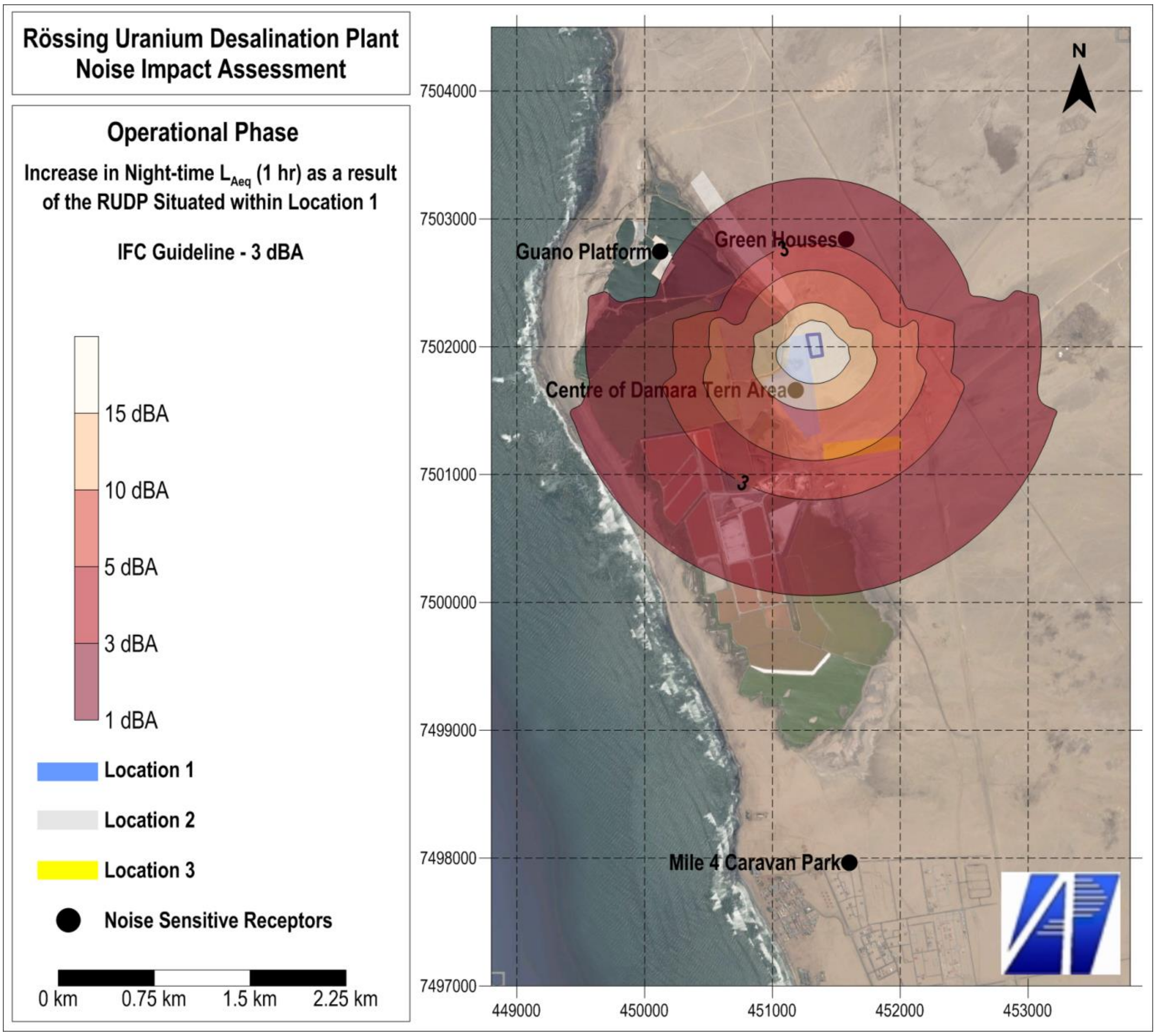


Figure 37: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1

8 MANAGEMENT, MITIGATION AND RECOMMENDATIONS

In the quantification of noise emissions and simulation of noise levels as a result of the proposed RUDP it was found that assessment criteria for human and bird exposure may be exceeded at the Green Houses and the Damara Tern areas, especially at night. The increase above the baseline will be notable to residents of the Green Houses and sporadic complaints with little community reaction can be expected.

To minimise the impact of construction and operational noise on the receiving environment it therefore recommended that the following measures be adopted as part of the RUDP noise management plan.

8.1 Good Engineering and Operational Practices

For general construction and operational activities the following good engineering practice should be applied:

- All diesel powered equipment and vehicles must be regularly maintained and kept at a high level of maintenance. This must particularly include the regular inspection and, if necessary, replacement of intake and exhaust silencers. Any change in the noise emission characteristics of equipment must serve as trigger for withdrawing it for maintenance.
- To minimise noise generation, vendors must be required to guarantee optimised equipment design noise levels.
- Acoustic attenuation devices should be installed on all ventilation outlet and high pressure gas or liquid should not be ventilated directly to the atmosphere, but through an attenuation chamber or device.
- Vibrating equipment must be on vibration isolation mountings.
- The site layout should be designed in such a manner that the noisiest sections of the plant are at the centre of the site, using surrounding buildings as noise attenuation shields.
- A mechanism to monitor noise levels, record and respond to complaints and mitigate impacts should be developed.

8.2 Operational Hours

It is recommended that, **as far is as feasible**, noise generating activities be limited to day-time hours (considered to be between 07:00 and 22:00) since noise impacts are most significant during the night. This includes:

- Limiting all construction activities to day-time hours;
- Limiting truck and other vehicle activity to and from the RUDP during the operational phase to day-time hours.

8.3 Acoustic Barriers

Acoustic barriers are proven to be effective in reducing environmental noise impacts. Acoustic barriers should be without gaps and have a **continuous minimum surface density of 10 kg/m^2** in order to minimize the transmission of sound through the barrier. Barriers should be located as close to the source or to the receptor location to be effective.

In addition to shielding provided by the building for sources located indoors, an acoustic barrier should be considered on the perimeter of the RUDP. This will provide additional shielding to residents at the Green Houses and the Damara Tern area from operational activities. The effects of such a barrier (a boundary wall 1.5 m higher than noise sources) on noise levels are presented in Figure 38 to Figure 41.

Total night-time noise levels at the Green Houses will reduce to within the night-time IFC guideline and the increase in noise level above the baseline can be reduced from less than 3 dBA to less than 1 dBA (i.e. virtually undetectable). Noise levels at the Damara Tern area can also be reduced to less than 60 dBA (the interim guideline proposed by Dooling & Popper, 2007) with the installation of a boundary wall/earthen berm.

8.4 Traffic

Although traffic volumes are expected to be low during the operational phase, construction phase traffic may be notable. The measures described below are considered good practice in reducing traffic related noise.

In general, road traffic noise is the combination of noise from individual vehicles in a traffic stream and is considered as a line source if the density of the traffic is high enough to distinguish it from a point source. The following general factors are considered the most significant with respect to road traffic noise generation:

- Traffic volumes i.e. average daily traffic.
- Average speed of traffic.
- Traffic composition i.e. percentage heavy vehicles.
- Road gradient.
- Road surface type and condition.
- Individual vehicle noise including:
    - Engine noise.
    - Transmission noise.
    - Contact noise (the interaction of tyres and the road surface).
    - Body, tray and load vibration.
    - Aerodynamic noise

In managing transport noise specifically related to trucks, efforts should be directed at:

- Minimizing individual vehicle engine, transmission and body noise/vibration. This is achieved through the implementation of an equipment maintenance program as was mentioned under Section 8.1, ‘Good Engineering and Operational Practices’.
- Minimize slopes by managing and planning road gradients to avoid the need for excessive acceleration/deceleration.
- Maintain road surface regularly to avoid corrugations, potholes etc.
- Avoid unnecessary idling times.
- Minimizing the need for trucks/equipment to reverse. This will reduce the frequency at which disturbing but necessary reverse warnings will occur. Alternatives to the traditional reverse ‘beeper’ alarm such as a ‘self-adjusting’ or ‘smart’ alarm could be considered. These alarms include a mechanism to detect the local noise level and automatically adjust the output of the alarm is so that it is 5 to 10 dB above the noise level in the vicinity of the moving equipment. The promotional material for some smart alarms

does state that the ability to adjust the level of the alarm is of advantage to those sites ‘with low ambient noise level’ (Burgess & McCarty, 2009).

8.5 Monitoring

It is recommended that short term 24-hour to 1-week sampling be conducted at the Green Houses, Damara Tern and Guano Platform areas during the construction and operational phases at least on an annual basis but also during breeding season at the Damara Tern area.

Monitoring should be conducted in accordance with the procedures specified by the IFC (2007) and SANS 10103 (2008). Samples, at least 24-hours in duration should include the following parameters: L_{Aeq}, L_{A90}, and the un-weighted octave band sound pressure levels (L_{Zeq}). In the interpretation and reporting of sampled environmental noise levels, use should be made of a trained specialist.

In addition to ambient noise monitoring it is recommended that source noise measurements of main RO building facades and sources located outside buildings be sampled to verify L_W’s applied in this study.

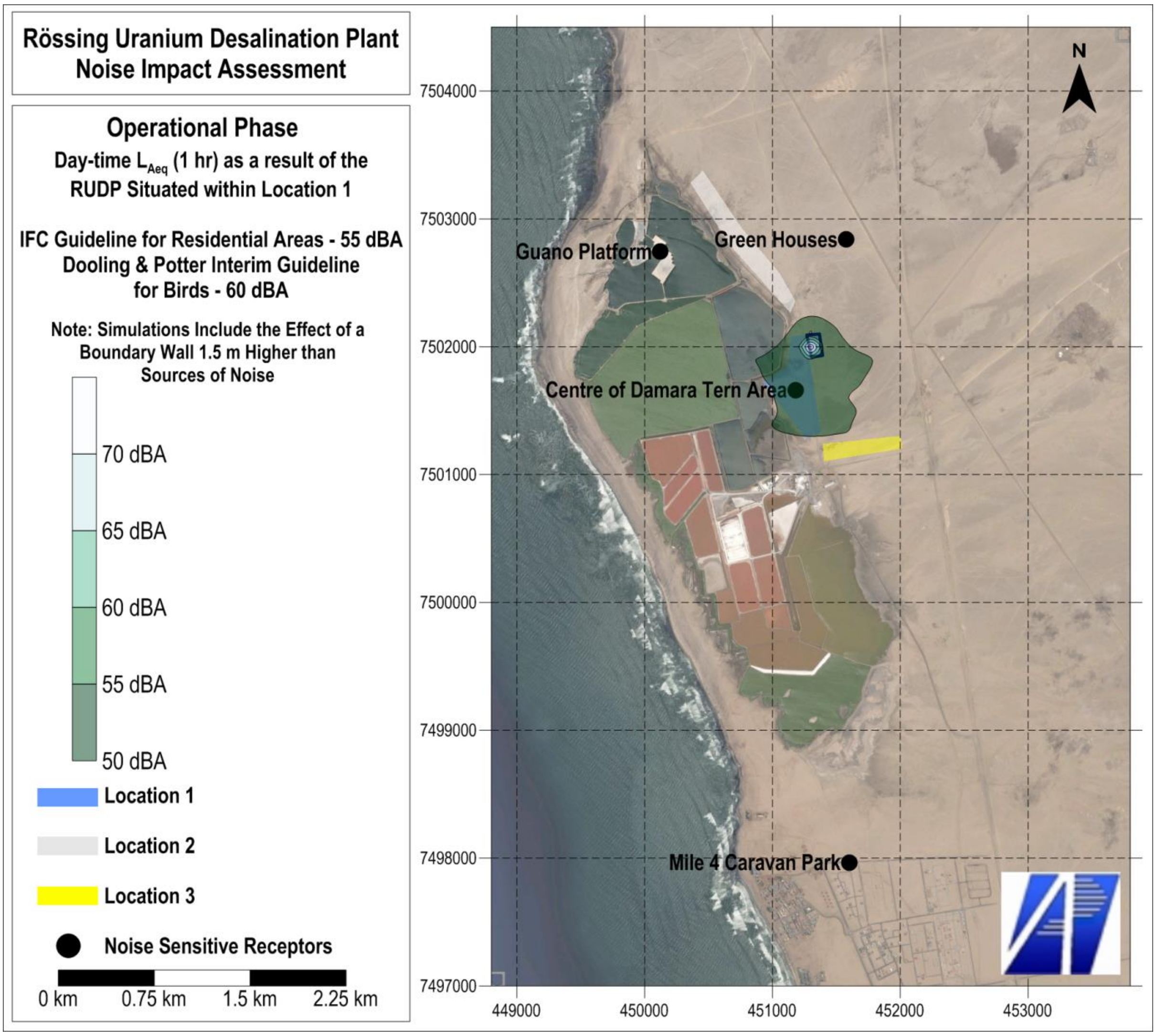


Figure 38: Isopleths of day-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1 including the effect of a boundary wall

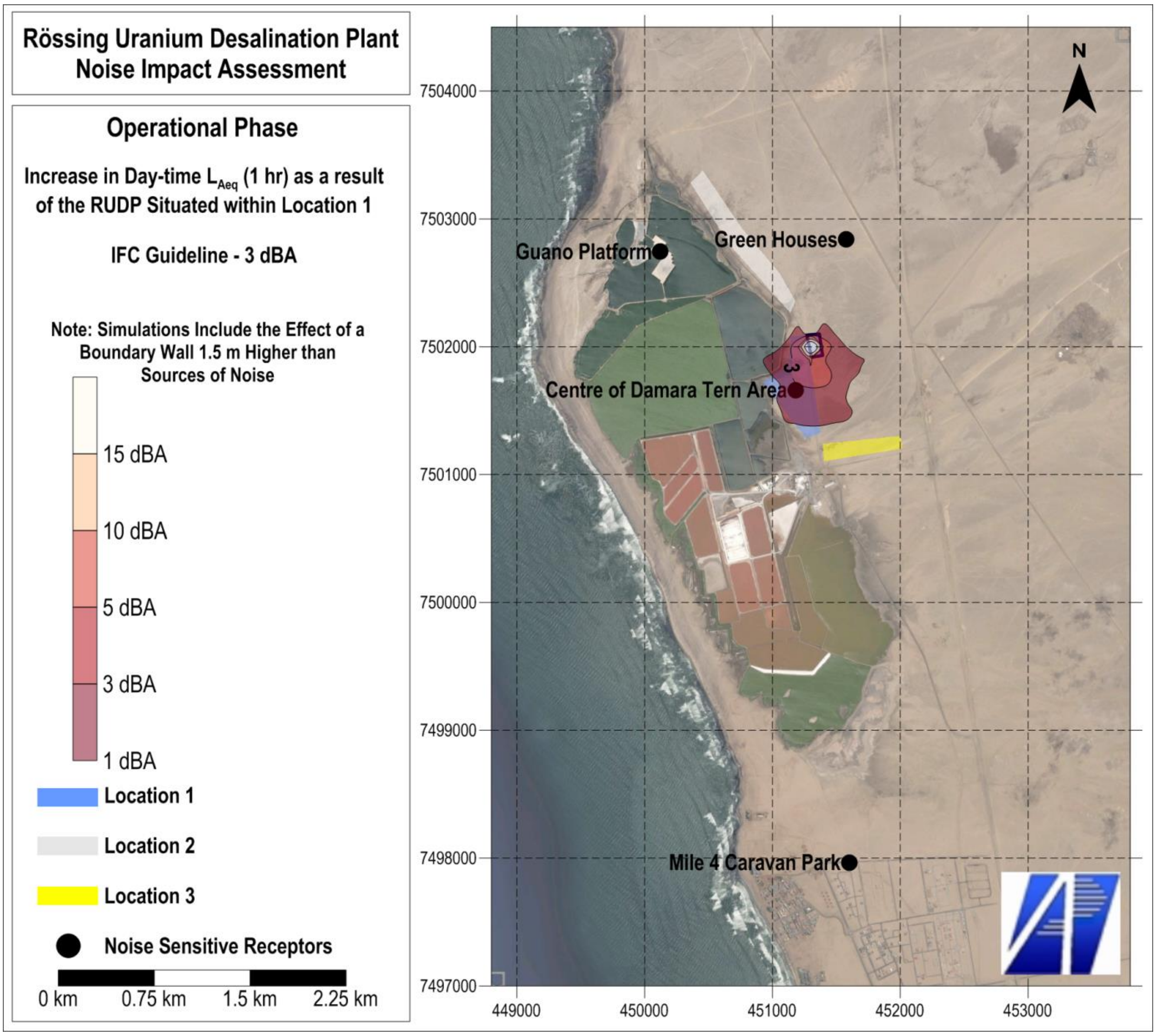


Figure 39: Isopleths of the increase in day-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1 including the effect of a boundary wall

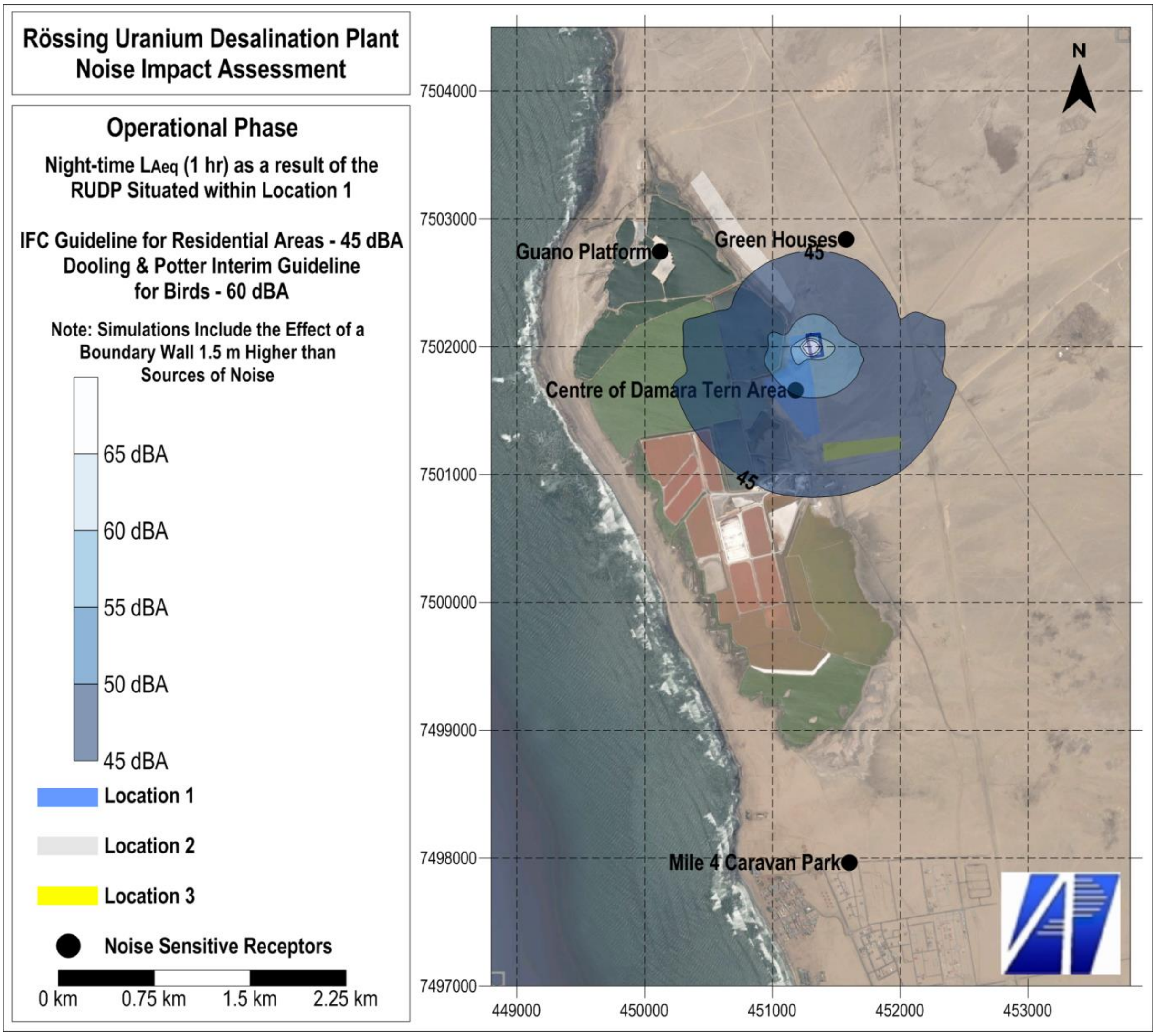


Figure 40: Isopleths of night-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1 including the effect of a boundary wall

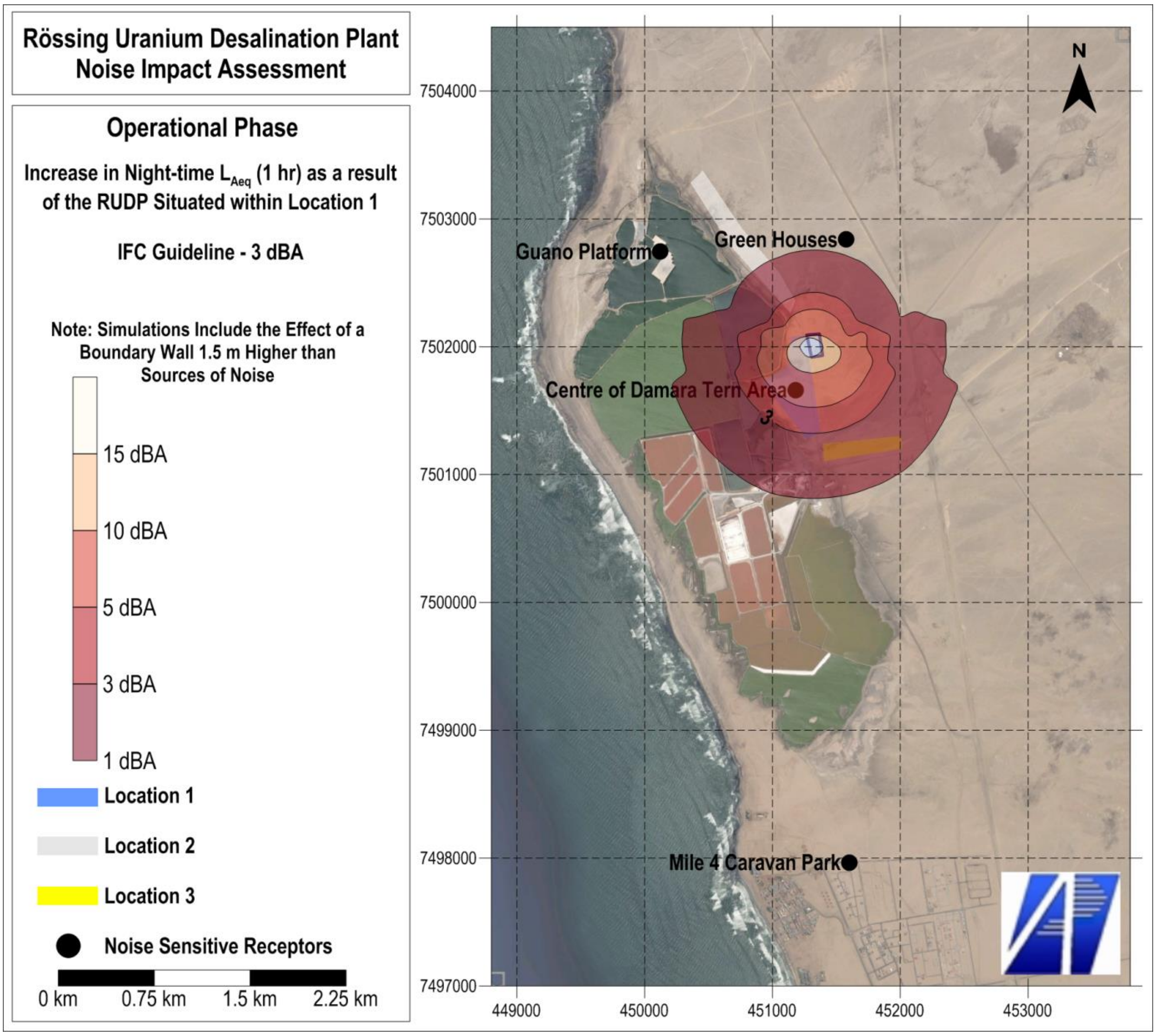


Figure 41: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the operational phase with the RUDP at the preferred site within Location 1 including the effect of a boundary wall

9 IMPACT SIGNIFICANCE

The significance of simulated noise impacts was determined in accordance with the procedure set out by Aurecon and SLR. In the interpretation of noise impact significance, the following should be noted:

- From a human perspective, environmental noise is assessed in terms its potential to cause annoyance.
- In the assessment of impacts on birds, criteria protecting birds against the effects of masking and other behavioural/physiological changes have been adopted.
- There are no distinguishing elements in significance of impacts associated with the location alternatives considered in the study.
- During the **construction p**hase, impacts on human receptors and birdlife are considered 'Very Low' (Table 14).
- With the installation of a boundary wall to act as an acoustic barrier, the significance of impacts on human receptors and birdlife during the **operational phase** will reduce from 'Low' (Table 15) to 'Very Low' (Table 16)
- The impact significance associated with the **decommission phase** will be similar or less than what was quantified for the construction phase, depending on potential changes to the ambient noise levels over the life of the project and the possible growth of residential areas closer to the facility.

It is concluded that, provided that the environmental noise mitigation and management measures recommended in this report are implemented and adhered to, significant noise implications are unlikely and the Project could proceed.

Table 14: Impact significance during the construction phase before mitigation

Construction Phase (Before Mitigation)							
NSR	**Extent (Spatial Scale)**	**Magnitude of Impact at Indicated Spatial Scale**	**Duration of Impact**	**Significance**	**Probability**	**Confidence**	**Reversibility**
Human	Local[(a)]	Very Low[(b)]	Short Term[(d)]	Very Low	Probable[(e)]	Sure[(f)]	Reversible[(h)]
Birdlife		Very Low[(c)]		Very Low		Unsure[(g)]	

Notes:

(a) Area of exceedance of assessment criteria on-site or within 1 km from site

(b) Environmental noise is mainly assessed for its potential to cause annoyance to communities. The slight increase above baseline noise levels (3 dBA and lower) indicates that social functions will remain unaltered.

(c) According to interim guideline proposed by Dooling & Popper (2007) adopted for the assessment of impacts on birds, social and/or natural functions and/ or processes remain will unaltered at levels below 60 dBA.

(d) Construction phase, up to 3 years.

(e) Estimated 5% to 95% chance of the impact occurring.

(f) A reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact on humans are available and have been applied in impact estimations.

(g) Limited information on and understanding of, the environmental factors potentially influencing the impact of noise on Damara Terns are available.

(h) The impact is reversible, within a period of 10 years.

Table 15: Impact significance during the operational phase before mitigation

Operational Phase (before mitigation)							
NSR	**Extent (Spatial Scale)**	**Magnitude of Impact at Indicated Spatial Scale**	**Duration of Impact**	**Significance**	**Probability**	**Confidence**	**Reversibility**
Human	Local[(a)]	Low[(b)]	Long Term[(d)]	Low	Probable[(e)]	Sure[(f)]	Reversible[(h)]
Birdlife		Low[(c)]		Low		Unsure[(g)]	

Notes:

(a) Although the areas of exceedance of assessment criteria extent further than 1 km from site (maximum 1.8 km), the impact is considered local, not regional.

(b) Environmental noise is mainly assessed for its potential to cause annoyance to communities. The notable increase above baseline noise levels (10 dBA and lower) indicates that social functions are slightly altered.

(c) According to interim guideline proposed by Dooling & Popper (2007) adopted for the assessment of impacts on birds, social and/or natural functions and/ or processes will be altered at levels exceeding but close to 60 dBA.

(d) More than 10 years.

(e) Estimated 5% to 95% chance of the impact occurring.

(f) A reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact on humans are available and have been applied in impact estimations.

(g) Limited information on and understanding of, the environmental factors potentially influencing the impact of noise on Damara Terns are available.

(h) The impact is reversible, within a period of 10 years.

Table 16: Impact significance during the operational phase (RUDP with boundary wall as acoustic barrier)

Operational Phase (RUDP with boundary wall as acoustic barrier)							
NSR	**Extent (Spatial Scale)**	**Magnitude of Impact at Indicated Spatial Scale**	**Duration of Impact**	**Significance**	**Probability**	**Confidence**	**Reversibility**
Human	Local[(a)]	Very Low[(b)]	Long Term[(d)]	Very Low	Probable[(e)]	Sure[(f)]	Reversible[(h)]
Birdlife		Very Low[(c)]		Very Low		Unsure[(g)]	

Notes:

(a) Although the areas of exceedance of assessment criteria extent further than 1 km from site (maximum 1.8 km), the impact is considered local, not regional.

(b) Environmental noise is mainly assessed for its potential to cause annoyance to communities. The slight increase above baseline noise levels (less than 3 dBA) indicates that social functions will remain unaltered.

(c) According to interim guideline proposed by Dooling & Popper (2007) adopted for the assessment of impacts on birds, social and/or natural functions and/ or processes remain will unaltered at levels below 60 dBA.

(d) More than 10 years.

(e) Estimated 5% to 95% chance of the impact occurring.

(f) A reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact on humans are available and have been applied in impact estimations.

(g) Limited information on and understanding of, the environmental factors potentially influencing the impact of noise on Damara Terns are available.

(h) The impact is reversible, within a period of 10 years.

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