

**Environmental Impact Assessment
Proposed KUDU CCGT Power Plant
at Uubvlei, near Oranjemund, Republic of Namibia**

VOLUME 2 : SPECIALIST STUDIES



Prepared by:

CSIR: Environmentek
P.O. Box 320
Stellenbosch 7600
Tel: + 27 21 888 2400
Fax: + 27 21 888 2693
Email: HFortuin@csir.co.za



Prepared for:

Namibia Power Corporation (Pty) Ltd
P.O. Box 2864
Windhoek, Namibia
Tel: + 264 61 205 4111
Fax: + 64 61 23 2805
Email: John.Langford@nampower.com.na



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Prepared for:	Namibia Power Corporation (Pty) Ltd P O Box 2864, WINDHOEK, Namibia
Prepared by:	CSIR-Environmentek, P O Box 320, STELLENBOSCH, 7599.
Authors:	Henri HG Fortuin
Scope:	<p>This Specialist Studies forms part of the process of planning and decision making for the proposed Kudu CCGT power plant at Uubvlei, near Oranjemund, Namibia. Its purpose is to present the findings of investigations for the EIA process. In particular, it will:</p> <ul style="list-style-type: none">• Identify any interactions between the proposed CCGT power plant and the environment;• Consider which of these aspects, if any, are likely to have a significant impact on the environment; and• Recommend measures that will enhance any positive impact and avoid any adverse negative impact, and if the latter cannot be avoided, to reduce its impact and ensure adequate protection during construction and operation of the proposed CCGT power plant. <p>The Specialist Studies Report is part of a series of reports and information documents issued during the environmental impact assessment process.</p>
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ABBREVIATIONS AND ACRONYMS USED

<i>BTX</i>	Benzene, toluene, xylene
<i>CBD</i>	Convention on Biological Diversity
<i>CCGT</i>	Combined cycle gas turbine
<i>Cl</i>	Chlorine
<i>CO₂</i>	Carbon dioxide
<i>CSIR</i>	Council for Scientific and Industrial Research
<i>DWAF</i>	Department of Water Affairs and Forestry (South Africa)
<i>ELV</i>	Emission limit values
<i>EA</i>	Environmental assessment
<i>EIA</i>	Environmental impact assessment
<i>EIR</i>	Environmental impact report
<i>EMP</i>	Environmental management plan
<i>EMS</i>	Environmental management system
<i>GT</i>	Gas turbine
<i>HSRG</i>	Heat recovery steam generator
<i>I&AP</i>	Interested and Affected Party
<i>IEM</i>	Integrated environmental management
<i>IFC</i>	International Finance Corporation
<i>IPCC</i>	Intergovernmental Panel on Climate Change
<i>MAI</i>	Mining Area One
<i>MAWRD</i>	Ministry of Agriculture, Water and Rural Development (Namibia)
<i>MET</i>	Ministry of Environment and Tourism (Namibia)
<i>MME</i>	Ministry of Mines and Energy (Namibia)
<i>MOU</i>	Memorandum of Understanding
<i>MW</i>	Megawatts
<i>NO_x</i>	Oxides of nitrogen
<i>NO₂</i>	Nitrogen dioxide
<i>OEM</i>	Original equipment manufacturer
<i>PEA</i>	Preliminary environmental assessment
<i>PM</i>	Particulate matter
<i>PM₁₀</i>	Particulate matter 10 microns or less
<i>SADC</i>	Southern African Development Community
<i>SAIEA</i>	Southern African Institute for Environmental Assessment
<i>SANS</i>	South African National Standard
<i>SAPP</i>	Southern African Power Pool
<i>SO₂</i>	Sulphur dioxide
<i>TSP</i>	Total suspended particulates
<i>US-EPA</i>	United States Environmental Protection Agency
<i>VOC</i>	Volatile organic compounds
<i>WHO</i>	World Health Organisation

Units used

dBA	Power gain in decibels
dB (A)	Power gain in decibels
J/m ² /day	Joules per square metre per day
mg/N m ³	Milligrams per Normal cubic metre
µg/l, µg/ℓ	Micrograms per litre
µg l ⁻¹ , µg ℓ ⁻¹	Micrograms per litre
Mm ³ /a	Million cubic metres per annum
m s ⁻¹	Metres per second
m ³ s ⁻¹	Cubic metres per second
ml l ⁻¹ , ml ℓ ⁻¹	Millilitres per litre
µg/m ³	Micrograms per cubic metre
M m ³ /a	Million cubic metres per annum
Psu	Practical salinity unit
ppm	Parts per million
‰	Parts per thousand
Δt	Difference in temperature

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ARCHAEOLOGICAL ASSESSMENT

INFRASTRUCTURE AND SITE SERVICES ASSESSMENT

AIR QUALITY ASSESSMENT

VEGETATION ASSESSMENT

TERRESTRIAL ECOLOGY AND FAUNA

ASSESSMENT OF COOLING WATER DISCHARGE

**ENVIRONMENTAL ASSESSMENT FOR
KUDU CCGT POWER PLANT AT
UUBVLEI NEAR ORANJEMUND,
NAMIBIA**

SOCIO-ECONOMIC IMPACT ASSESSMENT

UUBVLEI SITE

PREPARED FOR:

PREPARED BY:

Ted Rudd,
for Enviro Dynamics

Contact person:

Henri Fortuin
Tel: + 27 21 888-2412
Fax: + 27 21 888-2693

Email: hfortuin@csir.co.za



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ENVIRONMENTAL ASSESSEMNT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA

SOCIO-ECONOMIC IMPACT ASSESSMENT

1. INTRODUCTION

1.1 *Objectives*

The objective of this dedicated study is to carry out a comprehensive socio-economic assessment in order to evaluate the impact of the power plant located at Uubvlei during construction, operation and closure. These impacts are assessed in terms of magnitude, significance, frequency duration and probability. Cumulative effects have also been taken into account over the lifetime of the project which is estimated to between 20 and 40 years depending on the performance of the gas reserve.

Recommendations are made to maximise, positive impacts and to avoid or reduce to acceptable level, potentially negative impacts.

1.2 *Methodology and approach*

The socio-economic issues identified in the TOR, together with other issues raised in public meetings or through analysis of the receiving environment have been used to structure this report. It makes sense to divide all issues into three categories, covering the following: -

A. POPULATION, EMPLOYMENT AND SOCIAL SERVICES

- Population
- Employment
- Education and Skills
- Health and Welfare
- Social Services and Facilities
 - general
 - hospital
 - schools
 - recreation facilities
 - safety and security

B. INFRASTRUCTURE AND URBAN SERVICES

- Housing and Accommodation
- Communications Infrastructure
- Urban Infrastructural Services

C. ECONOMIC STRUCTURES AND URBAN MANAGEMENT

- Existing Economic Structure
- Future Economic Trends
- Urban Management
- Neighbouring Towns

Each socio-economic category features a description of the receiving environment, a discussion of the relevant characteristics of the imposed environment, a summary of recorded community concerns and an exercise to identify impacts. Thereafter, each individual impact is described, evaluated and summarised. Recommended mitigation objectives are made for each.

In August 2004, a full socio-economic impact assessment was prepared in respect of the proposed location of the CCGT Power Station at Site "D", some 2 kilometers to the west of Oranjemund. Thereafter, a decision was taken to consider an alternative site at Uubvlei some 25 kilometers further north. This study is thus essentially a review of the evaluation and findings of the Site "D" document which has been amended to incorporate differences in the impacts resulting from this change in location. Clearly the characteristics described for the receiving environment will derive from the new location of the imposing environment (ie the CCGT plant and construction camp) which is now significantly further away from Oranjemund.

As with the Site "D" report, emphasis is placed on the evaluation of impacts and the design of mitigations rather than on detailed descriptions of the receiving environment. Descriptions from the PEA are used as the main reference source. Updates of these descriptions to 2004, emphasise significant changes which have taken place, especially where these have influenced the extent or intensity of the potential impacts.

The statement on the national and regional context which follows has changed little since 1998. The information is taken largely from the PEA study updated from the 2001 census.

1.3 National and regional overview

Oranjemund is an isolated "private" and closed mining town situated in the south-western corner of Namibia at the mouth of the Orange River. The nearest towns are the diamond mining settlement of Alexander Bay on the South African side of the Orange River and Rosh Pinah, some 75km to the north-east. Rosh Pinah is a settlement serving two mines. Oranjemund falls within Mining Area No 1 which extends along the coast in a roughly 3km band from the Orange River mouth to Chaemaeis Bay south of Lüderitz. According to the 2001 Housing and Population Census, Oranjemund is the 22nd largest town in Namibia with a population of 4451.

Namibia is a sparsely populated country with an average population density in 2001 of roughly 1,8 persons per square kilometer. Although not regarded as a poor country by Africa standards, it displays a very high level of income disparity both geographically and culturally.

Oranjemund falls within the Karas Region, with the regional government located in Keetmanshoop. Karas is Namibia's most sparsely populated region, with a 2001 population of 69 329 at a density of 0,4 persons per square kilometer (CBS, 2003, P8). Settlement is largely

confined to widely scattered small towns. The harsh climate limits agricultural potential, so that mining is the region's biggest employer. Wages and salaries account for 69% of household income and much of this accrues to male migrant workers whose families remain in their places of origin, mainly in the north of Namibia (CBS, 2003, P8).

Informal settlement around the main urban centres is a feature of settlement in the Karas Region. In 2001, 29% of the potential labour force was unemployed and many of these have settled themselves as squatters in the hope of securing jobs (CBS, 2003, P8). Because it is a closed security town, no informal settlement has been allowed to develop around Oranjemund. However, the 6000 to 8000 people who inhabit the "Sand Hotel" informal settlement around Rosh Pinah are an indication of what could happen to the town if it were to be proclaimed and opened to the public.

2. POPULATION EMPLOYMENT AND SOCIAL SERVICES

2.1 Objectives

The most significant social impacts of the new development will be in respect of the existing population living and working in Oranjemund and Alexander Bay. This concerns not only potential job creation, but also the impact of new immigrants on social and recreational services and facilities, especially health, education, schools, public institutions, civic institutions, recreation facilities and sports fields.

2.2 Description of the receiving environment

2.2.1 Population

According to the 2001 Population and Household Census (Basic Analysis and Highlights), the official population of Oranjemund in 2001 was 4451, of which 2479 were males and 1972 were females. This compares to the official 1991 population of 6343, of which 4539 were males and 1804 were females. This indicates that the population living in Oranjemund declined by 30% between 1991 and 2001. At the same time, the ratio of male to female population changed from 2,5:1 to a more even 1,3:1.

The above official "census" figures do not correspond with the Namdeb Human Resources Department (HRD) who estimate that Oranjemund services a population of 10 000, of which only some 750 single men live in bachelor accommodation outside the town boundaries, within the mining area (Rentel, 2004).

The difference between the census count and HRD estimate is difficult to reconcile. On the one hand, it is acknowledged that the census may reflect an undercount due to a presence of "illegal" residents, whilst the HRD may not have updated its estimates recently.

For planning purposes, the population serviced by the town of Oranjemund should be estimated at between 6000 and 9000, of which at least 60% will be males.

2.2.2 Employment

It is estimated that the total number of people employed in the mining operations in and around Oranjemund is approximately 3000 (Rentel, 2004). This is a decline of some 25% since 1998 and is in line with strategy being implemented to reduce on-shore operations. This trend will continue, and it is stated that a further 50% reduction in the labour force will take place over the next 5 years (Rukamba, 2004).

Currently some 750 employees are resident in hostel accommodation at Uubvlei near mining operations 25 kilometres north of the town (see Diagram 1). This accommodation establishment has three main components; the main hostel, the first hostel annex and the second hostel annex. The old single quarters barracks are located nearby, but these are dilapidated and no longer occupied.

The overall capacity of the hostel is 1466 people. As stated above, however, the facility is currently only partially occupied. As land based mining has been reduced, hostel and single quarters employees have been gradually relocated to Oranjemund. Within 5 years, it is intended that all employees will live in Oranjemund and by 2009 the number of persons employed by Namdeb will be reduced to approximately 1500 and these will all be resident at Oranjemund.

The majority of the workforce is Namibian. Those who are employed from outside the country comprise skilled manpower not available in Namibia in the technical, professional and management fields.

All employees who are classified as unskilled labourers enjoy a wage rate which is three to four times higher than that of most other workers in Namibia in similar occupations. The impact of these workers on the local town economy is therefore significant.

2.2.3 Education and Skills

The majority of the workforce is unskilled and illiterate. For this reason, Namdeb initiated trade upgrading skills programmes in the early and mid – 1990's as well as courses in basic adult education. These continue up to the present time and a number of bursaries to study at universities and technikons have been awarded since 1995.

At the artisan and management level a policy of Namibianising resulted during the 1990's in the replacement of more experienced staff with newly qualified Namibians.

Excellent schooling facilities are available in town for primary and pre-primary education (see section 2.2.5). High schooling is only available at Alexander Bay or at boarding schools in Namibia and South Africa.

2.2.4 Health and Welfare

As is the case with the rest of Namibia, prevalence of HIV/AIDS among the workforce is high and constitutes the single highest risk in Oranjemund. Namdeb estimated in 1998 that 4.5% of their staff were HIV positive (Walmsley, Vol.1, P95).

With the initial intention of addressing the HIV/AIDS problem, Namdeb assisted in implementing the Oranjemund Health Education Programme (OHEP) which aims to educate the community in the prevention of AIDS, but also includes campaigns which target all common health problems – including sexually transmitted diseases, stress, drug addiction, alcohol abuse and marital / family problems.

All medical services for the mine and Oranjemund are provided by the Chief Medical Officer based at the town's hospital (see section 2.2.5). The clinical medical services provided include physiotherapy, dental, x-ray, laboratory, paramedical services, social therapy, occupational health and preventative health. Namdeb also provides a district surgeon.

Namdeb delivers social services to the community in the form of individual casework, family counselling and community development projects. Community health, family planning, baby and immunisation clinics are available once per week. Alcohol abuse is one of the main problems experienced by Namdeb employees and thus a branch of Alcoholics Anonymous has been established in the town.

2.2.5 Social Services and Facilities

The town of Oranjemund offers social services and facilities at a level usually only found in much bigger towns. These include health facilities, schools, a technical college, a crèche, a public library, parks, recreation facilities and sports fields.

Since 1982 a number of civic and commercial services have been outsourced or privatised. These include a pharmacy and optometrist, a dairy and piggery, a travel agency, bakery, butchery, shops, bars, restaurants and industrial enterprises.

A post office was established and many recreation clubs operate independently of Namdeb. Although Oranjemund remains a "closed" town, it nevertheless has developed a viable commercial service and industrial sector.

The main social and service facilities are as follows:

Hospital

Medical services for the mine and Oranjemund are provided in a 73-bed hospital situated in the town and administered by the Medical and Dental Department of Namdeb. It employs more than 80 members of staff. Specialist medical personnel include doctors, dental officers, registered nurses, a public health officer, physiotherapists and a pharmacist. The mine provides regular medical flights to Cape Town and Windhoek to facilitate consultation to either destination as the situation requires.

Schools

Oranjemund Private School has an enrolment of approximately 800 pupils at the primary section and 120 at the pre-primary section. There are some 60 teachers employed at the school. Although it receives a subsidy from the Namibian Government, the school is funded primarily by Namdeb and the parents.

The school has a policy of employing well qualified teachers and this, together with the favourable pupil/teacher ratio of 1:15, has set the school with an excellent reputation for academic achievement.

No high school is available in Oranjemund and pupils either make use of the facilities at Alexander Bay or must enrol in a boarding school elsewhere in Namibia or in South Africa.

Recreation Facilities

There are more than 30 social and recreation clubs in Oranjemund, including horse riding, yachting, golf, soccer, tennis, youth clubs and gymnasiums. Namdeb equips and maintains all clubs and children's' playgrounds. Staff work with parents to co-ordinate youth activities.

A number of social services and facilities also exist at the Uubvlei hostel and single quarters. These include full kitchen and dining facilities, a shop and informal market. Recreation facilities include game rooms, TV rooms, a beer garden and a somewhat neglected sports field. A community hall for approximately 600 people is relatively new. Other community facilities are a church, laundry and a postal agency.

2.2.6 Safety and Security

Oranjemund has always rated itself as a highly safe and secure town for its residents with an exceptionally low crime rate. This is partly due to the isolated nature of the town and its small size, but mostly because of the security measures which are implemented around the diamond industry. However, local residents and business operators report a recent increase in the crime rate which they attribute to the out sourcing of certain Namdeb functions and the operation of private business in town. This slight "opening" of the town has facilitated the influx of unemployed people who are blamed for the increase in crime.

2.3 Characteristics of the imposing environment

2.3.1 During Construction

The Uubvlei site is located 25 kilometers north of Oranjemund. Access for construction workers, plant and equipment will be through the urban area, so that the town will most certainly "feel" the construction activity.

The construction will take place over a 3 year period starting in 2006 according to the current schedule. The construction work force will vary from 600 to 1300 during various construction phases. This may constitute 20% or more of the combined population of Oranjemund at times.

The construction workforce will be housed in a dedicated construction camp close to the plant. It will comprise mainly single male unskilled labourers and semi-skilled artisans. The administrative functions and certain support facilities (eg mess hall, clinic, basic needs shops etc) for construction activity will need to be located at the construction camp.

Should the second phase of the plant be commissioned, then the construction period could be extended to five or six years. This is probable.

Once construction is completed, the construction camp will be demolished and the construction workers will be repatriated to their place of origin.

2.3.2 *During Operation*

Once the plant is operational, a permanent force of 50 – 60 largely skilled workers will be employed. This number will be supplemented by maintenance personnel during periods of routine maintenance. Operators will work in shifts and will have to be multi-skilled and be able to undertake basic maintenance. Most workers will be operators and technicians, with a few managers. It is probable that these employees will live in Oranjemund itself.

The estimated life of the plant is more than 20 years. However, this could be increased if the second phase is commissioned.

2.3.3 *Decommissioning*

Once the gas reserves have been exhausted (assuming new sources are not discovered), the power station would be decommissioned, the plant demolished and the site rehabilitated.

2.4 *Community concerns*

Three public meetings were held during the 1998 Preliminary Environmental Assessment (PEA) at Windhoek, Oranjemund and Alexander Bay. In respect of this Environmental Impact Assessment (EIA), four meetings were held in Windhoek, Oranjemund, Alexander Bay and Rosh Pinah in June 2004. An additional meeting was held at Oranjemund in March 2005 specifically to discuss the proposed location of the CCGT station at Uubvlei. The issues raised at these meetings, related to population, employment and social services issues are summarised in the table below.

CONSTRUCTION PHASE		OPERATION PHASE		DECOMMISSIONING
PEA 1998	EIA 2004	PEA 1998	EIA 2004	
Increase in crime				
Integration of old and new residents		Integration of old and new residents		
Stress on community facilities & services	Stress on community facilities & services			
Employment opportunities	Employment opportunities		Employment retrenchment	
Stress on recreation facilities		Stress on recreation facilities		Employment retrenchment
Uncontrolled population growth		Uncontrolled population growth		
	Urban Management			

	Health – esp HIV		Health – esp occupational risk	Urban Management
	Increased squatting at Rosh Pinah			
	Gembok poaching			

The most common concern expressed is the impact of the additional 600 to 1300 workers during the three years of the construction phase. There are fears about an increase in crime, about stress on community services and facilities (especially HIV health aspects) and on the recreation facilities of the town. These concerns relate to the challenge of integrating the temporary workers who may, at times, constitute a quarter of the population. Interestingly, the community meeting of March 2005 felt that the medical fraternity in Oranjemund would welcome the additional “work” which may be created by the Kudu project.

Another concern during the construction phase is the potential growth of squatter settlements on the town’s periphery by job speculators and retrenched workers. This is seen as the biggest challenge to urban management. It is a danger which will exist throughout the construction period, but will persist even after the plant is complete. If sufficient controls are exercised to prevent such squatting, there are fears from the Rosh Pinah community that speculative settlement will augment the already extensive “sand hotel” squatter area.

Social issues raised during the operation and decommissioning phase were less of a concern since less than 100 operations staff is involved. The main concerns were related to the impact of retrenched workers at the end of operations and the potential for health risks to workers and residents due to hazardous bi-products from the plant. The urban population would need assurances in this regard.

2.5 Identification of social impacts

Some of the issues raised in this section have economic or urban management impacts and these are dealt with in section 4 of this report. These relate particularly to the possible development of squatter settlements at Oranjemund and Rosh Pinah and to the economic impacts of retrenchments during and at the end of the construction and operation phase.

A total of eight social impacts are identified and are discussed below: -

2.5.1 Stress on Health Systems

Nature of Impact

The influx of between 600 and 1300 temporary workers during construction will place stress on the existing health care systems of the town which are currently designed to cater for Namdeb employees and their families only.

Extent of Impact

Since these new workers will live within 25 kilometers of Oranjemund and since it is unlikely that any extensive health facilities will be provided at Uubvlei, the stress will impact on the town itself. Other regional facilities and nearby towns will not be affected.

Duration of the Impact

The greatest impact will take place over the three years of the construction period. The impact of the 50 to 60 permanent employees during the operations period will continue for 20 to 40 years, depending on the life of the gas field and whether or not the second plant is commissioned.

Intensity

The most intense impact will take place during the 3 years of the construction period. If it is assumed that a new temporary clinic could be developed at the construction camp for minor and routine health matters, the town's hospital will have to deal with all serious medical problems experienced by the construction workforce.

Since this temporary workforce could constitute as much as 20% of the permanent population of the town, the impact could be significant. The incidence of HIV/AIDS in Oranjemund is already one of its most serious health problems and this will most certainly be exacerbated by the arrival of 600 – 1300 mostly male labourers. The intensity will be medium during the construction period, but low during operation.

Probability

It is a distinct possibility that an impact on the town's existing health services will take place during the construction period.

Cumulative Effects

It has been stated by Namdeb that it plans to decrease its workforce significantly over the next 5 years as it moves its mining emphasis from on- to off-shore. Should this take place, then the extra capacity in the health system so created will reduce the intensity, probability and significance of the impact.

Summary of Impact characteristics

IMPACT: STRESS ON HEALTH SYSTEMS					
CHARACTERISTICS		CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE	
Duration		short term	long term		
Intensity		medium	low	low	
Probability		probable	improbable	improbable	
Status		negative	negative	neutral	
Degree of Confidence		medium	medium	medium	
Significance	Before mit	medium / low	low	low	
	After mit	low	low	low	

Recommended Mitigation Objectives

- (i) A new temporary clinic should be developed in the construction camp in order to reduce the impact on the local hospital for minor and routine health matters;
- (ii) If Namdeb significantly reduces its workforce over the next 5 years, it may also plan to reduce resources allocated to the health system. It is essential that negotiations take place between Namdeb and NamPower to ensure that existing resources of the health system are maintained at least until the end of the construction period.

It is especially important that awareness programmes and all services and facilities related to counselling and treatment of HIV/AIDS patients are maintained during the construction period.

- (iii) A financial arrangement for the use of Namdeb health facilities by NamPower workers will have to be negotiated prior to the arrival of construction workers.

2.5.2 *Impact on Occupational Health*

Nature of Impact

It is a concern that the process of constructing the plant and of converting gas into power at Uubvlei may produce bi-products (dust and pollutants) which could be harmful to the health of the construction workers and the 50 to 60 employees who will work at the plant during the operational phase.r.

Extent of Impact

The extent of this impact would exclude the settlements of both Oranjemund and Alexander Bay.

Duration of Impact

During windy days, dust will be generated from building activity during the three years of the construction period. Should there be any health hazards during the operation of the plant (see elsewhere in this study), this will be a factor during the life of the plant.

Intensity

Due to the distance of the plant from Oranjemund and the prevailing wind, there is unlikely to be a disruptive impact on the town during the construction period. It is anticipated that little or no noxious emissions will occur during operation of the plant and that this aspect would therefore be innocuous with low intensity.

Probability

The proposed location of the plant (at Uubvlei) is 25 kilometers down-wind of Oranjemund. Under these circumstances there is a very low possibility that dust will be blown towards the town during construction and that this could constitute a health risk. The equivalent likelihood for Alexander Bay is even lower. It is improbable that emissions from the plant during its operation will constitute a health hazard. The technology for this type of plant has been tested and improved over many years of operation and the risks are well documented and generally regarded as low.

Cumulative Effects

The procedures for on-shore diamond mining by Namdeb also generates dust. However, Namdeb is in the process of scaling down its land based operations and has, to a large extent, already mined out the areas reasonably close to the town. For this reason, cumulative effects are not foreseen.

Summary of Impact Characteristics

IMPACT: STRESS ON OCCUPATIONAL HEALTH			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term	long term	short term (1 year)
Intensity	low	low	low
Probability	improbable	improbable	improbable
Status	negative	negative	neutral
Degree of Confidence	high	medium	medium
Significance	Before mit	low	low
	After mit	low	low

Recommended Mitigation Objectives

Assuming no harmful bi-products will be generated through the operation of the plant, then it will be necessary to implement an information campaign to reassure employees and residents that dangers do not exist.

2.5.3 Stress on Education, Social and Recreation Facilities

Nature of Impact

The influx of between 600 and 1300 temporary workers during the construction phase may place stress on the existing education, social and recreation facilities of the town which are currently designed to cater for Namdeb employees and their families only.

Extent of Impact

The extent of this impact will be limited to the town and its immediate environs. Other regional facilities and nearby towns will not be affected.

Duration of Impact

The most significant impact will take place over the three years of the construction period. The impact of permanent employees during the operations period will continue for 20 or more years depending on the life of the plant.

Intensity

The most intensive impact will take place during the construction period although this is expected to be relatively low, especially if essential social and recreational facilities are

provided at the construction camp. Since most of the temporary work force will be single men, school education for additional children will be a minor factor. However, there is no doubt that, unless barred from doing so, the workforce will make use of shops, banks, commercial facilities and certain recreation facilities not provided at the construction camp. However, since the construction camp will be located some 25 kilometers from the town, the workers will be dependent on local or organised transport to make journeys to town and this will correspond with leave or time-off. This may cause stress in certain areas but will also bring economic benefit in others. Overall, the impact will be manageable provided that a policy is agreed and managed between Namdeb and NamPower on the use of existing facilities. In this case the intensity will be low, even during the construction period.

Probability

There is a low likelihood that medium or high impact on the town's education, social and recreation facilities will occur at any period during the project.

Cumulative Effects

It has been stated by Namdeb that it plans to reduce its workforce significantly over the next 5 years as it moves its mining operation off-shore. Should this occur, then extra capacity in the education, social and recreation facilities will further reduce the intensity, probability and significance of the impact.

Summary of Impact Characteristics

IMPACT: STRESS ON EDUCATION, SOCIAL AND RECREATION FACILITIES			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term	long term	short term (1 year)
Intensity	low	low	low
Probability	improbable	improbable	improbable
Status	negative	negative	neutral
Degree of Confidence	medium	medium	medium
Significance	Before mit	low	low
	After mit	low	nil

Recommended Mitigation Objectives

- (i) Temporary commercial, service, social and recreational facilities should be provided at the construction camp to meet the most common needs of the workforce. These would include general shops, mess facilities, food outlets, bars and simple recreation facilities such as pool tables, volleyball courts, soccer field, etc.
- (ii) A financial and access arrangement for the use of Namdeb's specialist community and recreation facilities (eg library, parks, adult education, tennis courts, golf course, etc) should be concluded between NamPower and Namdeb and/or the managing clubs. This should be concluded before the arrival of workers and should be clearly publicised to all stakeholders.
- (iii) Access into Oranjemund by the workforce must be facilitated in order for them to use the commercial facilities and designated social and recreation facilities. It is not suggested that formal access controls be instituted, unless issues of safety and security (see paragraph 2.4.4) become serious. Provided that the most common needs are provided within the construction camp, this situation should be manageable.
- (iv) It would make sense to establish the construction camp within unoccupied portions of the existing Uubvlei hostel and single quarters. Apart from the economic benefit of utilising existing structures, the existing social and recreation facilities could be utilised, shared or enhanced depending on agreements to be reached between Nampower and Namdep.
- (v) The plant and construction camp are most likely to be established in a cordoned-off camp within the Mining Area. A corridor should be established between the camp and the town to facilitate free movement by vehicles. Alternatively, a system of supervised public transport should be created to give regular access to construction workers needing to make use of Oranjemund services.

2.5.4 *Stress due to increased Crime and Alcohol related Violence*

Nature of Impact

There is currently a very low level of theft and violent crime in Oranjemund. The influx of between 600 and 1300 low-income temporary workers during the construction period with free access to the town may result in increased levels of poverty induced crime. Alcohol abuse is already recognised problem amongst Namdeb employees and the influx of large numbers of single male employees could make this problem more extensive.

Extent Impact

The extent of this impact will be limited to the town and its immediate environs. Alexander Bay will be protected to a large extent by border controls, but illegal crossing of the river is possible.

Duration of Impact

This impact will only be an issue during the three year construction period.

Intensity

Due to the distance from Oranjemund of the proposed construction camp, the intensity of this impact is likely to be low. Provided that informal settlements are prevented from establishing at the town's periphery, then crime events resulting from severe poverty due to unemployment should not be significant. Alcohol abuse will most certainly take place and this can be expected to be problematic. Overall, the intensity of the safety and security impact should be regarded as low.

Probability

It is a distinct possibility that there will be an increase in alcohol abuse and associated violence. The impact of poverty related crime is less certain and its probability could therefore be seen as low.

Cumulative Effects

The advent of alcohol abuse will not be a new phenomena for the town. In this sense, the new workforce will serve to make an existing situation worse.

Summary of Impact Characteristics

IMPACT: STRESS DUE TO INCREASED CRIME AND ALCOHOL RELATED VIOLENCE			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term	long term	
Intensity	low	low	low
Probability	probable	improbable	improbable
Status	negative	negative	neutral
Degree of Confidence	medium	medium	medium
Significance	Before mit	medium / low	low
	After mit	low	low

Recommended Mitigation Objectives

- (i) It has already been recommended that temporary health, commercial, service, social and recreational facilities should be erected at the construction camp to meet the most common needs of the workforce. Apart from alleviating potential stress on the corresponding facilities in Oranjemund, this would also serve to minimise the number of visits to Oranjemund undertaken from the camp residents and therefore the opportunities for the perpetration of acts of crime.
- (ii) Should it be decided (as recommended) that the construction camp be located within a part or the whole of existing Uubvlei hostel and single quarters, then the developers should ensure that the facility is renovated to a higher standard. The facility is regarded by Namdeb workers as run-down and it would be socially unacceptable for the new workers to be housed in these facilities without a significant upgrade taking place. It is suggested that **all** accommodation be converted to single or double rooms.

- (iii) It is not suggested that a system of curfew or entrance control to Oranjemund is instituted unless a security problem becomes significant. The NAMPOL Station Commander in Oranjemund (W O de Jay) suggested that, provided contractors are properly screened to exclude known criminals, the increase in crime should not be significant. Existing law enforcement and residents need to be aware of the need for vigilance during the three year construction period.
- (iv) Existing facilities and services related to alcoholism and alcohol abuse should be augmented during the three year construction period. This should be discussed between Namdeb and NamPower and a financial contribution made if necessary.

2.5.5 Employment opportunity for Retrenched Namdeb workers

Nature of Impact

Namdeb have indicated that they are likely to scale down the current workforce by 50% over the next 5 years as mining changes from land- to sea-based operation. With construction of the plant due to commence in 2006, this may present an opportunity for retrenched Namdeb employees who fit required profiles to gain new employment in Oranjemund. This would be a social rather than an economic benefit to the individual and the community. Because of the sensitive nature of retrenchment, Namdeb is not in a position to discuss the possible breakdown of retrenchment workers and it is therefore impossible, at this stage, to evaluate this potential in any more detail (B Rukamba, 2004).

Extent of Impact

It is not possible that all retrenched employees could benefit from this opportunity. Much depends on the timing between retrenchments on the one hand and construction requirements on the other. Matching skills are also important and this is more likely to happen at the worker rather than artisan or manager level.

Duration of Impact

The opportunity will only present itself over the three year period of construction and at the beginning of the operation period.

Intensity

The intensity will be low to medium during the construction period and low during the operation period. The proportion of retrenched Namdeb workers who can be re-employed by NamPower will not be high given the problems of timing and skills matching.

Probability

The probability is low to medium and the impact is not likely to significantly influence the project design.

Cumulative Effects

The more Namdeb employees are employed in the construction of the plant, the less outside employees will be introduced into the system. This will serve to lessen some of the negative social impacts already identified, especially concerning safety and security.

Summary of Impact Characteristics

IMPACT: EMPLOYMENT OPPORTUNITY FOR RETRENCHED NAMDEB WORKERS			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term	long term	short term (1 year)
Intensity	Medium / low	low	low
Probability	probable	improbable	improbable
Status	positive	positive	neutral
Degree of Confidence	medium	medium	medium
Significance	Before mit	low	low
	After mit	low	low

Recommended Mitigation Objectives

In order to maximise the positive potential of this impact, Namdeb and NamPower should hold discussions aimed at co-ordinating their respective retrenchment and employment activities. This should be done well ahead of target dates so as to minimise disruption to all parties. Profiles of employees to be retrenched should be made available for evaluation by NamPower.

2.6 Summary of social impacts

2.6.1 Construction Period (3 years)

Practically all of the social impacts identified are significant only during the three year construction period.

Of the five social impacts identified, none fall into the category of high significance and / or high intensity. Only one is considered to have medium intensity. This means that it could have sufficient influence on the environment to affect project design or require alternative mitigation. This is:

- Stress on existing health systems (negative impact)

The remaining four social impacts are rated as having either a medium-low intensity or a low significance. This means that the impact will not have an influence on the project design. Helpful mitigations may be implemented but are not essential. These are:

- Impact on occupational health (negative impact)
- Stress due to increased crime and alcohol related violence (negative impact)
- Stress on education, social and recreation facilities (negative impact)
- Employment opportunities for retrenched Namdeb workers (positive impact)

2.6.2 Operational Period (20 – 40 years) and Decommissioning (1 year)

All five of the social impacts identified are rated as having either a low intensity or low significance.

3. INFRASTRUCTURE AND URBAN SERVICES

3.1 Relevance

The construction and operation of the plant will need infrastructural services such as water, sewage disposal, electricity, waste disposal, telecommunications, roads etc. Temporary and permanent workers will need housing. Such services can either be provided by linking in to existing town and mine infrastructure, or they will have to be provided anew. Either way, this will have impacts which need to be evaluated.

3.2 Description of the receiving environment

3.2.1 Housing and Accommodation

Namdeb's Allied Services Manager states that there are approximately 1200 family houses and 2000 single units which have been built for Namdeb employees. Approximately 750 of the single units are located outside the town at the hostel adjacent to Uubvlei (Rentel, 2004). As stated elsewhere, the accommodation at Uubvlei comprises a new dilapidated and disused single quarters and a newer hostel which can accommodate a maximum of 1476 people in three components as follows: -

- (a) The main hostel accommodates a maximum of 776 people housed in 4 blocks of 34 double rooms each (272 people), 3 blocks of 24 double rooms each (144 people) and 5 blocks each with 7 dormitories, each sleeping ten persons (250 people). Other related facilities include the kitchen and dining hall, a shop and informal market, a small postal agency, laundry, recreation hall and beer garden;
- (b) A first hostel annex accommodates a maximum of 372 people housed in 6 blocks each with 24 double and 8 single rooms and in 2 blocks each with 12 double and 4 single rooms. Other related facilities include a games room, two TV rooms and a community hall for approximately 600 people; and
- (c) A second hostel annex accommodates a maximum of 328 people in 4 blocks of double and single rooms with 82 people per block. Additional facilities include kitchens, TV room, pool room and a church.

The layout of the existing hostel and single quarters is shown in Diagram 2.

In preparation for off-shore mining operations, Namdeb has commenced with the construction of single quarter accommodation at Oranjemund for approximately 450 employees. Ultimately, all Namdeb accommodation will be in town and it is intended that the Uubvlei accommodation be demolished.

The new single quarters in Oranjemund will be constructed adjacent to an existing “contractors camp” which accommodates approximately 300 workers employed privately by firms operating in and around Oranjemund mainly in construction and maintenance. This area is adjacent to the town’s western gateway to be mining area.

3.2.2 Communications Infrastructure

By road, Oranjemund is accessible from three different directions

- from the east via the gravel road along the north bank of the Orange River from Rosh Pinah,
- from the south via a security gravel road from the Lüderitz-Aus road; and
- from South Africa via the Ernst Oppenheimer bridge seven kilometers south-east of Oranjemund.

The southern security road runs through the Sperrgebiet and is planned to be the route used to transport the main gas plant components from Lüderitz. The road from Aus via Rosh Pinah is to be upgraded and tarred. The section between Aus and Rosh Pinah is currently under construction.

There is an airport at both Oranjemund and Alexander Bay. Oranjemund has an automatic telephone exchange and full cellphone reception. The surface rights over most of the area are state owned.

3.2.3 Urban Infrastructure Services

(Review undertaken by Team’s Civil Engineer)

Two reservoirs at Swartkops with a capacity of 2000 m³ in total. There are 4 reservoirs in town with a storage capacity of 2500 m³ each with booster pumps at the town reservoirs with standby generator supply. The water pressure is about 5 bars in the system. See figure below.

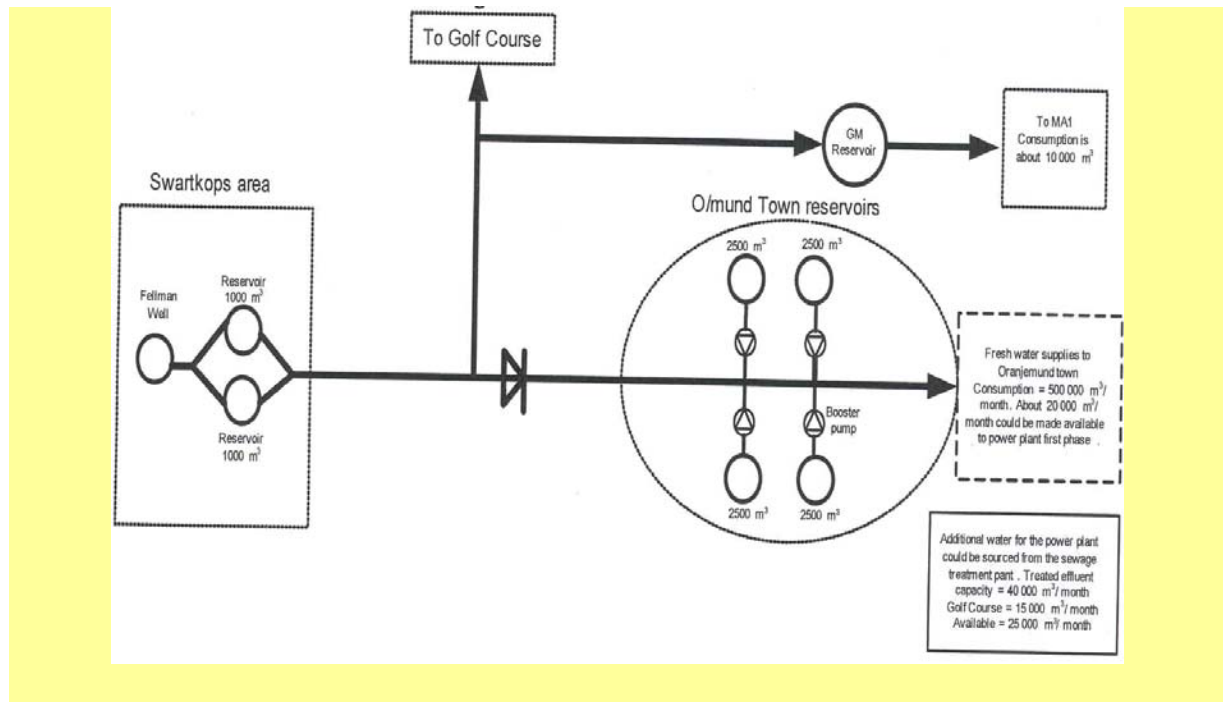


Figure 1

Irrigation water to parks and sports fields is a mixture of portable water and a separate system of semi-purified effluent from the sewage ponds.

Sewage Disposal

The town operates on a fully water borne system which is pumped to a single treatment site located south-west of the town

3.3 Characteristics of the imposing environment

3.3.1 During Construction

The construction workforce will be housed in a dedicated construction camp close to the plant. Consideration had been given in the PEA and during public consultation to locating the camp within the town boundary, but this option is rejected for the following reasons.

- the Plant is to be located some 25 kilometers to the south-west of the town and this would require significant daily commuting by workers;
- a suitable area in town near the western gate has, in the meantime been utilised by Namdeb as a local contractors camp. Furthermore, Namdeb are in the process of constructing new single quarters for their employees previously housed in the security area near mining operations;
- existing sewage infrastructure in the town will not cope with an additional 600 to 1300 people; and

- existing residents are concerned about possible negative social impacts on the town, especially related to safety and security and to possible overload on social and recreation facilities. They are more comfortable with the construction camp located at the plant.

The camp will comprise mainly single-quarters for the workforce, support facilities as well as offices and workshops. The population in the camp will range between 600 and 1300, depending on works being implemented.

The construction of the plant is planned to take 3 years, but this could be extended to 5 to 6 years if the second phase is commissioned. At the conclusion of construction works, the construction camp will be demolished and the area rehabilitated.

As already noted, Namdeb is in the process of relocating its existing 750 field workers from the Uubvlei hostel. It will make a lot of sense to utilise this facility for the construction camp. The current capacity is approximately 1466, of which a significant portion is already vacant.

3.3.2 During Operation

Once the plant is operational, a permanent force of 50 - 60 mainly skilled workers will be employed. It has already been agreed that they will be accommodated in Oranjemund in family houses to be constructed at a site already earmarked in the western sector of town.

3.3.3 Decommissioning

Upon decommissioning, the plant will be demolished and the site rehabilitated.

3.4 Community concerns

Only two concerns were raised at public meetings held in 1998 and 2004 which directly related to infrastructure and urban services. These were

- The creation of a housing shortage due to the influx of new urban residents; and
- The impact of increased traffic on road safety.

Both of these concerns related to the construction phase of the project only.

During the March 2005 public meeting, concerns were raised about the possible use of the Uubvlei hostel and single quarters as accommodation for the plant construction workers. The standard of these facilities have fallen into decline in recent years and are no longer considered fit for extended worker habitation. Nampower would have to ensure that these facilities are improved and upgraded to make them suitable for occupation for a further 3 to 6 years.

3.5 Identification of impacts on infrastructure and urban services

Three urban infrastructure impacts are identified. These are all linked to the construction phase of the project only and concern the impact of the 600 – 1300 temporary workers on the town's

housing and its sewage disposal system, and also concern the impact of additional traffic moving through the town.

3.5.1 Increased Urban Road Traffic

Nature of Impact

During the three year construction period there will be a significant increase in heavy and light vehicular traffic passing through Oranjemund on the way to and from the construction site. This could lead to traffic safety problems to resident vehicles and pedestrians.

Extent of the Impact

The main impact will be on the town of Oranjemund and the roads leading in and out, including the passage and border control facilities related to the Ernst Oppenheimer Bridge. A 10 kilometer impact radius is envisaged.

Duration of Impact

Very little increased traffic will be detected during the operational period. Most traffic disturbance will be from construction related traffic in the first 3 years.

Intensity

The most disruptive impact is likely to come from large delivery and construction vehicles moving through the town. There is also likely to be an increase in bus and taxi transport, especially over weekends and at the beginning and end of construction phases. Intensity is assessed to be medium – the streets will continue to function but they will be more busy.

Probability

There is a distinct possibility that the street flows, particularly the main streets, will be affected.

Cumulative Effects

None are foreseen.

Summary of Impact Characteristics

IMPACT: INCREASED URBAN ROAD TRAFFIC			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term	n/a	n/a
Intensity	medium	n/a	n/a
Probability	probable	n/a	n/a
Status	negative	n/a	n/a
Degree of Confidence	medium	n/a	n/a
Significance	Before mit	medium	n/a
	After mit	low	n/a

Recommended Mitigation Objectives

- (i) (All town through traffic, especially heavy delivery and construction vehicles, should be directed to the most southerly through route which runs along the northern extent of the town's industrial zone between the eastern and western gates to the town.
- (ii) Traffic calming measures, including speed bumps and speed limits should be imposed along strategic routes. There could be an increase in presence of traffic control personnel.
- (iii) Negotiations should take place between Namdeb and NamPower with a view to implementing traffic calming measures and also for improving long- and short-haul taxi and bus facilities.

3.5.2 Impact on Namdep's Housing Stock

Nature of Impact

Since it is intended to operate a separate contractor camp to house (probably at the Uubvlei hostel) the 600 – 1300 employees during the construction period, this will have no impact on the existing housing stock in Oranjemund. Should it be agreed with Namdeb utilise the whole or a portion of the Uubvlei hostel for the construction camp, then this will have a significant impact on Namdeb's relocation programme. Either they will have to accelerate the relocation programme to move all workers to Oranjemund within a year, or arrangements will have to be made to separate the existing hostel facilities so they can be shared between Namdeb and Nampower construction workers. The potential exists to create a close quarters conflict between mine and construction workers which may create security and management problems. During the operational period, however, the project intends to provide housing for 50 - 60 permanent employees within the town. This could

result in a 5% increase in the housing stock. Upon decommissioning of the plant, the houses may become redundant.

Extent of the Impact

The impact will affect the town of Oranjemund. It will also impact on the existing hostel at Uubvlei, depending on final agreements between Namdeb and Nampower regarding the use and development of these facilities.

Duration of Impact

The impact on Uubvlei would only apply during the construction phase. The impact on the town will take effect for the duration of the operational period – 20 to 40 years depending on the life of the gas field. In practical terms, however, the impact will no longer be felt a few years after the housing is constructed. An impact will again be felt upon closure and decommissioning when the houses become superfluous to needs.

Intensity

The impact during the construction phase will be medium to low depending on how the hostel facilities are deployed. The impact during the operational phase will be relatively innocuous with low intensity. It is unlikely that the construction of new houses will affect the functional environment of the town.

Probability

It is improbable (low likelihood) that the additional houses will impact the efficient operation of the town. It is probable, however, that the use of the Uubvlei hostel for construction workers will impact on Namdeb's worker housing programme.

Cumulative Effects

It is stated by Namdeb that it is likely to reduce its current workforce by 50% over the next 5 years. This being the case, it is possible that, by the year 2009 when operations commence, that sufficient Namdeb houses will become vacant as a result of retrenchments and that it will not be necessary to construct new houses at all. It is also unlikely that Namdeb will need the housing at Uubvlei for more than another year or so.

Summary of Impact Characteristics

IMPACT: IMPACT TO NAMDEB'S HOUSING STOCK			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	short term (3 yrs)	long term	short (1 year)
Intensity	medium / low	low	medium
Probability	probable	improbable	probable
Status	negative	negative	neutral
Degree of Confidence	medium	medium	low
Significance	before mit	medium	low

	After mit	low	low	low
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Recommended Mitigation Objectives

- (i) The occupational status of Namdeb's housing stock should be carefully monitored prior to commitment by NamPower to the construction of new housing for its operational employees. Should major vacancies be present, then a lease or sale agreement should be negotiated before resources are allocated to construct new houses in Oranjemund.
- (ii) If new housing is indeed built for operational employees, the design and construction of the houses should be sensitive to the 20 – 40 year lifespan of the project. With Namdeb also scaling down its operations, it is unlikely that the houses would be needed for other purpose after decommissioning of the plant.
- (iii) As stated elsewhere, it makes practical economic sense to utilise the Uubvlei hostel as the core for the construction workers camp. However, the difficulty in sharing such a facility may make this approach difficult. It is recommended that either :
 - Namdeb abandon the hostel and accelerate its programme to construct housing in Oranjemund for its remaining workers ahead of schedule; or
 - A new construction camp is developed on a suitable site separate from the hostel but adjacent to the plant.

The first of these options is preferred since it totally eliminates the potential problems of conflict between Namdeb and Nampower workers.

3.5.3 Impact on the Town's Reticulated Services

(Review to be undertaken by Team's Civil Engineers)

Nature of Impact

Although the existing sewage disposal system could cope with the additional dwellings in town anticipated during the operational period, there is no way it could accommodate the sewage from the 600 – 1300 construction workforce. It is therefore necessary that a separate sewage disposal and purification system be created for the construction camp.

Extent of the Impact

The impact of the new sewage disposal works will be local and limited to a 5km radius south and south-west of the town.

Duration of Impact

The impact duration will be short and limited to the 3 year life of the construction camp. However, assuming the new works are linked to the existing system, then the new infrastructure will become a permanent upgrade which can cater for the growth of the town well into the long-term future.

Intensity

If the works were to be totally independent, they could have a “medium” environmental intensity which could impact on the riverine or marine environment. If it is linked with the existing system, however, the impact could be lowered.

Probability

It is probable (reasonably likely) that the construction of a new sewage disposal works for the construction camp would have an impact on the natural environment if not properly mitigated.

Cumulative Effects

None foreseen.

Summary of Impact Characteristics

IMPACT: IMPACT ON THE TOWN'S RETICULATED SERVICES				
CHARACTERISTICS		CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration		short term (3 yrs)	long term	
Intensity		medium / low	low	low
Probability		improbable	improbable	improbable
Status		negative	negative	neutral
Degree of Confidence		medium	medium	medium
Significance	Before mit	low	low	low
	After mit	low	low	low

Recommended Mitigation Objectives

- (i) The sewage disposal system for the construction camp should not be designed as a temporary stand alone works. It should be interconnected with the town's existing purification works in such a way that it can operate in the future as an upgrade and extension to cater for the future long term growth of the town.
- (iv) The tandem operation of the new and existing purification works should be such that the final soakaway of purified effluent into to the desert is confined to one location only.

3.6 Summary of infrastructure and urban services

3.6.1 Construction Period

Two impacts are identified during the construction phase which fall into the category of medium or medium/low significance with medium intensity. This means that they could have sufficient influence on the environment to affect the project design or require alternative mitigation. These are: -

- Increased Urban Road Traffic (negative impact)
- Impact on Namdeb's Housing stock (negative impact)

There are no impacts of high significance and / or high intensity.

3.6.2 Operational Period (20 – 40 years) and Decommissioning Period (1 year)

There are no impacts of high/medium significance and/or high/medium intensity.

Two urban infrastructure impacts are rated as having low intensity and low significance. This means that the impact will not have an influence on the project design. Helpful mitigations may be implemented but are not essential. These are: -

- Impact on the Town's Housing Stock (negative impact)
- Impact on the Town's Sewage Disposal System (negative impact)

4. ECONOMIC STRUCTURE AND URBAN MANAGEMENT

4.1 Relevance

The economic viability of Oranjemund is dependent almost exclusively on the diamond mining operations of Namdeb, although secondary economic activity has started to take root. The development of the Kudu gas power plant has the potential to develop into one of the biggest income earners within the Karas Region and this could impact significantly on the future viability and management of the town.

4.2 Description of the receiving environment

4.2.1 Existing Economic Structure

The Karas regional economy is driven by a strong mining sector and a large non-tradable sector comprising government and public services. Other contributors are the financial sector, including banking and insurance, the agriculture sector and the retail and property sectors.

The Region's mining sector is a major contributor to GDP and, according to the National Labour Force Survey of 1997, provide 27,5% of the employment opportunities for the region's economically active population. However, 29% of the region's population aged 15 and over are not economically active (NDC, 2001, P8).

Diamonds mined by Namdeb at Oranjemund and south of Lüderitz constitute a major component of mining GDP. Other main contributors are copper / zinc / tin / silver / lead at Rosh Pinah, marble at Aus and gemstones at various localities. A number of new mining concessions have recently been allocated within the Sperrgebiet.

The local economy of Oranjemund is dominated by Namdeb activities. The town was originally established as a closed dormitory for the mine employees. The town was serviced and supplied by Namdeb in every way. Since 1990, however, Namdeb embarked on an "outsourcing" programme which allowed many entrepreneurs in Oranjemund to establish profitable small businesses in construction, maintenance and administrative services to the mine. Shops, restaurants, bars, travel agents, financial services etc have developed and this gives the town a more "open" feel similar to other towns in the region.

There are limited agricultural activities taking place in the vicinity of Oranjemund located on both banks of the Orange River. The main crops of regional importance are lucerne and fruit from orchards. A dairy and piggery are more localised for supply to Oranjemund.

A tourist opportunity is beginning to be developed in Oranjemund. In 1998, the Orange River Mouth became the first transborder Ramsar site in southern Africa. It is recognised as a wetland of international importance and has been formed into a transborder Wetland Park. With the recent submission to the Cabinet of a Land Use Plan for the Sperrgebiet, tourist operators are gearing for a greater opening up of this area to eco-tourists.

4.2.2 Future Economic Trends

The future economic potential of Oranjemund is dominated by the future of Namdeb mining activities. After 75 years of mining, on-shore operations are losing viability. New deposits and new technology have served to prolong closure, but Namdeb's current strategic thinking is that on-shore operations will more-or-less cease by 2010, at which time off-shore mining of the ocean bed will commence. In line with this strategy, current manpower will reduce by 50% over the next 5 years to position for the less labour intensive off-shore operations (Rukamba, 2004).

With the completion of the Sperrgebiet Land Use Plan, tourism is set for a growth phase. The whole Sperrgebiet area will operate as a National Park. The northern and eastern areas will be opened up to vehicle access and wilderness camps. Minor upgrading of tracks and the development of hiking trails is expected. Tourism operating out of Oranjemund is expected to grow significantly (WEC, 2003, P2).

Other economic projects are being considered for development in the vicinity of Oranjemund, including fish farming, aquaculture and extended agricultural produce (eg olives, grapes, dates, cotton), but viability depends, to a large extent, on the continued economic prosperity of the town.

4.2.3 Urban Management

For several years, Namdeb mine management has been investigating the merits of proclaiming Oranjemund into a formal open town. To this end, land use studies and a town plan have been drawn up by town planning consultants (SPC, 1998), and, at the same time, management consultants have mapped out a strategy to establish a caretaker development company (the Oranjemund Development Corporation – ODC) which will operate as a local authority independently of Namdeb (D&T, 1999, P2).

The current strategy of Namdeb on the future proclamation of the town has two components: -

- One, to complete all legal procedures necessary to proclaim the town, including town planning approval, land survey and deeds office registration; and
- Two, to build capacity in local governance by establishing the ODC. This will initially be wholly owned by Namdeb but would be allowed to operate as an independent local authority.

In this way, final proclamation of the town can be implemented at short notice, but can be withheld by Namdeb until such time as it makes social, economic and administrative sense (Rukamba, 2004).

4.2.4 Neighbouring Towns

This closest town to Oranjemund is Alexander Bay which is located on the southern bank of the Orange River mouth in South Africa. The town is also a closed diamond mining operation managed by Alexcor. Passage between the towns is controlled by normal immigration and customs controls which operate between the two countries.

The closest Namibian town is Rosh Pinah some 75 kilometers to the north-east. It is also a mining town which is managed jointly by the two adjacent zinc mines. However, it is not able to

exercise the same immigration control available to Oranjemund and Alexander Bay. Accordingly, and informal settlement of some 6000 to 8000 speculative employment seekers known as the “Sand Hotel” has developed adjacent to the town. This is causing major town management problems.

Whilst both Alexander Bay and Rosh Pinah will almost certainly derive economic benefit from being on the supply line to the Kudu Plant (especially during construction), it is likely that Rosh Pinah will receive more employment speculators targeting jobs in Oranjemund.

4.3 Characteristics of the imposing environment

4.3.1 During Construction

The combined salaries of 600 – 1300 employees during the construction of the plant will be paid monthly in Oranjemund. Most plant and machinery will be imported from outside the region, but many opportunities will be created for local construction and service enterprise.

From a town management point of view, the additional burden of managing greater numbers of residents, vehicles and land use situations will be felt.

4.3.2 During Operation

Once, the plant is commissioned and operational it will need urban services and management for its 60 – 60 permanent employees and for the plant itself by way of land, utilities, communications, etc. As a major industrial operator earning a significant income from sale of electricity, it will be liable to contribute to the cost of running the town.

4.3.3 Decommissioning

Whilst the economic contributions to the town will be significant during construction and operation, these will cease upon decommissioning of the power plant whenever this takes place. For a year or less, the operational phase employees will be replaced by contractors involved in demolishing the plant and rehabilitating the site. Thereafter, all human and economic activity related to Kudu will cease.

4.4 Community concerns

During the 1998 meetings held for the PEA, three main concerns were raised concerning economic impact on the town. These were

- Potential impact of the plant on existing diamond mining operations;
- Economic benefits to the town; and
- Impacts on the future of tourism.

Additional concerns and issues raised during the 2004 meetings

- Negative impact on the town's viability and management after decommissioning;
- Economic benefits and problems to Rosh Pinah;
- Economic spin-offs, eg in tourism and agriculture;
- Need for financial contributions (eg a trust fund) to mitigate decommissioning impacts.

4.5 Identification of impacts on economic structure and urban management

Five main economic and urban management impacts are identified. Four are linked to both the construction and operation phase of Kudu and one is relevant to the operation phase only. The five impacts identified are as follows: -

4.5.1 Impact on Namdeb diamond mining operations

Nature of Impact

Strategy decisions concerning the future of mining operations have already been made by Namdeb on the basis of economic and production criteria. The construction and operation of a major power station at Oranjemund is unlikely to impact on these decisions. Indirectly, however, the development could add value to the town and thereby defer the threat to the long term viability of Oranjemund brought by the downscaling of Namdeb mining operations. The opportunity for Kudu to take up retrenched Namdeb workers has already been explored in section 2.5.5 of this report.

Extent of Impact

This impact would have impact only within the mining activities operating out of Oranjemund.

Duration of Impact

Should any impact apply, it would take place over a long term period which would include the construction and operational phase of the project.

Intensity

Should any impact occur, it would be low impact.

Probability

The probability is low that the Plant will impact on the future economic operation of the diamond mine.

Cumulative Effects

None are foreseen.

Summary of Impact Characteristics

IMPACT: IMPACT NAMDEB DIAMOND MINING OPERATIONS				
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE	
Duration	short term (3 yrs)	long term 20 – 40 years	n/a	
Intensity	low	low	n/a	
Probability	improbable	improbable	n/a	
Status	neutral	neutral	n/a	
Degree of Confidence	medium	medium	n/a	
Significance	Before mit	low	low	n/a
	After mit	low	low	n/a

Recommended Mitigation Objectives

None.

4.5.2 Macro-Economic Spin-offs from the operation of the Plant

Nature of Impact

During the dry winter months, Namibia imports up to 50% of its power from South Africa. Growth in demand is some 4% per annum, resulting in an increase in projected demand from 380MW in 2003 to 540MW by 2012. The construction of a 800MW power plant by 2009 (with the possibility of a further 800MW in phase 2) would not only fully cater for Namibia's needs, but would set-up Namibia as a power exporting country. South Africa's power demand is expected to exceed supply by 2009.

Extent of Impact

In the sense that Namibia is likely to export excess power, the extent of this impact is both national and international.

Duration of Impact

The duration of this impact is long term. It will cease after the decommissioning of the plant.

Intensity

The positive impact of revenue from the sale of the power to South Africa will be high but will vary in intensity depending on the excess available for sale and the extend of South Africa's demand. The impact of the commissioning of a second plant would be high.

Probability

It is most likely that Namibia will be in a position to export power to South Africa at some time during the operation of the plant.

Cumulative Effects

None are foreseen.

Summary of Impact Characteristics

IMPACT: MACRO-ECONOMIC SPIN-OFFS FROM THE OPERATIONS OF THE PLANT				
CHARACTERISTICS		CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration		n/a	long term	n/a
Intensity		n/a	high	n/a
Probability		n/a	probable	n/a
Status		n/a	positive	n/a
Degree of Confidence		n/a	medium	n/a
Significance	Before mit	n/a	high	n/a
	After mit	n/a	high	n/a

Recommended Actions to Enhance the Benefit

As soon as the investment decision to proceed with the construction of the plant has been confirmed, negotiations to sell excess power to South Africa should be concluded as a matter of urgency.

4.5.3 Local Economic Spin-offs

Nature of Impact

The increased levels of employment and income during the construction phase will most certainly improve the economy of Oranjemund, not only through the generation of additional small private sector business, but also because of secondary employment in response for the increased need for services. Fledgling economic enterprises in the agricultural and service sector may be boosted into viability by the increased critical mass and, once established, could survive into the operational period as well.

Viability for conservation and eco-tourism ventures has already improved following the approval of the Sperrgebiet Land Use Plan and the eminent proclamation of the new National Park. The construction and operation of the plant could play a further positive role in tourism promotion as a result of improved road and air transport.

Both Alexander Bay and Rosh Pinah are likely to experience an increase in economic activity resulting from the passing through of people and vehicles destined for the Plant. This will be particularly felt in Rosh Pinah when the upgrading of the Aus-Oranjemund road has been completed and goods and services no longer have to route via South Africa and Alexander Bay.

Extent of Impact

Although the greatest impact will be felt in and around Oranjemund, the economic benefit will extend to the entire western part of the Karas Region and the north-western portion of the NW Cape.

Duration of Impact

The effects of this impact will be long term during the operation of the Plant, but the biggest impact will take place on the local economy during the 3 year construction period.

Intensity

Potentially, the increased economic activity generated by the Plant could have a medium to high positive impact on Oranjemund, especially in view of the parallel downscaling of mining activities. The intensity of impact on Rosh Pinah and Alexander Bay will be medium to low.

Probability

There is a distinct possibility that the extent and intensity of impact described above will materialise.

Cumulative Effects

The cumulative effects of the positive and negative local economic impacts generated from the construction and operation of the plant on the one hand and the negative impact of downscaling mining operations on the other have already been discussed above.

Summary of Impact Characteristics

IMPACT: LOCAL ECONOMIC SPIN-OFFS				
CHARACTERISTICS		CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration		short term	long term	n/a
Intensity		medium	medium	n/a
Probability		probable	probable	n/a
Status		positive	positive	n/a
Degree of Confidence		medium	medium	n/a
Significance	Before mit	medium	medium	n/a
	After mit	high	medium	n/a

Recommended Actions to Enhance the Benefit

Every effort should be made to maximise opportunities for local business to benefit from the services which will be needed at the construction camp. Those services which can be outsourced (eg catering, shopping, recreation facilities etc) should be identified prior to construction and offered on tender to the business local business community.

4.5.4 Impact on Local Governance

Nature of Impact

Potentially, the increased population and need for urban services during the construction period could increase the need for and viability of proclaiming the town and constituting a democratically elected local authority. However, the conditions necessary for a viable town will remain uncertain due to the potential decline in the mine population due to downscaling. It must also be said that the economic activity associated with construction is short term and the conditions for a viable settlement need to be proved during the long term operation phase.

It is likely that Namdeb will have to subsidise the operation of the town's services for a long time even should it proceed with proclamation. In any event, an equitable financial advance to town management will have to be made by NamPower whether it be by way of an operational contribution or, following proclamation, as rates and taxes. In this way, the Plant is a positive development towards the financial viability of Oranjemund.

Extent of Impact

The impact of local governance will be limited to the boundaries of the settlement of Oranjemund.

Duration of Impact

The effects of this impact will be long term for the full operational life of the Plant.

Intensity

The most positive indicators for the proclamation of the town would appear to be during the three year construction of the Plant. This would be misleading however, since the true intensity of this impact is during the long term operational period when intensity will actually be low.

Probability

It is probable (distinct possibility) that the extent and intensity of the impact on local governance estimated above will materialise.

Cumulative Effects

In view of the parallel downscaling of mining activities, the intensity of the economic activity generated by the Plant on local governance is likely to be downgraded to low.

Summary of Impact Characteristics

IMPACT: IMPACT ON LOCAL GOVERNANCE					
CHARACTERISTICS		CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE	
Duration		short term (3 yrs)	long term	n/a	
Intensity		medium	low	n/a	
Probability		probable	probable	n/a	
Status		negative	positive	n/a	
Degree of Confidence		medium	medium	n/a	
Significance	Before mit	medium	low	n/a	
	After mit	low	low	n/a	

Recommended Mitigation Objectives

- (i) Namdeb should defer any decision to proclaim Oranjemund and hand over management of a local authority until after construction of the Plant has been completed and normal operations have commenced. The interim ODC town management company should be re-constituted to include representatives from NamPower with perhaps one representative from other private business.
- (ii) Consideration could be given to the levy of shadow rates and taxes on properties operated by non-Namdeb concerns. In this way, the culture of paying tax to the local authority will have been established if and when Namdeb initiates the full proclamation of the town.

4.5.5 *The Impact of Informal Employment Speculators (Squatters)*

Nature of Impact

It is a natural phenomenon in Namibian towns that unemployed or underemployed persons move to urban areas in search of employment. They generally set themselves up in informal "squatter" settlements on the periphery of towns where they have access to some urban services and are strategically placed to react to employment offers. An informal settlement of some 6000 to 8000 people has developed at Rosh Pinah on the basis of perceived job opportunities at the two local mines. It is a reality that, once established, these become permanent features of the town's land use profile.

No informal settlements have developed at Oranjemund or Alexander Bay. This is because the towns are closed and because strict security enforcement has ensured that these could not develop. There is no doubt, however, that the combined force of proclaiming and opening Oranjemund and of commencing construction on the Kudu Plant will result in the spontaneous development of a large informal settlement in a very short period of time.

If Oranjemund remains closed, however, it is equally as likely that employment speculators will move to Rosh Pinah as the closest town to the perceived new opportunities.

Extent of Impact

The potential growth of new or enlarged informal settlements will be limited to Oranjemund and Rosh Pinah.

Duration of Impact

The impact will be long-term; as long as there exists the perception of employment opportunities.

Intensity

The intensity is likely to be medium to high, especially during the construction period when a significant number of jobs are likely to be available. Intensity should drop to low during the operation period.

Probability

It is highly probable that, without mitigation, job speculators will converge on Oranjemund if they are permitted to do so, and that at least a proportion of these will move to Rosh Pinah if they are not.

Cumulative Effects

None are foreseen.

Summary of Impact Characteristics

IMPACT: IMPACT ON INFORMAL EMPLOYMENT SPECULATORS				
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE	
Duration	short term	long term	n/a	
Intensity	medium / high	medium / low	n/a	
Probability	highly probable	probable	n/a	
Status	negative	negative	n/a	
Degree of Confidence	medium	medium	n/a	
Significance	Before mit	medium / high	medium	n/a
	After mit	low	low	n/a

Recommended Mitigation Objectives

- (i) In order to prevent high magnitude informal settlement at Oranjemund, Namdeb should defer any decision to proclaim and open the town until the operational phase has commenced.

- (ii) NamPower should require that the recruitment of artisans and labourers by the contractor be carried out in Keetmanshoop. This may help to reduce the number of employment speculators moving to Rosh Pinah. This policy could be reviewed once construction of the Plant is completed.

4.5.6 *The Impact of Decommissioning*

Nature of Impact

Once the Plant has been decommissioned and the site rehabilitated, the town will lose the population, level of economic activity, rates and taxes and consumption of urban services associated with the Plant's operation. Assuming that the town by this stage has been proclaimed and is managed by a conventional local authority, its potentially fragile economic balance may be overturned.

Extent of Impact

This will affect the viability of Oranjemund to operate as a local authority.

Duration of Impact

Following the final closure of the Plant, such an impact would be permanent.

Intensity

This is difficult to predict since this event will only take place 20 to 40 years from now. Hopefully by then, the economy of the town has sufficiently evolved so that the impact would not be fatal. If the viability remains marginal, however, the intensity should be considered as potentially high.

Probability

Since this is an impact which will only take place in the long term future, outcomes are uncertain.

Cumulative Effects

The viability of Oranjemund in, say, 2040, will depend on the cumulative influence of a number of economic forces, including Kudu, the diamond mining operation as well as other local and regional economic endeavours.

Summary of Impact Characteristics

IMPACT: IMPACT ON DECOMMISSIONING			
CHARACTERISTICS	CONSTRUCTION PHASE	OPERATION PHASE	DECOMMISSIONING PHASE
Duration	n/a	n/a	permanent
Intensity	n/a	n/a	uncertain
Probability	n/a	n/a	uncertain
Status	n/a	n/a	neutral to negative
Degree of Confidence	n/a	n/a	low
Significance	Before mit	n/a	low
	After mit	n/a	low

Recommended Actions to Enhance the Benefit

It is difficult to devise mitigations which could safeguard against a negative economic impact which will not occur for another 25 years or more. It is suggested, however, that any future local authority set up a tax revenue item which is to be placed in trust for the future eventually that either the mine or the plant or both cease to operate. This needs to be a significant amount of money if it is to have any practical value. The main contributors should be Namdeb and NamPower, but all businesses should make some contribution.

4.6 Summary of economic structure and urban management impacts

4.6.1 Construction Period (3 years)

Three impacts fall into the category of medium / high significance and / or impact and are therefore considered to have sufficient influence on the environment to affect the project design or require alternative mitigation. These are: -

- Local Economic Spin-offs (positive impact);
- Impact on Local Governance (neutral impact); and
- Impact on Informal Employment Speculators (negative impact).

The impact of the Kudu project on Namdeb mining operations was evaluated to have low significance and low impact.

4.6.2 Operations Period (20 – 40 years) and Decommissioning Period (1 year)

The impact on Namdeb mining operations was again seen as low significance and low impact during the operation period, as was the impact of Kudu on local governance.

Three impacts scored medium or high impact and / or significance within the operation period and one after decommissioning. These were: -

- Macro-economic Spin-offs (positive impact);
- Local Economic Spin-offs (positive impact);
- Impact of Informal Employment Speculators (negative impact); and
- Impact on decommissioning (negative impact).

5. SUMMARY OF SIGNIFICANT SOCIO-ECONOMIC IMPACTS

5.1 *Identification significant impacts*

For the purposes of this summary, significant socio-economic impacts are regarded as those which display high to medium significance and / or high to medium impact. This means that they have sufficient influence on the environment to affect the project design or require alternative mitigation actions. They are therefore important. Eight such impacts have been identified in this analysis as follows:

Social Impact

- Stress on existing health systems (-) (construction period)

Infrastructure and Urban Services

- Increased urban road traffic (-) (construction period)
- Impact on the Namdeb's housing stock (-) (construction period)

Economic Structure and Urban Management

- Macro-economic spin-offs (+) (operation period)
- Local Economic spin-offs (+) (construction and operation period)
- Impact on local governance (neutral) (construction period)
- Impact of Informal Employment Speculators (-) (construction and operation period)
- Impact of Decommissioning (-) (decommissioning period)

5.2 *Summary of recommended mitigations and actions to enhance benefits*

(A) Develop temporary facilities within the construction camp to reduce impact on local services and facilities. These should include: -

- clinic for minor and routine health matters;
- commercial, service, social and recreational facilities;
- mess facilities.

(B) Negotiations should take place between Namdeb and NamPower on financial and administrative arrangements with a view to: -

- ensure that existing health resources are maintained at least until the end of the construction period;
 - reinforce existing law enforcement resources;
 - the augmentation of existing facilities and services related to alcoholism and alcohol abuse;
 - the routing of all heavy vehicles to the town's southerly through-route past the industrial zone, and the construction of speed calming measures;
 - the upgrading of public transport facilities;
 - the design of the sewage disposal works for the contractors camp which should be able to operate in future as an upgrade and extension of the town's works;
 - the establishment of a joint town management company and the establishment of an interim taxation system.
- (C) Employ dust reduction construction practices including where practical, the use of water, the use of labour construction methods and the limiting of activity during windy conditions.
- (D) The mounting of a publicity campaign to ensure workers that no harmful bi-products are generated by the plant.
- (E) It makes practical economic sense to utilise the Uubvlei hostel near the proposed CCGT plant as the core for developing the construction workers camp. In order to avoid the security and management difficulties in sharing this facility, it is recommended that Namdeb abandon the hostel for use by Nampower and accelerate its programme to construct new housing in Oranjemund for the remaining hostel residents ahead of schedule.
- (F) The acquisition of the Uubvlei hostel for a construction camp will not absolve Nampower for investing in a substantial renovation and upgrade of the facilities which have become run-down over recent years. If possible, only single and double rooms should be provided.
- (G) Outsource as many services as possible to be provided at the construction camp on a tender basis.
- (H) Namdeb should defer any decision to proclaim Oranjemund and to establish an independent local authority until after construction of the Plant has been completed. This is partly to avoid the establishment of local governance in an abnormal economic environment, but is also intended to minimise potential for the development of informal settlements.
- (I) The interim town management company (ODC) should include representatives from NamPower and possibly a representative from private business.

- (J) Consideration should be given to the levy of shadow rates and taxes and the establishment of a trust fund to assist the town after the closure of either the Kudu plant or the cessation of mining activities.
- (K) In order to deter the growth of informal settlements at Oranjemund or Rosh Pinah, NamPower should carry out the recruitment of construction personnel for the plant at Keetmanshoop, at least during the construction period.

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PERSONAL COMMUNICATIONS

Mr B Kasumba, Property Maintenance Manager, June 2004.

Mr B Rukamba, Business Development Manager, June 2004.

Mr W Rentel, Allied Services Manager, June 2004.

Mr P Wood, Environmental Management Co-ordinator, June 2004.

**ENVIRONMENTAL IMPACT ASSESSMENT FOR
THE PROPOSED CCGT POWER PLANT AT
UUBVLEI NEAR ORANJEMUND, NAMIBIA**

ARCHAEOLOGICAL ASSESSMENT

PREPARED FOR:

*Namibia Power Corporation (Pty) Ltd
P O Box 2864
WINDHOEK
Namibia*

PREPARED BY:

*Dr Dieter Noli
P O Box 357
Lüderitz
Namibia*

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Executive Summary

Introduction

This report forms the archaeological component of an Environmental Impact Assessment conducted for the construction of a gas-powered power station at Uubvlei, near Oranjemund in Mining Area 1, located in the Namibian Diamond Area or “Sperrgebiet” (closed area).

Methods

Starting with an in-depth literature review, the study continued with a comprehensive field survey in May 2005. The results were then discussed with respect to the known archaeology of the area.

The affected archaeological environment

Related archaeological and historical information suggest that Early Stone Age, Middle Stone Age, Late Stone Age and historical material, covering the period from about one million years ago to the present, can readily be found in the entire Sperrgebiet. In addition, the coastal region concerned is known for its buried sites, while flooded sites are a distinct possibility. No archaeological material was actually found at the intended construction site, the laydown site or the alternative accommodation site.

Impact of construction and operation

The construction of the plant itself, being scheduled to take place on a mined-out site, would not threaten the archaeological record. Neither would the power line routes - which have been inspected independently – the existing access routes, or the suggested construction camp and laydown site.

Recommendations for mitigating measures and monitoring

Compliance with EMPs must be enforced.

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APPENDIX: Figure 1. Location of proposed CCGT site at Uubvlei

1. INTRODUCTION

1.1 *The region*

The Sperrgebiet is a unique piece of access-controlled desert some 300 km long and 100 km wide, located in the south-western Namib. Most of it lies within the rough open rectangle formed by the Luedertiz-Aus road to the north, the Orange River to the south, and the Atlantic shoreline to the west. It was created in 1908 to protect the interests of the diamond mining industry, a purpose it serves to this day.

It is uncertain, however, how long the Sperrgebiet will continue to exist in its current form. Namdeb (Namibian De Beers), which once controlled the entire area, now only retains its coastal and riverside Exclusive Prospecting Licenses (EPLs), having recently handed the rest of what used to be the Diamond Area over to the Department of Environment and Tourism (DET). The interior part of the Sperrgebiet lying to the north of the road between Luederitz and Aus has been part of the Namib-Naukluft Park for several years. The access to the interior of the rest of the Sperrgebiet is currently controlled by Namdeb on behalf of DET. Numerous EPLs have, however, been granted to other companies to prospect in the all the areas of the Sperrgebiet that Namdeb has vacated. The entire Sperrgebiet is currently in the process of having its status changed to that of a National Park, and most of it will become a wilderness area.

1.2 *The project*

Nampower intends to erect and operate a combined cycle gas turbine (CCGT) power station at Uubvlei in Mining Area 1 (MA 1), about 25 km north of Oranjemund.

1.3 *This study*

The purpose of this study is to conduct the archaeological component of an Environmental Impact Assessment (EIA) for the proposed CCGT power station.

1.4 *The study area*

The study area is located within the borders of MA 1, shown in Figure 1 (Appendix). The terrain is made up of low vegetated dune hummocks which have largely been disturbed by previous mining and prospecting efforts.

2. METHODS

2.1 Literature review and map study

The study commenced with an in-depth review of all the published and unpublished literature relevant to the history and prehistory of the south-western Namib in general and the Sperrgebiet in particular, special attention being paid the study area. Following this, 1: 50 000 Trigonometric Survey maps and 1: 100 000 German maps from 1913 were used to make a detailed map study of the research area. These exercises provided a rough idea of the kind of archaeological sites that could be expected to be in the study area, where they might be found and what kind of material they could contain. Where applicable, relevant modified and unmodified sections from previous reports by this author (e.g. Noli 1998) were included in this report.

2.2 Field trip

After the above preparations, a site visit was conducted, the area being traversed on foot and inspected for archaeological material.

2.3 Problems and Limitations

Provided that the Environmental Management Plan (EMP) is adhered to, there are no identifiable problems or limitations.

3. THE AFFECTED ARCHAEOLOGICAL ENVIRONMENT

3.1 Relevant background information

Davis and Walsh (1955) drew attention to the existence of ESA material in the diamondiferous raised beaches north of Oranjemund. Rudner and Grattan-Bellew (1964) reported ESA, MSA and LSA material from along the Sperrgebiet coastal region, and Rudner (1968) reported on pottery from the same area. Corvinus (1977, 1983) found ESA, MSA and LSA material between Arriesdrift and Obib on the northern banks of the Orange River, and ESA material on the raised beaches to the north of Oranjemund. Wendt (1972, 1975a, 1975b, 1976, 1978, 1980, 1981) conducted extensive research on the history, rock art, ESA, MSA and LSA of those parts of the south-western Namib lying outside the Sperrgebiet. Cruz-Urbe and Klein (1983) reported on some of the faunal remains of Wendt's excavations, as did Avery (1985). Noli (1989) investigated the archaeology of the Koichab River Area to the north of the road between Luederitz and Aus. Noli (1995) reported on an archaeological survey of the Sperrgebiet coastline and its boundary with the Orange River. Noli (1998) investigated the archaeology along the road from Luederitz to

Oranjemund, Sendlingsdrift, Rosh Pinah and Aus. The above sources, combined with personal observations, suggest the following scenario:

ESA artefacts such as hand-axes, cleavers, knives, scrapers, discoids, picks, spheroids, choppers, untrimmed flakes and cores made from river cobbles are found on the Proto/Meso-Orange deposits along the Orange River below Sendlingsdrif. These deposits are 50-80m high banks of sand, gavel and stones which were deposited by the Orange River some 17 million years ago, after which the river cut through them, so that they now form bluffs overlooking the river. At one time similar artefacts made from beach cobbles were found on the raised beaches between Oranjemund and Affenruecken, but these sites have now been largely destroyed by mining activities. The ESA artefacts are from the Acheulian industry, indicating an age of between about one million and 200 000 years. Their distribution suggests that ESA people used the Orange River valley as a route to the coast, and ventured up the coast for some 70 km, but did not penetrate into the interior of the Namib desert. The amount of cores, flakes and half-finished tools, as well as numerous cores with pieces which can be re-fitted, indicate that the tools were manufactured along the Orange River. So far however, only one living site has been found, located some four km north of the Orange River at Obib. This raises the question as to where the other living sites are. As the mean sea level was lower during much of the ESA than it is today, many coastal ESA sites could have been drowned, while floods could have destroyed any ESA sites located in the sandy area right next to the river. Isolated ESA artefacts have been found away from the coast and from the Orange River, but these are of little significance, as they could easily have been brought in by MSA or LSA people as sources of raw material.

MSA artefacts in the form of blades, points, scrapers and flakes have been found within about 12 km of the Sperrgebiet coastline, mainly at vantage points such as the tops of hills, or at present or past water sources such as springs and dry pans in presently inhospitable areas. This suggests that conditions may have been slightly wetter than they are at present during at least some of the MSA period. MSA sites are rarely found closer to the coast itself than about 3 km, a phenomena that could be attributed to changes in sea level, which may have drowned most coastal MSA sites. As was the case with ESA artefacts, MSA artefacts also occur on the Proto/Meso-Orange River deposits along the Orange River below Sendlingsdrif, and may have occurred more numerous next to the river itself before floods destroyed them. In addition, MSA artefacts also occurred on vantage points along the river. Accounts of MSA material being found well away from both the coastline and the river are limited but convincing, and both open sites and rock shelters have been reported. The most spectacular rock shelter is the Apollo 11 site, excavated by Wendt, the evidence from which suggested an MSA occupation until about 25 000 years ago. This may clash slightly with the general view that the MSA lasted from about 200 000 years ago until about 40 000 years ago in southern Africa, but the exact time period of the MSA does vary a somewhat from site to site. In 1988 Mr. Daan Marais found a fossilized human skullcap near Oranjemund. Efforts are currently under way to determine its age, but it is thought to be from the MSA.

The LSA is generally believed to have lasted from about 40 000 years to ago to the present. In addition to stone tools such as flakes, cores, microliths (stone tools small enough to fit into a matchbox) and grindstones, it includes ostrich eggshell water containers, ostrich eggshell beads, seabird eggshell, seashells, bone, pottery, glass, metal, charcoal and wood. LSA sites are

located along the actual coastline in the form of shell middens, and at water sources near the coast and along natural routes to the interior. It would therefore seem that, while LSA man inhabited the coast, the desert itself was merely travelled through. The lower Orange River, being both a water source and a natural route to the interior, is rich in LSA sites, which are concentrated in the sandy area lying between the river and the Proto/Meso-Orange deposits. The LSA inhabitants of the area, like the MSA people before them, made extensive use of open sites, but did not hesitate to use rock shelters when these were conveniently located. The coastal evidence suggests that sites with formal microlithic tools may date to between 5600 and about 2400 years ago, whereas evidence from the interior suggests that microliths may have been introduced about 10 000 years ago. This is not necessarily a contradiction, since all coastal LSA sites much older than about 5000 years were in any event drowned by rising sea levels. Pottery is generally taken as having been introduced into southern Africa about 2000 years ago. With three exceptions, however, all dated sites with pottery in southern Namibia are from the last 500 years, so that pottery sites can generally be taken as being both free of microliths and being only about 500 years old in the south-western Namib. Stone circles and graves, though rarely directly dated, are generally attributed to the LSA. LSA people probably only entered the Namib Desert after good rains, never permanently or even on a regular basis.

Both painted and engraved rock art exists in the area. A painted rock slab from the Apollo 11 cave has been reliably dated to 28 000 years, but the age of the rest of the art, as well as the identity of the authors, is still very much under discussion. According to Wendt (1978), however, the heavily patinated naturalistic engravings of both humans and animals should be attributed to "Bushmen", and may be about 6 000 or 8 000 years old. The abstract engravings should, on the other hand, be attributed to the Nama of Bethanien, a scenario which would mean that they were only made during the last 500 years.

The end of the LSA coexisted with the beginning of historic times. It would seem that hunting and gathering Nama in possession of ceramics entered the southern Namib some 500 years ago, either displacing or absorbing the remnants of the original population. These Nama may have been the "Bushmen" referred to by the early travellers. Who the original inhabitants were is not known, but small groups of Damaras lived at least as far south as the 26th parallel prior to the 19th century. In the course of the 19th century both the "Bushmen" and the Damara were displaced, enslaved or exterminated by various waves of nomadic Nama herders, who had first crossed the Orange River from the south in the 17th century. The Nama herders were in turn subjugated by the German colonial forces, which were expelled by the South Africans during WWI. In 1931 the police rounded up the last two groups of free-roaming hunter-gatherers of the south-western Namib in the vicinity of the Aurus Mountains. The adults were variously charged with trespassing in the diamond area, having unlicensed dogs and weapons, and the possession of klipspringer and gemsbok skins and gemsbok meat, and were jailed for up to five months. Once their survival strategies had been curtailed, the Namib nomads ceased to exist.

The legacy left by the Namib nomads is not only made up of the archaeological record, but also of an intricate system of roads and tracks. The reason for this is that the first Germans used the last Bushmen as guides. As these Germans were either travelling on foot, or on horseback, or with ox wagons, they were very reliant on the ready availability of water en route. It follows that the Bushmen would have guided the colonials along the best routes with the best water sources.

These routes, dutifully mapped by the Germans, eventually became paths, tracks and dirt roads, still leading past the water sources, which often became the locations of the farmhouses, or even of towns. Inside the Sperrgebiet, where many of the German tracks fell into disuse after WWI, and where the Bushmen no longer roam, the old routes have now completely disappeared. They can, however, still be followed by the simple expedient of using German maps pre-dating WWI, especially the 1:100 000 series prepared by Sprigade and Lotz (1913). These maps not only show the routes with great accuracy, but also indicate the waterholes. Along these routes and at the waterholes, German artefacts can be found, and archaeological sites abound.

The German and subsequent mining activities, which commenced in 1908 with the discovery of diamonds in the vicinity of Kolmanskop, have also left a substantial amount of traces in the Sperrgebiet. These, however, are mainly limited to a narrow coastal strip some 16 km wide, the most of the earlier activity having taken place between Luedertiz in the north and Bogenfels in the south. The remains are largely in the form of four major ghost towns (Kolmanskop, Elisabeth Bay, Pomona, Bogenfels), ruined diamond plants, abandoned diamond workings, disused narrow gauge railway lines and derelict mining equipment. Due to the proximity of the sea, the moisture from the fogs and the strong winds that the coastal strip is known for, these historical remains are rapidly deteriorating. Some of the houses (one or two in each of the ghost towns) have been restored and are being maintained, but these represent the minority.

While the modern mining period – which started in the late 1920's with the discovery of diamonds in the vicinity of the Orange River mouth – was initially limited to the coastal strip between Chamais in the north and Oranjemund in the south, this is no longer the case. The modern plant at Elizabeth Bay, the pocket beaches, the workings along the Orange River itself and the efforts of land and sea-based subcontractors have ensured that the entire coastline of the Sperrgebiet, as well as the adjacent banks of the Orange river, are being subjected to extensive mining and prospecting activities.

3.2 Buried sites

While it could be argued that archaeological sites are clearly recognisable, this is sadly not the case. The mining process is not geared to identify archaeological material. Late in 2002 an elephant tusk turned up on a conveyor belt in the mining area at Plant 3, near Oranjemund. No other elephant bones were found at the time. This means that, with the exception of that one tusk, an entire elephant was mined, loaded, transported to the crusher and processed unseen. The bones may well have been buried, but that is exactly the point: We don't know what is buried, and there is as yet no mechanism in place to find out. Corvenius(1983) spent a lot of her time picking over mine dumps for stone tools, and drew attention to the vast amount of buried archaeological material that exists in the mining area near the Orange River mouth. Hart and Halkett (1999) did an assessment of the archaeological baseline surveys that had been conducted by this author in the Sperrgebiet from 1995 to 1999, voicing their thoughts on the subject of buried sites as follows:

“Of particular concern are deeply buried archaeological sites relating to the Emian marine transgression of about 120 000 years ago. A site of this type (of which there are only a few in the

world) was exposed at Boegoeberg south of Alexander Bay when a cave at the end of a buried gully was broken open to mine diamondiferous gravels. Unfortunately the bulk of the archaeological material was mined out of it before archaeologists had the opportunity to study the site in detail. This impact was unmitigatable and resulted in the loss of heritage of international importance.... Potentially sensitive areas will need to be identified and monitored during mining operations. Identified sites need to be conserved or mitigated.”

It follows that the occurrence of buried archaeological sites at ANY part of the Sperrgebiet coastline cannot be ruled out.

3.3 Flooded sites

Rises in sea levels had reached, in comparison to today's mean sea level, -60 m by about 40 000 B.P. (before present), -20 m by 7130 B.P. and + 3.6 m by 4940 B.P., dropping to + 1.5 m by 1190 B.P. (Noli 1989). It follows that most LSA coastal sites probably date from the last 5000 years, earlier sites having been drowned. This means that throwing up sea walls and excavating to below the high water mark need NOT necessarily only involve archaeologically barren deposits. Handaxes, for instance have been located in both Table Bay and False Bay, in South Africa (Werz & Flemming 1991). Even the occurrence of shipwreck material cannot be excluded. The mechanisms, however, for locating, identifying and preserving underwater archaeological sites are as yet not very well developed. It is only very recently that the Southern African Institute of Maritime Archaeology (SAIMA) has started looking into this matter. The possibility, however, of the gradual development of scientific, public, political and legislative awareness of 'wet' archaeology has to be noted.

3.4 The latest research developments

The latest archaeological research developments in the Sperrgebiet (Noli 2003) made the suggestion that the prehistoric inhabitants of the area may have exploited the land snail *Trigonephrus*. While a previous report (Noli 1998) had made the connection between the land snail and archaeological sites in deflation hollows, it had been thought that the snails had been there because of the deflation hollows, not because of the archaeological sites.

The discovery, however, of a snail shell midden in front of a cave at Buntfeldschuh, demonstrated that their occurrence was the function of people, rather than of nature. This led to the investigation of several concentrations of land snail shells in the GP pan area, on a high dune ridge adjacent to the northern shore of the lower Orange River, near Oranjemund, all of which turned out to be archaeological sites associated with either LSA or MSA material. This came as quite a surprise, since the ridge is very exposed to the prevailing winds. A perusal of the relevant literature (Pallet 1995), however, revealed that the snails, while living on sand sheets and low dunes, are only active at night or in the early morning in the winter, during rain or heavy fog, when the surrounding desert is moist.

It follows that, in order to harvest the snails, prehistoric man would have to have been waiting for them first thing in the morning in their preferred habitat, on the natural dew trap formed by the exposed dune ridge. Thus, while things may have been more comfortable for man in the brushwood along the river, the snails were on the ridge, so that was where man had to overnight if he wanted to exploit them early in the morning.

It was furthermore noticed that three of the archaeological sites associated with snail shells were also associated with what appeared to be remains of bushman's candle wax that had been molten in a fire. Since bushman's candles (*Sarcocaulon crassicaule* REHM / *Sarcocaulon burmanni*) occur on the same dune ridge, the possibility exists that they were used to cook the snails. Certainly, since the snail shells are not broken, it is only by cooking the snails or by placing them next to a fire to kill them that it would have been possible to extract them from their shells. Experiments with live snails will, however, have to be conducted to see how exactly they react to being subjected to heat. The occurrence of fossils of these snails in association with subsurface Acheulian artefacts in MA 1 (Corvinus 1983) suggests that they may have been utilised by ESA people as well.

The implications of this research means that archaeological sites can now easily be identified at a distance by means of their snail content. This method has only recently revealed that the sandy wastes of the interior of the Sperrgebiet – once thought to be comparatively barren with respect to cultural material – may actually be rich in archaeological sites.

3.5 Sites located during this study

No archaeological material was located during the field survey.

3.6 Sensitivity to disturbance

Archaeology is the reconstruction of the past based on the physical remains of that past. It follows that the mechanics of archaeology are very similar to detective work. The only difference is that, unlike a detective, who inspects the room the morning after the murder, the archaeologist inspects the rock shelter thousands of years after the event, carefully sifting through rubble and refuse.

For this reason the slightest disturbance at an archaeological site amounts to tampering with the already very sketchy evidence, thus making the task of the archaeologist difficult, if not impossible. It cannot be stressed enough that not only the physical integrity of the material evidence – for instance a stone tool such as a hand axe – is important but also the context in which it has been found.

Archaeological sites from any given time period are finite and do not seed or regenerate in any way. It follows that they cannot be rehabilitated. This makes them highly sensitive to any form of disturbance.

4. IMPACT OF CONSTRUCTION

4.1 Sources of risk

The process of construction, operation and decommission of the power plant would only put the archaeological record at risk in the highly unlikely event of an undisturbed buried pocket of archaeological material being unearthed during the construction process

4.2 Impact identification

The impact concerned would be in the form of a massive surface and subsurface disturbance, which would either physically destroy the archaeological evidence or remove it from its original context, thus robbing it of its scientific value.

4.3 Assessment

The impact would be general, permanent, all-encompassing, and unavoidable..

TABLE 1. IMPACT AT THE CONSTRUCTION SITE

DESTRUCTION/DISTURBANCE OF ARCHAEOLOGICAL MATERIAL	
<i>Nature of impact</i>	The actual processes of construction, operation and decommission – to the extent that they cause surface or subsurface disturbances – may either destroy or disturb subsurface archaeological material.
<i>Extent</i>	Specific, as the disturbance will only be taking place in the Uubvlei area.
<i>Duration</i>	Permanent, as archaeological material and its context are irreplaceable.
<i>Intensity</i>	High, as the construction process will completely eliminate all archaeological evidence it encounters
<i>Probability</i>	Definite, the impact from the construction process is guaranteed to take place.
<i>Status of impact</i>	Negative, since a healthy environment should retain its archaeological evidence
<i>Degree of confidence</i>	High, since the study area is unlikely to contain undisturbed archaeological material.
<i>Significance</i>	Low, due to the fact that the area has already been disturbed.

5. RECOMMENDATIONS FOR MITIGATING MEASURES AND MONITORING

The mitigation measures must be included in the EMP and heavy penalties must be exacted for any transgressions. Regular compliance audits must be conducted and verified by an independent assessor.

6. CONCLUSIONS AND RECOMMENDATIONS

While no archaeological material was found in the study area, the related archaeological evidence for the Sperrgebiet it suggests that a very strong possibility of subsurface archaeological material exists in the entire region.

Due to the disturbed nature of the study area, however, the chances of construction activities encountering undisturbed pockets of subsurface archaeological material can be considered to be insignificant.

The only realistic threat to the archaeological record would therefore occur if the construction took place at a site other than that which was investigated.

It is therefore recommended that full compliance be enforced with respect to the final EMP by means of stringent independent monitoring and strict penalty clauses.

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APPENDIX

ENVIRONMENTAL ASSESSMENT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA

INFRASTRUCTURE AND SITE SERVICES ASSESSMENT

UUBVLEI SITE

(Revised May 2005)

PREPARED FOR:

PREPARED BY:

***V Fischer-Buder,
for Consulting Services Africa***

Contact person:

Henri Fortuin

Tel: + 27 21 888-2412

Fax: + 27 21 888-2693

Email: hfortuin@csir.co.za



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ENVIRONMENTAL ASSESSMENT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA INFRASTRUCTURE AND SITE SERVICES ASSESSMENT

1. INTRODUCTION

1.1 Objectives

The objective of this study is to carry out an assessment of the options for infrastructure and site services of the power plant located at Uubvlei during construction, operation and closure. Various options for the provision of workers accommodation, services and communications infrastructure are evaluated in terms of their suitability and recommendations are made on the best alternatives. The lifetime of the project is estimated to be between 20 and 40 years depending on the extent and duration of the gas reserve.

Recommendations are made to maximise positive impacts and to avoid or reduce to acceptable level, potentially negative impacts.

1.2 Methodology and approach

A number of issues regarding site services and infrastructure were identified in the TOR, and these are dealt with under the following headings in this report:

A. WORKERS ACCOMMODATION

- Options for Housing and Accommodation for the construction phase
- Recreation Facilities

B. INFRASTRUCTURE AND SERVICES

- Communications Infrastructure
- Urban Infrastructural Services

2. WORKERS ACCOMMODATION

2.1 Background

The workforce for the construction and operation of the plant will consist of between 600 and 1300 mostly unskilled or semi-skilled construction workers, and between 50 and 70 skilled operations staff respectively. The construction phase is expected to last for 3 years starting in 2006, and the life of the plant will be between 20 and 40 years. Temporary and permanent workers will need housing. Such accommodation can either be provided by linking into existing town and mine infrastructure, or they will have to be provided new.

2.2 Construction Period

The expected construction period of the Project is 30 months.

The peak manpower requirement of 1300 workers will occur during the period of major building construction which will be less than 12 months.

2.3 Temporary Accommodation Camp

The first option would be to construct new temporary accommodation for the construction workforce. A suitable site adjacent to the construction site has been identified. Accommodation for up to 1300 workers will be necessary. The camp should consist of the following:

1. Housing: approximately 500 rooms (prefab container type) with ablution facilities
2. Canteen and kitchen to seat 450-500 people per meal in 3 sessions. Bulk food stores, cold and freezing facilities.
3. Recreation facilities: one or two buildings, with various bar facilities.
a TV/movie/multipurpose hall.
a number of smaller halls for pool tables, etc
private lounges, office facilities for management
soccer field.

The camp would require to have full electrical, water and sewage reticulation, streets with area lighting, a perimeter fence. The camp will be in use for about 2 ½ years, after which it would have to be removed completely. In the case that the second phase of the power station is constructed following on the first phase, the accommodation facilities would be required for an additional 2 ½ years.

2.4 Existing Accommodation At Uubvlei

The proposed plant site at Uubvlei is located adjacent to the existing Namdeb workshops and a Workers Hostel Complex. The accommodation at Uubvlei consists of a dilapidated and

disused single quarters and a newer hostel which can accommodate a maximum of 1476 people in three components as follows: -

- (a) The main hostel accommodates a maximum of 776 people housed in 4 blocks of 34 double rooms each (272 people), 3 blocks of 24 double rooms each (144 people) and 5 blocks each with 7 dormitories, each sleeping ten persons (250 people). Other related facilities include the kitchen and dining hall, a shop and informal market, a small postal agency, laundry, recreation hall and beer garden;
- (b) A first hostel annex accommodates a maximum of 372 people housed in 6 blocks each with 24 double and 8 single rooms and in 2 blocks each with 12 double and 4 single rooms. Other related facilities include a games room, two TV rooms and a community hall for approximately 600 people; and
- (c) A second hostel annex accommodates a maximum of 328 people in 4 blocks of double and single rooms with 82 people per block. Additional facilities include kitchens, TV room, pool room and a church.

Currently some 750 Namdeb employees are resident in the hostel accommodation although the overall capacity of the hostel is 1476 people. The facility is therefore currently only partially occupied. As Namdeb's land based mining has been reduced, hostel and single quarters employees have been gradually relocated to Oranjemund. Within 5 years, it is intended that all employees will live in Oranjemund.

2.4.1 During Construction

If this hostel complex could be made available for the plant construction, it would be suitably sized and located to serve as accommodation for the construction workforce at its peak. However, this would imply that all Namdeb employees would have to be moved to other accommodation in Oranjemund sooner than currently planned to avoid security and other related problems.

The entire hostel complex would have to be renovated and dormitory blocks would have to be converted to single or double rooms to make the complex suitable for the housing of the temporary workers.

Adoption of this second option rather than establishing a new accommodation camp (subject to agreement with Namdeb and the client) will lessen the environmental impact.

2.4.2 During Operation

Once the plant is operational, a permanent force of 50 – 60 largely skilled workers will be employed. This number will be augmented by maintenance personnel during periods of planned plant maintenance. Operators will work in shifts and will have to be skilled and be able to undertake basic maintenance. Most workers will be operators and technicians, with a few professionals and managers. It is probable that these employees will live in Oranjemund itself and commute to the plant.

The estimated life of the plant is more than 20 years. However, this could be increased if the second phase is commissioned.

2.4.3 Decommissioning

Once the gas reserves have been exhausted (assuming new sources are not discovered), the power station would be decommissioned, the plant demolished and the site rehabilitated. The construction workforce accommodation – regardless of which of the two options above is implemented – would be removed and the area rehabilitated immediately following completion of the second phase of the power station construction.

3. INFRASTRUCTURE AND URBAN SERVICES

3.1 Background

Infrastructural services such as water, sewage disposal, electricity, waste disposal, telecommunications, security fences, roads etc. will be required for both the construction and the operation phases of the plant. Such services can either be provided by making use of existing town and mine infrastructure, or they will have to be constructed as part of the plant. Either way, this will have impacts which need to be evaluated.

3.2 Infrastructure

3.2.1 Communications Infrastructure

The proposed plant site at Uubvlei is 25 km north of Oranjemund, reachable by the tarred coastal road from Oranjemund.

By road, Oranjemund is accessible from three different directions

- from the east via the gravel road along the north bank of the Orange River from Rosh Pinah,
- from the north via a security gravel road from the Lüderitz-Aus road; and

- from South Africa via the Ernst Oppenheimer bridge seven kilometers south-east of Oranjemund.

The southern security road runs through the Sperrgebiet and is planned to be the route used to transport the main gas plant components from Lüderitz. The road from Aus via Rosh Pinah is to be upgraded and tarred. The section between Aus and Rosh Pinah is currently under construction.

Additional local roads will have to be constructed for heavy vehicles as follows:

- From the site to the tarred coastal road from Oranjemund. This road will have to be constructed to bear heavy and extra-heavy vehicle traffic. It will also link into a road between the workers accommodation and the plant site.
- From the site to the cooling water pump station and pipelines. This road will only be able to be planned once the final design of the cooling water installation has been completed, and the exact route can be established.
- From the site to the gravel / aggregate pit or quarry. Routing will depend on the borrow pit location. This road should be removed once construction of Phase 2 of the powerstation has been completed, so as far as this first phase is concerned, it should remain for future use.
- A road to the proposed potable water abstraction point for boiler make-up water at Hohenfels ±16km upstream on the Orange River from Oranjemund is required. The existing road along the river to Sendelingsdrift can probably be used for most of the distance, but some access road may have to be constructed at the abstraction point.

In general, the roads to be used daily should be tarred, while the other roads could be constructed as gravel roads with salt surface. Such roads would need more regular maintenance than the tarred roads. Tarred roads will need to be maintained on a regular basis, and a proposed maintenance regime – depending on the condition of the existing roads – is either a slurry seal at a 5 year cycle or a 13mm bitumen rubber layer every 7 years. Actual maintenance requirements should be assessed by regular inspections of qualified persons and will depend to a large degree on road usage and the amount of heavy vehicle traffic.

No salt roads should be constructed on or close to the powerstation site, due to the additional corrosion problem caused.

There are airports at both Oranjemund and Alexander Bay.

Oranjemund has an automatic telephone exchange and full cellphone reception. Both of these services will have to be extended to the site, and negotiations will have to be held with Telecom Namibia and MTC respectively in this regard.

3.2.2 Urban Infrastructure Services

3.2.2.1 Water Supplies

1. Potable water for both construction and for the construction camp will most likely be taken from the Oranjemund municipal supply system. A pipeline should follow the route of the

coastal access road from Oranjemund to the site for easy maintenance and to reduce the impact on the environment as far as possible. Construction materials of the pipeline should be non-corrodible, and the pipeline should be installed underground to reduce corrosion. A pump station will have to be built near the offtake from the existing Oranjemund reticulation

2. Boiler make-up water will most likely be piped to the site from an abstraction point at Hohenfels upstream on the Orange River. This pipe should follow the road between the site and Hohenfels, and should run parallel to the potable water pipe from Oranjemund to the site. Decisions on exact route, construction above or below ground, materials selection, etc., will have to be taken at final design stage. Air and scour valves should be constructed to resist corrosion and vandalism.
3. Cooling water pipeline routes and supply principles need to be resolved before commenting.

3.2.2.2 Electricity Supplies

Two 30kV overhead powerlines run past the construction site at a distance of about 0,5 km. The lines are part of the NamDeb infrastructure, and are the power supplies to the Namdeb workshop at Uubvlei. A power supply for the duration of the construction period will have to be negotiated either by the EPC contractor or by the principals. Up to 1 MVA will be required for the construction period, and this supply option is far more attractive than the alternative of generating own power using Diesel generators. If the EPC contractor generates own power, the management of the powerstation, Diesel and lubricants, and service spares will have to follow the same principles as those of the construction equipment fleet on site. Any overhead powerlines or structures constructed to supply power to the camp and the site will have to be removed at the end of the contract.

3.2.2.3 Waste Water

The sewage generated by the existing hostel complex at Uubvlei is piped to the sea and discharged into the ocean without any treatment. If the EPC contractor does reach agreement with Namdeb regarding the use of the hostel complex as accommodation for the construction workforce, then he will have to upgrade the existing sewage installation. Upgrade will have to include a treatment plant so that the sewage ultimately discharged into the sea meets the applicable Namibian standards. A license to operate the sewage system will have to be obtained from MET. The existing outfall pipe will be able to be re-used, but may have to be extended to comply with the licensing requirements.

If a new temporary construction camp is built, a new sewage disposal works will have to be constructed.

Two options exist for this item:

- Sewage and waste water from both the temporary accommodation camp and the powerstation could be disposed of in the Oranjemund municipal treatment works. These are situated south of the town, have sufficient spare capacity for the full 1300 temporary workforce, and a 27 km long rising main and connection to the existing sewer outfall line from the town would have to be constructed. Depending on the topography of the route along the road between Uubvlei and the town, a number of pump stations would have to be incorporated in the rising main to handle the sewage flow over this distance. This option has the advantage of making use of the

existing facilities of Oranjemund and would not create a new effluent source for the project. However, costs would very likely be prohibitive in comparison with a sea discharge option.

- Sewage could be discharged to sea after treatment, with an outfall pipe following the route of the existing hostel line. One pumpstation will be required at the site, as well as one at the construction camp, to pump the waste water to the treatment works. The pumpstation and rising main from the powerstation site should be permanent, and the construction camp pumpstation could make use of the same rising main, with connection and pumpstation to be removed after completion of the construction phase. The pipeline should be installed underground, with the route following that of the existing hostel pipe line. Proper maintenance and operation of the whole sewage installation will be required, to ensure compliance with general health standards and to minimize the impact on the environment.

3.2.2.4 Solid Waste Disposal and Management

During construction the major source of solid waste will be:

1. Packaging: plastic, glass, metal containers, strapping, wrapping and paper, wood and polystyrene etc. Cement will probably be delivered in bulk, not in pockets.
2. General domestic type refuse from the construction camp.
3. Excess construction materials as rubble, breakages, discarded items and materials (builder's rubble).
4. Hazardous waste in the form of used oils, hydraulic fluids, paints, paint containers, solvents and containers, batteries etc.

It is probable that equipment and plant will arrive on site in one-way containers.

Environmentally sensitive construction materials will include: cement, concrete additives, lubricants, fuels, gases, solvents and paints. Paints will most probably be the largest item after Diesel fuel and cement, since corrosion protection will require very good painting systems applied to all exposed surfaces. Depending on design details, this should also include all concrete surfaces. Concrete additives may be required to assist in salt and sulphate resistance of foundations, footings, surface beds and foundation walls, as well as all concrete building structures. Prevention of spills, leaks and the proper disposal of empty containers will require special management.

Buildings and areas where petroleum products and gases, solvents, paints and other products ruled by SABS 0228 are to be stored, handled and dispensed will have to be constructed in compliance with SABS 0262 and SABS 089 respectively. In addition, the licencing requirements for a fuel depot and dispensing site set by the Ministry of Mines and Energy will have to be complied with.

During the operational phase of the powerstation, a much smaller volume of waste will be produced, but will include items like batteries, waste oils and lubricants, packaging materials of spares and consumables, paints and solvents as well as scrapped parts and components.

For both phases, the recommended option is to make use of the Oranjemund waste disposal facility, and to deal with normal and hazardous waste under a waste management plan in a responsible manner. No new waste landfill site should be established for the plant near Uubvlei, as this would have to be fully rehabilitated during the decommissioning stage of the plant.

3.3 Summary of potential impacts of infrastructure and urban services

3.3.1 Construction Period

Four impacts are identified during the construction phase which may have significant environmental impacts. This means that they could have sufficient influence on the environment to affect the project design or require alternative mitigation. These are: -

- Roads Construction
- Construction of water pipe lines
- Sewage Disposal
- Waste Disposal

The construction of roads should be planned together with a management plan for their regular maintenance. No off-road vehicle traffic should be permitted. The condition of road surfaces should be maintained at a level of quality which would ensure that no corrugations or potholes exist. This will assist in preventing vehicles from driving on road shoulders or from creating new tracks and access routes to avoid roads in poor condition.

The proposed options for water supplies envisage pipe line routes adjacent to roads, to reduce any impact on the environment. Routes may in some cases be somewhat longer than if a direct route was chosen, but this would ensure that no new service tracks would be necessary through potentially sensitive areas.

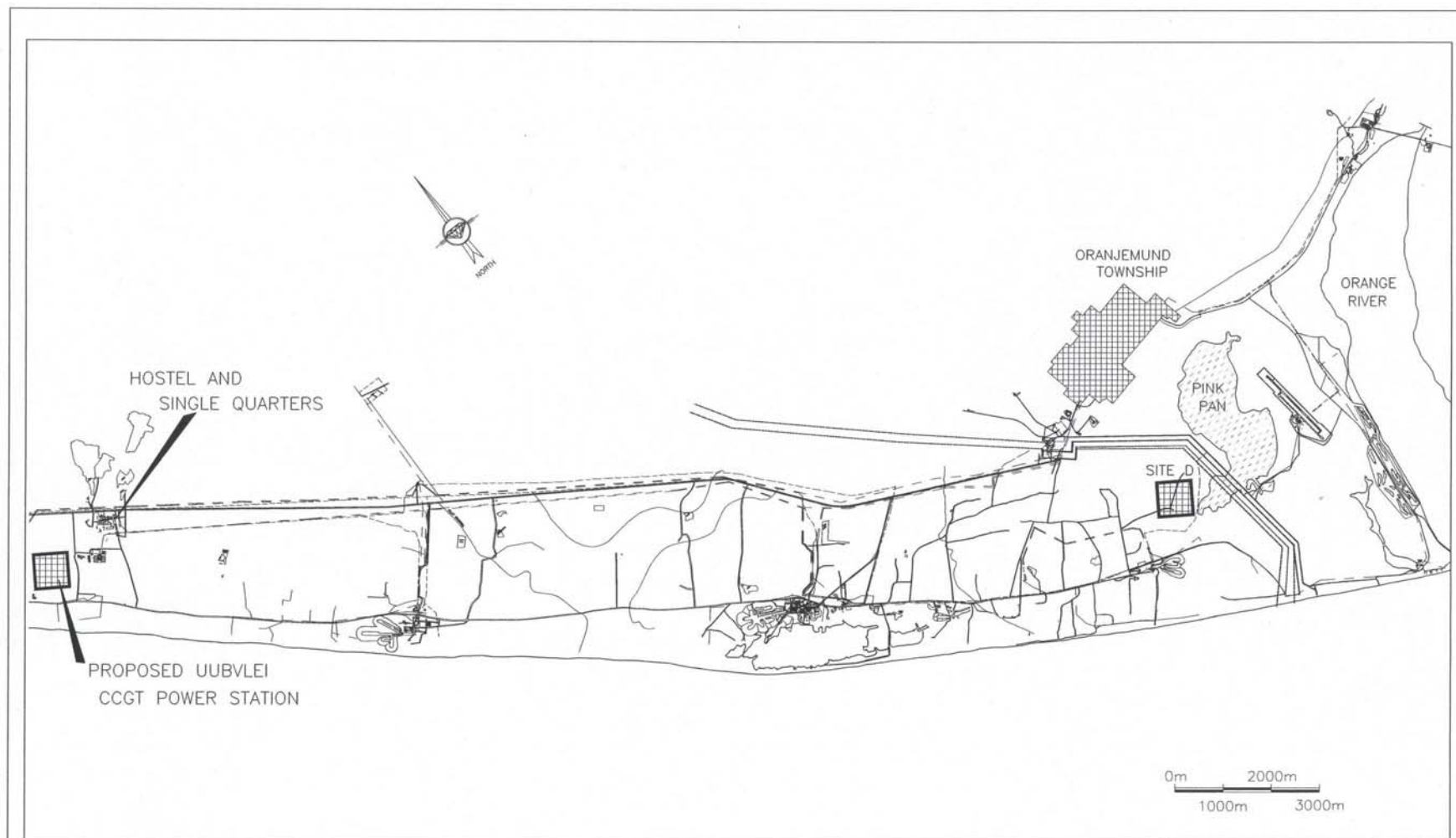
Sewage disposal into the sea as proposed as the best option must be managed to set environmental and health standards and in strict accordance with the licensing requirements.

Waste handling and disposal should be done to a strict management plan to eliminate the risk of accidental spillages or disposal of waste to a location other than the Oranjemund waste dump. The management plan will have to include waste collection and transport by truck to Oranjemund.

There are no impacts of high significance and / or high intensity.

3.3.2 Operational Period (20 – 40 years) and Decommissioning Period (1 year)

There are no impacts of high/medium significance and/or high/medium intensity.




DATE: APRIL 2005
Plan No: UUBVLEI_1

DIAGRAM 1
LOCATION OF UUBVLEI HOSTEL
AND SINGLE QUARTERS

ENV-D-C 2004-026

**AIR QUALITY SPECIALIST STUDY FOR
THE PROPOSED KUDU COMBINED CYCLE
GAS TURBINE POWER STATION AT
UUBVLEI, NAMIBIA**

**Issued by:
Division of Water, Environment and Forestry Technology,
CSIR
P O Box 17001, Congella, 4013, South Africa**

**A RAGHUNANDAN
G SCOTT
M ZUNCKEL
S PILLAY
M A OOSTHUIZEN
M MATOOANE**

JUNE 2005

REPORT APPROVAL

TITLE: Air quality specialist study for the proposed Kudu Combined Cycle Gas Turbine Power Station at Uubvlei, Namibia

CONSULTANTS: Division of Water, Environment and Forestry Technology

AUTHORS: A. Raghunandan, G. Scott, M. Zunckel, S. Pillay, M. Oosthuizen, M. Matooane

REPORT STATUS: Final

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APPROVAL:

YES	NO
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SIGNATURE:.....

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Executive Summary

The Kudu Power Project proposes to use natural gas from the Kudu Gas field located 170km offshore in Namibian territorial waters, for the purpose of generating electricity at an 800MW combined cycle gas turbine (CCGT) power station at Uubvlei, approximately 25 km north of Oranjemund.

This specialist air quality study for the proposed site comprises four main components. The first component is a description of the receiving environment, followed by air dispersion modelling which is used to estimate the concentration of pollutants in the ambient environment as a result of emissions from the proposed development. This is followed by a risk assessment of the predicted concentrations to human health and the potential impact on vegetation in the surrounding area. The last component is an assessment of the potential impacts which considers their significance, extent, duration and intensity.

Air dispersion modelling was undertaken using the US-EPA approved CALPUFF suite of models, to predict ambient air pollution concentrations and deposition rates. Four development scenarios were modelled i.e. 800 MW gas-fired, 1600 MW gas-fired, 800 MW oil-fired and 1600 MW oil-fired. All scenarios take NO_x mitigation into account. The pollutants modeled include NO_x, SO₂ and PM₁₀. The results of the dispersion modelling were assessed in a human health risk assessment and a vegetation impact assessment.

Based on the results of the dispersion modelling and risk assessments the following conclusions may be drawn:

- For PM₁₀ and NO_x, no acute or chronic health effects are expected in any healthy or sensitive individuals from the emissions of the proposed CCGT power station at the proposed site.
- For 1-hour SO₂ concentrations from the oil stack at double capacity, individuals at the site are at risk.
- Dust generated during the construction phase, particularly after the early excavation period may have a nuisance impact beyond the immediate region under windy conditions. Management measures to minimize or mitigate the impact must be implemented.
- The proposed development will not have a significant impact on the surrounding vegetation.

Based on a comprehensive air quality modelling exercise, using the best available input data, and risk assessments, it is apparent that impacts from emissions from the proposed Kudu CCGT power station are limited to the immediate area surrounding the plant, they will however persist for the lifetime of the plant. The intensity of the impact are expected to be low.

The predicted ambient concentrations at the Uubvlei site are slightly higher than those modelled at Site D, Oranjemund. This is attributed to the differences in topography and local meteorology between the two sites.

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GLOSSARY OF ACRONYMS, ABBREVIATIONS AND DEFINITIONS

ADD	Average Daily Dose
AHSMOG	Adventist Health Study of Smog
ATSDR	Agency for Toxic Substances and Disease Registry (USA)
CALPUFF	California Puff Model
CCGT	Combined Cycle Gas Turbine
CCINFO	Canadian Centre for Occupational Health and Safety Information Systems
CO ₂	Carbon Dioxide
COPC	Compounds of Potential Concern
CSIR	Council for Scientific and Industrial Research
DRL	Dose Response Level
HEI	Health Effects Institute
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IDZ	Industrial Development Zone
IRIS	Integrated Risk Information System (USA EPA)
ISC3	Industrial Source Complex Model
Km	Kilometer
LADD	Lifetime Average Daily Dose
LOAEL	Lowest Observed Adverse Effect Level
m	Meter
MRL	Minimal Risk Level
MW	Megawatts
NO ₂	Nitrogen Dioxide
NO _x	Oxides of Nitrogen
NOAEL	No Observed Adverse Effects Level
PM _{2.5}	All condensed material suspended in air that has a mean aerodynamic diameter of 2.5 micrometers or less
PM ₁₀	All condensed material suspended in air that has a mean aerodynamic diameter of 10 micrometers or less
PM	Particulate Matter
REL	Reference Exposure Level
RfC/RfD	Reference Concentration or Reference Dose
SAWS	South African Weather Service
SO ₂	Sulphur Dioxide
TAPM	The Air Pollution Model
TLV	Threshold Limit Value
TSP	Total Suspended Particulates
UF	Uncertainty Factor
µg/m ³	Micrograms per cubic meter
USA	United States of America
US-EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	World Health Organisation

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AIR QUALITY AND HUMAN HEALTH SPECIALIST STUDY FOR THE PROPOSED KUDU COMBINED CYCLE GAS TURBINE POWER STATION AT UUBVLEI, NAMIBIA

1. INTRODUCTION AND BACKGROUND INFORMATION

Namibia's electrical power demand has grown from 225 MW in 1992 to 378 MW in 2003, representing a 59% growth in demand over an 11-year period. Projected demand has been estimated to increase annually at 4% over the next 8 years. Namibia currently has three electricity generation sources, a coal-fired thermal power station at Windhoek (120 MW), a diesel powered station at Walvis Bay (24 MW) and a hydro-electric power station at Ruacana (249 MW). The excessive cost of coal landed at Windhoek makes the production of electricity at the Windhoek station uneconomical. In addition, Ruacana is a run-of-river hydro-electric power station and the water storage capacity is limited. Power generation at the Ruacana station is limited by the water flow in the Kunene River, which is highly variable due to seasonal fluctuations in rainfall. These factors have a major impact on NamPower's ability to supply demand from its own generating facilities with the bulk of the demand imported from South Africa.

The Kudu Power Project proposes to use natural gas from the Kudu Gas field located 170km offshore in Namibian territorial waters, for the purpose of generating electricity at an 800MW combined cycle gas turbine (CCGT) power station at Uubvlei, approximately 25 km north of Oranjemund (Figure 1.1).

A study by Black and Veatch in 1997 identified Oranjemund as the most preferable location for the power station. Oranjemund is a small diamond mining town owned by Namdeb Corporation. The town is located near the mouth of the Orange River in the south-western corner of Namibia. The Orange River forms the border between Namibia to the north and South Africa to the south. An air quality specialist assessment was undertaken for Site D at Oranjemund (CSIR, 2004b). However due to concerns raised by Namdeb it was decided to investigate the Uubvlei site as an alternative.

The Kudu Power Project comprises three main developments:

- 1) The development of the Kudu gas field, construction of a pipeline to the power plant and gas conditioning plant adjacent to the power station;
- 2) The construction and operation of the power plant;
- 3) The construction of power lines from the power station to feed into the Namibian and South African power grids.

This study will only address the second of the proposed developments, i.e. the construction and operation of the CCGT power station at Uubvlei.

CSIR Environmentek has been appointed as the lead consultant by NamPower to manage the EIA. In order to investigate the potential impacts associated with the proposed power station, specialist studies have to be undertaken, drawing on the issues and concerns raised during the Feasibility and Scoping Phase of the project. This report details the results of the Air Quality Specialist Study at Uubvlei. The terms of reference for the study are detailed in Section 2.

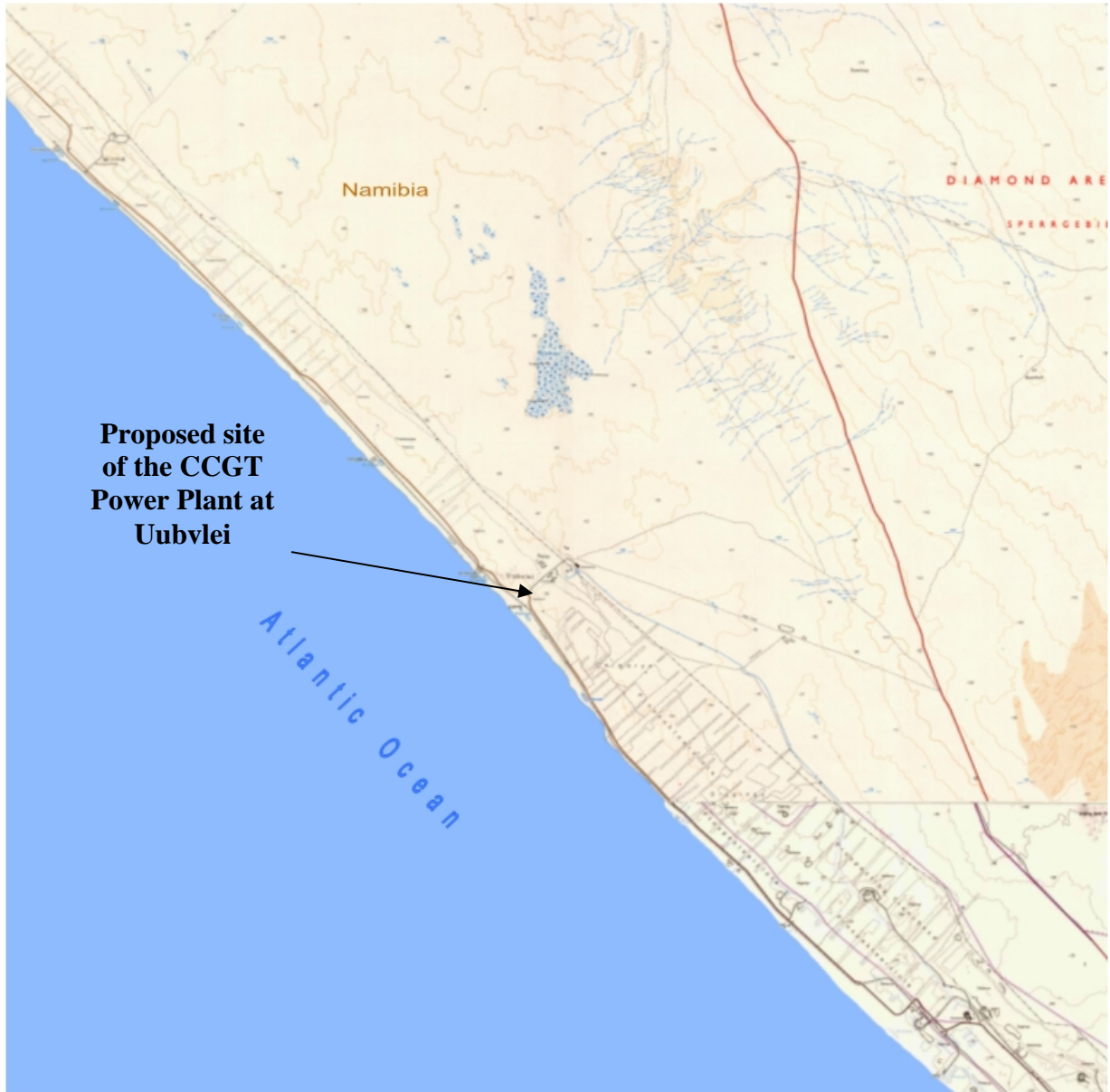


Figure 1.1: Proposed location of the Kudu CCGT Power Station in Uubvlei

2. TERMS OF REFERENCE

This Air Quality Specialist Study will address the generation and subsequent dispersion of air pollution from the proposed CCGT power station at Uubvlei, approximately 25 km north of Oranjemund. The study will also assess the potential impacts of air pollutants resulting from power generation process on human health and the surrounding vegetation. The study will be required to achieve the following objectives:

1. To outline the approach to the study, identifying assumptions and sources of information.
2. To briefly describe the affected environment and its sensitivity in terms of this study.
3. To identify current and potential future sources of risk to the environment during construction, commissioning and operation of the project.
4. To quantify, wherever possible, the potential direct and cumulative effects.
5. To assess the significance of the impacts.

This will be achieved through the following components:

Description of the affected environment

Including a site visit, this component includes a discussion of the prevailing meteorology, the current status of air quality in the study area, a description of the receiving environment with regard to potential receptor communities and their sensitivity in terms of the proposed project.

Verification of emissions

This component will be done in collaboration with the representatives of Nampower and other relevant stakeholders, to agree on emission parameters for the proposed project and other emissions in the study area.

Identification of pollutants of concern

Pollutants of concern will be identified based on the emissions inventory and the risk that the various pollutants pose to human health and the environment.

Air dispersion modelling

Air dispersion modelling will be conducted using the United States Environmental Protection Agency (US-EPA) approved CALPUFF suite of models. Surface meteorological data from the South African Weather Service (SAWS) monitoring station in Alexander Bay will be used in conjunction with modelled data from the CSIRO TAPM model. Dispersion modelling was conducted for a number of emission scenarios and considered commissioning, normal operations, and potential upset conditions.

The dispersion modelling will result in estimations of the concentration of selected pollutants in the ambient environment for three exposure periods, namely maximum 1-hour, maximum 24-hour and annual average.

The modelled results will be evaluated in terms of the Namibian and South African air quality guidelines as well as other relevant international air quality guidelines and standards, such as the World Health Organisation (WHO) and the World Bank.

Human health risk assessment (HHRA)

The HHRA will follow generally accepted United States Environmental Protection Agency (US-EPA) protocol. The modelled data will be used to assess the potential exposure of identified sensitive human receptor communities. The exposure will, in turn, be used to calculate the risk of these communities to the pollutants of concern.

Vegetation Risk Assessment

The vegetation risk assessment will compare the modelled ambient and deposition data with the results of field and laboratory experiments on the impact of air pollution on vegetation.

Emissions of pollutants that have potential regional and global scale impacts

These emissions will not be modelled, however the potential impacts will be assessed qualitatively.

Impact assessment

The significance of potential impacts will be described in terms of provided and accepted guidelines/standards. Similarly, the nature of all potential impacts will be described according to accepted EIA convention. Impacts will be described before and after proposed mitigation.

3. APPROACH TO THE STUDY

This specialist study comprises four main components. The first component is a description of the receiving environment, followed by air dispersion modelling which is used to estimate the concentration of pollutants in the ambient environment as a result of emissions from the proposed development. This is followed by a risk assessment of the predicted concentrations to human health and the potential impact on vegetation in the surrounding area. The last component is an assessment of the potential impacts which considers their significance, extent, duration and intensity.

3.1 Description of the Affected Environment

A site visit is conducted to Oranjemund and Uubvlei during this component of the study. The intention is to develop a familiarity with the study area and the development site and to assess the relative location of potentially sensitive receptors relative to the proposed development, with consideration of prevailing winds. The site visit also allows an opportunity to identify other sources of air pollution in the area and allows the opportunity to source site specific information relative to the study.

The meteorological description of the study area is based on observations from the South African Weather Service (SAWS) station based at Alexander Bay and seven modelled sites. The modelled sites were generated using The Air Pollution Model (TAPM). TAPM is a prognostic meteorological and dispersion model developed by the CSIRO in Australia (Hurley, 1999). This model assists in overcoming a lack of site-specific meteorological information, by generating surface and upper air data that can be used in dispersion modelling exercises. There is no ambient air quality monitoring currently being undertaken in the study area.

3.2 Dispersion Modelling

A variety of models are available for air dispersion studies. The selection of the most appropriate model for an air quality assessment needs to consider the complexity of the problem and factors such as the nature of the development, its sources, the physical and chemical characteristics of the pollutants that are emitted and the physical location of the source.

For example, a simple box or screening model could be used in a modelling exercise that requires a broad-level assessment of the dispersion of a single pollutant from a single source over flat topography. In a more complex modelling exercise, the Industrial Source Complex Model (ISC3) could be used to simulate the dispersion of pollutants over relatively flat terrain from an industrial complex that comprises multi-point and diffuse sources. Although the topography in the Uubvlei area is relatively simple, the proximity of the study area to the Atlantic Ocean requires a specialised modelling approach. The US-EPA's Californian Puff (CALPUFF) dispersion model is such a model. It is a Lagrangian model that treats emissions as a series of puffs. CALPUFF has the ability to simulate dispersion over complex terrain and also for calm winds (< 2 m/s).

3.2.1 Meteorological Model - CALMET

CALMET is a meteorological model that includes a wind field generator containing objective analysis and parameterized treatments of slope flows, terrain effects and terrain blocking effects. This meteorological pre-processor produces gridded fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables for input into the CALPUFF dispersion model.

CALMET requires geophysical data including gridded fields of terrain elevation and land use categories. This data was accessed from geophysical data bases for a 25 km x 25 km modelling domain at a 1km resolution. The topography in the vicinity of the proposed site is relatively simple and the main topographic features were well resolved at the selected resolution.

The CALMET pre-processor requires as input, hourly values for discrete points of:

- Dry bulb temperature
- Wind speed
- Wind direction
- Cloud amount and height
- Relative humidity
- Surface pressure
- Sea surface temperature
- Temperature and wind data from upper air soundings

All available monitored hourly average meteorological data from the Alexander Bay station for 2000 and 2001 were considered as inputs to the dispersion modelling. The observed data from the Alexander Bay station was augmented with model derived surface and upper air meteorological data at nine selected points within the modelling domain (Figure 3.1). The Australian CSIRO meteorological processor, The Air Pollution Model (TAPM) (www.dar.csiro.au/tapm) was used to generate hourly wind speed, wind direction, temperature and surface pressure at each of the locations. TAPM was also used to generate hourly upper air sounding data consisting of wind speed, wind direction and temperature at 15 levels from the surface to approximately 3000 m at each of the nine stations.



Figure 3.1: Location of TAPM stations

The meteorological component of TAPM is an incompressible, non-hydrostatic, primitive equation model with terrain following vertical coordinates for three-dimensional simulations (Hurley, 1999). The model solves the momentum equations for horizontal wind components, the incompressible continuity equation for vertical velocity, the scalar equations for potential temperature and specific humidity of water vapour, cloud and rain water. The synoptic scale pressure gradient is represented explicitly in horizontal momentum equations as a function of the synoptic wind, which is input to TAPM. TAPM includes parameterisation for vegetative canopy, soil and radiative fluxes.

TAPM has been successfully applied in previous dispersion modelling exercises undertaken in South Africa by the CSIR (CSIR Environmentek, 2002 & 2004b). The model has been extensively verified in Australia and other international locations. The CSIRO has verified the model at the following sites in Australia, Kwinana, Perth, Pilbara, Cape Grim, Melbourne, Newcastle, Sydney, Mount Isa and Port Pirie. TAPM has been validated in the following international location, Kuala Lumpur (Malaysia) as well as for Kincaid and Indianapolis (USA) international tracer datasets. TAPM data, together with monitored data provide comprehensive surface and upper air data coverage of the study area.

3.2.2 The CALPUFF Model

CALPUFF is a multi-layer, multi-species non-steady state puff dispersion model, which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF uses three-dimensional meteorological fields developed by CALMET.

CALPUFF contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer-range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects.

The model employs dispersion equations based on a Gaussian distribution of pollutants across the puff. It also takes into account the complex arrangement of emissions from stacks, represented as point sources. As with any mathematical environmental model, the CALPUFF model represents a simplification of the many complex processes involved in determining the outcome, in this case ground level concentrations of pollutants. The effects of topography on the height of the puff are considered by CALPUFF for the different atmospheric stability categories, i.e. stable, unstable and neutral. CALPUFF compares favorably to other approved regulatory models currently used in air dispersion studies (i.e. ADMS and ISC3).

The model requires the following input data:

- Three-dimensional meteorological data output from CALMET
- Emission data, plant layout and dimensions.

NamPower provided plant dimension information used in the modelling exercise and all the emission data.

A network of uniformly spaced receptor points, 1 km apart, has been used, covering a 25 km by 25 km study area of approximately 625 km², centered on the proposed site (Figure 3.1).

3.2.3 Emission Scenarios

A range of emission scenarios is proposed for the assessment of the Kudu CCGT Power Station. Details of these emissions scenarios are presented in Table 3.1 below. The proposed development will be the major source of industrial air pollution in the study area. Domestic emissions from the Uubvlei area are not included in the emissions inventory. Natural sources of air pollution are also not considered in this modelling exercise i.e. sand storms and sea spray. However the potential impacts of these natural sources are considered in terms of mitigation measures in Section 10.

Table 3.1: Emission scenarios modelled

Scenario	Sources	Pollutants To Be Modelled
Construction	Roads and construction site	Particulates
800 MW generating capacity: Normal operations		
Gas cycle only	CCGT power station	NO _x
Fuel oil cycle only	CCGT power station	SO ₂ , NO _x , Particulates
1600 MW generating capacity: Normal operations		
Gas cycle only	CCGT power station	NO _x
Fuel oil cycle only	CCGT power station	SO ₂ , NO _x , Particulates

A detailed emissions inventory for the proposed CCGT power station and the different operational scenarios is presented in Section 8.

3.3 Assessment of Potential Impacts on Human Health

3.3.1 Risk Assessment Approach

Risk assessment is the general process of identifying the probable negative effects of exposure to a hazardous agent or situation. A risk is the potential adverse effect that could be caused by a hazard. Risk is determined by the nature of the hazard, exposure potential, exposure population characteristics, likelihood of occurrence and magnitude of exposure. The hazard is therefore the chemical, physical or biological agent or set of conditions that has a potential to cause harm.

A Health Risk Assessment is defined by the US-EPA as a qualitative and/or quantitative process conducted to characterise the nature and magnitude of risks to public health from exposure to hazardous substances released from specific sites.

Any health risk assessment follows a defined procedure in order to determine the risk potential. This procedure, developed by the National Academy of Science in the USA, is as follows:

- Hazard identification
- Exposure assessment
- Dose-response assessment
- Risk characterisation
- Risk communication

Hazard identification is aimed at determining if exposure to a particular substance could result in adverse human health effects. It typically focuses on agent-specific data such as:

- Physico-chemical properties relevant to exposure
- Sources, routes and patterns of exposure

- Structure-activity relationships
- Metabolic and pharmacokinetic properties
- Short-term *in vivo* and *in vitro* tests
- Long-term animal studies
- Human exposure studies
- Human epidemiological studies.

Exposure assessment involves the determination of the emissions, pathways and rate of movement of a substance as well as its transformation and degradation in the environment. This information is used to estimate the concentration/doses to which human populations are or may be exposed.

Monitored or modelled environmental data for various media is used to calculate a numeric estimate of the pollutant dose individuals are likely to receive. Quantitative exposure assessment focuses on the following areas:

- Determination of environmental concentrations through source and emissions characterization, monitoring, and/or environmental fate, transport, and deposition modelling.
- Estimation of the magnitude, duration, and frequency of human exposure for relevant subpopulations according to geographic distribution, activity patterns, and population estimates.
- Estimating the dose received, usually expressed as an oral/dermal Maximum/Average Daily Dose (ADD) for acute, sub-chronic, or chronic exposures to non-carcinogens, or as an oral/dermal Lifetime Average Daily Dose (LADD) or adjusted inhalation concentration for carcinogens.

Exposure may be influenced by patterns of behaviour that may vary significantly among countries or regions according to culture, education and climate. When conducting an exposure assessment, time-activity patterns (the time people spend in different microenvironments and their activities in those environments) should ideally be evaluated. Important patterns to consider include spatial distributions (commuting), food consumption (e.g. quantities consumed and sources, such as home-grown vegetables), time spent outdoors vs. indoors, and specific activities (such as swimming). Specific behaviour may also significantly contribute to or minimise exposure, for example personal hygiene and smoking habits. Exposure assessment is typically the most difficult part of the health risk assessment and is most prone to uncertainties.

Dose-response assessment is the estimation of the relationship between dose, or level of intake of a substance, and the incidence and severity of an effect. The dose-response relationship is ascertained from toxicological information supplied from:

- Human epidemiological studies
- Human exposure studies
- Animal exposure studies
- Short-term *in vivo* and *in vitro* tests.

Although dose-response estimates based on human data are preferable, those derived from animal data are often used when appropriate human studies are limited or not available. Factors such as pre-existing illness, exposure to other stressors and nutritional status should ideally be considered for the dose-response estimate calculations.

Numeric benchmark values obtained from literature are used to describe the dose-response relationships. The benchmark values most commonly used are:

- Reference dose (RfD) or reference concentration (RfC); these benchmark values represent the pollutant levels that, if ingested or inhaled over a specified time period no adverse non-cancer health effects will occur. The Californian EPA equivalent is the Reference Exposure Level (REL) and that of the Agency for Toxic Substances and Disease Registry (ATSDR), the Minimum Risk Level (MRL).
- Oral slope factor and inhalation unit risk; these benchmark values are used to describe the cancer potency of ingested or inhaled pollutants respectively.

Risk characterisation combines all the information obtained in the previous three steps of the risk assessment to describe the public health consequences of exposure to the pollutant of interest. It can be a qualitative or quantitative process.

Whereas a qualitative risk characterisation is purely a descriptive assessment, the product of a quantitative risk characterisation is a numeric estimate of the public health consequences of exposure to the pollutant. Two types of risk estimates are calculated in a quantitative health risk assessment:

- The cancer risk, which is the probability of individuals developing cancer from exposure to a hazardous substance,
- The hazard quotient (HQ), which describes the potential for developing toxic effects (other than cancer) from exposure to a hazardous substance.

Risk characterization in a quantitative health risk assessment can vary from a single exposure medium, single exposure pathway through to multi-media and multi-pathway exposure. A multi-pathway, multi-media health risk assessment refers to a health risk assessment in which risk of exposure to pollutants present in multiple environmental media (soil, water, food, air, plants) and all possible routes in which these pollutants may enter the human body (inhalation, ingestion, dermal) are evaluated. The environmental pollutants commonly assessed in a multi-media/multi-pathway health risk assessment are metals, polycyclic aromatic hydrocarbons, chlorinated hydrocarbons and pesticides.

The advantage of a health risk assessment over other environmental health linkage methods (observational studies or analytical epidemiology studies) is that a health risk assessment is predictive in nature and uses existing exposure data to quantify health effects of exposure to a certain substance (Briggs *et al.*, 1996). It can therefore be conducted in a much shorter period of time than the other methods, which is also more economic.

Uncertainties and limitations

The actual risk associated with a hazard can only be assessed and measured once damage due to exposure to that hazard has occurred. Human health risk assessment is a *predictive* process that is able to assess the likelihood of adverse health effects occurring as a result of exposure to a hazardous substance. The risks can therefore only be *estimations* of what could occur, and as such have uncertainty associated with them. Human health risk assessments are generally quite conservative as they include many safety factors that are built into the process. The final risk estimate is therefore likely to overstate the actual risk.

Uncertainty in health risk assessments can be classified into three types (Finkel, 1990, US EPA, 1998):

- Variable uncertainty
- Model uncertainty
- Decision-rule uncertainty

Variable uncertainty occurs when variables appearing in equations cannot be measured precisely or accurately, either due to equipment limitations or spatial/temporal variances in the quantities being measured. Areas in which variable uncertainty may occur include:

- The determination of pollutant emissions
- The use of population demographics or statistics
- The determination of activity patterns and health status of individuals.
- The determination of ambient levels of the pollutants under consideration.

Model uncertainty is associated with all models (and equations) used in all phases of the risk assessment, including:

- Animal models used as surrogates for testing human carcinogenicity.
- The dose-response models used in extrapolations in the determination of health benchmark values such as RfCs, MRLs, and TLVs.
- The use of computer models to quantify exposure and risk.

Decision-rule uncertainty is associated with the manner in which the risk assessor conducts the study. This may include:

- The selection of the compounds of potential concern to be included in the risk assessment.
- The use of national and international ambient pollutant guidelines/standards as significant values with which health effects may be associated.
- The decision as to which exposure pathways are most significant.
- Decision on the size distribution and concentrations of particles.

3.3.2 The EPA Risk*Assistant™ Model

The study team, in the health assessment portion of this study, used equations from the computer model Risk*Assistant™.

Risk*Assistant™ is a computer software model developed by the Hampshire Research Institute to conduct human health risk assessments quickly and efficiently and is sponsored by the US EPA.

3.3.3 Definition of Receptors for Risk Assessment for this Study

Hazard identification

The hazard identification process, to determine the compounds of potential concern (COPC) for this study, was carried out through extensive literature searches where the most recent and reliable information on each pollutant was used.

The selection of pollutants of concern for this study is defined as the major pollutants typically emitted from CCGT power production operations. These are listed in Table 3.2. Quantitative health risk assessments were required only for SO₂, NO_x and PM. Other pollutants were considered in a qualitative manner.

Table 3.2: Compounds of potential concern and health endpoints.

Medium	Compounds of potential concern	Health endpoint
Air	Sulphur Dioxide (SO ₂)	Broncho-constriction
	Oxides of Nitrogen (NO _x)	Increased risk of respiratory infection
	Particulate Matter (PM)	Respiratory, cardiovascular effects

Selection of receptor points

The receptor points chosen for this study include the proposed site. The selection criteria for these receptor points are:

- Geographical spread around the proposed development.
- Location of human settlements where exposure is most likely to occur in order to protect the most sensitive individuals.
- Location of areas with natural vegetation and cultivated lands.
- Location of recreational and tourist areas.

Exposure assessment

The exposure assessment considers the following:

- The emissions and pathways of the pollutants in the environment.
- The estimated concentrations (or doses) of the pollutants that the target population is exposed to.
- The target population exposed to the pollutants, and the target organs in the body which are affected by exposure to the pollutants.
- The magnitude, frequency and duration of exposure of the target population, as well as behaviour patterns, geographic distribution and population size of the target population. Since behaviour patterns of the specific communities are not known, default values according to the EPA exposure factors handbook have been used (EPA, 1996).
- The estimated dose received (van Leeuwen and Hermens, 1995; Paustenbach, 1989).

The exposure assessment scenarios are shown in Table 3.3. Risks are determined for a normal adult and a child of 10 years old, representing a sensitive individual.

Table 3.3: Emission and exposure scenarios for SO₂, PM and NO_x

PM			
	Receptor	Receptor point	Time
Construction activities	Adult Child (10years)	All receptor points	1 hour 24 hour Annual
Sulphur Dioxide, TSP and NO _x			
CCGT – normal / upset / shut down	Adult Child (10years)	All receptor points	1 hour 24 hour Annual
CCGT – double capacity			

This study only considers air pollution from the proposed power station. The limitation of this approach is that urban air pollution sources such as domestic fuel use and motor vehicle emissions are not considered, neither are emissions from the local diamond mining industry. The impact of air pollution *per se* is therefore not considered quantitatively but an assumption is made that indoor and outdoor air pollution concentrations are similar. It is important to note

that maximum 1-hour and 24-hour concentrations are used in the risk assessment. The results therefore do not present ranges, but rather the worst-case scenario.

Dose-response assessment

The dose-response assessment is the process of identifying the relationship between the exposure level or dose and the severity of the health effects likely to be experienced. Dose-response can be affected by population characteristics such as age, sex, lifestyle, occupation and existing diseases, among other things (van Leeuwen and Hermens, 1995; Paustenbach, 1989).

The preferred guidelines or standards used in a human health risk assessment are obviously those set on the basis of health effects in human beings and not those incorporating economic or social factors. For this reason the proposed new South African standards are used where possible. If there is no existing or proposed guideline/standard for a specific pollutant or exposure period, then other guidelines that are also based on human health, from regulatory authorities such as the US EPA and WHO, are used.

Benchmark values, such as guidelines and standards, are derived by applying uncertainty factors (UF) to the no-observed-adverse-level (NOAEL), as follows:

$$\text{NOAEL} / (Uf_a * Uf_h * Uf_s * Uf_l)$$

Where: Uf_a = animal to human extrapolation, UF = 1 to 10
 Uf_h = average human to sensitive human, UF = 1 to 10
 Uf_s = sub-chronic to chronic exposure, UF = 1 to 10
 Uf_l = LOAEL to NOAEL, UF = 1 to 10

The maximum UF, if only one uncertainty factor is taken into account, will be 10. If two extrapolations are made, a maximum UF of 100 will be applicable. Therefore, a UF of 10 or less reflects a high confidence in the study from which the benchmark value was derived.

For this study the following acute and chronic dose-response levels are used:

- Sulphur dioxide 1-hour California EPA Standard of 660 $\mu\text{g}/\text{m}^3$ (252 ppb), the uncertainty factor is 1 suggesting a low degree of uncertainty in the standard. This standard is based on studies conducted on humans with the health end point being “respiratory system irritation”.
- Sulphur dioxide 24-hour average World Health Organisation (WHO) air quality guideline of 125 $\mu\text{g}/\text{m}^3$ (48 ppb), the uncertainty factor is 2 therefore a low degree of uncertainty is associated with this guideline. The guideline level is based on the health endpoint of “exacerbations of respiratory symptoms in sensitive individuals”.
- Sulphur dioxide annual average WHO air quality guideline of 50 $\mu\text{g}/\text{m}^3$ (19 ppb), the uncertainty factor is 2 therefore a low degree of uncertainty is associated with this guideline. The guideline level is based on the health endpoint of “exacerbations of respiratory symptoms in sensitive individuals”.
- Nitrogen dioxide 1-hour average WHO air quality guideline of 200 $\mu\text{g}/\text{m}^3$, the uncertainty factor is 0.5, therefore a low degree of uncertainty. The guideline is based on “slight changes in lung functions of asthmatics”.
- Nitrogen dioxide annual average WHO air quality guideline of 40 $\mu\text{g}/\text{m}^3$, the uncertainty factor is 0.5, therefore a low degree of uncertainty. The guideline is based on “slight changes in lung functions of asthmatics”.
- Proposed South African 24-hour standard of 300 $\mu\text{g}/\text{m}^3$ for TSP
- Proposed South African annual standard of 100 $\mu\text{g}/\text{m}^3$ for TSP

Risk Characterisation

Following the calculation of the Average Daily and hourly doses, the Hazard Quotient (HQ) is determined for both acute and chronic health effects through the following equation. This equation is, in essence, the exposure assessment value divided by the dose-response value.

$$HQ = ADD / DRL$$

Where

HQ	= hazard quotient
ADD	= average daily dose (or average hourly dose taking inhalation rate and body weight into account),
DRL	= dose-response level (benchmark value).

The hazard quotient provides an indication of the likelihood of adverse health effects being experienced in the following way:

HQ < 1 indicates that there is no risk of adverse health effects due to exposure to the pollutant.

HQ > 1 implies that there is an increasing risk of adverse health effects likely to be experienced, predominantly in sensitive individuals.

HQ of 10 implies that the ADD is ten times more than the DRL, therefore not only are sensitive individuals likely to experience health effects but healthy individuals will also begin to experience adverse health effects.

3.4 Assessment of Impacts on Vegetation

NO_x was identified as important in terms of potential damage to vegetation in the study area. The potential impacts of NO_x on vegetation in the study area is based on published data on effects of atmospheric pollutants on vegetation, the results of air dispersion modelling for NO_x emissions from the proposed Kudu CCGT Power Station and the specialist studies on vegetation (Burke, 1998; Mannheimer, 2004) in the area around the proposed site. It must be noted that existing data on impacts of air pollution are essentially based on observations and experimental evidence for industrialised northern hemisphere countries. Information of potential impacts on local flora is very poorly documented, both in terms of field and laboratory investigations (Olbrich and van Tienhoven, 1998). Thus caution must be exercised in extrapolating published information to the current situation that is being assessed.

3.5 Impact Assessment

The impacts of the proposed development are described in terms of the following criteria, and the definitions thereof are presented below.

3.5.1 Extent

Where it specifies distance, area, space or range over which the impact is likely to occur:

- Local – where the impact will extend only as far as the activity.
- Site – where the impact will extend to the site and the immediate surroundings.
- Region – where the impact will extend to the province.
- National – where the impact will be of national importance or significance.
- Global – where the impact will have global importance or significance.

3.5.2 Duration

Where it is indicated the lifetime of the impact will be as follows:

- Short term – 0 to 5 years.
- Medium term – 5 to 15 years.
- Long term – where the impact will cease after the operational life of the activity.
- Permanent – where mitigation either by natural process or human intervention will not occur in such a way or in such a time span that the impact can be considered transient.

3.5.3 Intensity

Where it is established whether the impact is destructive or benign and is indicated as:

- Low – where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected.
- Medium – where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way.
- High – where natural, cultural and social functions or processes are altered to the extent that it will temporarily or permanently cease.

3.5.4 Probability of Occurrence

Where it describes the likelihood of the impact actually occurring as:

- Low – where the possibility of the impact materializing is very low, either because of design or historic experience.
- Medium – where there is a distinct possibility that the impact will occur.
- High – where it is most likely that the impact will occur.

3.5.5 Confidence and Status

A statement of the confidence in the assessment of the significance of the impact is made, based on available information and specialist knowledge. A description of the status of the impact identifies whether the impact will be positive (a benefit), negative (a cost) or neutral.

3.5.6 Significance of Impact

The assessment of the significance of the impact is based on the following:

- Low – where the impact will not have an influence on the decision or require to be significantly accommodated in the project design.
- Medium – where it could have an influence on the environment which will require modification of the project design or alternative mitigation.
- High – where it could have a “no-go” implication for the project regardless of any possible mitigation.

4. AIR POLLUTION SOURCES FROM THE PROPOSED KUDU CCGT POWER STATION PROJECT

An activity such as the proposed project will impact on the environment. This section describes the various stages of the CCGT electricity production process. Anticipated gaseous emissions, sources of these emissions and the various control measures that need to be implemented in order to contain pollution within the stipulated limits at each stage will also be highlighted.

4.1 Fugitive Emissions

Emissions to the atmosphere will occur during the construction, commissioning and operational phase of the project. Fugitive dust emissions will result from the following activities on the site:

- Site preparation
- Movement of vehicles
- Construction

Mitigation measures to control fugitive emissions are detailed in Section 10 of this report.

4.2 The Power Generation Process

The CCGT technology is replacing conventional coal-fired steam power stations internationally, particularly in the Northern Hemisphere and areas with a reliable supply of natural gas.

The proposed power plant at Uubvlei shall be a nominal 800 MW sized CCGT power plant consisting of 2 single shaft CCGT units. Each unit shall consist of a gas turbine, a waste heat recovery boiler and a steam boiler.

The gas turbine compresses air and delivers it to a combustion chamber. In the combustion chamber, the natural gas is introduced and burnt resulting in hot, high-pressure combustion gas which is then delivered to a power turbine. The hot high-pressure gasses are expanded through the power turbine, part of the gas turbine, thereby producing electricity in an electricity generator.

The hot exhaust gasses that have passed through the turbine will then be used in the waste recovery boiler to heat demineralised water to produce steam at a relatively high temperature and pressure. The high pressure steam produced will be used to drive a steam turbine to generate additional electricity. The steam leaving the steam turbine will pass through a condenser where it will be condensed and the resultant water returned to the waste heat recovery boiler for re-use. The steam turbine condenser will be cooled by once through circulation of seawater or saline groundwater.

From an air quality perspective, air pollution from a CCGT system will be minimal and it offers the greatest overall environmental advantage of conventional fossil-fuel operations (Proops et al., 1996).

CCGT power stations have a considerably higher operational thermal efficiency (~55%) compared with conventional coal-fired power stations (up to 34%) (Blakemore et al., 1998). Natural gas possesses a much lower carbon-content than coal and petroleum and in comparison produces lesser emissions of CO₂ and NO_x and negligible quantities of sulphur dioxide and black smoke per unit of energy consumed (Blakemore et al., 2001).

The combination of using natural gas and employing CCGT technology in a power station ultimately reduces CO₂ by 50% per unit of generated power (Blakemore et al., 1998). There will be negligible emissions of dust or particulates during the normal operation of the plant (Energy Management News, 2002). The main atmospheric emissions of concern from the proposed power station will be the oxides of nitrogen. However, according to Blakemore et al. (2001) a CCGT power stations will produce an 81% reduction of NO_x per unit of power of that generated by an equivalent coal-fired plant. The Air Pollution Control Office, Department of Environmental Affairs and Tourism, Pretoria, states that power stations in South Africa should emit no more than 300mg/m³ of NO₂ (Energy Management News, 2002).

5. AIR POLLUTANTS FROM THE COMBINED CYCLE GAS TURBINE POWER GENERATION PROCESS – THEIR NATURE AND EFFECT

5.1 Oxides of Nitrogen (NO_x)

5.1.1 Nature and Characteristics

The concentrations modelled are for NO_x but since NO_x in the atmosphere is rapidly oxidised to NO₂, the human health risk characterisation was performed using NO₂ concentrations as proxy for NO_x. NO₂ is a non-flammable gas with a stinging odour. It is a strong oxidizing agent that reacts in the air to form corrosive nitric acid and toxic organic nitrates. NO₂ also plays an important role in the atmospheric reactions that produce surface ozone or smog.

5.1.2 Sources

NO_x is produced by the reaction of nitrogen and oxygen in combustion processes. It is produced naturally by bacterial and volcanic action, and lightning. Man-made emissions stem mainly from burning fuel in motor vehicles, electric power plants, and other industrial, commercial, and residential sources (Kerosene heaters and gas stoves). Other atmospheric contributions come from non-combustion processes, e.g. nitric acid manufacture, welding processes and the use of explosives.

The main source of NO_x from the proposed Kudu CCGT power station development is stack emissions from both the gas and fuel oil cycles.

5.1.3 Environmental Effects

In the atmosphere, NO₂ reacts with water vapour to produce nitric acid. This acidic pollution can be transported over long distances by wind and deposited as acid rain, causing the acidification of soils, lakes, and streams, accelerated corrosion of buildings and monuments and damages paintwork. NO₂ is also a major source of fine particulate pollution which decreases visibility, and contributes to surface ozone formation through its reaction with VOCs in the presence of sunlight.

5.1.4 Health Effects

NO₂ is a gas; therefore, the route of exposure will be inhalation (CCINFO, 1998). People will be exposed to inhalation of NO₂ by inhaling contaminated ambient air or air from unvented indoor domestic fuel burning or tobacco smoke. The widespread use of unvented combustion appliances in homes is responsible for indoor NO₂ concentrations that exceed those found outdoors (WHO, 1987).

The seriousness of effects from NO₂ depends more on the concentration and not necessarily on the length of exposure. The onset of some symptoms can be delayed for up to 36 hours (CCINFO, 1998). The site of deposition for NO₂ is the distal lung (Costa and Amdur, 1996). In the lung the NO₂ reacts with moisture in the fluids of the respiratory tract to form nitrous and nitric acids (WHO, 1997).

NO₂ caused decrements in lung function, particularly increased airway resistance in resting healthy individuals at 2-hour concentrations as low as 4700 µg/m³ (WHO, 1997). Increased airway responsiveness to broncho constrictive agents in exercising healthy, non-smoking subjects was the result when they were exposed to 2800 µg/m³ NO₂ for 1 hour (WHO, 1997).

Some studies reported that exposure of asthmatics to NO₂ may cause increased airway

responsiveness to provocative mediators (such as sulphur dioxide), which may already begin at $380 \mu\text{g}/\text{m}^3$ (WHO, 1997). Nose, eye and throat irritation can occur at concentrations between 20000 to $33000 \mu\text{g}/\text{m}^3$. Other symptoms may include coughing, dyspnoea (a feeling of inability to breath), headache and nausea. At concentrations of 33000 to $130000 \mu\text{g}/\text{m}^3$, irreversible inflammation of the lungs may develop. Concentrations of approximately $200000 \mu\text{g}/\text{m}^3$ lead to potentially fatal pulmonary oedema and progressive blockage of the small airways (CCINFO, 1998). Romieu and Hernandez-Avila (2003) also reported that exposure to NO_2 leads to immune system effects.

According to the World Health Organisation (WHO), despite the large number of acute controlled exposure studies in humans, there is no evidence of a clearly defined concentration-response for NO_2 . A lowest observed adverse effect level (LOAEL), based on slight changes in lung function in asthmatics, is given as a range between 365-565 $\mu\text{g}/\text{m}^3$ (200-300 ppb) (WHO, 2000).

Chronic exposure

Reports of lung effects from long-term exposure to low levels of NO_2 are inconsistent (CCINFO, 1998). Chronic exposure to NO_2 increases the risk to respiratory tract infection in young children (WHO, 1997).

The recommended long-term guidance value, based on epidemiological studies of increased risk of respiratory illness in children, is $40 \mu\text{g}/\text{m}^3$ as an annual average (WHO, 1997). The association between outdoor NO_2 and respiratory health is not clear. There is some evidence that the duration of respiratory illness may be increased at higher ambient NO_2 levels. A difficulty is to distinguish effects of NO_2 from other associated pollutants (WHO, 1997).

The WHO states that despite the fact that there is no particular epidemiological study or group of studies that supports a specific numerical value for an annual NO_2 guideline, there is still a need to protect the public from chronic exposure to NO_2 (WHO, 2000).

5.1.5 Mechanism of Action

About 80 to 90% of inhaled NO_2 is absorbed through the lungs (CCINFO, 1998). Nitrogen dioxide (present in the blood as the nitrite (NO_2)-ion) oxidises unsaturated membrane lipids and proteins, which then results in the loss of control of cell permeability. The dominant product of oxidation of unsaturated lipids is peroxide. Acute exposure to $750 \mu\text{g}/\text{m}^3$ NO_2 can result in lipid peroxidases (WHO, 1997).

5.1.6 Susceptible population

People with chronic respiratory problems will be more susceptible to exposure to NO_2 . People with a vitamin C deficiency may be more susceptible, as vitamin C inhibits the oxidation reactions of nitrogen dioxide in the body (WHO, 1997).

5.2 Particulate Matter (PM)

5.2.1 Nature and Characteristics

Particulate matter (PM) is a broad term used for particles found in the atmosphere, including soil dust, dirt, soot, smoke, pollen, ashes, aerosols and liquid droplets. These particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke while others can only be detected with an electron microscope. These particles come in a wide range of sizes and are classified as "fine" particles if they are

less than 2.5 micrometers in diameter and coarser-size particles if they are larger than 2.5 micrometers. PM originate from a wide variety of natural and manmade sources. Particulate matter can vary widely in chemical and physical composition.

5.2.2 Sources

Fine particles (PM_{2.5} and smaller) penetrate into the gas exchange region of the lungs, result from fuel combustion from motor vehicles, power generation, and industrial facilities, as well as from residential fireplaces and wood stoves. Coarse particles (PM₁₀ and larger) are generally emitted from sources, such as vehicles traveling on unpaved roads (fugitive dust), materials handling, crushing and grinding operations, and as natural windblown dust. Some particles are directly emitted into the air (Fig. 5.1). They come from a variety of sources such as cars, trucks, buses, factory and utility smokestacks, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood.

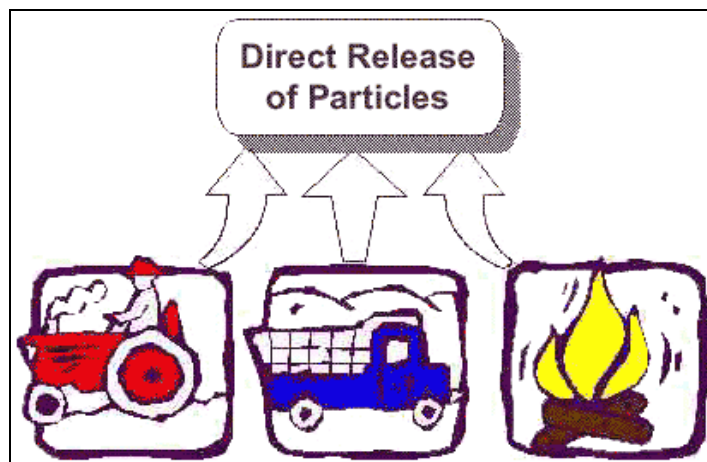


Figure 5.1: Direct release of particles (<http://www.epa.gov/air/urbanair/pm/what1.html>)

In other cases, particles may be formed in the air from the chemical change of gases (Figure 5.2). They are indirectly formed when gases from burning fuels such as SO₂, NO_x, and volatile organic compounds (VOCs) react with other compounds in the air in the presence of sunlight and water vapor. These can result from fuel combustion in motor vehicles, at power plants, and in other industrial processes. Their chemical and physical compositions vary depending on location, time of year and weather.

Sources of particulate matter from the proposed Kudu CCGT power station development include dust generated during the construction phase. Particulate emissions will result from the combustion of fuel oil when gas is unavailable.

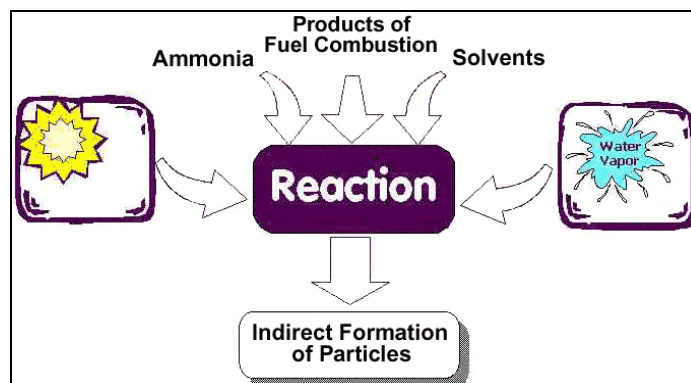


Figure 5.2: Indirect release of particles (<http://www.epa.gov/air/urbanair/pm/what1.html>)

5.2.3 Environmental Effects

Particulate matter is the major source of haze that reduces visibility. It can be transported over long distances by wind and then settle on ground or water through dry and wet deposition. This harms the environment by changing the nutrient and chemical balance of soil and water. It also causes erosion and staining of structures such as monuments and statues. Soot is the main culprit that stains and damages stone and other materials. These airborne particles also can cause damage to paints and other building materials.

5.2.4 Health Effects

The health effects of particulates can range from negligible to potentially fatal depending on particle size, chemical composition, mass inhaled, route of exposure (WHO, 1999) and the number of particles per unit volume of air (<PM_{2.5}) (Lippmann, 2003). Health effects associated with particulate matter include both the acute (short-term) and chronic (long-term) effects (Brunekreef and Holgate, 2002). Acute effects include amongst others daily mortality, increased hospital admissions for exacerbations of respiratory illnesses such as asthma while chronic effects may include respiratory mortality (WHO, 1999). Fine particulate matter (PM_{2.5}) is regarded as more of an indicator for health effects than coarse particles (>PM_{2.5}) (Lippmann, 1998). US EPA's scientific review concluded that fine particles, which penetrate deeply into the lungs, are more likely than coarse particles to contribute to the health effects (e.g., premature mortality and hospital admissions). Lippmann (1998) also reported that particulate matter with a diameter smaller than 2.5 (<PM_{2.5}) yielded stronger associations with adverse health effects than both PM₁₀ and TSP. This could be related to the fact that coarse particles are more likely to be trapped by the nasal hairs leading to a limited effect on the respiratory system (Lippmann, 1998). However there are studies showing coarse particulate matter induces adverse effects. Wilson and Spengler (1996) reported that the estimated effect of PM₁₀ across daily time-series mortality studies shows a statistically significant effect. These results are similar to those reported by Levy and co-workers which indicated that for every 10 µg/m³ increase in PM₁₀ over 24 hours an increase in acute morbidity, such as asthma attacks and bronchitis, were reported (Levy *et al.*, 2000).

Metal and organic compounds of particles can induce inflammatory responses. Inflammatory responses damage epithelial cells and macrophages. HEI studies also found that particles with higher metal levels induced a greater inflammatory response and that diesel particles can cause inflammation in healthy subjects (HEI, 2002).

Sub-chronic and chronic health effects

Long-term repeated exposure to particulates may increase the risk of chronic respiratory disease, and the risk of cardio-respiratory mortality (Wilson and Spengler, 1996). A critical review of about 200 scientific publications by The Air and Waste Management Association on ambient particulates and health, found no evidence that long-term low-level exposure to particles, apart from repeated short-term increases in particle concentrations, is associated with adverse health effects (Vedal, 1997). There is thus controversy among scientists in the field.

One group acknowledged that it is impossible to set a standard that will be totally protective against all adverse effects and therefore recommended a concentration at which health effects on individuals are likely to be small and the very large majority of individuals will be unaffected. A differing opinion is that a threshold for adversity can be identified and a margin of safety can be applied (Lippmann, 1998).

In the light of the different opinions and the large costs of air pollution abatement, reanalyses

of three of the largest US cohort studies was recently conducted by independent scientists. The findings of the reanalyses largely confirmed the original findings, namely robust associations between mortality rates and levels of particulate matter (Brunekreef and Holgate, 2002).

5.2.5 Mechanism of Action

The exact mechanism of action for the observed health effects from particulate matter is not known (Martin *et al*, 1997; Monn 2001). Human studies show pro-inflammatory effects that involve both epithelial cells and macrophages (Brunekreef and Holgate, 2002). Some recent research suggests that particles (particularly the ultra fine ones) or particle components may physically move out of airways into the bloodstream to trigger effects at distant sites (HEI, 2002).

5.2.6 Susceptibility of Population

People with chronic obstructive pulmonary and/or cardiovascular disease, asthmatics, the elderly and children, are more at risk to the inhalation of particulates than normal healthy people (Pope, 2000; Zanobetti *et al*, 2000).

5.3 Sulphur Dioxide (SO₂)

5.3.1 Nature and Characteristics

Sulphur dioxide (SO₂) is a colourless gas with a stinging odour. It reacts on the surface of various airborne solid particles, is soluble in water and can be oxidised within airborne water droplets to form acid aerosols.

5.3.2 Sources

Natural sources of SO₂ include releases from volcanoes, oceans, biological decay and forest fires. The most important anthropogenic sources include fossil fuel combustion, metal smelting, manufacture of sulphuric acid, conversion of wood pulp to paper, incineration of refuse and production of elemental sulphur. Coal burning is the single largest man-made source of SO₂ accounting for about 50% of annual global emissions. Smaller sources include residential, commercial and industrial space heating.

Sources of SO₂ from the proposed Kudu CCGT power station development include the combustion of fuel oil when gas is unavailable.

5.3.3 Environmental Effects

SO₂ is one of the main precursors of acid rain. In the atmosphere, SO₂ oxidizes and combines with water vapour forming sulphuric acid (H₂SO₄), which is the main component of acid rain. This acidic pollution can be transported by wind and deposited as acid rain vast distances from the source. This contributes to the acidification of lakes and streams, accelerated corrosion of buildings. SO₂ corrodes metal, deteriorates electrical installations, paper, textiles, paints, construction materials, and historical monuments. It also damages trees and crops by causing injuries to leaves and reducing photosynthesis. Microscopic acid aerosols impair visibility and contribute to climate change.

5.3.4 Public Exposure

Sulphur dioxide is a gas; therefore, the route of exposure will be inhalation. 40-90% of inhaled sulphur dioxide is absorbed in the moist upper respiratory tract (CCINFO, 1998). People are exposed to sulphur dioxide by inhalation of contaminated ambient air (industries, power stations and domestic coal burning), as well as by unvented indoor coal burning.

5.3.5 Health Effects

Acute

Sulphur dioxide is a moderate to strong irritant. Most sulphur dioxide only penetrates as far as the nose and throat, with minimal amounts reaching the lungs, unless the person is breathing heavily, breathing only through the mouth, or if the concentration of sulphur dioxide is high (CCINFO, 1998). The acute response to sulphur dioxide is rapid (Folinsbee, 1992), about 5 to 10 minutes in asthmatics (significant increase in airway resistance within 2 minutes). Acute responses occur within the first few minutes after commencement of inhalation. Further exposure does not increase effects (WHO, 1999). Effects such as a reduction in lung function, an increase in airway resistance, wheezing and shortness of breath, are enhanced by exercise that increases the volume of air inspired, as it allows SO₂ to penetrate further into the respiratory tract (WHO, 1999).

An exposure of 1 to 6 hours to 1 ppm (1 000 ppb or 2 618 µg/m³) produced a reversible decrease in lung function in sensitive people (CCINFO, 1998). A 10 to 30 minute exposure to concentrations as low as 5 ppm, (5 000 ppb or 13 089 µg/m³) has produced broncho constriction in human volunteers (CCINFO, 1998). The acute health effects experienced in sensitive and healthy individuals after acute exposure to sulphur dioxide are listed in Table 5.1. Epidemiological studies have found associations between hospital admissions for chronic obstructive pulmonary disease and low levels (less than 200 µg/m³ (or 76 ppb)) of SO₂ (Brunekreef *et al*, 1995).

Table 5.1: Acute health effects experienced in sensitive and healthy individuals after acute exposure to sulphur dioxide.

Normal healthy subjects	Reference	Sensitive subjects	Reference
1 ppm (2 600 µg/m ³) Pulmonary function changes (during exercise)	Costa & Amdur, 1996	1 ppm (2 600 µg/m ³) Rapid broncho-constriction	Costa and Amdur, 1996
		0.5 ppm (1 300 µg/m ³) Wheezing and shortness of breath (during exercise) Max mid exp flowrate (MMFR) significantly decreased while resting	Folinsbee, 1992 Harrison, 1998 WHO, 1987
		0,25 to 1 ppm (650 to 2 600 µg/m ³) Broncho-constriction in mild asthmatics during exercise	Costa & Amdur, 1996

Chronic

Evidence for effects of sulphur dioxide other than short-term bronchoconstriction is less direct (Lippmann, 1992). Workers exposed to a daily average of 5 000 ppb (13 089 µg/m³) showed a higher incidence of chronic bronchitis (CCINFO, 1998). Human studies showed that repeated exposure to sulphur dioxide levels below 5 000 ppb (13 089 µg/m³) resulted in pulmonary impairment (CCINFO, 1998) (probably due to repeated episodes of bronchoconstriction).

Most studies on humans and animals have indicated that 49 to 90% or more of inhaled sulphur dioxide is absorbed in the moist upper respiratory tract where it is quickly converted to sulphuric acid (CCINFO, 1998). Sulphuric acid imparts irritation to respiratory tissues through its acidity. Inhaled sulphur dioxide is slowly removed from the respiratory tract. After absorption in the blood stream the sulphuric acid is widely distributed throughout the body, quickly converted to sulphite and bisulphite, which in turn is oxidised to sulphate in the liver and excreted in the urine (CCINFO, 1998).

In a cohort study in the US, the Adventist Health Study of Smog (AHSMOG), 6338 non-smoking Seventh-day Adventists were followed from 1977 to 1987. The AHSMOG study did not show positive associations between long-term concentrations of ambient particles and an increased risk of mortality. Mortality data from the AHSMOG study were updated through to 1992 and then reanalysed. Through the reanalysis, not only an association between mortality rates and particulate levels became evident, but an association between long-term SO₂ exposure and an increased risk of lung cancer mortality in men and women was also found (Abbey *et. al.*, 1999).

5.2.6 Susceptibility of population

Sensitive subjects include asthmatics, the elderly, children and individuals with impediments to nasal breathing, such as a deviated nasal septum (Folinsbee, 1992).

5.4 Other Emissions

5.4.1 Greenhouse Gases

Carbon dioxide (CO₂) is referred to a greenhouse gas because of its global warming potential. Greenhouse gases allow sunlight, which is radiated in the visible and ultraviolet spectra, to enter the atmosphere unimpeded. When it strikes the Earth's surface it is absorbed and reradiated as infrared radiation. Some is reflected as infrared radiation (heat). Greenhouse gases tend to absorb this reradiated and reflected infrared radiation, trapping the heat in the atmosphere.

Carbon Dioxide

Carbon dioxide (CO₂) occurs naturally in the atmosphere and is also produced in all combustion processes. It is uniformly distributed over the earth's surface. Commercially, CO₂ is used as a refrigerant (dry ice), in beverage carbonation, and in fire extinguishers. Carbon dioxide is released into the atmosphere when carbon-containing fossil fuels such as oil, natural gas and coal are burned in air, but also through the burning of forests and savanna. As a result of the tremendous worldwide consumption of such fossil fuels and deforestation, the amount of CO₂ in the atmosphere has increased over the past century (Fig. 5.3), presently rising at a rate of about 1 ppm per year. Major changes in global climate could result from a continued increase in CO₂ concentration, as it is one of the most important greenhouse gases.

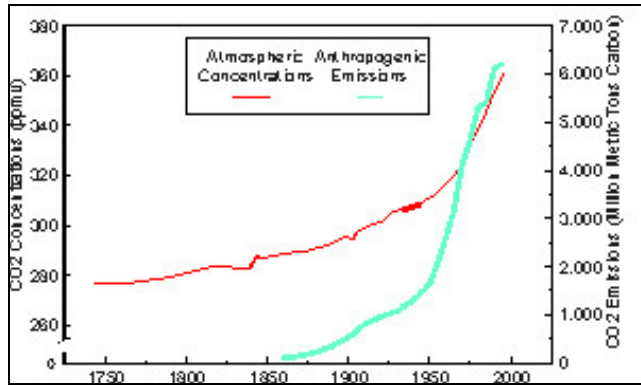


Figure 5.3: Trends in atmospheric concentrations and anthropogenic emissions of carbon dioxide

(<http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html>)

Concentrations of CO₂ in the atmosphere are regulated by numerous processes collectively known as the carbon cycle (Fig. 5.4). Natural processes, such as plant photosynthesis and respiration, dominate the movement of carbon dioxide between the atmosphere and carbon sinks on land and in the oceans. While these natural processes can remove some of the net 6.6 billion metric tons of anthropogenic carbon dioxide emissions produced each year, an estimated 3.3 billion metric tons of this carbon is added to the atmosphere annually in the form of carbon dioxide.

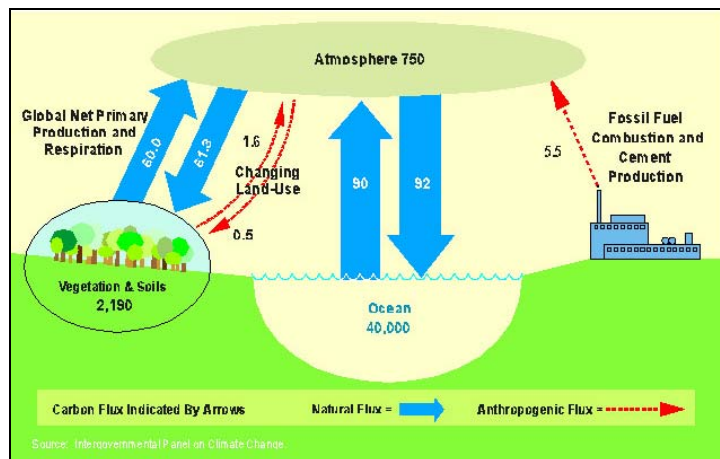


Figure 5.4: Global carbon cycle (billion metric tons)

(<http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html>)

The main health effect of CO₂ is asphyxiation and will not be considered in the human health risk assessment of this study.

5.4.2 Dust

Construction Dust

Dust emissions will result mainly from gas pipeline construction, power station site preparation work and power line construction, which may include scraping, grading, loading, digging, compacting, light-duty vehicle travel, excavation activities and back fill operations during the early stages of construction. During windy conditions this dust may have negative impacts beyond the construction site. Contractors and site agents may be required to adopt the required dust control measures to cut down dust emissions to an acceptable level while carrying out construction works. This will be a temporary source of emissions. Proposed mitigation measures are discussed further in Section 11.

Operational Dust

No dust emissions are anticipated from the operational site, however the site is located in an inherently dusty environment. Recommendations for the rehabilitation of the site after construction is completed are provided in Section 11. In addition, recommendations are provided to reduce the impact of wind blown dust on the operational power station. These are also detailed in Section 11 of this report.

5.6 Summary of Pollutants Assessed

A summary of the pollutants assessed in this study is presented in Table 5.2 below.

Table 5.2: Summary of the pollutants assessed

Pollutant	Modelled	Health Risk Assessment	Qualitative Assessment
PM	Yes	Yes	No
SO₂	Yes	Yes	No
NO_x	Yes	Yes	No
CO₂	No	No	Yes
CO	No	No	Yes
Dust	No	No	Yes
Water Vapour	No	No	Yes

6. THE CLIMATOLOGY OF THE STUDY AREA

The climate of the study area is strongly influenced by the cold Benguela current which runs in a northerly direction along the coast. Although the area is located in a desert, cool, foggy conditions occur most mornings and strong southerly winds are a distinct feature of the afternoons. Temperatures along the coastal strip are modified by the cold ocean, but rise sharply inland. The area is arid with rainfall mostly restricted to the winter months. Very hot, dry and dusty conditions occur occasionally in winter when the offshore (north-easterly) berg winds develop.

The Namibian Meteorological Service's nearest station is located at Luderitz, however there are plans to expand the monitoring network to include Oranjemund in the future. Detailed information pertaining to the climate of the study area is presented below based on observations at the South African Weather Service station at Alexander Bay. The station is located approximately 30 km to the southeast of the proposed site of the power station and can be considered fairly representative of the area.

6.1 Temperature

Average temperatures in Alexander Bay are mild throughout the year with slightly cooler temperatures in winter. The average daily maximum temperature in summer is 23.5°C with extremes exceeding 40°C. In winter the average maximum temperature is 20.8°C with extremes in the region of 35°C. Annual average 08h00 and 14h00 relative humidity levels are 84% and 53% respectively. Monthly averages and extreme temperatures from the South African Weather Service (SAWS) 27-year climate record (SAWB, 1990) are presented in Table 6.1.

Table 6.1: Mean monthly and monthly extreme temperatures at Alexander Bay including average monthly rainfall and fog days

Month	Temperature (°C)			Rainfall (mm)	Fog Days
	Average	Maximum	Minimum		
Jan	19.8	24.4	15.1	1	4.0
Feb	19.6	24.1	15.1	3	6.5
Mar	19.2	24.3	14.2	2	10.5
Apr	18.2	23.8	12.6	4	12.6
May	17.0	23.2	10.7	4	11.3
Jun	15.7	21.6	9.8	9	8.0
Jul	14.9	21.0	8.8	5	9.4
Aug	14.7	20.5	8.9	7	8.2
Sep	15.5	20.9	10.1	3	5.7
Oct	16.6	21.7	11.5	5	3.7
Nov	17.9	22.8	13.0	1	4.6
Dec	18.9	23.5	14.4	2	4.3
Annual	17.3	22.6	12.0	46	89

6.2 Precipitation

Alexander Bay receives an annual average rainfall of 46mm. The majority of the rain falls in the winter months, however the area receives very limited annual rainfall with no month exceeding 10mm on average. Mean monthly rainfall totals from the SAWS 27-year climate record (SAWB, 1990) are presented in Table 6.1. The majority of the precipitation received in the area is in the form of fog deposition.

6.3 Wind

The prevailing winds in Alexander Bay are predominantly southerly, associated with strong anti-cyclonic circulation in the southern Atlantic Ocean (Figure 6.1). The annual frequency of occurrence of southerly winds is approximately 30%. The average annual wind speed is 4.6 m/s and the station experienced calm conditions for only 5.8% of the observation period. The other dominant wind patterns are on-shore (west / south-westerly) and off-shore (easterly). On-shore winds tend to be stronger than the off-shore winds and this can be attributed to the cold Benguela current that flows up the west coast of southern Africa.

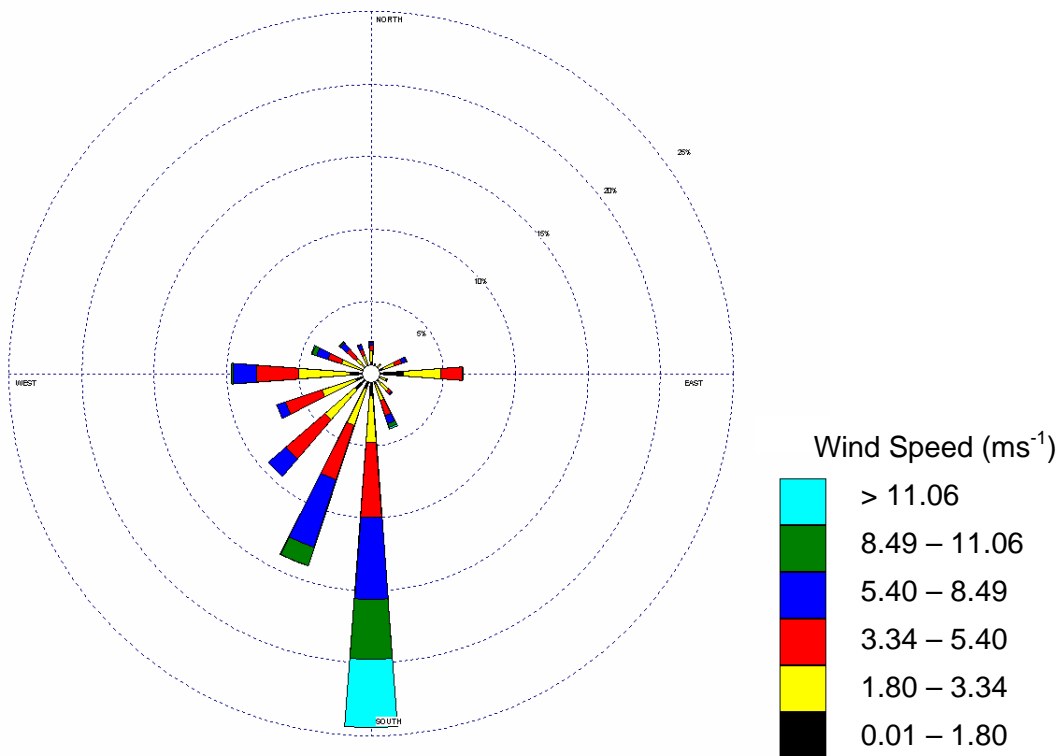


Figure 6.1: Wind rose for Alexander Bay for 2000 and 2001

7. AIR QUALITY IN UUBVLEI

7.1 Existing Air Quality

The ambient air quality of Uubvlei is good, although dust storms do occur on a regular basis, particularly in the winter when easterly off-shore winds are more common. Visibility along the coast is often reduced as a result of the frequent fog and salt spray. As such, the only pollutant of concern would be particulate matter, which has more of a nuisance value than human health impact except in the case of fine particulate matter that can enter the respiratory system.

Industrial sources of air pollution in the study area are limited to the activities associated with the diamond mining along the coastline. Here the air pollution generating activities include dust generation during excavation and screening, and diesel emissions from generators at the recovery unit.

Other sources of air pollution are the episodic use of an incinerator at the Alexander Bay Hospital, emissions from the infrequent activity at the airports in Oranjemund and Alexander Bay, and emissions from a very small motor vehicle fleet in the two centres. There is currently no ambient air quality monitoring in the study area. These emissions are small and have no bearing on air quality in the study area.

7.2 Receiving Environment

The proposed site exists in a very disturbed mining area where nobody resides permanently. The closest areas to the proposed site where people reside are Oranjemund, approximately 23 km away, and Alexander Bay, some 30 km away, both areas to the southeast.

Due to the mining activities, the vegetation in the mining area is very sparse and in a constantly disturbed state. Beyond the mining area the vegetation may be described as sparse, consisting of low hammock, stabilised hammock and, coastal hammock vegetation, or xerophytes (plants that have adapted to low moisture condition). Wetland and riparian vegetation exists in the Orange River Valley.

8. SOURCE INVENTORY

This section presents the emissions data used by CALPUFF to simulate the dispersion of pollution from the proposed power station in Uubvlei. CALPUFF requires several types of information pertaining to emissions. This information includes:

- The exact location of each source;
- Stack diameter;
- Height of release of each source;
- Exit temperature;
- Exit velocity;
- Emission rate for each pollutant from each source.

The emission data for the gas-fired scenarios was provided by Siemens, while the emission data for the oil-fired scenarios were calculated based on emission factors provided in the US-EPA Compilation of Emission Factors - AP42 (US-EPA, 2004). It was assumed that there would be no atmospheric emissions from the gas conditioning plant. The stack parameter and the emissions data for the proposed power station are summarised in Table 8.1. The emissions data presented are for one single shaft unit (400MW). The proposed power station would have a generating capacity of 800 MW, or two shaft units. A double capacity (1600 MW) scenario was also modelled, assuming four shafts.

The air quality specialist team conducted the assessment for a stack height of 60 m, taking NO_x mitigation into account for all scenarios.

Stone and Webster (1998) assessed the option of using fuel oil as a standby fuel in the case of failure of the gas supply. The natural gas supply to the plant would have a 96% guaranteed availability, representing an annual downtime of 14.6 days, but the maximum continuous gas supply interruption is specified as 5 – 7 days. The standby liquid fuel consumption by the power station was estimated to be a maximum of 3100 m³/day (Stone and Webster, 1998). Table 8.1 shows the emission characteristics based on the two different fuel types.

Table 8.1: Summary of stack parameters and emission rates per shaft for the Kudu CCGT Power Plant

Parameter	Fuel Gas	Fuel Oil
Emission Temperature	361.2 K	373.2 K
Emission Exit Velocity	21.5 m/s	21.5 m/s
Stack Height	60 m	60 m
Stack Diameter:	6.4 m	6.4 m
Emission Rate – NO _x	30.28 g/s	72.67 g/s
Emission Rate – SO ₂	0.0 g/s	168.99 g/s
Emission Rate – PM	0.0 g/s	4.31 g/s

All emissions from the proposed Kudu CCGT conform to the emission requirements of the World Bank when operating under natural gas and No. 2 fuel oil. Table 8.2 summarises the World Bank requirements for emissions and the anticipated emissions from the proposed development.

Table 8.2: Summary of World Bank Emission Requirements and Kudu CCGT Emissions

Pollutant	Gas-Fired Scenario		No 2 Fuel Oil-Fired Scenario	
	World Bank Guidelines	Kudu CCGT	World Bank Guidelines	Kudu CCGT
NO _x	125 mg/Nm ³	50 mg/Nm ³	165 mg/Nm ³	120 mg/Nm ³
SO ₂	2000 mg/Nm ³	0.0 mg/Nm ³	2000 mg/Nm ³	264 mg/Nm ³
Particulate Matter	50 mg/Nm ³	0.0 mg/Nm ³	50 mg/Nm ³	6.7 mg/Nm ³

9. IMPACT ASSESSMENT – AIR QUALITY PREDICTIONS AND POTENTIAL HEALTH IMPLICATIONS

The assessment of potential impacts on human health is based on the following: nature of the impact, extent, duration, intensity and probability. The nature of the impact, i.e. how health is likely to be impacted has already been described in Section 5. The extent, duration and intensity are described in this section using the dispersion modelling results for the identified pollutants of concern and the defined emission scenarios.

The dispersion patterns for NO_x, SO₂ and PM are described for the proposed Kudu CCGT power plant under a range of operating scenarios. At present, Namibia does not have any national air quality guidelines or standards in place. Guidelines from the South African Atmospheric Pollution Prevention Act (APPA) (Act 45 of 1965) have been applied in Namibia. South Africa has a new air quality management Act (Act 39 of 2004) that was signed into force in February 2005. This Act makes provision for the introduction of ambient air quality standards that will replace the guidelines specified under APPA although the proposed standards are not enforced as yet. In this light, it is deemed inappropriate to apply APPA guidelines in this assessment. Rather, World Health Organisation (WHO) guidelines for NO_x, World Bank standards and the proposed new ambient air quality standards for South Africa have been applied in the assessment (Table 9.1).

Table 9.1: Air quality guidelines, standards and proposed limit values for SO₂, NO₂, and PM₁₀.

	1-hour	24-hour	Annual
SO₂	¹ 350 µg m ⁻³ or 134 ppb	^{1 & 3} 125 µg m ⁻³ or 48 ppb	^{1 & 3} 50 µg m ⁻³ or 19 ppb
NO₂	^{1 & 3} 200 µg m ⁻³ or 106 ppb ² 380 µg m ⁻³ or 200 ppb	² 187 µg m ⁻³ or 100 ppb	¹ 40 µg m ⁻³ or 21 ppb ³ 40 µg m ⁻³ or 21 ppb ² 94 µg m ⁻³ or 50 ppb
PM₁₀		¹ 75 µg m ⁻³ ² 180 µg m ⁻³	¹ 40 µg m ⁻³ ² 60 µg m ⁻³

¹: Proposed South African limit values (SANS, 2004)

²: South African Air Quality Guidelines

³: World Health Organisation Guidelines (WHO, 1999)

The isopleth maps reflect the annual average, 24-hour maximum and 1-hour maximum concentrations. Model outputs for annual periods represent the actual predicted average for 2 years of meteorological data. The 24-hour and 1-hour maxima represent the worst-case scenario and is the highest concentration modelled at each receptor point. For the isopleth maps the maximum value modelled at each grid point at any time in the year is used to calculate the isopleths. In reality no such day or hour is likely to occur but provides an indication as to the potential worst-case scenario.

The health risk assessment is based on the worst-case scenario as specified above at the receptor points identified in Section 3.2.4. This conservative approach means that if the risk to human health is found to be low, then the chance of an adverse impact on health is minimal and even sensitive individuals will not be affected by the emissions from the proposed plant. Risks were evaluated for a child of 10 years and an adult of between 18-65+ years of age at the site only.

9.1 Oxides of Nitrogen

9.1.1 NO_x 1-hour Maximum – Gas-Fired Power Station (800 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 1-hour ambient concentration for NO_x from the gas-fired power station operating at an 800 MW capacity is presented in Figure 9.1. The plume extends in a northerly and easterly direction following the prevailing synoptic winds. The highest concentrations (185.5 µg/m³) occurs approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean. Modelled ambient concentrations do not exceed any of the standards or guideline values.

Risk Scenario

Results based on an exposure scenario of 1-hour gas stack single capacity indicates that receptors at the site, are not likely to develop NO₂ associated adverse health effects given the fact that all calculated HQs are below the safety margin of 1.

9.1.2 NO_x 1-hour Maximum – Gas-Fired Power Station (1600 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 1-hour ambient concentration for NO_x from the gas-fired power station operating at a 1600 MW capacity is presented in Figure 9.2. The dispersion pattern again reflects the strong influence of the synoptic wind patterns, with general dispersion to the north and east. The maximum modelled concentration (370.9 µg/m³) is observed approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean. The modelled concentration exceeds the WHO guideline (200 µg/m³) and the proposed new South African ambient standard (200 µg/m³) for NO₂ in places.

Risk Scenario

For the scenario based on 1-hour gas stack double capacity, the HQs are also below 1 indicating that receptors at the site, even the most sensitive, are not likely to develop NO₂ associated adverse health effects.

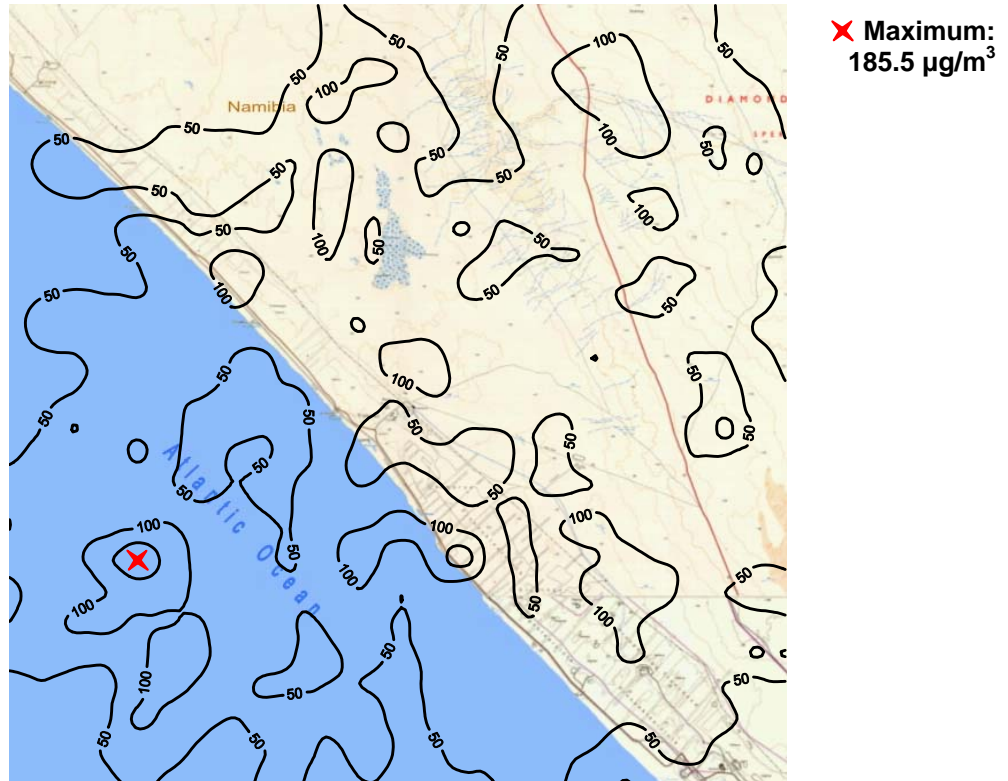


Figure 9.1: Maximum 1-hour NO_x concentration for the gas-fired power station operating at 800 MW capacity

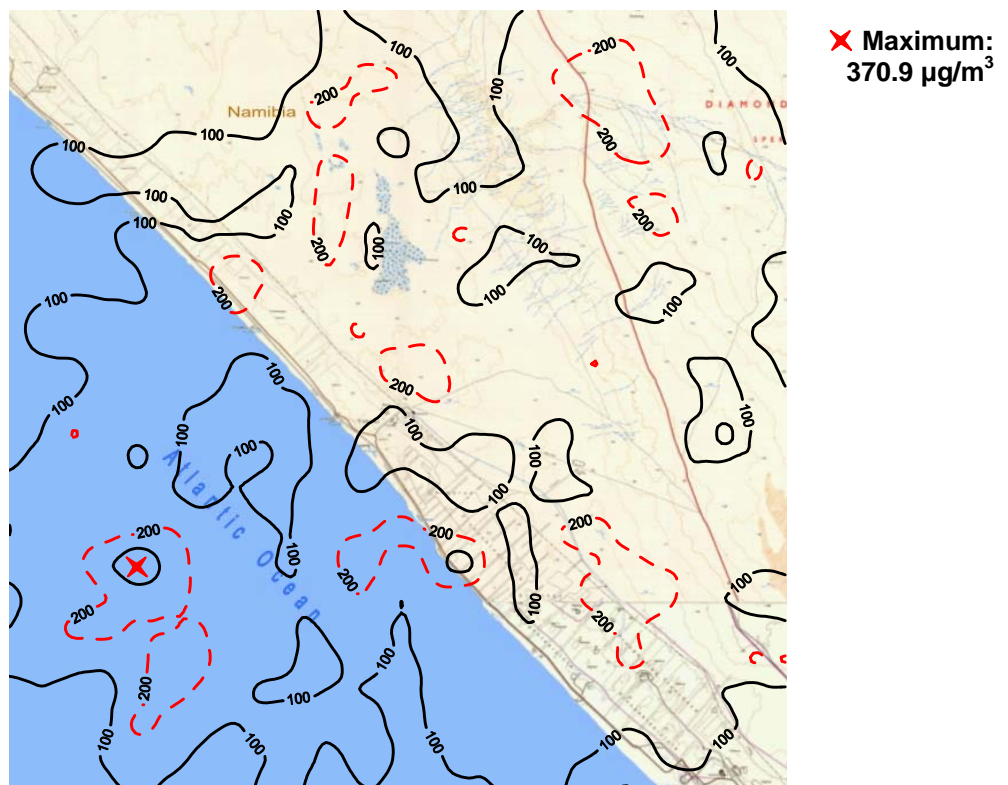


Figure 9.2: Maximum 1-hour NO_x concentration for the gas-fired power station operating at 1600 MW capacity . Red dashes indicate proposed South African Air limit values and WHO guidelines

9.1.3 NO_x 1-hour Maximum – Oil-Fired Power Station (800 MW Capacity)

Ambient Concentrations

The maximum 1-hour ambient concentration dispersion pattern for NO_x from the fuel oil-fired power station operating at an 800 MW capacity is presented in Figure 9.3. The maximum modelled concentration is 304.1 µg/m³. The dispersion pattern is similar to that observed for the gas-fired scenario with the highest concentration occurring approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean.

The modelled ambient concentrations exceed the WHO guideline and the proposed new South African ambient standard for NO₂.

Risk Scenario

Using modelled concentrations for the oil stack single capacity scenario, the receptor exposure to 1-hour NO₂ concentrations lead to hazard quotients (HQs) below the safety margin of 1. This indicates that receptors, even the most sensitive ones are unlikely to have any adverse effects at the site, when exposed to the modelled 1-hour NO₂ concentrations.

9.1.4 NO_x 1-hour Maximum – Oil-Fired Power Station (1600 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 1-hour ambient concentration for NO_x from the oil-fired power station at double capacity (1600 MW) is presented in Figure 9.4. Dispersion again is to the north and east, a reflection of the influence of the synoptic wind patterns. The highest 1-hour maximum concentration (608.1 µg/m³) is observed approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean. The WHO guideline, the proposed new South African ambient standards concentration guideline and the South African air quality guideline (380 µg/m³) is exceeded.

Risk Scenario

Exposure scenarios based on modelled 1-hour NO₂ concentrations from the oil stack double capacity also show that receptors are not likely to develop NO₂ associated adverse health effects. Calculated hazard quotients for the site are all below the safety margin of 1.

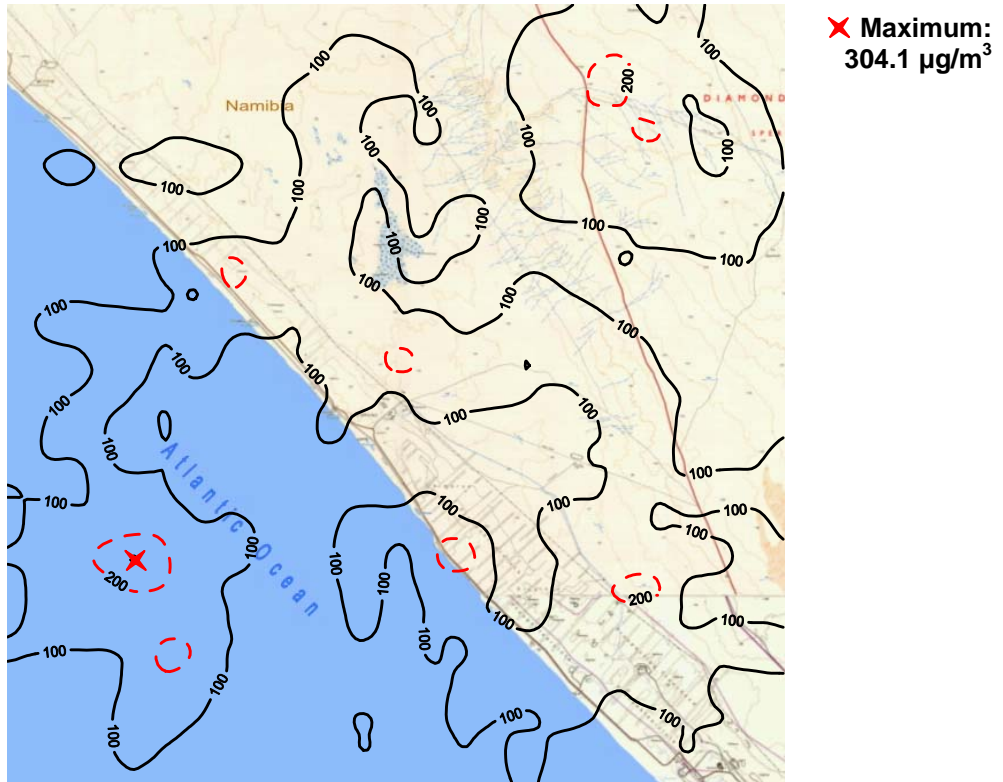


Figure 9.3: Maximum 1-hour NO_x concentration for the oil-fired power station operating at 800 MW capacity. Red dashes indicate proposed South African Air limit values and WHO guidelines

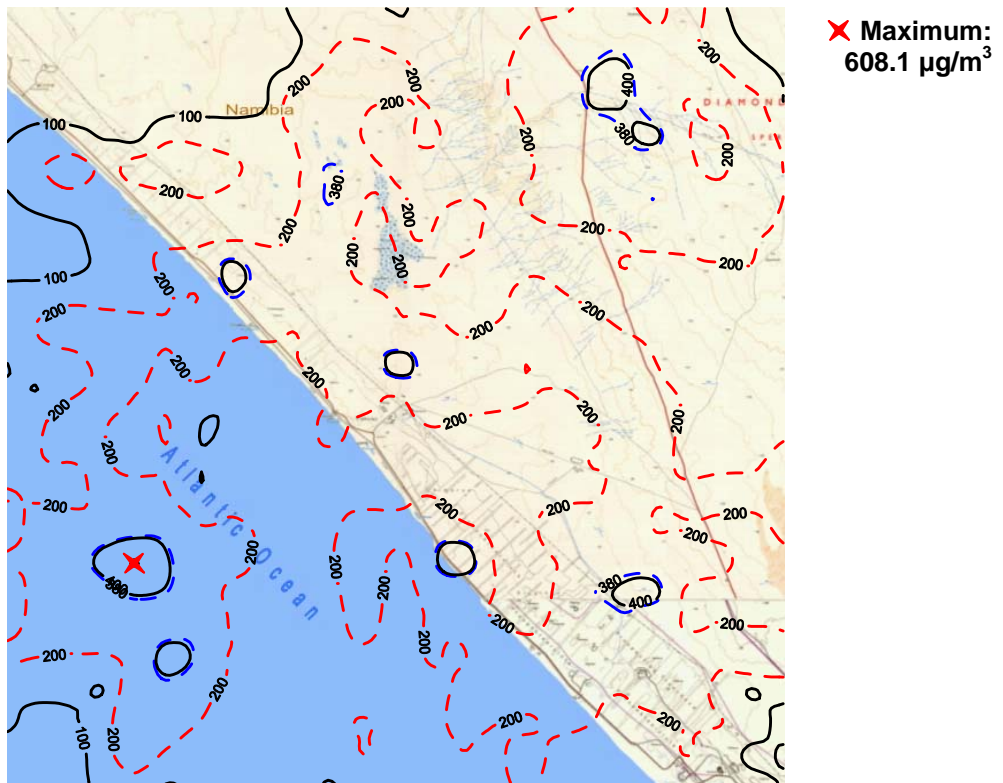


Figure 9.4: Maximum 1-hour NO_x concentration for the oil-fired power station operating at 1600 MW capacity. Red dashes indicate proposed South African Air limit values and WHO guidelines; blue dashes indicate South African Air Quality Guidelines

9.1.5 NO_x Annual Average

Ambient concentrations

The WHO annual guideline value for NO₂ is 40 µg/m³. Dispersion mostly follows the prevailing wind southerly winds and is therefore concentrated in a plume to the north of the site. The annual modelled concentrations for NO_x do not exceed this value anywhere in the study area for the four emission scenarios. The maximum modelled annual NO_x concentrations for the four scenarios are presented in Table 9.2.

Table 9.2: Maximum modelled annual ambient concentrations of NO_x for the four emission scenarios

Scenario	Annual Average (ug/m ³)	Location
Gas-Fired (800 MW)	1.19	~ 4 km north of the plant, near Uubvlei
Gas-Fired (1600 MW)	2.38	~ 4 km north of the plant, near Uubvlei
Oil-Fired (800 MW)	1.75	~ 4 km north of the plant, near Uubvlei
Oil-Fired (1600 MW)	3.51	~ 4 km north of the plant, near Uubvlei

Risk Scenario

Gas-Fired Capacity - 800MW

The annual NO₂ gas stack single capacity scenario shows that receptors are unlikely to develop NO₂ associated adverse effects. This is indicated by the low (below 1) HQs calculated for all receptors including the most sensitive, the child of 10 years.

Gas-Fired Capacity - 1600MW

The results of the annual gas stack double capacity scenario indicate that HQs are in the range of 0.003. This indicates that receptors, including the most sensitive, are not likely to develop NO₂ associated adverse health effects as a result of chronic exposures.

Oil-Fired Capacity - 800MW

The annual oil stack single capacity scenario shows that HQs for all receptors, even the most sensitive, are below the safety margin of 1. Under this annual exposure scenario, receptors at the site are not likely to develop chronic NO₂ associated adverse health effects.

Oil-Fired Capacity -1600MW

The results of the scenario for the annual oil stack double capacity indicate that the HQs are all below the safety margin of 1. The low HQs indicate that all receptors at the site, including the most sensitive, are not likely to develop chronic NO₂ associated adverse health effects.

Discussion

The results above show that for the acute and chronic NO₂ exposure scenarios, hazard quotients are all below the safety margin of 1 for all scenarios at the site.

9.2 Sulphur Dioxide

Since humans, especially asthmatics, react within minutes when exposed to SO₂, risk characterisation was performed for 1-hour and 24-hour exposure scenarios. The reference concentration used for determining HQs was the proposed South African 1-hour standard of 350 µg/m³. This concentration is stricter than the 660 µg/m³ of the Californian EPA.

9.2.1 SO₂ 1-hour Maximum – Oil-Fired Power Station (800 MW Capacity)

Ambient Concentrations

The maximum 1-hour ambient concentration dispersion pattern for SO₂ from the No. 2 fuel oil-fired power station operating at an 800 MW capacity is presented in Figure 9.5. The plume extends in a northerly and easterly direction following the prevailing synoptic winds. The highest concentrations (971.1 µg/m³) is observed approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean. The modelled ambient concentrations are above the proposed new South African ambient standard (350 µg/m³) for SO₂. There are no 1-hour guidelines or standards quoted for the World Bank or the World Health Organisation.

Risk Scenario

Using modelled SO₂ concentrations for the abovementioned scenario at the site, the receptor exposure to 1-hour concentration lead to HQs below the safety margin of 1. This indicates that it would be highly unlikely for any individual, even sensitive individuals, to develop adverse health effects as a result of exposure to SO₂ at the modelled 1-hour concentrations.

9.2.2 SO₂ 1-hour Maximum – Oil-Fired Power Station (1600 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 1-hour ambient concentration for SO₂ from the No. 2 fuel oil-fired power station at double capacity (1600 MW) is presented in Figure 9.6. Dispersion again is to the north and east, a reflection of the influence of the synoptic wind patterns. The highest 1-hour maximum concentration of 1942.2 µg/m³ occurs approximately 8 km to the southwest of the proposed plant, over the Atlantic Ocean. The modelled ambient concentrations are above the proposed new South African ambient standard (350 µg/m³) for SO₂. There are no 1-hour guidelines or standards quoted for the World Bank or the World Health Organisation.

Risk Scenario

The Hazard Quotients calculated (1.28 and 1.29), based on the modelled 1-hour SO₂ concentrations from the oil stack at double capacity using the proposed South African standard of 350 µg/m³ as a reference concentration, indicate that individuals at the site are at risk. When using the Californian-EPA standard of 660 µg/m³ HQs are below 1, indicating no risk to any individual. It must be noted that this risk was calculated for individuals on site, thus an occupational environment and it is highly unlikely that sensitive individuals, such as children, asthmatics and the elderly will work at an industrial site. The recommended South African occupational exposure limit-recommended limit (OEL-RL) for SO₂ is 5000 µg/m³ measured as an 8-hour time-weighted average.

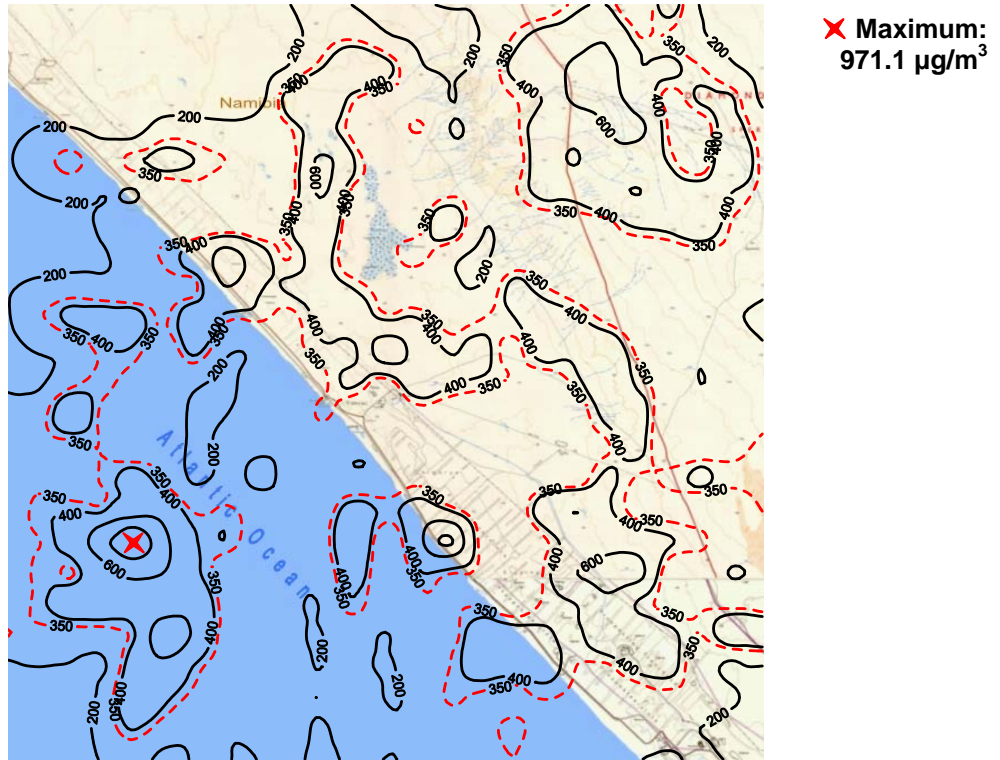


Figure 9.5: Maximum 1-hour SO₂ concentration for the oil-fired power station operating at 800 MW capacity. Red dashes indicate proposed South African Air limit values

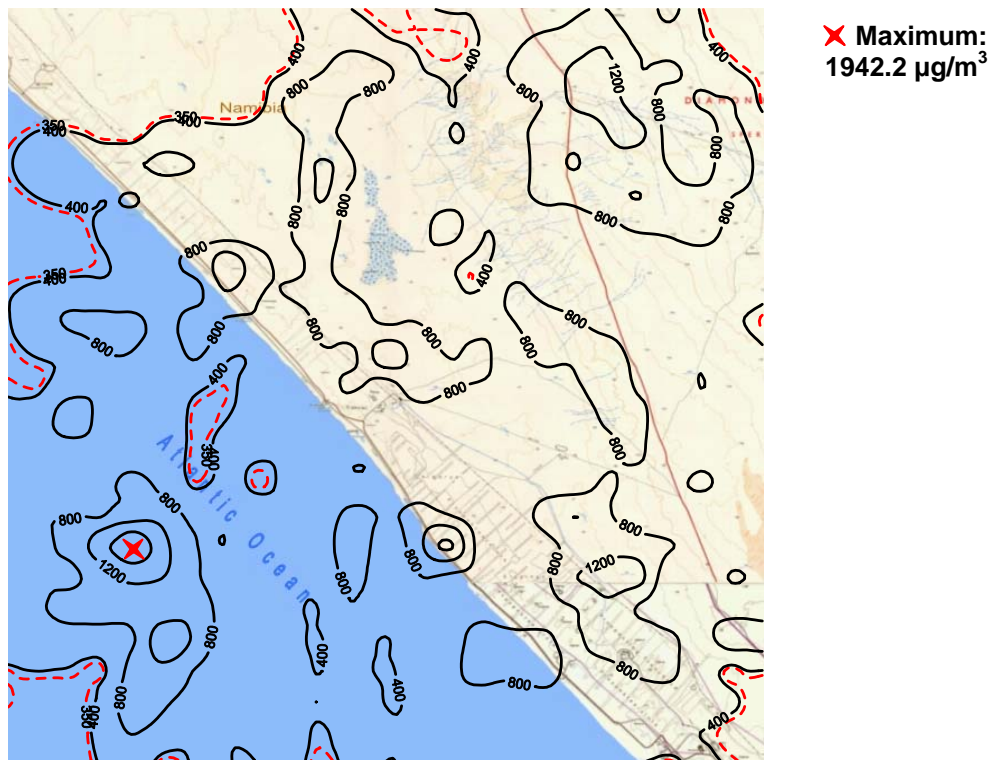


Figure 9.6: Maximum 1-hour SO₂ concentration for the oil-fired power station operating at 1600 MW capacity. Red dashes indicate proposed South African Air limit values

9.2.3 SO₂ 24-hour Maximum – Oil-Fired Power Station (800 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 24-hour ambient concentration for SO₂ from the oil-fired power station operating at an 800 MW capacity is presented in Figure 9.7. The maximum modelled concentration is 81.15 µg/m³. The dispersion pattern is similar to that observed for the 1-hour maximum scenario with the highest concentration occurring approximately 9 km to the southeast of the proposed plant, between the coast and the shifting sand dunes. The modelled concentrations are well below the WHO and proposed new South African ambient standard of 125 µg/m³.

Risk Scenario

Results based on modelled 24-hour SO₂ concentrations for the single capacity scenario, indicate that it would be highly unlikely for any individual to develop adverse health effects, since all HQs calculated were below one.

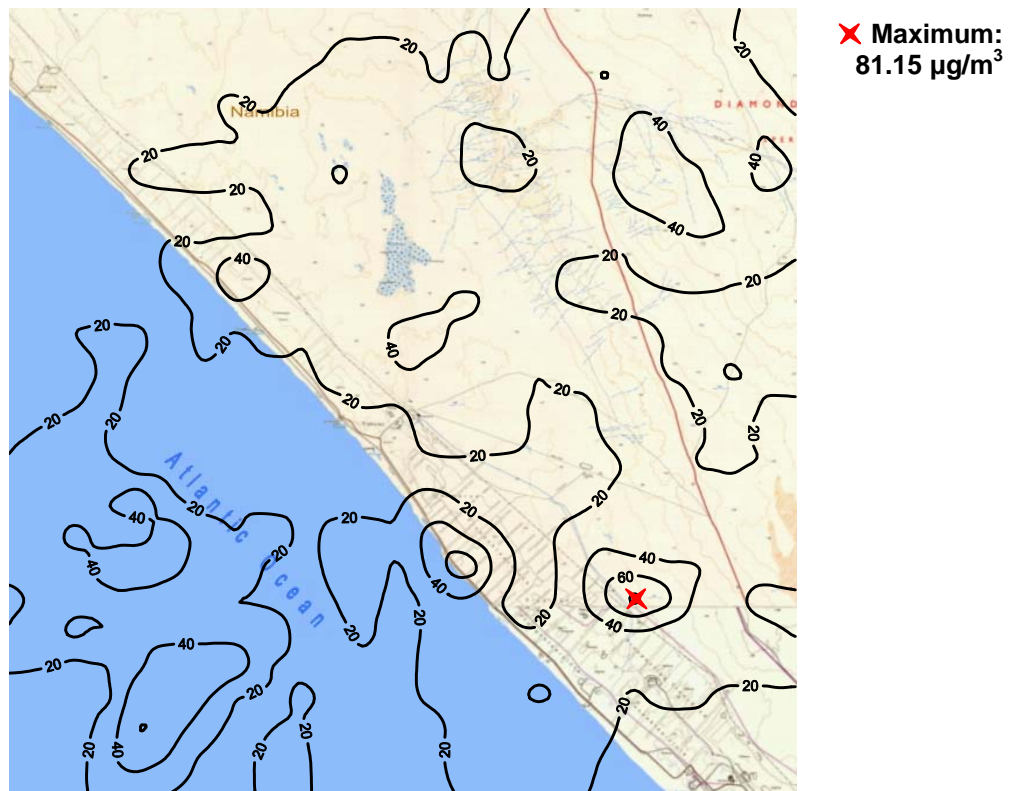


Figure 9.7: Maximum 24-hour SO₂ concentration for the gas-fired power station operating at 800 MW capacity

9.2.4 SO₂ 24-hour Maximum – Oil-Fired Power Station (1600 MW Capacity)

Ambient Concentrations

The isopleth plot for the maximum 24-hour ambient concentration for SO₂ from the oil-fired power station operating at a 1600 MW capacity is presented in Figure 9.8. The dispersion pattern reflects the strong influence of the synoptic wind patterns, with general dispersion to the north and north east. The maximum modelled concentration is 162.3 µg/m³ and is observed approximately 9 km to the southeast of the proposed plant, between the coast and

the shifting sand dunes. The modelled concentrations exceeds the WHO and proposed South African ambient standards concentration of 125 $\mu\text{g}/\text{m}^3$.

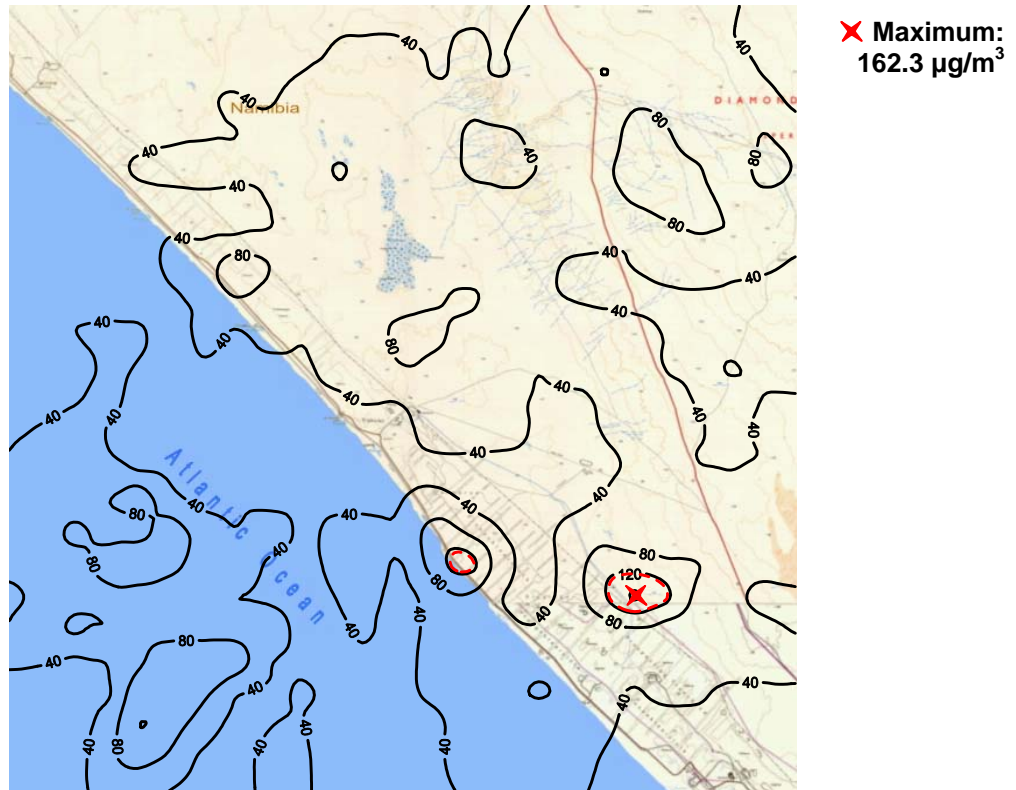


Figure 9.8: Maximum 24-hour SO₂ concentration for the gas-fired power station operating at 1600 MW capacity. Red dashes indicate proposed South African Air limit values and WHO guidelines

Risk Scenario

Results based on modelled 24-hour SO₂ concentrations for the double capacity scenario of the oil stack at the site, indicate that it is not likely for any individual, even sensitive individuals, to develop adverse health effects as a result of exposure at these concentrations.

Discussion

In total, the abovementioned results for the SO₂ exposure scenarios indicate that it would be unlikely for individuals on site to develop adverse health effects due to SO₂ exposure at these modelled concentrations.

9.3 Total Suspended Particulate Matter

Particulate matter will be emitted when the Kudu CCGT plant operates on No. 2 fuel oil. This fuel type generates a small particulate emission. The results of the dispersion modelling for the maximum 24-hour and annual average concentrations are presented in Table 9.3 and 9.4 respectively. A summary of the risk characterization and calculations are presented. The risk characterization for Particulate Matter was done qualitatively, since there are no reference concentrations for Total Suspended Particulate Matter (TSP).

9.3.1 TSP 24-hour Maximum – Oil-Fired Power Station (800 MW & 1600 MW Capacity)

Table 9.3 summarises the maximum 24-hour modelled results for particulate matter from the Kudu CCGT operating with No. 2 fuel oil. The modelled results are compared with the current South African guidelines for TSP. The maximum modelled results are less than 1% of the current South African guideline.

Table 9.3: Summary of modelled 24-hour maximum TSP results

Operational Scenario	South African Guideline	Kudu CCGT Modelled Results
800 MW	300 $\mu\text{g}/\text{m}^3$	2.12 $\mu\text{g}/\text{m}^3$
1600 MW	300 $\mu\text{g}/\text{m}^3$	4.32 $\mu\text{g}/\text{m}^3$

9.3.2 TSP Annual Average – Oil-Fired Power Station (800 MW & 1600 MW Capacity)

Table 9.4 summarises the annual average modelled results for particulate matter from the Kudu CCGT operating with No. 2 fuel oil. The modelled results are compared with the current South African guidelines for TSP. The maximum modelled results are less than 1% of the current South African guideline.

Table 9.4: Summary of modelled annual average TSP results

Operational Scenario	South African Guideline	Kudu CCGT Modelled Results
800 MW	100 $\mu\text{g}/\text{m}^3$	0.14 $\mu\text{g}/\text{m}^3$
1600 MW	100 $\mu\text{g}/\text{m}^3$	0.29 $\mu\text{g}/\text{m}^3$

The abovementioned concentrations modelled for TSP from the oil stack were all well below the current South African guidelines of 300 $\mu\text{g}/\text{m}^3$ for a 24-hour average and 100 $\mu\text{g}/\text{m}^3$ for an annual average. The modelled concentrations are even below the proposed South African PM₁₀ standards.

9.4 Comparison with Site D Study

The predicted ambient concentrations at the Uubvlei site are slightly higher than those modelled at Site D, Oranjemund. This is attributed to the differences in topography and local meteorology between the two sites.

9.5 Greenhouse Gases

A greenhouse gas (GHG) is transparent to shortwave radiation emitted by the sun but has the ability to absorb the longwave radiation emitted by the surface of the earth, resulting in a warming of the atmosphere, producing what is known as the greenhouse effect. Examples of GHGs include water vapour, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO), ozone (O₃) and chlorofluorocarbons (CFCs). These gases have atmospheric lifetimes ranging from a few years to many decades.

The individual effect of the wide range of GHGs is represented by a parameter known as the Global Warming Potential (GWP). The GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of CO₂ calculated over 100 years. Thus, the GWP of CO₂ is defined as 1.

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in New York on 9 May 1992. The Convention aims to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Namibia ratified the UNFCCC in May 1995.

Namibia has a small industrial sector and a relatively small economy which is not energy-intensive, as it relies primarily on agriculture, fisheries and mining of minerals, which require little secondary processing. At present, energy is imported as petroleum products, electricity and coal. In comparison to other countries emissions of carbon dioxide generated from electricity related activities in Namibia are low (1 800 Gg of CO₂ - 1994 estimate). The transport sector is responsible for emitting about 50% of total national CO₂ emissions due to the distributions of goods and services over vast distances. Enteric fermentation in cattle and sheep contributes 98% of the CH₄ emissions. Emissions of NO₂ are small and mostly derived from the savannas burning.

Consequently, Namibia has minimal impact on global greenhouse gas (GHG) emissions. In 1994, the greenhouse gas emissions from Namibia were 5 614 Gg CO₂ equivalent, which accounted for less than 0.05% of global CO₂ equivalent emissions. Namibia was also estimated to be a net sink for carbon dioxide in 1994 due to the large uptake of carbon dioxide by trees. This is mainly due to increasing magnitude of bush encroachment in Namibia's vast rangeland. According to the IPCC (2000), it is estimated that the amount of carbon taken up by natural vegetation in Namibia in 1994 makes up approximately 0.1% of the total net uptake by land ecosystems globally.

A 1600 MW CCGT plant will produce approximately 150 kg/s of CO₂ when firing on natural gas (CSIR, 2003). It is assumed that an 800 MW CCGT plant will produce approximately 75 kg/s, resulting in an emission of 2 500 Gg or 45% of the entire CO₂ equivalent of Namibia, based on 1994 figures. A double capacity CCGT plant will result in an 82% increase in the GHG emissions from Namibia, based on 1994 figures. While this figure indicates a large increase the overall emissions of CO₂ remain in global terms.

10. ASSESSMENT OF IMPACTS OF AIR QUALITY ON VEGETATION

10.1 Impacts of Air Pollution on Vegetation

10.1.1 Introduction

Early investigations into the impacts of air pollution on vegetation were largely triggered by symptoms noted in forest species and evidence of forest decline in industrialized Europe. With the exception of some attention to commercial crop plants (Holt, 1987; Mackenzie and el Ashry, 1989) most research and field studies up to the present day are still largely concentrated on these forest tree species and the associated vegetation with these habitats. However, there has more recently been some studies on other habitats such as freshwater lakes, various types of wetlands and grasslands but these have again been undertaken in northern hemisphere environments. There is a paucity of information on air pollution in developing countries and the World Health Organisation has identified that “more research is needed in Mediterranean, tropical and subtropical vegetation zones” (WHO Regional office for Europe, Copenhagen, Denmark, 2000).

Common air pollutants impacting on vegetation have been identified as NO_x, ammonia, sulphur dioxide and ozone. The contribution of these pollutants to injury of any vegetation type is dependent on ambient concentration, and very importantly, on the “mix” of pollutants present in a particular area. This is due to synergistic effects that result in greater damage than may be caused by single pollutants acting alone (Mansfield and McCune, 1987; McCormick, 1997). This is due in part to complex chemical interactions that occur in the environment e.g. NO_x promotes the production of ozone which actually contributes to most of the damages noted. In addition, exposure to multiple stressors may impact severely on the capacity of plants to allocate resources to protect against stressors.

As a result of the large number of variables that affect plant condition in the field it becomes exceedingly difficult to establish relationships between pollutant levels and plant responses (symptoms). Environmental extrapolation of laboratory studies on the effects of particular air pollutants is bedeviled by the complexity of the chemical reactions occurring in the atmosphere, biochemical processes in different soil types, and interactions between plants, insects and pathogens. Visual symptoms of air pollutant damage and those attributable to pests and pathogens may often be very similar in the field e.g. necrosis, foliar deformities.

Another complexity in assessing air pollution impacts is that obvious symptoms may only manifest after decades of exposure. This is especially true if the impacts involve slow changes in species distributions (composition and abundance) within particular vegetation types.

10.1.2 Impacts of NO_x on Vegetation

The major air pollutants relevant to vegetation impacts in this category are nitrogen dioxide (NO₂) and nitrous oxide (NO). The ratio of these pollutants in a particular environment is influenced by environmental factors including atmospheric moisture conditions. Any assessment of the impacts of these pollutants is complicated by the fact that nitrogen is a primary macronutrient which, under certain concentrations, may induce “positive” effects such as increased productivity of above ground parts especially in the shorter term. The impacts of NO_x on vegetation may be summarized as follows (de Vries and Gregor, 1991).

Direct impacts on the receptor

NO₂ and NO, mainly taken up via the stomata, dissolve at the cell surfaces and lead to elevation of cellular nitrates and nitrites which are reduced to ammonia (by enzymes) and incorporated into organic compounds. This assimilation results in the observed increase in productivity. However above certain concentrations cellular damage may occur and symptoms may present as necrosis on the leaves. Owing to its solubility NO₂ is more phytotoxic than NO. It is important to note that the increased productivity described above is not necessarily a positive impact. It has been shown that “more luxuriant” growth may result in inefficient winter hardening, thus contributing to increased frost sensitivity (Pitelka and Raynal, 1989), increased susceptibility to predation due to better nutritional value and reduced production of anti-feedants such as phenolics (Brunsting and Heil, 1985), decrease in drought resistance due to higher ratios of above and below ground parts (increase transpiration losses and less efficient root uptake), and in the longer term, imbalance soil nutrient conditions (other essential nutrients e.g. calcium and magnesium become limiting). Ultimately such fertilization may lead to changes in community structure and species composition in particular environments.

Indirect Effects due to Nitrogen Enrichment in Soils

Improved soil nitrogen conditions lead to similar effects as described above in terms of increased productivity but the same negative longer term impacts would apply

Increased Impacts due to Interaction with Other Pollutants

The chemical reactions occurring between different pollutants (SO₂, ozone) in the atmosphere, internally within the plant leaves, after wet and dry deposition onto plants and soils, is complex. Strong evidence indicates that nitrogen oxides promote the development of ozone, and that the impacts from a mix of pollutants are often synergistic i.e. greater than the sum of the individual expected impacts. Thus the damage to vegetation is determined by mix of pollutants present and the environmental conditions (temperature, moisture, sunlight etc.) prevalent in an area.

10.1.3 Critical Loads for NO_x

The development of critical loads for nitrogen inputs for different vegetation types is extremely difficult because of the numerous physicochemical environmental variables operating in natural ecosystems, the sensitivity of different species to nitrogen enrichment, the complexity of natural and anthropogenic stressors and varying climatic conditions. Such complexities often prevent the establishment of cause and effect relationships (Evans and Lewin, 1985), which are vital to establishment of recommended ambient levels or deposition rates for NO_x (and any other pollutant). In addition laboratory studies to study visual symptoms of pollutant loads usually involve the use of very high concentrations of pollutants. Such levels rarely occur even in industrialised countries, except near certain industries such as nitric acid production facilities. Nonetheless it is recognised that visual symptoms (e.g. necrosis) may be preceded by changes in biochemical, physiological and ultrastructural changes that impact on plant health (de Vries and Gregor 1991). The duration of exposure to particular pollutant levels is also critically important and short term (hours) increased levels may be less significant to plant communities as it may be to impact on human health. Thus the determination of critical levels should aim at the lowest effect concentration (i.e. concentration inducing plant response) that a plant community is exposed to over long term periods.

Based on limited data de Vries and Gregor (1991) estimated the following guideline for ambient levels of NO_x to protect sensitive plant communities.

Annual Average	4 hour average
30 ug/m ³	95ug/m ³

The capacity to assimilate NO_x (as a nutrient) without significant changes in community structure will vary significantly amongst community types. In general vegetation communities which are adapted to exist under low nutrient conditions are likely to be most sensitive to additional nitrogen inputs. NO_x deposition rates for various northern hemisphere vegetation community types were provided by World Health Organisation (WHO Regional Office for Europe, Copenhagen, Denmark, 2000). None of these vegetation types are similar to the communities that are present in this study area. Thus in the absence of more appropriate data, nitrogen deposition rates for Lowland Dry Heathlands are included below as this community type exhibits some xerophytic characteristics and may occur on relatively nutrient poor soils.

Vegetation Community	Critical Load
Lowland Dry Heathlands	1500-2000 mg/m ² /annum

10.2. Assessment of Impact of NO_x in the Study Area

10.2.1 Situational Analysis of the Study Area

Soil and climatic condition dictate the vegetation types present in the area and most species (with the exception of most of those that occur along the floodplain of the Orange River) display varying degrees of adaptation to xerophytic conditions. Low growing succulents are thus characteristic of vegetation in most of the study area. As expected under such semi-arid conditions, vegetation cover is sparse. Within the diamond mining area repeated disturbance has all but destroyed previously existing flora. The vegetation communities present are listed below (Burke, 1998; Mannheimer, 2004):

Coastal hummocks – characterised by a low coverage of about 5% with *Salsola nollothensis* which is adapted to withstand continuous burial by mobile sands

Stabilized hummocks – more stable sands result in improved diversity and cover is about 15%. Dominant species are *Othonna furcata* and *Ruschia spinosa* (protected species). *Brownanthus namibensis*, a Namib endemic also occurs. All three species are however, common along the Namibian coast

Low hummock – Dominant species are *Salsola nollothensis*, *Brownanthus namibensis* and *Sueda plumosa*. Cover is approximately 10%

Salt pan vegetation – Similar dominants to low hummock vegetation. The characteristic species *Limonium dyeri* is a Sperrgebiet endemic but, is common to salt pans along the coast. Cover varies from 5-15%

Outcrop Vegetation – Occurs on schistose outcrop east of Oranjemund. Specialised flora is adapted to utilize fog moisture. Dominants are *Othonna cylindrica*, *Ruschia spinosa* and *Psammophora modesta*. Several species may be regarded as being of conservation significance and cover is approximately 10%

Wetland and Riparian vegetation – Along the river the reed, *Phragmites australis* and a few species of sedges occur. Landward of these, the riparian vegetation form dense

woodlands along the floodplain with *Rhus pendulina* and *Tamarix usnoides* forming the dominants. Near the mouth intertidal marshes are characterised by the grass, *Sporobolus virginicus* and the salt tolerant succulent, *Sarcocornia pillansii*

10.2.2 Relevant Air Quality Modelling

As stated previously, with the exception of acute effects that may result from oil-fired operations, high concentrations of pollutants such as NO_x and SO_2 , vegetation impacts are usually indicated by chronic exposure to effective levels of a particular pollutant. Thus the annual averages for worst case operational conditions (1600 MW gas-fired and 1600 oil-fired MW) for ambient NO_x levels and dry deposition rates were modelled for assessment of potential impacts on vegetation in the study area (Figures 10.1-10.4). The low rainfall in the area makes wet deposition relatively insignificant in comparison to dry deposition although it is recognized that frequent fogs may scavenge pollutants from the lower atmosphere, thus increasing the expected levels of “wet” deposition.

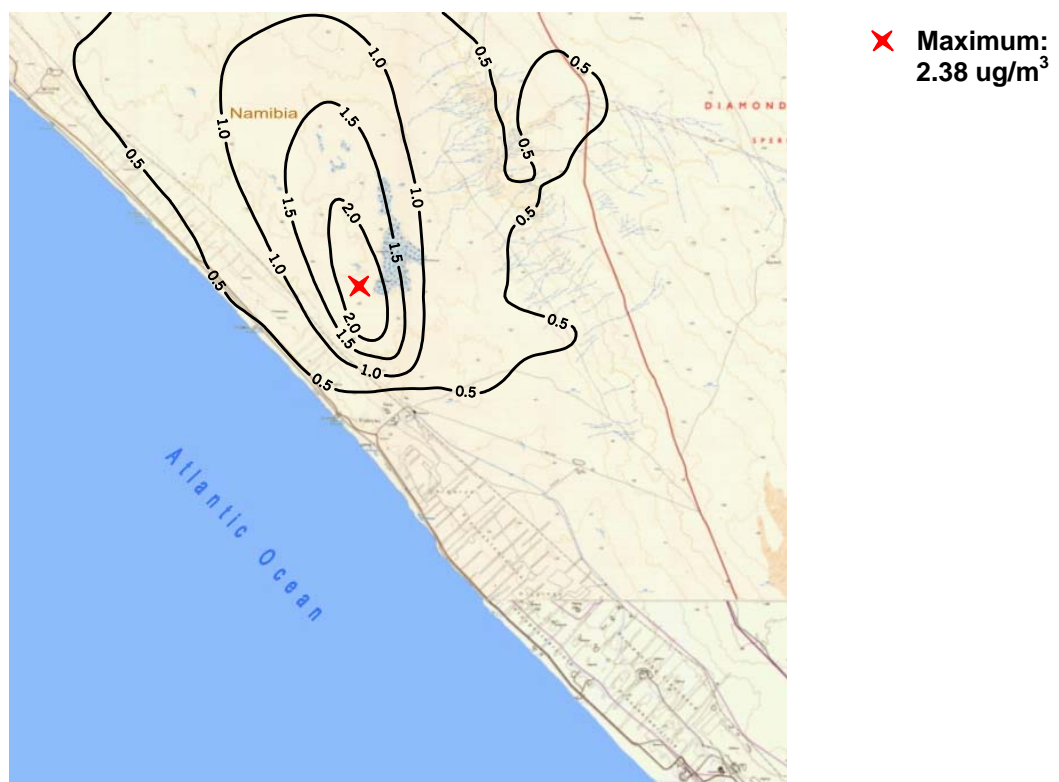


Figure 10.1: Annual average ambient concentration of NO_x ($\mu\text{g}/\text{m}^3$) for the gas-fired power station operating at 1600MW capacity

Maximum concentrations expected for the gas-fired station at double capacity is 2.38 $\mu\text{g}/\text{m}^3$ and maximum levels, as with the coal-fired scenario, is expected to occur approximately 4 km north of the plant, near Uubvlei swamp.

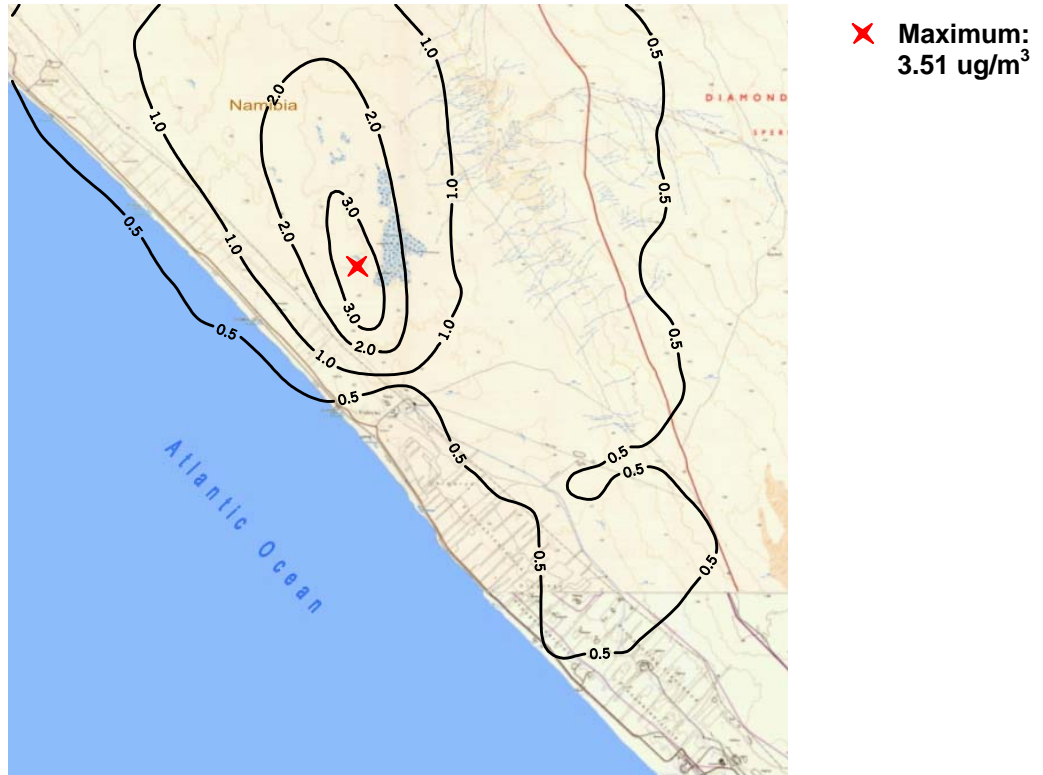


Figure 10.2: Annual average ambient concentration of NO_x (ug/m³) for the oil-fired power station operating at 1600 MW capacity

According to the model the maximum annual average ambient concentration expected is 3.51 ug/m³ and maximum levels are expected to occur approximately 4 km north of the plant, near Uubvlei swamp.

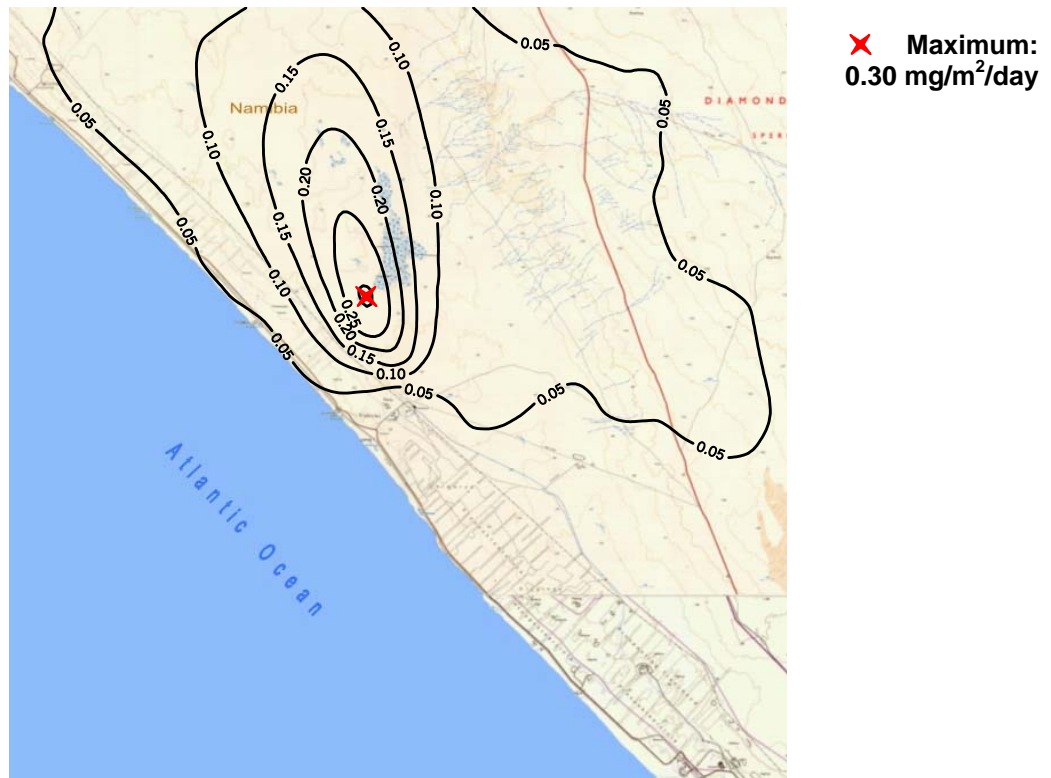


Figure 10.3: Annual average dry deposition rates (mg/m²/day) for the gas-fired power station operating at 1600MW capacity

The maximum dry deposition rate for NO_x is 0.30 mg/m²/day and the area subjected to these maxima is as described for the oil-fired power plant.

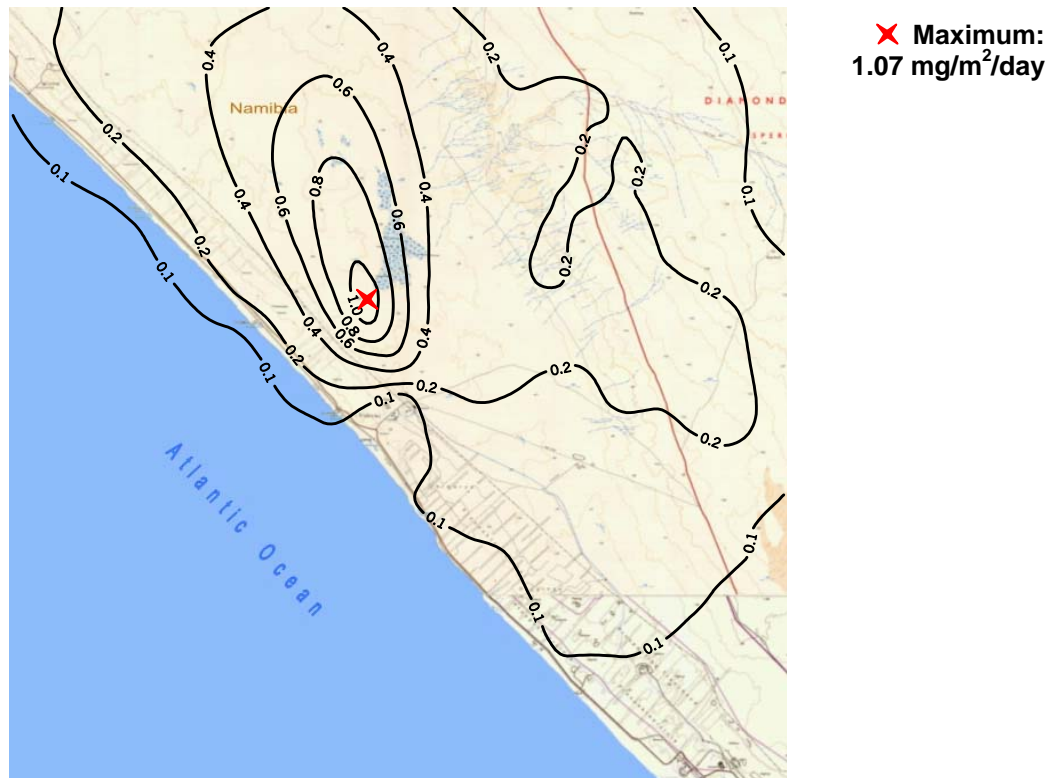


Figure 10.4: Annual average dry deposition rates (mg/m²/day) for the oil-fired power station operating at 1600MW capacity

The maximum deposition rate for NO_x in the study area for the double capacity oil-fired power generation is 1.07 mg/m²/day and such maxima are expected to occur approximately 4 km north of the plant, near Uubvlei swamp.

10.2.2 Vegetation Impact Assessment

This assessment places emphasis on the potential for impact of worst case scenarios for the different operating conditions (1600 MW gas or oil-fired generation) i.e. maximum ambient concentrations and deposition rates for NO_x. Values obtained from air quality modelling for average annual ambient concentration levels could be compared directly with the guideline value obtained from the literature. However for deposition rates, guideline values were only obtained for average annual deposition rates while the modelling conducted was for average daily deposition rates. The annual deposition rates was calculated based on the assumption that the power plant would run 97% of the year on gas and 3% of the year on oil. The environmental loading for nitrogen based on maximum values for the study area is presented in Table 10.1.

Table 10.1: Environmental loading of Nitrogen

	Annual Average Ambient Concentration ug/m ³		Annual Deposition Rate mg/m ² /annum	
	1600MW Gas	1600MW Oil	1600MW Gas	1600MW Oil
Maximum in Study Area	2.38	3.51	109.5	390.55
Guideline Value	30		1500	

Ambient Concentrations

As indicated in the table above, the maximum average annual concentrations for ambient NO_x are well below the guideline value, which in itself, is a relatively conservative estimate designed to protect the sensitive species from impacts that may occur (physiological, ultrastructural) prior to the appearance of any visual symptoms. Maximum concentrations will occur in an area near the Uubvlei swamp. The dominant vegetation in this area is most likely to be that which characterises low hummocks. The low ambient concentrations indicate that significant impact on this vegetation type is unlikely to occur.

NO_x Deposition Rates

As indicated previously, dry deposition was considered the most significant mode of transfer of this pollutant to the vegetation in the area. However due to frequent fogs wet deposition will increase the overall transfer of NO_x to the vegetation. Nonetheless, it was still considered that dry deposition will be the major source of NO_x transfer by far.

The area of maximum potential impact is essentially the same as described for ambient NO_x concentrations above, and would thus have a vegetation cover characteristic of low hummocks i.e. succulent herbs and shrubs. The maximum annual dry deposition rate of 390.55 mg/m²/annum for the oil-fired option is well below the guideline of 1500 mg/m²/annum. However it must also be noted that this guideline is used tentatively in this assessment as it was developed for different vegetation type (Lowland Dry Heathlands). The vegetation cover in the study area is predominantly xerophytic and occurs under very poor nutrient conditions thus making it relatively difficult to assess the significance of additional nitrogen input in terms of impacts due to nutrient enrichment. However, impacts are unlikely to be significant since productivity in this environment is also limited by prevailing low moisture conditions. In terms of flood plain vegetation, effects due to enrichment from atmospheric transfer of nitrogen would be negligible in comparison to that from river flow.

Assessment of Potential Impacts

It must also be noted that no information exists on the impact of air pollutants on flora occurring in the study area. As such this assessment describes **potential** impacts based on published information of impacts on other floral communities, experiments on crop plants (see section 10.1.2) and knowledge of the vegetation types and environmental conditions occurring in the study area. Nitrogen loading rates as discussed above indicate that the probability of occurrence for most of these potential impacts would be low. Nonetheless in the absence of information on actual impacts on the highly specialised vegetation types that predominate in the area, it would be prudent to indicate what impacts may occur even if the likelihood is very small. This would also inform the design of monitoring and research programmes that may need to be undertaken. The potential impacts of exposure to NO_x are listed below and the assessment (extent, duration, probability, significance etc.) of each of these is summarized in Table 10.2.

- Nitrogen enrichment may lead to the production of plants that appear more luxuriant but are less “hardy”, and thus in the longer term, become more susceptible to impacts of long dry periods (water stress), increased insect predation due to increased levels of soft tissues and lower production of protective chemicals such as phenolics and temperature extremes
- Nitrogen enrichment may lead to longer term nutrient imbalances due to changes in ratios of root and shoot production or through depletion of other essential nutrients in the soil (the latter being highly unlikely in this environment where overall productivity is very low, but could occur in the microenvironment of individual plants)

- Nitrogen enrichment may lead to changes in community structure in the longer term. In this environment grasses may increase in dominance leading to potential loss of some succulent species

Table 10.2: Assessment of Potential Impacts of Air Quality on Vegetation in the Study Area

IMPACT	STATUS	EXTENT	INTENSITY	DURATION	PROBABILITY	SIGNIFICANCE
Nitrogen enrichment causing water stress, increased predation etc.	Negative	Local	Low	Medium/ Long term	Low	Low
Nitrogen enrichment causing soil nutrient imbalances	Negative	Local	Low	Medium/ Long term	Low	Low
Nitrogen enrichment causing changes in community structure	Negative	Local	Low	Long term	Low	Low

10.3 Discussion

This assessment of impacts of air quality from the proposed power plant development essentially addressed pollution from NO_x. With the exception of acute exposures due to emissions under oil-fired operations which may produce short term acute effects, vegetation generally responds to longer term ambient concentrations and deposition rates for various pollutants. Thus the annual ambient concentrations and deposition rates are more appropriate for assessment impacts of air quality on vegetation.

The modelling of NO_x emissions for the proposed development indicates that levels would be well below those that would indicate potential for impact. However, as indicated in Table 10.2, confidence levels for this assessment was low due to lack of data on effects that may occur in the very specialised vegetation that is characteristic of the study area.

The second potential threat to succulent vegetation is the possibility that nitrogen enrichment may result in the grasses out-competing the succulents, which are adapted to poor nutrient conditions, and in the long term this could lead to community changes. Nitrogen loading assessment for this type of vegetation requires investigation. The impact of NO_x on floodplain vegetation was considered insignificant.

The overall assessment on the impact of the proposed development on vegetation indicates that the significance of impacts are low based on pollutant loads and the distribution of the vegetation types on a regional (Namibian coast) scale. Assessment of the data did not indicate any fatal flaws.

The predicted ambient concentrations at the Uubvlei site are slightly higher than those modelled at Site D, Oranjemund. This is attributed to the differences in topography and local meteorology between the two sites.

11. POLLUTION ABATEMENT AND MITIGATION

11.1 During Construction

Sand and dust is readily liberated during windy conditions in the study area. This makes it imperative that dust generated through construction activities of the proposed CCGT power station is minimized through focused management and adherence to dust minimization practices. The dust management plan during construction should include the following:

- Removal of vegetation limited to only what is necessary to accommodate construction activities.
- Traffic control measures to limit vehicle-entrained dust from unpaved roads e.g. by limiting vehicle speeds and by restricting traffic volumes.
- Re-vegetation of the construction terraces once all the construction is completed, and when the laydown area is vacated.

11.2 Pollution Control Capacity

It is recommended that the CCGT power plant is fitted with a dry low NO_x burner for gas-fired operation and water injection for liquid fuel to minimize the production of NO_x.

11.3 Monitoring

There is currently no ambient air quality monitoring in the vicinity of the proposed development. It is recommended that a survey of the ambient air quality is undertaken following the commissioning of the 800 MW power station. This survey could be achieved through the use of passive sampling equipment. The results of this preliminary study should inform the long term monitoring programme for the area.

11.4 Summary of Impact Assessment of the Proposed CCGT Power Plant

Table 11.1 provides a summary of the potential impact of the proposed CCGT on human health. The significance of the impact takes into account the nature of the impact, the extent, duration, intensity, probability of occurrence and confidence in the predicted modelling results.

Table 11.1: Summary Impact Assessment of the Proposed NamPower CCGT Power Station

Pollutant	Impact of Pollutant							
	Extent	Duration	Intensity	Probability of Impact	Status	Confidence	Significance (without mitigation)	Significance (with mitigation)
NO _x – oil	Local	Long term	Low	Improbable	Negative	High	Low	Low
NO _x – gas	Local	Long term	Low	Improbable	Negative	High	Low	Low
SO ₂ – oil	Local	Long term	Low	Improbable	Negative	Medium	Low	Low
TSP – oil	Local	Long term	Low	Improbable	Negative	High	Low	Low
CO ₂	Global	Long term to permanent	Medium	Probable	Negative	Medium	Low	Low
Fugitive Dust	Immediate area	Long term	Low	Probable	Negative	Medium	Low	Low

Extent – this indicates whether the impact will be local and limited to the immediate area of the development, limited to within 5km of the development, or whether the impact may be realised regionally, nationally or even internationally.

Duration – this reviews the lifetime of the impact, as being short term (0 – 5 years), medium (5 – 15 years), long term (>15 years but where the impacts will cease after the operation of the site) or permanent.

Intensity – this establishes whether the impact is destructive or innocuous and is described as either low (where no environmental functions and processes are affected), medium (where the environment continues to function but in a modified way) or high (where environmental functions and processes are altered such that they temporarily or permanently cease).

Probability – this considers the likelihood of the impact occurring and is described as improbable (low likelihood), probable (distinct likelihood), highly probable (most likely) or definite (impact will occur regardless of prevention measures).

Status of the impact – a description as to whether the impact will be positive (a benefit), negative (a cost) or neutral.

Degree of Confidence – the degree of confidence in the predictions, based on the availability of information and specialist knowledge.

12. PERMIT REQUIREMENTS

In terms of the proposed Pollution Control and Waste Management Bill, an air pollution license will be required for the discharge of pollutants to the air, subject to air pollution objectives that are set, standards, treatment processes, the contents of an environmental assessment, and an air pollution action plan that stipulates the best possible means for reducing and preventing the discharge of pollutants to the air. The Atmospheric Pollution Prevention Ordinance 11 of 1976 is administered by the Namibian Ministry of Health, and in terms of section 5 any person carrying on a “scheduled process” within a “controlled area” has to obtain a registration certificate from the Department of Health. The Act lists 72 processes in Schedule 2, which includes:

“29. *Power stations: That is to say, processes which –*

“33. *Producer gas works: That is to say, processes in which producer gas is made from coal and in which raw producer gas is transmitted or used”*

34. *Gas and coke works: That is to say, processes (not being producer gas works) in which...*”

According to Section 5 and 6 of the Ordinance, the premises in which the scheduled process will be conducted must be registered and a registration certificate (air pollution permit) obtained.

13. CONCLUSIONS

The specialist air study has considered the impact of emissions from the proposed Kudu CCGT Power Station in Uubvlei, on human health and the surrounding vegetation. This has been conducted using the outputs of dispersion modelling using CALPUFF for a health and vegetation risk assessment. NO_x, SO₂, particulate and CO₂ emissions from the proposed plant were assessed. The extent of pollution dispersion has been illustrated using isopleth maps and more specific concentrations at receptor points have been used in assessing the risk to health. The proposed site of the CCGT power plant was used as a receptor.

Based on the results of the dispersion modelling and risk assessments the following conclusions may be drawn:

- For PM₁₀ and NO_x, no acute or chronic health effects are expected in any healthy or sensitive individuals from the emissions of the proposed CCGT power station at the proposed site.
- For 1-hour SO₂ concentrations from the oil stack at double capacity, individuals at the site are at risk.
- Dust generated during the construction phase, particularly after the early excavation period may have a nuisance impact beyond the immediate region under windy conditions. Management measures to minimize or mitigate the impact must be implemented.
- The proposed development will not have a significant impact on the surrounding vegetation.

Based on a comprehensive air quality modelling exercise, using the best available input data, and risk assessments, it is apparent that impacts from emissions from the proposed Kudu CCGT power station are limited to the immediate area surrounding the plant, they will however persist for the lifetime of the plant, but the intensity of the impact are low.

The predicted ambient concentrations at the Uubvlei site are slightly higher than those modelled at Site D, Oranjemund. This is attributed to the differences in topography and local meteorology between the two sites.

14. RECOMMENDATIONS

14.1 Construction

- Remove only limited vegetation to accommodate construction activities.
- Spray unpaved site roads with water routinely throughout construction to contain dust. Water can be used as a wetting or binding agent on the unpaved roads and terraces.
- Implement traffic control mechanisms to limit vehicle-entrained dust from unpaved roads e.g. by limiting vehicle speeds and by restricting traffic volumes.
- Re-vegetation of the construction terraces once all the construction is completed, and when the laydown area is vacated.

14.2 Commissioning and Operations

- All equipment must be subject to regular inspection and maintenance to ensure efficient operation.
- It is recommended that, where possible, oil-fired operation should not occur under calm or light on-shore wind conditions.

14.3 Monitoring and Further Studies

- An ambient air quality monitoring programme must be established following the commissioning of the plant. This could initially be achieved through a passive monitoring network and the results from this survey could inform future monitoring at the site.
- Quantify air emissions through continuous emission monitoring.
- Regular (annual) monitoring of vegetation is recommended. The first survey should be undertaken prior to commissioning of the power plant to establish a baseline condition. The following recommendations are made with regard to monitoring surveys:
 - Sampling sites should be selected on the basis of vegetation types present in the area (Burke, 2004) and air dispersion modelling (this report).
 - The community composition and species distributions within each vegetation type must be recorded.
 - Field visual observations of plant condition should be undertaken with special attention to endemics and species considered to be of conservation significance. Observations should include indications of chlorosis, necrosis, deformities, changes in growth patterns (stunting or increase above ground productivity) and phenological changes.
 - Microscopic observations of foliage to determine cuticular erosion or other impacts should be conducted.
 - Any increase in predation of plants or presence of pathogens should be assessed.

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ENVIRONMENTAL ASSESSMENT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA

VEGETATION ASSESSMENT

PREPARED FOR:

PREPARED BY:

C.A. Mannheimer

Contact person:

Henri Fortuin

Tel: + 27 21 888-2412

Fax: + 27 21 888-2693

Email: hfortuin@csir.co.za



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ENVIRONMENTAL ASSESSMENT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA

VEGETATION ASSESSMENT

1. TERMS OF REFERENCE AND OBJECTIVES

The consultant was requested to perform the botanical specialist contribution to the Environmental Impact Assessment and Environmental Management Plan for the proposed Kudu Combined Cycle Gas Turbine power plant north of Oranjemund, by means of a field reconnaissance survey and review of relevant information. The vegetation was to be considered regarding sensitivity to disturbance created by the proposed power plant, including both direct and indirect impacts.

The main objectives of the study were:

- Assessment of perturbations to the flora expected from development and operations at the Uubvlei Site.
- To make recommendations on mitigation of expected negative impacts on vegetation during construction and operational phases.

2. APPROACH

The study comprised:

- Review of the PEA and other relevant information, including known plant species distribution according to the National Herbarium Database (SPMNDB) and species and area conservation status.
- One site visit and field survey of the Uubvlei surrounds, undertaken during March 2005.
- Preparation of a field report.

Nomenclature largely follows Craven (Ed.) 1999. No specimens were collected due to security restrictions that apply to Mining Area 1 as a whole.

3. LEGAL AND POLICY REQUIREMENTS

3.1 Acts and ordinances

Plant species are protected by various mechanisms in Namibia, including Nature Conservation Ordinance No. 4 of 1975, including amendments, and Forestry Act No. 72 of 1968.

3.2 Namibian commitment to international standards and/or guidelines

Namibia is a signatory to the Convention on Biodiversity, committing it to the preservation of species, particularly rare and endemic species, within its boundaries. As a signatory also to the Convention to Combat desertification it is also bound to prevent excessive land degradation that may threaten livelihoods.

3.3 National policies and guidelines

The Sperrgebiet is soon to be gazetted as a national park.

The Uubvlei Site *per se* falls into Zone 6, a Managed Resource Protected Area. These areas are to be managed mainly for the sustainable use of natural ecosystems in the long term, thus they should be available in future for some land use that meets the objectives of the protected area.

4. DESCRIPTION OF SURVEYED AREAS AND RECOMMENDATIONS

The greater area concerned falls into the northern section of the Succulent Karoo Biome, which is regarded as a global biodiversity hotspot, and is thus important in global as well as regional and national terms. This makes only absolutely unavoidable damage acceptable. Williamson (1997) designated this part more specifically as the Lower Orange River Zone, which falls within the Desert and Succulent Steppe as defined by Giess (1971). Winter and summer rains are possible, with rainfall averaging 51 mm per annum, and coastal fog playing an important role in the moisture regime of many organisms. Due to oceanic influences temperatures are moderate compared with much of Namibia, with mean daily temperature approximately 22°C. Winds, which are often very strong, occur throughout the year, mainly from the south-west, although warm north-easterly winds occur sporadically during winter. Terrestrial habitats that could be affected by the proposed development include coastal hummocks and plains.

4.1 Mined-out area (Uubvlei plant site, new access road, construction laydown area, alternate accommodation area)

Mining is not a sustainable activity, and in the past has already severely disturbed this site as regards flora, with the result that there is a depauperate vegetation on the site itself, as well as north and south of it throughout the mined-out area (Figure 1, orange-hatching). This makes it an ideal site from a vegetation point of view. The existing vegetation, dominated by *Brownanthus arenosus*, *Eberlanzia sedoides*, *Zygophyllum clavatum*, *Lycium tetrandrum* and *Salsola* sp., has re-established itself since the area was mined-out approximately two decades ago. Similar reestablishment of these species may be anticipated over the long term. Although *B. arenosus* is near-endemic, and *E. sedoides* is an endemic and protected species, they are relatively common along a considerable stretch of the coastal plains, and have already shown their propensity for re-establishing themselves once disturbance ceases. No other species of pressing conservation concern were observed in the mined-out area.

No mitigatory measures can be suggested for this site, but it should be emphasized that impacts such as clearing for roads and other structures on any remaining pristine or less disturbed vegetation in the direct surrounds should be minimized in the hope of later recolonisation of the habitat (see 4.2). Any levelling of artificially created dunes and covering of previously exposed bedrock may be expected to favour re-establishment of the original *status quo* regarding vegetation.

It is recommended that the area directly south of the proposed plant site (i.e. between it and the east-west road) be utilised for construction laydown (east of the new access road) and an alternative accommodation site for the workforce (west of the new access road), should the existing hostels be deemed unsuitable. This area is within the mined-out zone (Figure 1), so less new damage to vegetation will be caused.

4.2 Low hummock and coastal plain vegetation (powerline access)

Directly to the east of the plant site the vegetation is largely undisturbed. The vegetation in this area is dominated by low-growing succulents, including *B. arenosus*, *B. marlothii*, *Stoeberia beetzii*, *Othonna furcata* and *Sarcocaulon patersonii*. In addition, *Cephalophyllum ebracteatum* is quite common, as is *Asparagus capensis*, and both *Crassula atropurpurea* var. *cultriformis* and *Juttadinteria deserticola* occur occasionally. *Tridentea pachyrrhiza* a near-endemic, protected species with a restricted distribution was found (collectors number CM 2682, live plant collection NBRI). With the exception of the last-mentioned species, this assemblage of species is typical of the coastal plains, but less diverse areas of sandy hummocks dominated by the grass *Cladoraphis cyperoides* intervene occasionally towards the western sections. Most of the plant species observed here are found in similar habitats along the coast of the southern Namib, but as several of the species are endemics, and/or protected (Table 1), and *J. deserticola* and *T. pachyrrhiza* are thought to occur at a very low density throughout their ranges, it is absolutely essential that unnecessary collateral damage, particularly that due to uncontrolled vehicle activity should be held to a minimum by usage of strictly designated access roads and turning points. This is additionally important because several more species of conservation concern have been recorded in this area previously, although they were not seen during the survey. These include the endemic red data species *Tromotriche aperta* and *Euphorbia cibdela*, as well as *Stapelia*

gariensis, a protected species. **The undisturbed nature of this zone, as well as occurrence of species of high conservation importance makes it unacceptable as a construction laydown and accomodation site, particularly as previously disturbed areas are available and suitable for that purpose to the south of the plant site.**

Impacts on this vegetation type may be expected during construction and operational phases, because it will be traversed by several powerlines and service tracks. **In order to minimize disturbance, routes (preferably a single route) and turning points, should be identified and demarcated before construction activities commence and the making of new tracks due to corrugations or any other excuses should be strictly prohibited. Offenders should be subject to penalties.**

If sufficient control is exercised, later recolonisation of damaged areas (as may already be seen within the mining area) may be expected, reducing long-term defacement and restoring reasonably natural habitats and ecosystems.

Family	species	endemic (E), near-endemic (nE)	Protected (P) by legislation
Aizoaceae	<i>Brownanthus arenosus</i>	nE	
	<i>Cephalophyllum ebracteatum</i>		P
	<i>Eberlanzia sedoides</i>	E	P
	<i>Juttadinteria deserticola</i>	E	P
Crassulaceae	<i>Crassula atropurpurea</i> var. <i>cultriformis</i>		P
Apocynaceae	<i>Tridentea pachyrrhiza</i>	nE	P

Table1: Protected and endemic species found during the field survey

4.3 Coastal hummock vegetation (Pipeline landing zone)

To the west of the Uubvlei plant site lies the mined-out foreshore area and the mining ponds, and along the shoreline there appears to be an area of coastal hummock vegetation, probably characterized mainly by *Salsola nollothensis*. This area was not seen by the consultant as the time made available in the high security area was insufficient. These will be traversed by the pipelines for intake of gas and cooling water, and the flushing of heated water and waste.

The mined-out foreshore zone and ponds habitat has already been extensively compromised, to such an extent that none of the proposed construction would compromise it any further.

The rest of the area appears, from aerial photographs, to consist of coastal *Salsola* hummocks. These occur reasonably frequently further north and south along the Namibian coast where similar conditions prevail. *S. nollothensis* is not of conservation concern at present.

Beyond prevention of unnecessary collateral damage, no mitigation measures are suggested.

5. GENERAL RECOMMENDATIONS

There should be consultation with NAMDEB regarding their rehabilitation plans for the surrounding area, in order that environmental monitoring and decommissioning activities of all parties concerned may be aligned and consistent.

The appointment of a **knowledgeable** environmental officer **with authority**, particularly during the construction phase, of this plant as well as other sections of the planned network, is highly recommended. Previous experience has indicated that this would probably be the only successful way to ensure compliance of contractors with recommendations of the environmental management plan (EMP). Contractors should be educated regarding the EMP for the construction phase, and should face fixed penalties for transgressions.

Consultation with the National Botanical Research Institute (Dr. G.L. Maggs-Kölling) and/or Mr. Trygve Cooper of the Ministry of Environment and Tourism (Lüderitz) regarding possible removal and rescue of species (particularly protected taxa) with potential use in screening trials, national nursery/horticultural programmes or for rehabilitation trials could be considered as a public relations exercise and contribution to conservation.

6. ASSUMPTIONS AND CONSTRAINTS

It was assumed that the only new road (besides the service tracks and necessary construction access tracks) would be the new access road designated on figure 1.

It was not possible to access the coastal hummocks west of the mining ponds due to time constraints. It is thus assumed rather than known for certain that these dunes harbour *Salsola nollothensis* rather than another species. This assumption is based on observations further south in the mining area.

Ideally this study should have been undertaken during the rainy season (i.e. winter), because only then can annual and geophytic species be included in the survey.

7. SUMMARY

There are no plant species of sufficient conservation concern in any of the above habitats to warrant rejection of the Uubvlei site, or to justify enforcement of any costly rescue operations. Nevertheless, habitat destruction along the southern Namib coast has already been considerable, and so further disturbance should be held to a minimum. The endemic and protected species that occur in the zone east of the plant site make it unsuitable for establishment of a large accommodation site or for selection as a construction laydown site.

Most of the damage to vegetation is likely to be due to vehicles during the construction phase. Careful planning and demarcation of access routes prior to construction, together with enforcement of guidelines, will go a long way towards limiting this damage, and conserving as much of the natural habitat as possible.

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**ENVIRONMENTAL ASSESSMENT FOR
KUDU CCGT POWER PLANT AT
UUBVLEI NEAR ORANJEMUND,
NAMIBIA**

***GENERAL TERRESTRIAL ECOLOGY AND
FAUNA EXCLUDING BIRDS***

PREPARED BY:

***John Pallett,
Environmental Evaluation
Associates of Namibia (EEAN) (Pty) Ltd.***

Contact person:

Henri Fortuin
Tel: + 27 21 888-2412
Fax: + 27 21 888-2693

Email: hfortuin@csir.co.za



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ENVIRONMENTAL ASSESSMENT FOR KUDU CCGT POWER PLANT AT UUBVLEI NEAR ORANJEMUND, NAMIBIA

GENERAL TERRESTRIAL ECOLOGY AND FAUNA EXCLUDING BIRDS

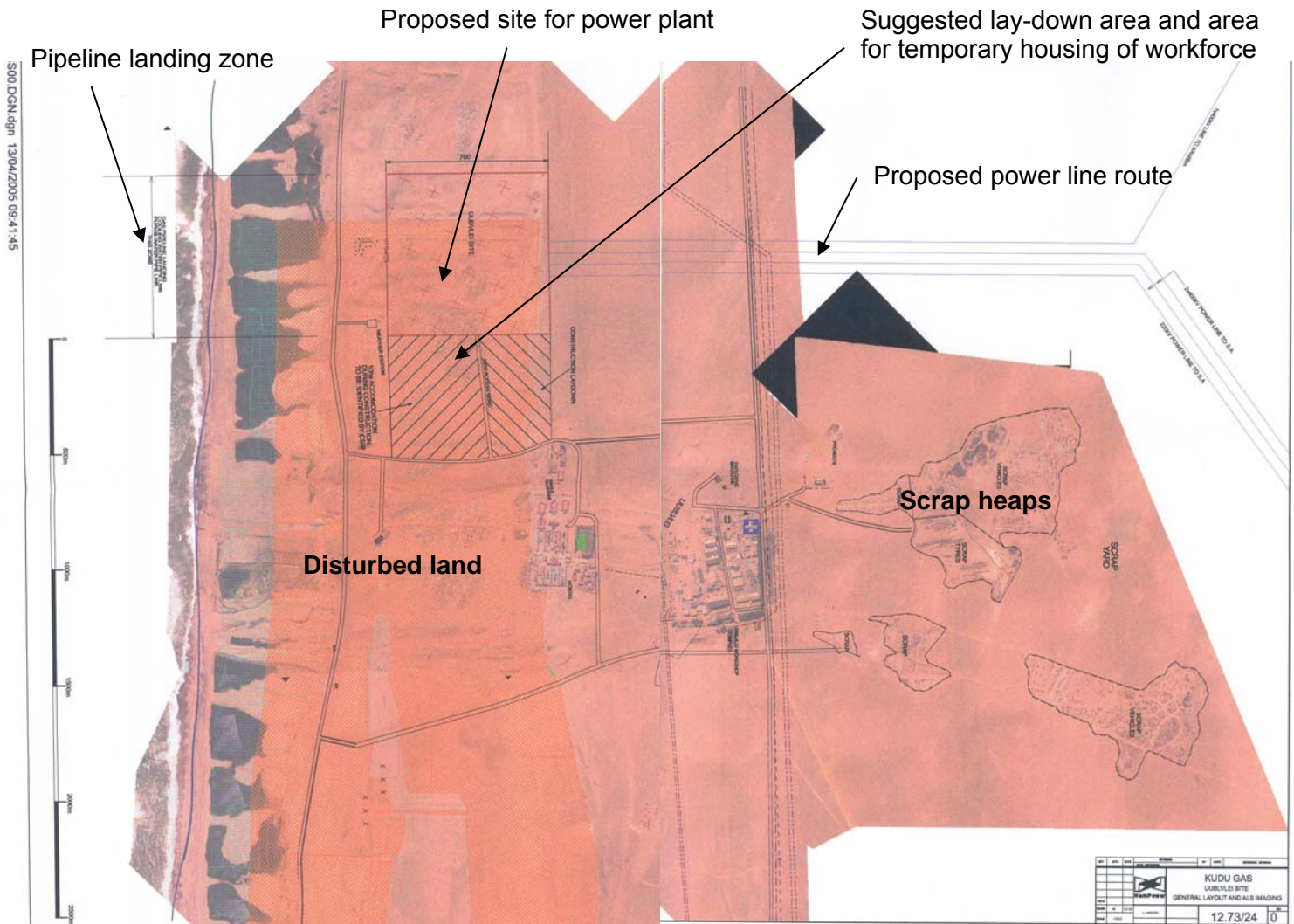
1. AREAS TO BE ASSESSED

- area of power plant itself, fuel oil depot, lay-down area, path of pipelines carrying cooling water and effluent, and possible location of temporary accommodation for construction workers
- area that may be affected by air emissions during operation
- area that might be affected during emergencies in construction and operational phases

2. DESCRIPTION OF HABITATS AND FAUNA IN RECEIVING ENVIRONMENT

Parts of the area at Uubvlei in Mining Area 1 (MA1) are already greatly disturbed by diamond-mining activities and by scrap-heaps of metal, old equipment and used tyres, but there are also areas that are relatively unspoilt within MA1. Figure 1 shows the distribution of existing natural habitats and disturbed areas that puts the present power-plant proposal into context.

Figure 1. Map of Uubvlei area showing the extent of land disturbed by diamond mining operations (orange hatching) and proposed situation of the power station and associated activities. Boundaries of habitat zones are not indicated as these were not mapped at the site.



Habitat and fauna descriptions provided here are derived from the work done on plants for this EIA by Mannheimer (2005), as well as earlier studies of vegetation (Burke 1998), insects (Marais 1998) and small mammals and reptiles (Griffin 1998) done for the Preliminary Environmental Assessment of this project (Nampower 1998) and the Wet Overburden Mining System EIA (Namdeb 2003), and general literature on the Sperrgebiet (Griffin 1995, Pallett 1995).

2.1 Low hummocks and coastal plains

Uubvlei is situated in the area of low hummocks and coastal plain vegetation that is described in the vegetation assessment. Areas disturbed by earlier mining have depauperate vegetation and presumably similar fauna. During mining, the soil in these areas has been excavated, sieved and dumped back, and some re-establishment of plants has subsequently taken place.

Recolonisation by invertebrates and small vertebrate animals has probably also taken place, but the extent of this has not been ascertained.

Where this habitat has not been disturbed by mining, it supports an interesting array of plant species and is home to some specialised fauna. Lichens are an important feature in this habitat, growing on hummocks of *Salsola* and *Brownanthus*. Lichens in general in Namibia are poorly known, and this area even less because of the restrictions of Diamond Area 1 (Wessels 1994), so it is not known if any species are endemic to a limited area here, or are of any conservation significance for other reasons.

On the fauna side, most of the ecological action in this area, like in much of the Namib, is carried out by small animals that can shelter from the harsh conditions of strong winds and meagre rainfall, and that can take advantage of the moisture provided by fog. Evidence of animal activity is seen in spider webs in most of the plants, tracks of snails, beetles, lizards, snakes, larks and hares on the ground, tracks of beetle larvae and legless lizards just beneath the surface, burrows of scorpions and small rodents, and various other signs of cryptic life. It is impossible to provide species lists, and in any case these would be meaningless, so mention will be made of only a few species that are known to be of conservation significance.

The habitat supports a well-developed, mainly sand-living invertebrate fauna with a large but unspecified number of endemic species (Marais 1998).

Of the amphibians, a noteworthy species is the desert rain frog (*Breviceps macrops*), which might even be a separate species from adjacent Namaqualand populations. If this is the case, Namibian responsibility for this species, (presently classified as Insufficiently Known & Endemic, Griffin 1999) would increase considerably (Griffin 1998). This unusual frog depends on fog moisture, confining it to a thin belt close to the coast, and lives in sandy hummock habitat in the Sperrgebiet only, much of which has been or will be destroyed in diamond mining operations.

Amongst reptiles, species of concern are the Namaqua dwarf adder (*Bitis schneideri*, also called twin-spotted adder) classified as Insufficiently Known [Griffin 1999] and possibly some underground-living lizards (legless skinks of the genus *Typhlosaurus*) which have still to be confirmed. These species are also confined to the vegetated hummock habitat, and are thus threatened by mining activities (Griffin 1998). The Namaqua dwarf adder is known to exist in two colour morphs, dark and pale, and these may be separate species. Thus the conservation status for this possible species complex is raised, but not yet officially designated.

No mammals of conservation significance occur in this area.

Large areas of 'low hummock' vegetation type on the southern Namibian coast have been, or are destined to be, destroyed or considerably degraded by diamond mining operations. The areas of this habitat that have not been disturbed are growing smaller, so every effort should be made to leave them undisturbed.

There is also an aesthetic element to this argument. The environmental damage done by mining covers very large areas of the southern coastal Sperrgebiet, leaving scars on the landscape that are most conspicuous from the air as one flies in or out of Oranjemund (the way most visitors to this area witness Mining Area 1). Why increase this damage unnecessarily? The emphasis in all

future human activities in the Sperrgebiet should be on confining them to areas that are already disturbed, rather than on spreading the disturbance further.

2.2 Coastal hummock habitat

The foreshore area has been completely mined out, leaving little of the original vegetation and fauna. This area was not visited during the field assessment, but is assumed to support depauperate remnants of the original vegetation and animals, namely hummocks around *Salsola* bushes, and fauna similar to the low hummock habitat immediately inland.

3. ENVIRONMENTAL IMPACTS CAUSED BY CONSTRUCTION OF THE POWER PLANT, AND MITIGATORY ACTIONS

3.1 Clearance of area for power plant buildings, roads, lay-down area and temporary accommodation for construction workers

The proposed site of the power plant is in the previously mined area, where land is already disturbed. Construction here will have little further impact on the vegetation and flora, and we fully support this decision for the siting of the main works.

Any of the other structures that will be associated with the power plant, access roads, a materials lay-down area, and possible temporary accommodation for the construction workforce, should also be situated on disturbed land. Due to the possible presence of amphibians and reptiles of conservation concern, and the trend of gradual reduction of their habitat, all activities should be confined (as far as possible) to areas that are already disturbed. They should not be situated on undisturbed land.

Accommodation that could be used to house the workforce during construction is the Namdeb hostel less than one kilometre distant from the Uubvlei site. If, for some reason, the hostel will not be used, then it is recommended that the accommodation site be situated immediately south of and adjacent to the power station site, on land that has already been disturbed for mining.

Similarly, the proposed lay-down area is recommended to be immediately south of and adjacent to the power station site, on land that has already been disturbed for mining.

Construction activities should not be allowed to spill over into undisturbed low hummock habitat, as this can quickly spread and destroy a much wider area of this kind of hummock vegetation and its associated fauna. Roads for vehicles should be clearly demarcated and drivers instructed to keep strictly to these tracks only.

If it is unavoidable to extend activities onto undisturbed land, then rehabilitation procedures, as recommended and carried out by Namdeb, should be done. This involves preparation before construction begins, by moving plants and as much of their surrounding substrate as possible, from areas that will be excavated to others where they are safe.

The motivation for rehabilitating whole pieces of habitat is based entirely on protecting reptile species of high conservation concern. Capture and relocation of these species in the impacted areas, as described below, is an alternative, satisfactory mitigation.

Even in areas that are already disturbed, it would be useful, and a significant indication of NamPower's commitment to conservation, to relocate individuals of the Namaqua dwarf adder and *Typhlosaurus* legless skink species from the area to be directly impacted. Since partial revegetation of the area has occurred and so long as the substrate is still sandy, it is likely that these reptiles have recolonised the area.

Reptile specialists recommend that individuals of these species should be collected and possibly relocated to an area of similar habitat that is not disturbed, nearby. This would involve some fieldwork to locate and catch the reptiles by the specialists who are concerned, namely Peter Cunningham of the Polytechnic of Namibia and/or Stuart Hebbard of Swakopmund Snake Park, who are willing to undertake this. Ideally these specialists would like to start a captive breeding programme of the Namaqua dwarf adder that would help to clarify the taxonomic status of the different morphs, as well as to build up numbers of this/these species.

Removal and relocation of these reptiles is viewed as helpful mitigation of the impact of disturbance to the population of this/these species. The captive breeding programme is not necessary, but could be promoted by NamPower as evidence of their commitment to making a positive contribution to the environment.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
Land clearance for Uubvlei site or any of the associated sites eg fuel depot, temporary accommodation, lay-down area, roads.	If done on undisturbed land, loss of low hummock habitat and its associated biota.	Local, regional, national, international levels – moderate due to presence of Red Data reptile species	Use sites that have been previously disturbed by mining. If using undisturbed sites is unavoidable, follow normal Namdeb rehabilitation guidelines before clearing or construction activities start.	All levels – low. All levels – low.

3.2 Possibility of raised dust levels and increased air pollution during construction

Construction activities, most particularly clearing of the surface where the power plant and associated structures will be built, and making access roads, could raise clouds of dust. This effect will be short-lived, and will probably not increase dust levels significantly more than the area already experiences from mining activities. Plants, lichens and animals that inhabit this area are probably frequently exposed to strong sand-laden winds, so there will be no difference for

them. Namdeb already does dust suppression in its mining areas; this should be practiced for the new developments.

It is not known what level of air pollution is envisaged from construction activities, but it will probably be low. Strong winds at the coast, experienced on an almost daily basis, will disperse pollutants so that there is no hazardous buildup.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
Clearing of construction areas and roads, and air pollution created during construction	Will create dust and smoke, but it will probably be dispersed quickly in the strong winds	Local, regional, national, international levels - low	Do dust suppression if and when necessary.	All levels – low.

3.3 Disposal of construction wastes

Waste disposal facilities are available for the town of Oranjemund, and should be used for disposal of building wastes as well as domestic wastes produced in the living areas of construction staff. This will prevent litter blowing around and contaminating surrounding areas. In addition to this standard procedure for waste disposal, a 2.5m high diamond mesh fence should be erected around the hostel area to catch any wind-blown litter. The fence-line should be cleared regularly, at least daily, to prevent litter escaping.

Hazardous waste generated in Oranjemund is delivered by Namdeb to the Windhoek hazardous waste disposal facility at Kupferberg. The same should be done with any hazardous waste generated during construction and operation.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
Construction	Creation of building waste materials	Local level – moderate. Regional, national, international levels - low	Use existing waste disposal facilities at Oranjemund or hazardous waste facility at Windhoek.	All levels – low.
			Erect a high (2.5m) diamond mesh fence around the hostel area to catch wind-blown litter, and clear litter off it daily.	All levels – low.

4. ENVIRONMENTAL IMPACTS CAUSED BY OPERATION OF THE POWER PLANT DURING GAS-FIRED AND OIL-FIRED CONDITIONS, AND SUGGESTED MITIGATORY ACTIONS

4.1 *Impact of air-borne pollutants on fauna and flora*

According to the project description, emissions from burning of gas in the power plant will be very low, so air-borne pollution is expected to be not significant. This is the situation when the power plant burns gas. There will be times when the gas supply is not sufficiently consistent, during which the fuel supply will be switched to diesel. It is estimated this will happen not more than 2-3% of the operating time. During these periods air-borne emissions will be from burning diesel, which is more harmful than emissions from gas. Also, fog tends to 'scavenge' sulphur dioxide from oil-based smoke to form mild acid precipitation, so that it ends up being more harmful than gas smoke on two counts.

The impact on the affected area is completely unknown, so it will need to be monitored. It is suggested that plants and lichens in the affected area and in a 'control' area be individually marked and monitored on a yearly basis to assess this.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
Gas-fired and diesel-fired operation of the power station	Air pollution, especially from running on diesel during fogs, might cause 'acid-rain' and damage lichens, plants in surrounding area	Unknown.	Measure and monitor plant and lichen condition to assess impact and to suggest methods to mitigate.	Unknown.

4.2 *Intake and discharge of water on the beach*

Extraction of seawater from beach wells, and discharge of effluent in the sea, are not expected to have any impacts on the terrestrial fauna. Pipelines for these purposes will traverse disturbed land lying between the shore and the power plant, so they will also have negligible impacts.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
Placement of pipelines for intake and discharge of cooling water	Little impact if done on disturbed land.	All levels - low	Not necessary.	

5. ENVIRONMENTAL IMPACTS DURING EMERGENCIES (DURING CONSTRUCTION AND OPERATION)

There has been no indication what sort of emergencies might be expected in a project of this nature. Emergency contingency plans are covered elsewhere in the report.

Sourcing of diesel to go into the fuel oil tanker depot is not specified. Safety guidelines implemented by Namdeb for sourcing of their fuel need to be assessed for appropriateness and to develop measures that can be applied to Nampower. Namibia has an oil-spill contingency plan that is coordinated by the Emergency Response Unit in the Ministry of Works, Transport and Communication. Nampower and its contractors should familiarize itself with steps to avoid an oil-spill accident and what to do in the event of such an accident.

All biota in the immediately affected area of the low hummock habitat would be threatened as a result of an oil spill, but, assuming it was confined to a small area, the overall impact would be small. Greater negative impact would probably be caused by emergency vehicles driving indiscriminately around the accident site. An emergency strategy, that needs to be fully elaborated, should include actions to confine the extent of the accident and to quickly demarcate access routes to minimise further damage by vehicles.

<i>Activity</i>	<i>Impact</i>	<i>Significance</i>	<i>Mitigation</i>	<i>Significance after mitigation</i>
An accident or emergency such as a fire or oil-spill	Impossible to predict, it would depend on the scale and type of emergency. Habitat damage from indiscriminate driving of emergency vehicles would increase negative impact.	Impossible to predict.	Elaborate an emergency strategy, which includes actions to reduce unnecessary driving around accident site.	Could reduce scale and extent of damage to habitat and fauna.

6. GENERAL COMMENTS AND RECOMMENDATIONS

Compared to the widespread environmental damage that has already taken place in the mining areas of the Sperrgebiet, construction and operation of the power plant at Uubvlei will have little negative environmental impact. By the same token, it is necessary to reduce or prevent further damage that would increase the cumulative impact that already exists. Hence our emphasis on confining all activities, as far as possible, to land that is already disturbed by mining. Human disturbance that extends into unspoiled natural habitat could negatively impact on populations of amphibians and reptiles that are restricted to the fog belt of the southern coastal Sperrgebiet, and that have probably already suffered declines due to diamond mining operations.

Unnecessary environmental damage during construction could be prevented or minimised by employing a knowledgeable, respected and 'hard-nosed' environmental officer to oversee compliance with the recommendations made above and to prosecute infringements.

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**Kudu Power Plant
Environmental Impact Assessment:**

**Assessment of a proposed cooling water
discharge into the marine environment
at a location near Uubvley, Namibia**

PREPARED BY:

CSIR Division of Water, Environment
and Forestry Technology
P O Box 320
Stellenbosch 7599

PREPARED FOR:

Namibia Power Corporation (Pty) Ltd
P.O. Box 2864
Windhoek, Namibia

DATE:

April 2005

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This report was prepared by:

R. C. van Ballegooyen

CSIR Environmentek

A. Pulfrich & A. Penney

Pisces Environmental Services (Pty) Ltd,
PO Box 31228, Tokai 7966

C.N. Steffani

Independent Consultant, 21 Skippers End,
Zeekoevlei 7941, for Pisces Environmental
Services (Pty) Ltd

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Kudu Power Plant Environmental Impact Assessment: Assessment of a cooling water discharge into the marine environment at a location near Uubvley, Namibia

Scope

This report provides a preliminary environmental impact assessment of the use of seawater cooling in the proposed 800 MW nominal capacity gas fired combined cycle power station at Uubvley, located in southern Namibia approximately 25 km north of the Orange River mouth. The seawater cooling option assessed here is an evaporative seawater cooling system where the heated brine (purge water) is discharged via a pipeline (into an approximate water depth ranging between 15 and 18 m) or as a shoreline discharge. This preliminary environmental assessment provides:

- A basic description of the physical and biological environment into which the purge water discharge will occur.
- A preliminary characterisation of the anticipated change in the physical and chemical environment due to the discharge of a heated purge water brine and associated biocide into the marine environment.
- A preliminary assessment of the relative severity of the various impacts based on the identified beneficial uses in the area.
- Recommendations as to which of the potential environmental impacts and/or engineering aspects may require further investigation.

This preliminary environmental impact assessment comprises a desk-top study that utilises the currently accessible published and unpublished information on the environment, model and field studies of the physical behaviour of heated brine discharges and their ecological effects and a limited plume dispersion modelling study using the CORMIX mixing zone expert system

The ecological assessment of the discharges beyond the surf zone were undertaken by Dr Andrea Pulfrich and Andrew Penney of Pisces Environmental Services (Pty) Ltd while those for the surf-zone were undertaken by the CSIR.



R VAN BALLEGOOYEN

Coastal Processes

Environmentek CSIR

Stellenbosch, South Africa

April 2005

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1. BACKGROUND AND BRIEF

NamPower proposes to establish a 800 MW nominal capacity gas fired combined cycle gas turbine (CCGT) power plant at Oranjemund in southern Namibia that is planned to be commissioned in 2009. This will be powered by natural gas supplied from the Kudu gas field located 170 km offshore in Namibian territorial waters. The natural gas reserves within the Kudu Gas Field are sufficient for a 800 MW nominal capacity power plant, operating for a minimum of 20 years, without the need for additional appraisal drilling. It is anticipated that, if additional gas reserves are proven after 2-3 years of gas production, and the demand for electricity warrants it, the second phase of the project, an additional 800 MW nominal capacity CCGT power plant, will be commissioned in 2014.

A full Environmental Impact Assessment (EIA) was conducted by the CSIR in collaboration with Envirosolutions in 2004. The EIA considered the construction, operation and decommissioning phases of the power station at site D (CSIR, 2004). The EIA report was reviewed and a positive Record of Decision was issued by Namibian Ministry of Environment and Tourism (MET) in January 2005.

Notwithstanding MET approval of Site D as the preferred site for the power station, Nampower decided in February 2005 to investigate the possibility of locating the power station at Uubvley, some 25 kilometres north of Oranjemund, and to commission another EIA for the construction, operation and decommissioning phases of the power station at Uubvley.

The combined cycle system proposed produces waste (latent) heat. It is proposed to use seawater cooling to dissipate this waste heat. Potential cooling technologies that could be used are:

- a direct (once-through) cooling
- an evaporative seawater cooling system
- a dry cooling system

It is proposed that the heated effluent will be discharged either via a pipeline into a water depth of between approximately 15 m and 21 m or as a shoreline discharge¹ at Uubvley located approximately 25 km north of the Orange River mouth (Figure 1). It is expected that the discharged effluent will modify the receiving environment.

This study comprises the specialist environmental assessment of the purge water discharge and low volume aqueous discharges associated with a CCGT power plant as well as associated upstream facilities as specified by Nampower and its development partners.

The objectives of the study are to provide:

- A basic description of the physical and biological environment into which the thermal discharge will occur.
- A preliminary characterisation of the anticipated change in the physical and chemical environment due to the discharge of a heated purge water brine and associated biocide into the marine environment.
- A preliminary assessment of the relative severity of the various impacts based on the identified beneficial or designated uses in the area.
- Recommendations as to which of the potential environmental impacts and/or engineering aspects of the project may require further investigation.

The assessment presented below is a desk-top study utilising the currently accessible published and unpublished information on the environment, preliminary model and field studies of the physical behaviour of thermal discharges and their ecological effects and a limited plume dispersion modelling study using the CORMIX mixing zone expert system.

¹ *Note: International best practise is not to discharge into “sensitive” environments where this can be avoided. The recently drafted South African Operational Policy for the disposal of land-derived water containing waste to the marine environment (RSA DWAF, 2004b), based on a review of international best practise and international trends in marine waste disposal policy, states that the surf-zone should be considered a sensitive environment for the following reasons that are also relevant to this study:*

- *Because discharges to the surf zone do not have a distinct ‘initial dilution process’ as encountered in offshore discharges (i.e. dilution generated by jet momentum and buoyancy effects that occur between the outlet ports and the sea surface), it is most likely that there will be a zone of non-compliance in the receiving environment, unless the constituent concentration in the wastewater is equal to the environmental quality objectives (i.e. ‘compliance at end of pipe’).*
- *The complex physical dynamics encountered in the surf zone significantly reduces the accuracy with which transport and dispersion processes can be quantified, a key requirement in assessing the suitability of disposal of land-derived wastewater to the marine environment as an option*
- *These ecologically sensitive areas are transition areas between the land and the sea, providing unique habitats for a diversity of biota.*

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In this report the assessment of potential environmental impacts is undertaken in accordance with:

- the **operational policies of the International Finance Corporation** (IFC, 1998) that, *inter alia*, require that the assessment is undertaken within the country's overall policy framework and national legislation.
- the **World Bank Water Quality Guidelines** for new thermal power plants (World Bank (1998) as well as other Water Quality Guidelines considered to be of relevance (*e.g.* RSA DWAF, 1995 and ANZECC, 2000)
- and international best practice that includes principles such as the ***precautionary approach*** (whereby, if there is uncertainty in the nature and severity of a potential impact, conservative assumptions are made with respect to the significance and potential severity of the said impact).

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2. ENVIRONMENTAL DESCRIPTION

2.1 Physical Environment

The area considered in this environmental description comprises the intertidal zone, the nearshore shallow water (< 40 m depth) and the offshore deeper water (> 40 m) marine environment, extending from the north bank of the Orange River mouth to ~50 km north of the river mouth. However, some of the data presented are more regional in nature, *e.g.* the wind and wave climate, nearshore currents, *etc.* The description of the physical environment that follows is based largely on that given in Carter and van Ballegooyen (1998) and van Ballegooyen *et al.* (2004).

2.1.1 Winds

Winds and weather in the region are controlled by the interaction of the south Atlantic anticyclone, eastward moving mid-latitude cyclones and the atmosphere pressure field over the subcontinent (Kamstra, 1985). This generally leads to strong zonal pressure gradients at the coast and the resultant fresh to strong equatorward winds. These strong equatorwards winds are interrupted by the passing of coastal lows with which are associated periods of calm or NW wind conditions. Figure 2 shows seasonal wind distributions for the sea area adjacent to the Orange River mouth. The winds are predominantly from the S - SE sector. These are based on Voluntary Observing Ships (VOS) data stored in the Southern African Data Centre for Oceanography (SADCO). NW winds occur throughout the year although at a far lower frequency than the S/SE winds. The occurrence of NW wind conditions is greatest in winter, a period when short duration easterly “berg wind” conditions also occur. Gales occur at their highest frequency in spring (2.23%) with the balance of the seasons showing ~1% occurrences of gale force winds.

2.1.2 Waves

Seasonal swell roses for the region drawn from Voluntary Observing Ships (VOS) data stored in the Southern African Data Centre for Oceanography (SADCO) show that the largest waves originate from the S - SW sectors that may attain a wave height of 4 – 7 m offshore. These are generated by mid-latitude cyclones. There is no strong seasonal variation except for a slight increase in swell from the WSW-W direction sector in winter. Minimal swell originates from the WNW through N to the SE direction sector in the offshore zone.

The exceedance curves for wave rider data for the region immediately offshore of Port Nolloth, located 100 km south of the Orange River, show that highest waves occur in winter

whilst the summer wave regime is lowest in almost all exceedance categories. Wave periods show a strong mode at 10 – 15 seconds and a weaker mode at approximately 8 seconds (Table 1). The long period is associated with swell generated by distant forcing, whilst the 8 second mode is linked to locally generated seas. Rossouw (1982) observed a similar energy distribution off the Orange River mouth. Most of the wave energy impinging on the coast is contained within the long period swells.

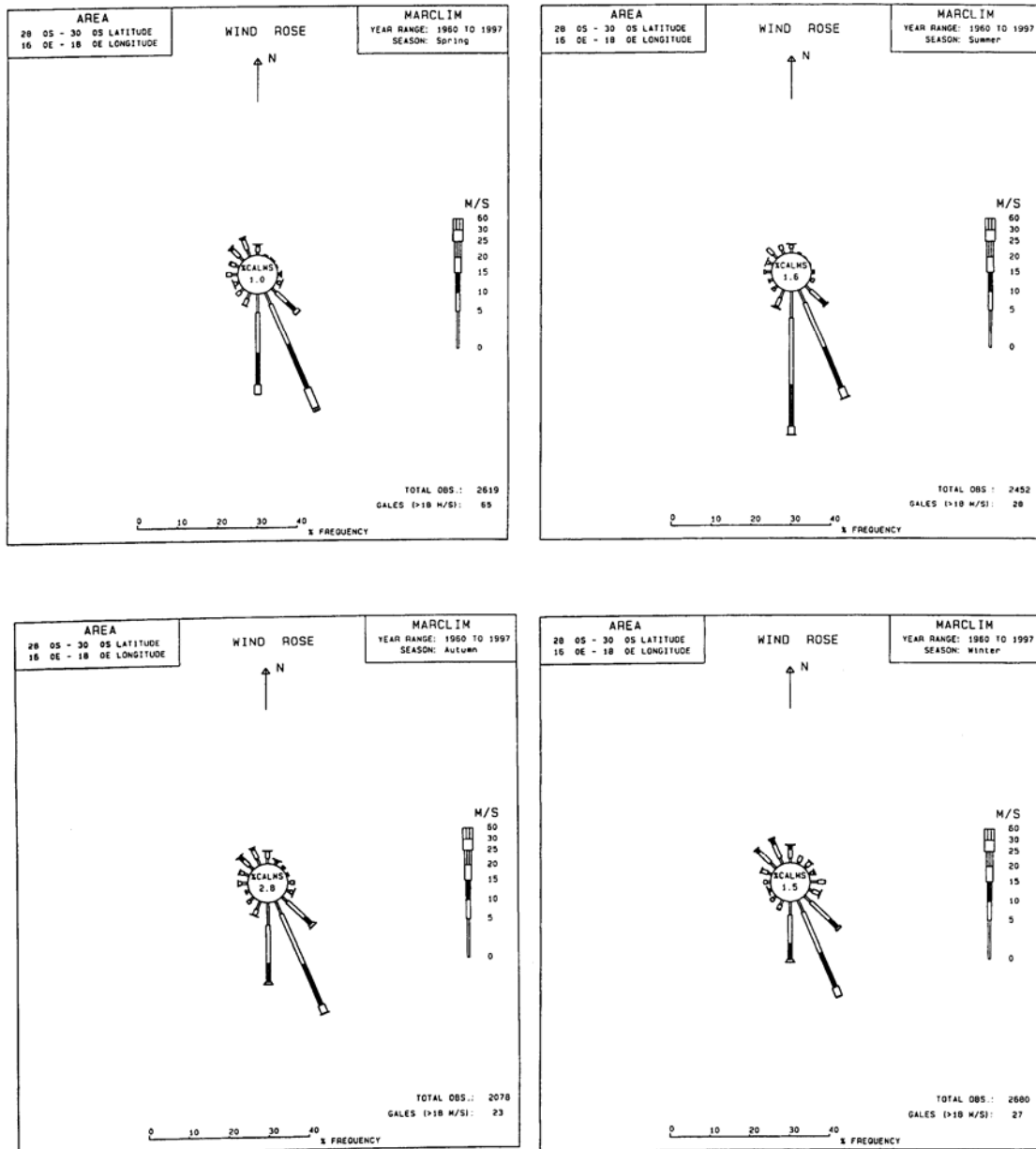


Figure 2: Seasonal wind roses for the offshore marine environment adjacent to the Orange River Mouth. (VOS data from SADCO).

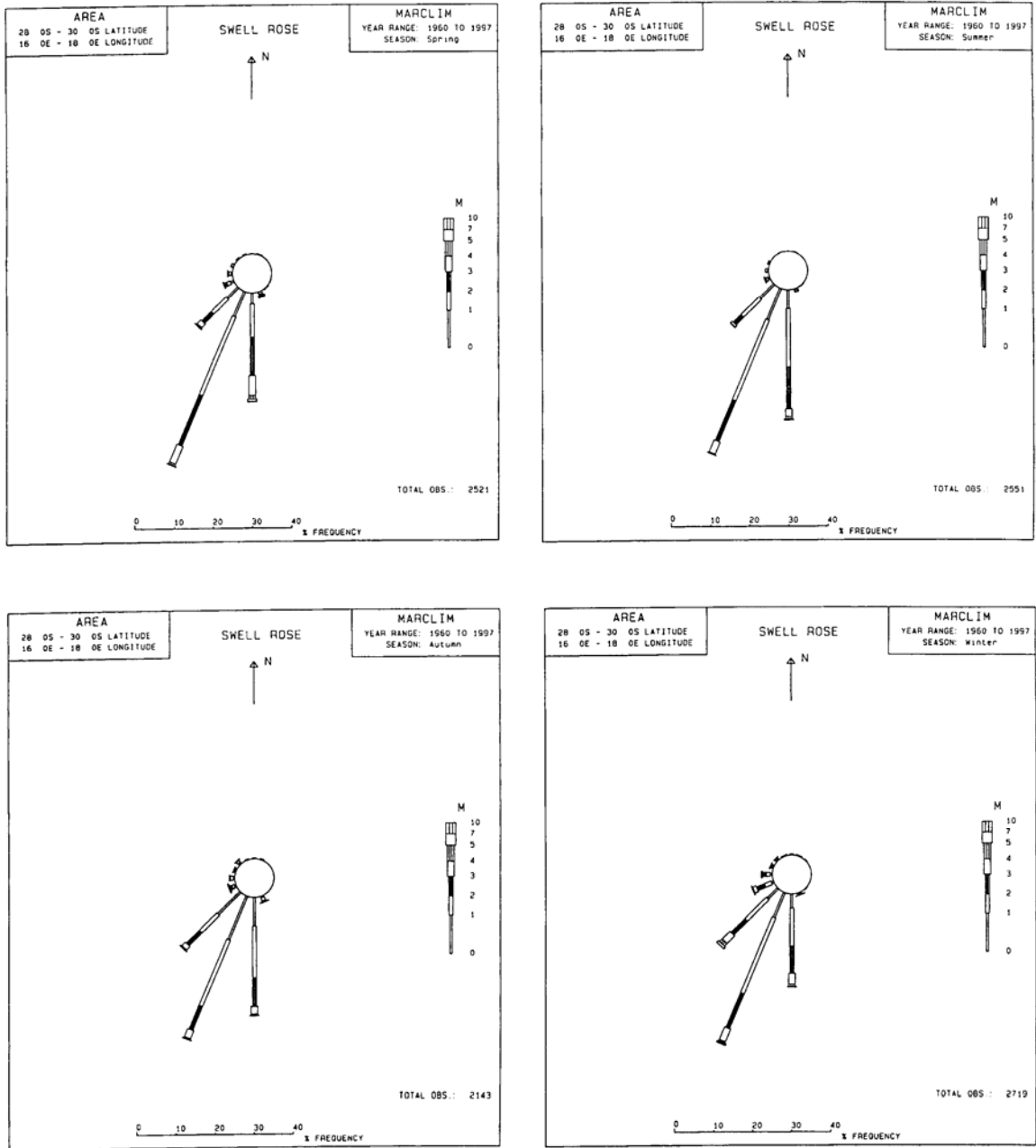


Figure 3: Seasonal swell roses for the offshore marine environment adjacent to the Orange River Mouth. (VOS data from SADCO).

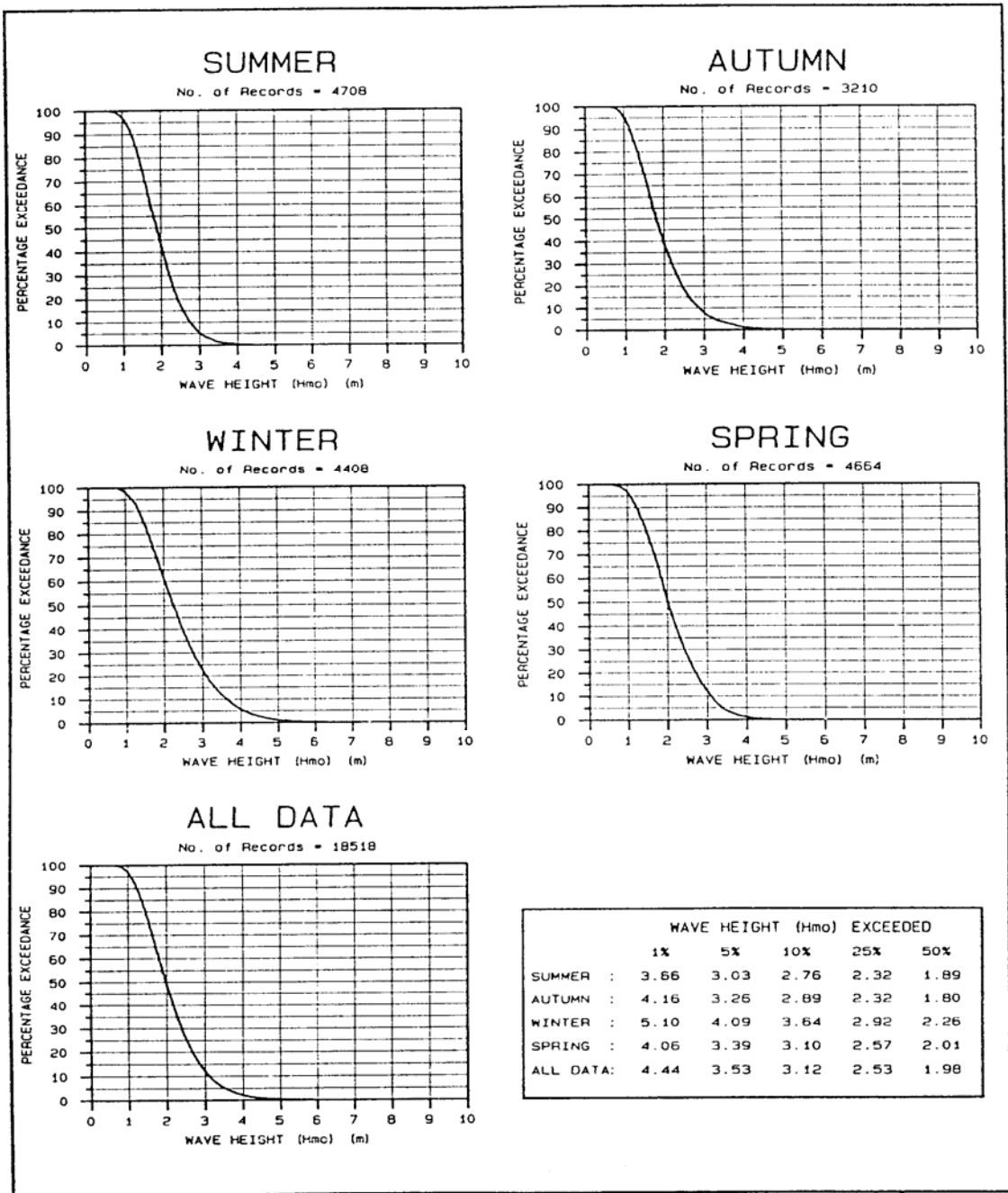


Figure 4: Seasonal and annual significant wave height exceedance curves measured at a 100 m deep site off Port Nolloth. (Data from EDM database, Environmentek, CSIR).

Table 1: Wave height versus period occurrence and exceedance tables for the wave energy off Port Nolloth. (Data from EDM database, Environmentek, CSIR).

OCCURRENCE DISTRIBUTION:

Wave Height Hmo (m)	Peak Energy Period (Tp) (seconds)																TOTAL	
	5.51	5.51	5.82	6.17	6.56	7.01	7.53	8.13	8.83	9.66	10.67	11.91	13.47	15.52	18.29	22.26		22.26
0.0- 0.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.00
0.5- 1.0	0.08	---	0.01	0.01	0.03	0.02	0.04	0.12	0.32	0.55	0.78	0.75	0.27	0.16	0.03	---	---	3.15
1.0- 1.5	0.29	---	0.17	0.25	0.30	0.29	0.32	0.53	1.14	2.74	5.10	4.78	2.43	0.87	0.10	0.01	---	19.33
1.5- 2.0	0.16	---	0.09	0.25	0.36	0.45	0.64	0.74	1.10	2.79	6.78	8.61	4.97	1.34	0.17	0.01	---	28.45
2.0- 2.5	0.01	---	0.05	0.10	0.18	0.19	0.32	0.59	0.96	1.68	4.45	7.93	5.46	1.09	0.19	---	---	23.19
2.5- 3.0	0.01	---	---	0.01	0.02	0.06	0.10	0.26	0.39	0.75	1.83	4.70	4.26	1.09	0.16	0.01	---	13.62
3.0- 3.5	---	---	---	---	0.01	0.02	0.03	0.06	0.14	0.28	0.69	1.75	2.83	1.11	0.11	0.01	---	7.03
3.5- 4.0	---	---	---	---	---	---	0.01	0.01	0.02	0.08	0.12	0.57	1.38	0.81	0.07	---	---	3.06
4.0- 4.5	---	---	---	---	---	---	---	---	---	---	0.04	0.15	0.56	0.51	0.03	---	---	1.29
4.5- 5.0	---	---	---	---	---	---	---	---	---	---	---	0.03	0.19	0.28	0.04	0.01	---	0.55
5.0- 5.5	---	---	---	---	---	---	---	---	---	---	---	0.01	0.02	0.12	0.01	0.01	---	0.17
5.5- 6.0	---	---	---	---	---	---	---	---	---	---	---	---	0.03	0.09	0.01	---	---	0.12
6.0- 6.5	---	---	---	---	---	---	---	---	---	---	---	---	0.01	0.03	---	---	---	0.03
6.5- 7.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.00
TOTAL	0.5	0.0	0.3	0.6	0.9	1.0	1.5	2.3	4.1	8.9	19.8	29.3	22.4	7.5	0.9	0.1	0.0	100.00

EXCEEDANCE DISTRIBUTION:

Wave Height Hmo (m)	Peak Energy Period (Tp) (seconds)																TOTAL	
	5.51	5.51	5.82	6.17	6.56	7.01	7.53	8.13	8.83	9.66	10.67	11.91	13.47	15.52	18.29	22.26		22.26
> 0.0	0.53	---	0.32	0.61	0.89	1.03	1.47	2.30	4.06	8.86	19.78	29.27	22.40	7.50	0.92	0.05	---	99.99
> 0.5	0.53	---	0.32	0.61	0.89	1.03	1.47	2.30	4.06	8.86	19.78	29.27	22.40	7.50	0.92	0.05	---	99.99
> 1.0	0.45	---	0.32	0.60	0.86	1.01	1.43	2.18	3.74	8.32	19.00	28.53	22.13	7.33	0.89	0.05	---	96.84
> 1.5	0.17	---	0.15	0.36	0.56	0.72	1.10	1.65	2.60	5.58	13.90	23.75	19.70	6.46	0.78	0.05	---	77.51
> 2.0	0.01	---	0.05	0.11	0.21	0.27	0.46	0.91	1.50	2.79	7.12	15.14	14.73	5.12	0.61	0.04	---	49.06
> 2.5	0.01	---	---	0.01	0.03	0.08	0.14	0.32	0.55	1.11	2.67	7.21	9.27	4.03	0.42	0.04	---	25.87
> 3.0	---	---	---	---	0.01	0.02	0.03	0.06	0.16	0.36	0.85	2.51	5.01	2.94	0.26	0.03	---	12.24
> 3.5	---	---	---	---	---	---	0.01	0.01	0.02	0.08	0.16	0.76	2.18	1.84	0.16	0.02	---	5.22
> 4.0	---	---	---	---	---	---	---	---	---	---	0.04	0.19	0.80	1.03	0.09	0.02	---	2.16
> 4.5	---	---	---	---	---	---	---	---	---	---	---	0.04	0.25	0.51	0.05	0.02	---	0.87
> 5.0	---	---	---	---	---	---	---	---	---	---	---	0.01	0.05	0.24	0.02	0.01	---	0.32
> 5.5	---	---	---	---	---	---	---	---	---	---	---	---	0.04	0.11	0.01	---	---	0.16
> 6.0	---	---	---	---	---	---	---	---	---	---	---	---	0.01	0.03	---	---	---	0.03
> 6.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.00

Hmo = In physical terms Hmo represents the average height of the third largest waves in the wave recording. It is obtained from the wave spectrum. It is defined as:

$$Hmo = 4m_0^{0.5} \text{ metres}$$

where m_0 is the 0th moment of the spectrum obtained from a 17.5 minute recording.

Tp = Spectral Peak Period defined as that period, in seconds, at which the maximum spectral density occurs over the whole spectrum.

Directional wave data in existence for this region include both nearshore and offshore data as indicated in Table 2 below. In addition, further directional wave data are presently being measured at a location north of Oranjemund.

Table 2: Table of existing directional wave measurements offshore of Oranjemund.

Station	Coverage Period	Position	Water Depth	Sampling Interval (hours)	Data Return	Actual data availability
Nearshore Oranjemund	1/10/96 to 26/11/98 (intermittent)	28° 34.4' S 16° 17.8' S	20 m	6 hourly	21 months of data	28/4/98 1200Z to 26/11/98 0000Z
Offshore Oranjemund	8/3/98 to 13/4/99	28° 37.6' S 14° 34.8' S	175 m	½ hourly	86%	8/3/98 15h00Z to 3/5/98 1500Z and 27/6/98 06h00Z to 13/4/98 0300Z

2.1.3 Tides

In common with the rest of the southern African coast, tides are semi-diurnal. Table 3 lists the tidal statistics for Port Nolloth, south of the Orange River mouth.

Table 3: Tide statistics for Port Nolloth from the S A Tide Tables (SAN, 1998). All levels are referenced to Chart Datum

Lowest Astronomical Tide (LAT)	0.00 m
Mean Low Water Springs (MLWS)	0.27 m
Mean Low Water Neaps (MLWN)	0.77 m
Mean (Sea) Level (MSL)	1.08 m
Mean High Water Neaps (MHWN)	1.39 m
Mean High Water Springs (MHWS)	1.90 m
Highest Astronomical Tide (HAT)	2.22 m

2.1.4 Coastal Currents

Surface currents are mainly wind-driven and flow to the NW (Shillington *et al.*, 1990). Current velocities in broad continental shelf areas such as that adjacent to the Orange River are generally $0.10 - 0.20 \text{ m.s}^{-1}$ (Boyd and Oberholster, 1994) where the flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington *et al.*, 1990; Nelson and Hutchings, 1983). Fluctuation periods of these flows are 3 – 10 days and velocities are $0.15 - 0.20 \text{ m.s}^{-1}$. Near bottom shelf flow is mainly poleward (Nelson, 1989) with low velocities of typically 0.05 m.s^{-1} . In the absence of major changes in bathymetry the tidal flows along this section of the coastline are of the order of a few cm.s^{-1} .

Current measurements made in a water depth of approximately 20 m some 5 km north of the proposed discharge location indicated mean current speeds of approximately 0.1 m.s^{-1} (summer) to 0.2 m.s^{-1} (spring) with a standard deviation of $> 0.1 \text{ m.s}^{-1}$. Peak current speeds measured are of the order of 0.4 m.s^{-1} to 0.6 m.s^{-1} (CSIR, 1997a, 2002). These data show frequent current reversals but a long term mean current residual of approximately 0.04 m.s^{-1} in an approximate NW (alongshore) direction.

2.1.5 Surf-zone current and processes

Typically wave-driven flows dominate in the surf zone (characteristically 150 m to 250 m wide), with the influence of waves on currents extending out to the base of the wave effect ($\sim 40 \text{ m}$, Rogers, 1979). The influence of wave-driven flows extends beyond the surf zone in the form of rip currents. Longshore currents are driven by the momentum flux of shoaling waves approaching the shoreline at an angle, while cross-shelf currents are driven by the shoaling waves. The magnitude of these currents is determined primarily by wave height, wave period, angle of incidence of the wave at the coast and bathymetry.

Nearshore velocities have not been reported and are difficult to estimate because of acceleration features such as surf zone rips and sandbanks. However, computational model estimates using nearshore profiles and wave conditions representative of this coastal region suggest time-averaged northerly longshore flows which have a cross-shore mean of roughly 0.2 to 0.3 m.s^{-1} . Instantaneous measurements of cross-shore averaged longshore velocities are often much larger. Surf zone-averaged longshore velocities in other exposed coastal regions have been observed to exceed 1.5 m.s^{-1} (CSIR, 1993). The current speeds simulated in a recent modelling exercise approximately 10 to 15 km south of the discharge location indicate typical northward peak current speeds of between 1.0 m.s^{-1} to 1.5 m.s^{-1} (with extremes exceeding 2 m.s^{-1}) in the surf zone for high wave conditions (CSIR, 2002). UNIBEST-LT model simulations (WL | delft hydraulics, 1993) with SSE wave conditions having a significant wave height (H_s) of $\sim 3.5 \text{ m}$ are assumed to provide estimates of the maximum longshore flows likely to be observed in this region. These wave conditions result in simulated peak northerly longshore flows of 1.8 m.s^{-1} and cross-shore averaged longshore flows of approximately 0.9 m.s^{-1} . The southerly longshore flows are considered to remain below 0.5 m.s^{-1} . Additional estimates of typical cross-shore averaged flows in the surf zone are contained in Section 4.2.2.

The nearshore flows are sufficient to generate an estimated longshore sediment transport of $0.5 \times 10^6 - 2 \times 10^6$ tonnes per year in the region located immediately north of the Orange River mouth (CSIR, 1996a).

2.1.6 Upwelling and coastal temperatures

The major oceanographic feature of the region is coastal upwelling which is driven by equatorward winds (Shannon, 1985). The water that upwells is primarily South Atlantic Central Water with temperatures 6 to 16°C and salinities 34.5 to 35.5 psu². Upwelling is modulated both by the orography of the coast and the topography of the continental shelf. Areas with steep continental shelf topography are preferred upwelling sites (Taunton-Clark, 1985). The closest upwelling nodes to the Orange River mouth are the Namaqua cell, centred on Kleinsee, in the south and the Lüderitz upwelling cell in the north. Both are perennial upwelling sites (Shannon, 1985).

At the Orange River mouth average sea surface temperatures in winter are 12 – 13°C, spring 13 – 14°C, summer 14 – 15°C and autumn 13 – 14°C (Boyd and Agenbag, 1985). Similar ranges are evident in the long term monthly mean coastal sea surface temperatures for Lüderitz in the north with those for Port Nolloth in the south being some 1°C lower than those reported above (Greenwood and Taunton-Clark, 1992, 1994). During episodic large Orange River floods, *e.g.* March 1988, nearshore sea surface temperatures may attain 23.5 – 24.5°C (Shillington *et al.*, 1990). Nearshore sea surface temperatures during ‘normal’ summer floods probably attain similar levels but these will not extend very far from the river mouth itself.

The salinity of upwelled waters in this region is typically 34.8 to 34.85 psu while the waters reaching the surface during upwelling typically contain about 5 ml.ℓ⁻¹ of dissolved oxygen (Chapman and Shannon, 1985).

2.1.7 Sediment supply and distribution

Most of the sediment distributed in the nearshore in the vicinity of the Orange River mouth is supplied by the river, however there are significant discharges of sediments from mining operations in this region that are likely to result in accretion effects both north of the discharge and south of the Orange River mouth. Rogers (1979) estimates that the mean annual sediment discharge through the Orange River is 60 x 10⁶ tonnes, but may vary between 8 x 10⁶ to 326 x 10⁶ tonnes. Approximately 90% of the sediment is carried in suspension leading to the characteristic high turbidity of the Orange River in the lower reaches.

² In the normal oceanic salinity ranges, 1 psu = 1 ppt (‰)

Sediments are flushed into the ocean by summer floods, the Orange River catchment being a summer rainfall area. Episodic floods, such as the 1988 floods, can dump huge amounts of sediment into the ocean in very short periods. Bremner *et al.* (1990) estimate that the sediment discharge for March 1988, the flood peak, was 64.2×10^6 tonnes. This declined to 7.3×10^6 tonnes for May, after the flood had subsided.

The sand and gravel component of the sediment is initially deposited on the ebbtide delta extending from the river mouth to 40 m depth (Rogers, 1979). Mud bypasses the delta and deposits in deeper (40 – 120 m) water offshore of the river mouth and to the south (Mabote *et al.*, 1997). The transport mechanism for this is the weak poleward flow of the bottom waters (Nelson, 1989).

The ebbtide delta is above the wave base and sand is re-suspended and transported shorewards and alongshore by the characteristically large waves (Rogers, 1979). It is this sand that nourishes the beaches and sand dunes that occur extensively north of the Orange River.

The powerful easterly 'berg' winds occurring along the Namibian coastline in autumn and winter also play a significant role in sediment input into the coastal marine environment, potentially contributing the same order of magnitude of sediments as the annual estimated input of sediment by the Orange River (Lane and Carter, 1999). For example, during a single berg-wind event in May 1979, it is estimated that 50 million tonnes of dust were transported into the sea by extensive sandstorms along much of the coast from Cape Frio in the north to Kleinsee in the south (Shannon and Anderson, 1982). Satellite imagery indicates that these winds are locally intensified by topographic features such as river valleys (Shannon, 1985). Most of this dust would originally have been derived from river floods into the sea, and been transported northwards, onto the beaches and inland along aeolian wind transport corridors, to form the vast dune fields of the Namib desert. These 'berg' wind events effectively reverse this process for short periods, and return some of these aeolian sediments to the sea. Transport up 150 km offshore has been observed for a single wind event that was particularly pronounced in the vicinity of the Orange River.

2.2 Biological Communities

Biogeographically the southern Namibian coastline falls into the cold temperate Namaqua Province. The intertidal and subtidal ecology of the area is shaped by the influence of the Benguela upwelling system, with the strongest upwelling cell on the entire west coast being centred at Lüderitz (Shannon, 1985).

The proposed discharge sites at Uubvley fall within Namdeb Diamond Corporation's Mining Area 1. The coastline of Mining Area 1 (MA1) is dominated by sandy beaches, with rocky habitats being represented only by occasional small rocky outcrops and wave-cut platforms north of Mittag (Figure 5). The benthic communities within these nearshore habitats are ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure or depth zone. No endangered, or rare species have been reported for the area. These biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability. The communities 'typical' of the region are described below, focussing only on dominant, commercially important and conspicuous species, as well as potentially threatened species.

2.2.1 Beach and nearshore ecology

The structure and composition of the macrofaunal communities of intertidal beaches is largely dependent on sand particle size, beach slope and degree of wave energy. Three morphodynamic beach types are described: dissipative, reflective and intermediate beaches (McLachlan *et al.*, 1993). Generally, dissipative beaches are flat with fine sand and the wave energy dissipates in the surf-zone, resulting in less turbulent conditions in the intertidal region. These beaches usually harbour the richest intertidal macrofaunal communities. Reflective beaches are coarse grained with steep intertidal beach faces. The relative absence of a surf-zone causes the waves to break directly on the shore causing a high turnover of sand, which in turn results in depauperate macrofaunal communities. Intermediate beach conditions exist between these extremes and have a very variable species composition (McArdle and McLachlan, 1991; McLachlan *et al.*, 1993; Jaramillo *et al.*, 1995).

The beaches immediately north of the Orange River mouth are characterised by medium, well sorted sands in the size range 373 – 505 μm (McLachlan and de Ruyck, 1993) and are classified as being of the reflective type. Intertidal macrofauna is thus sparse and consists of five crustacean species: *Talorchestia quadrispinosa* (supralittoral), *Excirolana natalensis* and *Eurydice longicornis* (midshore) and *Mandibuloboxus* sp. and *Gastrosaccus psammodytes* on the lower shore. Abundances per species range from 23 no. $\cdot\text{m}^{-2}$ for *E. longicornis* to 1065 for *E. natalensis*. Due to the large sediment fluxes, total biomass estimates are relatively low, ranging from 0.01 – 18.6 $\text{g}\cdot\text{m}^{-2}$.

Reflective beaches are dynamic and consequently the species that do occur are usually opportunistic (Bally, 1987). Another factor that may contribute to the sparse fauna in this specific area is the occurrence of low salinity events associated with the release of summer flood water from the Orange River. Shillington *et al.* (1990) show that 50% dilution of seawater by freshwater extended 8 – 16 km offshore of the river mouth during the 1988 flood. Although this was an extreme event (return period 10 – 15 years, Swart *et al.*, 1990) it

is likely that the more regular, smaller summer floods will impact beaches and nearshore waters immediately adjacent to the river mouth.

There are no available data on the ecology of unconsolidated sediments in shallow nearshore environments near the Orange River mouth, and only a general account of benthic nearshore communities of the southern African West Coast, summarized from Lane and Carter (1999), can thus be provided. Similar to the intertidal zone, sediment fluxes will be large, thereby leading to an unstable benthic habitat (see above). It is therefore expected that nearshore benthic macrofaunal biomass will likewise be low.

The marine macrobenthos of unconsolidated sediments comprises all organisms that live on, or in the top 20 cm, of the seabed. The inner turbulent zone extends from the low water spring mark (LWS) to a depth of about 2 m. The mysid *Gastrosaccus* spp., the ribbon worm *Cerebratulus fuscus* and the cumacean *Cumopsis robusta* are typical of this zone, although they generally also partially extend into the intertidal zone above. In areas with suitable swash climate (not likely on reflective beaches, see above) the plough snail *Bullia digitalis* and adults of the white mussel *Donax serra* can be present. In the transition zone (2–5 m depth) extreme turbulence is experienced, and as a consequence it typically harbours the lowest diversity. Typical fauna of this zone include amphipods such as *Cunicus profundus* and deep burrowing polychaetes such as *Cirriformia tentaculata* and *Lumbrineris tetraura*. The outer turbulent zone, where turbulence is significantly decreased and species diversity is again much higher, extends below 5 m depth. In addition to the polychaetes of the transition zone, other polychaetes in this zone include *Pectinaria capensis*, *Sabellides luderitzi*, *Nephtys capensis* and *Orbinia angrapequensis*. The sea pen *Virgularia schultzei* is also common, as is the whelk *Bullia laevis* and a host of amphipod species. The three-spotted swimming crab *Ovalipes punctatus* can also occur.

The surf-zone and outer turbulent zone habitats of sandy beaches are considered to be important nursery habitats for marine fishes (Modde, 1980; Lasiak, 1981; Kinoshita and Fujita, 1988; Clark *et al.*, 1994). However, the composition and abundance of the individual assemblages seems to be heavily dependent on wave exposure (Blaber and Blaber, 1980; Potter *et al.*, 1990; Clark, 1997a, b). Surf-zone fish communities off the West Coast of southern Africa have been studied by Clark (1997a, b), Clark *et al.* (1998) and Meyer *et al.* (1998). Only five species have been recorded off beaches on the southern *Sperrgebiet* coast, these being harders (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*), False Bay klipfish (*Clinus latipennis*), Super klipvis (*C. superciliosus*) and galjoen (*Dichistius capensis*). In contrast, species richness and abundance are relatively high in sheltered and semi-exposed surf-zone areas such as Elizabeth Bay, and include over 20 species from 17 different families. As few permanent estuaries exist along this stretch of coast, it is likely that many of these

species make extensive use of sheltered surf-zone habitats along the *Sperrgebiet* coast as nursery areas (Clark *et al.*, 1998; Meyer *et al.*, 1998).

No systematic studies have been undertaken of fish communities frequenting nearshore soft sediments in southern Namibia, but kob (*Argyrosomus* sp.), westcoast steenbras (*Lithognathus aureti*) and white stumpnose are favoured angling fish in the area. Experimental and commercial gillnet catches from nearshore soft sediments south of the Orange River have also reported catches of shallow water hake (*Merluccius capensis*), gurnards (*Chelidonichthys capensis*) and West Coast sole (*Austroglussus microlepis*), as well as St Joseph sharks (*Callorhynchus capensis*), elf (*Pomatomus saltatrix*) and hound sharks (*Mustelus mustelus*) (Pulfrich, 2002).

2.2.2 Rocky intertidal ecology

Where rocky substrata occur in the intertidal and nearshore regions along the coastline of MA1, these are characterised by benthic communities typical of the southern African West Coast, differing only with exposure to wave action. Some authors, however, have predicted that intertidal rocky shore communities in the *Sperrgebiet* may vary more than elsewhere (Meyer *et al.*, 1998) due to the proximity to the northern Namib biogeographic province and thus species at the edge of their distribution ranges, and to the overriding influence of sand along the coastline exerting an ecological influence on the communities.

Like sandy shores, West Coast rocky intertidal shores can be divided into five zones on the basis of their characteristic biological communities. Tolerance to the physical stresses associated with life on the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce these five zones. The biological zones, however, also correspond roughly to zones based on tidal heights.

In general, sheltered shores are diverse with a relatively low biomass and conversely, exposed and semi-exposed shores harbour a high biomass with low species diversity (Bustamante *et al.*, 1997). In MA1 intertidal fauna and flora have been studied on sheltered to semi-exposed rocky shores off some of the pocket beaches (Meyer *et al.*, 1998; Clark *et al.*, 2004). The following descriptions are summarised from these studies and from Lane & Carter (1999).

Supralittoral fringe – Littorina zone - The supralittoral fringe, is the uppermost part of the shore most exposed to air, thus perhaps having more in common with the terrestrial environment. The supralittoral is characterised by low species diversity, with the tiny gastropod *Littorina africana*, and the red algae *Porphyra capensis* constituting the most common macroscopic life.

Upper midlittoral – Upper Balanoid zone - The upper midlittoral is characterised by the limpets *Scutellastra granularis* and *Siphonaria capensis* (Gastropoda, Mollusca), which are present on almost all shores. The gastropods *Nucella dubia*, and *Helcion pectunculus* are variably present, as are low densities of the barnacles *Chthamalus dentatus*, *Tetraclita serrata* and *Octomeris angulosa*. Flora is best represented by the leafy green alga *Ulva* spp., with the crustose coralline *Hildenbrandia rubra* being present in damp depressions.

Lower midlittoral – Lower Balanoid zone - Toward the lower shore, biological communities are determined by exposure to wave action. Sheltered shores are dominated by grazers, principally the limpets *S. granularis*, *Cymbula granatina* and a diversity of foliose algae. The gastropods *Burnupena* spp. and the starfish *Patriella exigua* are also common. Filter-feeder biomass, however, is low on sheltered shores. Limpets (particularly *C. granatina*) often reach extraordinary population densities, feeding on drift kelp that accumulates there, and restricting algal biomass (Bustamante *et al.*, 1995).

On exposed and semi-exposed shores throughout the region *C. granatina* is virtually absent, and almost all of the primary space may be occupied by filter-feeders, principally the invasive Mediterranean mussel *Mytilus galloprovincialis*, the black mussel *Choromytilus meridionalis*, and/or the reef building polychaete *Gunnarea capensis* (Bustamante & Branch, 1996). Specifically, wave action enhances filter-feeders (McQuaid & Branch, 1985) by increasing the concentration and turnover of particulate food (Engledow & Bolton, 1994; Bustamante & Branch, 1996), leading to an elevation of overall biomass (Bustamante *et al.*, 1995). Several algal species are associated with the *Gunnarea* reefs, notably *Ceramium* sp., *Leathesia difformis*, *Caulacanthus ustulatus* and *Cladophora*.

Sublittoral fringe – Argenvillei zone - Along the well-marked sublittoral fringe on semi-exposed and exposed shores, the limpet *Scutellastra argenvillei* dominates except where it has been displaced by *M. galloprovincialis*. Densities can exceed over 450 m⁻², often excluding all other species. The kelp *Laminaria pallida schinzii* dominates the algal diversity in this zone, and where limpet densities are lower, there is variable representation of the flora and fauna described for the lower midlittoral above. This includes the anemone *Aulactinia reynaudi*, other patellid limpets (*S. cochlear*), numerous whelk species and the sea urchin *Parechinus angulosus*. On more exposed shores, the mussels *Aulacomya ater*, *C. meridionalis* and *M. galloprovincialis* may dominate. Most of these species extend into the subtidal below.

2.2.3 Rocky subtidal habitats and kelp beds

The biological communities of sublittoral reef habitats can be broadly grouped into an inshore zone (from the supralittoral fringe to a depth of ~10 m), and an offshore zone (below 10 m depth). The shift in communities from the flora-dominated inshore zone to the fauna-dominated offshore zone is not knife-edge, however, representing instead a continuum of species distributions, merely with changing abundances. As wave exposure is moderated with depth, wave action is less significant in structuring the communities than in the intertidal, with prevailing currents, and the vertical distribution of oxygen and nutrients playing more important roles.

Research on subtidal organisms along the Namibian coastline has been limited. Current knowledge is primarily restricted to macrobenthic reef communities in depths of less than 30 m in the area around Lüderitz (Tomalin, 1993; Parkins & Branch, 1996, 1997; Pulfrich, 1998a; 1998b; Pulfrich and Penney, 1998; 1999a; 2001). The following descriptions are summarised from these studies.

Rocky subtidal habitats along the southern Namibian coastline are dominated by kelp beds (*Laminaria pallida schinzii* and *Ecklonia maxima*). As wave exposure in the region is very high, kelp beds play a major role in absorbing and dissipating much of the wave energy reaching the shore, thereby providing important semi-exposed and sheltered habitats for a wide diversity of both marine flora and fauna. The community structure of the subtidal benthos is typical of the southern African West Coast kelp bed environment. In the inshore zone, the benthos is largely dominated by algae, in particular the kelp *L. pallida schinzii*, which forms a canopy to a height of about 2 m in the immediate subtidal region to a depth of ~10 m. *Ecklonia maxima*, which is the dominant species along the South African coastline, is poorly represented in southern Namibia. Growing beneath the kelp canopy and epiphytically on the kelps themselves are a diversity of understory algae which provide both food and shelter for predators, grazers and filter-feeders associated with the kelp bed ecosystem. These plants and animals all have specialised habitat and niche requirements, and together form complex communities with highly inter-related food webs.

The sublittoral invertebrate fauna is dominated by suspension and filter feeders, such as the ribbed mussel *Aulacomya ater* and Cape Reef worm *Gunnarea capensis*, a variety of sponges, and the sea cucumbers. Grazers are less common with most herbivory being restricted to grazing of juvenile algae or debris feeding of detached macrophytes. Predators in the sublittoral include the starfish (*Henricia ornata*), various feather and brittle stars, gastropods (*Nucella* spp. and *Burnupena* spp.), and the commercially important rock lobster *Jasus lalandii*. The depth distribution and availability of rock lobsters is strongly influenced by environmental conditions (Newman & Pollock, 1971; Pollock, 1978; Beyers, 1979; Pollock

and Beyers, 1981; Bailey *et al.*, 1985; Pollock & Shannon, 1987; Tomalin, 1993; amongst others). In the winter months the lobsters occur offshore in deep waters up to 130 m depth, whilst during the summer months of upwelling they migrate inshore in response to declining offshore bottom oxygen levels (Pollock & Shannon, 1987). This inshore migration and concentration of the resource into shallower, better-oxygenated water coincides with the commercial fishing season (Noli & Grobler, 1998).

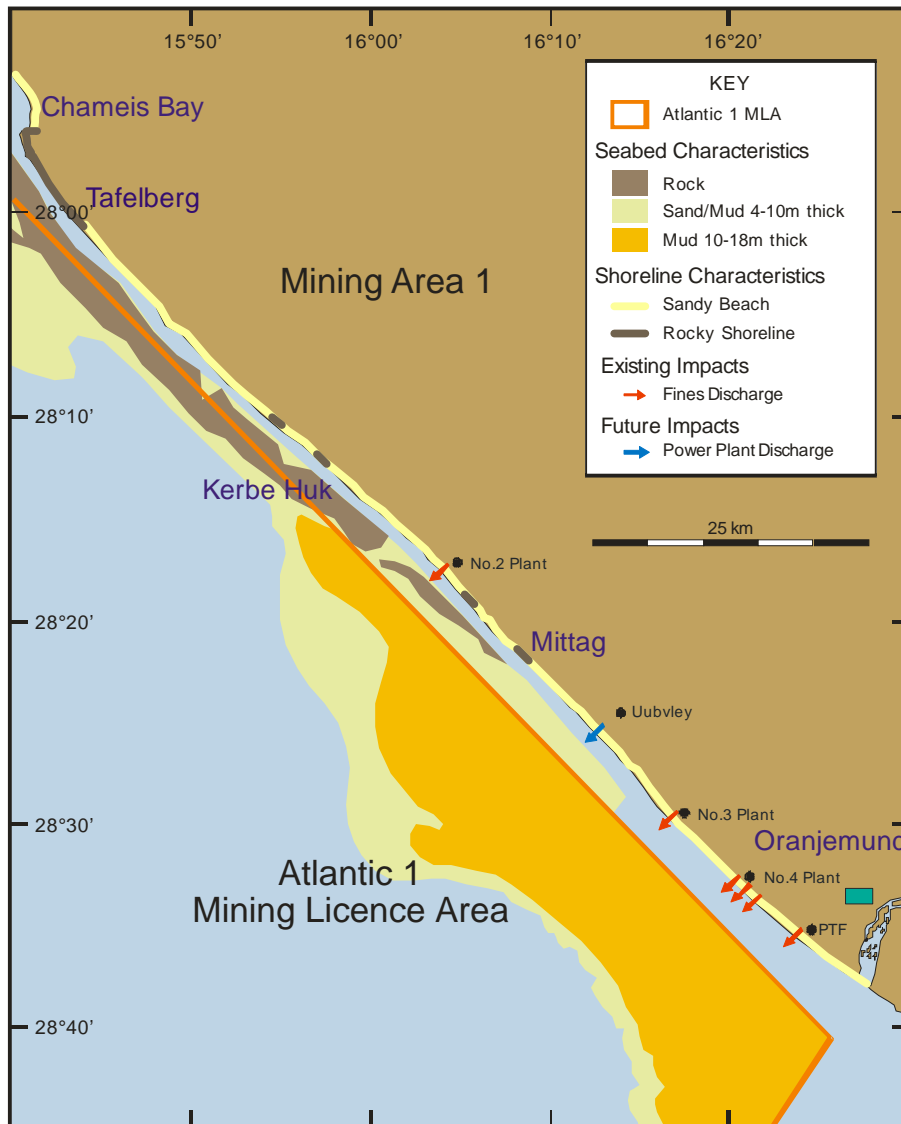


Figure 5: Map of the coastline of Mining Area 1 indicating the proposed location of the power plant in relation to coastal and nearshore features mentioned in the text. The distribution of nearshore sediments is also shown.

The fish fauna of rocky reefs off the southern African West Coast has not been specifically studied, and it is necessary to refer to fish catches for a review. Shore- and boat-angling is extremely limited along the southern Namibian *Sperrgebiet* coastline due to restricted access by the public. Catches from northern Namaqualand and the area around Lüderitz, however, cite the common and widespread hottentot (*Pachmetopon blochii*), the galjoen (*Dichistius capensis*), snoek (*Thryxites atun*), maned blennies (*Scartella emarginata*), and blacktail (*Diplodus sargus*) as being common reef-associated species (Sauer & Erasmus, 1997; Brouwer *et al.*, 1997; Sakko, 1998).

2.2.4 Offshore ecology

Whilst numerous studies have been conducted on southern African West Coast continental shelf macrobenthos, most of these have focused on mining or pollution impacts (*e.g.* Environmental Evaluation Unit, 1996; Parkins and Field, 1998; Pulfrich and Penney, 1999b; Goosen *et al.*, 2000; Steffani and Pulfrich, 2004). The only systematic study investigating macrobenthic community distributions across the continental shelf is that of Christie (1974) off Lamberts Bay (South Africa). The description below is drawn from this work.

Biomass distributions show four clear regions across the continental shelf. From the shore to 80 m deep biomass ranges from 3.6 g.m⁻² dry weight to 16.2 g.m⁻². This comparatively low biomass reflects the high depositional environment on the inner continental shelf. The biota is dominated by molluscs, polychaete worms and cnidarians. Sediment texture at these depths is almost exclusively dominated by fine sands.

The midshelf mudbelt (70–120 m depth) is a particularly rich benthic habitat, and biomass attains 60.3 g.m⁻². The fauna is dominated by both scavenging and carnivorous polychaete worms, as well as cnidarians. The comparatively high benthic biomass in this region represents a food resource to carnivores such as the mantis shrimp, cephalopods and demersal fish species (Lane and Carter, 1999). Sediment texture in the mudbelt is dominated by silts and clays, and very fine sands.

Outside of this rich zone biomass declines to 4.9 g.m⁻² at 200 m depth and then is consistently low (<3 g.m⁻²) on the outer shelf. Crustacea increase in relative importance in the biota with amphipods comprising the major component. Sediment texture is dominated by very fine sands.

Benthic community structure is to a large degree determined by sediment characteristics (*e.g.* Christie, 1974; Warwick *et al.*, 1991; Yates *et al.*, 1993; Desprez, 2000; van Dalssen *et al.*, 2000), but complex interactions between physical and biological factors at the sediment–

water interface may also play an important role (Snelgrove and Butman, 1994; Seiderer and Newell, 1999). For example, on the southern Namibian coastline, the role of oxygen levels in structuring macrofaunal abundances cannot be excluded.

Offshore fish communities consist of pelagic and demersal species. Pelagic species include anchovy (*Engraulis capensis*), pilchard (*Sardinops sagax*), round herring (*Etrumeus whiteheadi*), chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*). These species typically occur in mixed shoals of various sizes (Crawford *et al.*, 1987). Whilst these pelagic fish occur predominantly offshore, shoals may occasionally move into the nearshore areas. They spawn downstream of major upwelling centres in spring and summer, and their eggs and larvae are subsequently carried up the coast in northward flowing waters. Recruitment success relies on the interaction of oceanographic events, and is thus subject to spatial and temporal variability. Consequently the abundance of adults and juveniles of these small pelagic fish is highly variable both within and between species. Large pelagic species include tunas, billfish and pelagic sharks, which migrate throughout the southern oceans, between surface and deep waters (> 300 m) and have a highly seasonal distribution in the Benguela. Demersal communities comprise deepwater species (> 200 m) such as deep-water hakes (*Merluccius paradoxus*), monkfish (*Lophius upsicephalus*), and kingklip (*Genypterus capensis*), and more shallow water species dominated by Cape hake (*Merluccius capensis*) and including jacobever (*Helicolenus dactylopterus*), angelfish/ pomfret (*Brama brama*), and gurnards (*Chelidonichthys capensis*), as well as white squid and catshark. The distribution of the latter shelf community varies seasonally (Lane and Carter, 1999; Hampton *et al.*, 1999).

Marine mammals occurring off the southern Namibian coastline include 35 species of whales and dolphins, including the endemic Heaviside's Dolphin *Cephalorhynchus heavisidii*, and two species of seals of which the Cape fur seal (*Arctocephalus pusillus pusillus*) is the most common (Lane and Carter, 1999). In southern Namibia, Cape fur seals occur at numerous breeding sites on the mainland and on nearshore islands and reefs.

2.3 Beneficial Uses of the Area

2.3.1 Diamond mining and other industrial uses

The alternative site at Uubvley currently under consideration for the construction of a power plant for the Kudu Power Project falls within Namdeb Diamond Corporation's Mining Area 1. Diamonds have been extracted from coastal deposits for decades, with the consequence that the coastline and even the landscape between the Orange River mouth and Chameis Bay in the north, has been physically and irreversibly altered to an artificially accreted shoreline, backed by flooded excavations, overburden dumps and in places,

exposed bedrock areas. The by-products of the land-based gravel treatment and diamond extraction process include the disposal of oversize tailings on overburden dumps in the vicinity of the treatment facilities, and the discharge of hydraulically charged fine tailings onto the beach. Between 1968 and 2001, a total of ~287 million tonnes of material were discharged into the sea off MA1, at an average annual rate of ~8.5 million tonnes. In addition to the disposal of fines, it is estimated that ~3.4 million tonnes of overburden are used annually for direct nourishment and maintenance of the extensive seawalls in MA1 (Smith *et al.*, 1999).

In addition to the above there may be industrial uses of the coastal and marine resources. These include:

- Water abstraction for mining and/or gravel processing, or as cooling water.
- Water abstraction for domestic use (after desalination).
- Mariculture ventures in the ponds, should the appropriate infrastructure to maintain efficient water exchange be introduced.

As public access to the mining area presently remains restricted, human utilisation of the beach and nearshore areas north of the Orange River mouth is limited. Furthermore, the rough seas, high degree of turbulence, strong winds, swift surf-zone currents and cold sea water temperatures are not conducive to recreational activities such as swimming, yachting, small-craft boating, sea kayaking, surfing, jetskiing or scuba-diving.

2.3.2 Pelagic and demersal fisheries

The commercial fisheries targeting pelagic and demersal species are primarily concentrated offshore around the central Namibian continental shelf (O'Toole and Boyer, 1998). Although 40% of Namibian demersal catches are from the southern region, the fishing grounds off MA1 are seldom visited by the commercial fleets due to the extended distances from the major fishing harbours of Lüderitz and Walvis Bay. Other than rock lobsters, which are dealt with in detail below, no other known biological resources are exploited as food organisms in the nearshore region.

2.3.3 The rock lobster fishery

The commercial rock lobster fishery in Namibia is centred around Lüderitz and forms an important part of the coastal economy of southern Namibia, with annual catches valued at about US\$ 4 million (Stuttaford, 1998). The general fishing area ranges from approximately Kerbe Huk 60 km north of the Orange River, to Sylvia Hill 130 km north of Lüderitz. The fishery is managed by the implementation of a commercial fishing season from November to

April, a size limit of 65 mm carapace length, and an annually determined total allowable catch (TAC) which currently stands at 405 tonnes. At present the Namibian rock lobster fleet consists of ~25 vessels (D. Bester, MFMR, *pers. comm.*). Fishing is conducted with rectangular traps set in 10–40 m depth from wooden deck boats. Traps are usually set in the late afternoon and allowed to soak overnight before being retrieved the following morning. In addition these vessels may carry a fleet of small dinghies that may be deployed in shallow water under calm conditions (Barkai & Bergh 1996). It is thus primarily an inshore fishery, although rock lobsters have been caught by traps and bottom-trawl in deeper water.

In the southern region, Kerbe Huk is the most important fishing ground with an annual TAC of 70 tonnes (Figure 6). Most of the effort is directed at the area between Panther Head and Mittag (Marine Dredging Project, 2004; H. Ndjaula, MFMR Lüderitz, *pers. comm.*), with three specific fishing areas within the Kerbe Huk region being targeted by the vessels, which may fish in water as shallow as 7 m when conditions permit (J. Calaca, rock lobster fisherman, *pers. comm.*). It has to be noted though that these rock lobster fishing positions are fairly approximate, as the fishing industry does not use GPS units, and only provides approximate fishing positions, usually based on landmarks, when reporting catches.

After the most recent environmentally induced decline of the rock lobster resource between 1989 and 1991, the total Namibian rock lobster landings have remained relatively stable at around 330 tonnes (K. Grobler, MFMR Lüderitz, *pers. comm.*). Catches from the southern fishing areas contribute 20–25% to the total Namibian landings (C. Grobler, MFMR Lüderitz, *pers. comm.*). Total landings from the southern areas have increased steadily from 62 tonnes in the 1998/1999 season to 80 tonnes in the 2001/2002 season. Catch per unit effort, however, has dropped by 50% over the same period. Of the total rock lobster fleet of ~25 vessels, between 10 and 15 large boats (20 m in length; D. Bester, MFMR, *pers. comm.*) may fish in the Kerbe Huk area during the commercial season. These vessels are based in Lüderitz, and during an oncoming sea, may take as long as 18 hours to reach the fishing grounds. Consequently the fleet is accompanied by a “carrier” vessel, which ferries supplies from Lüderitz, and transports the catch back to port whilst the fleet is fishing in the south.

Although the commercial fishing season opens in early November, during the first two months of the season, fishing is restricted to the southern lobster grounds. Rock lobster fishing effort south of Lüderitz is thus primarily limited to a relatively short period of time. Only in years when fishers struggle to fill their quotas will they continue fishing on the southern grounds, particularly in the Kerbe Huk area, into January or February. Exceptions to this annual fishing pattern do, however, occur. For example, during the 2003/2004 season most of the quota was fished in the Kerbe Huk area, with the season in the south being extended to May due to poor catches from the grounds north of Lüderitz. The low

catches have primarily been attributed to extended periods of unusually high swell conditions (>2 m) during the fishing season (K. Grobler, MFMR Lüderitz, *pers. comm.*).

Despite the extended distance from Lüderitz and past declining catches from the region, these southern fishing grounds remain important to the commercial industry. Lobsters caught in the south are on average larger than those from the northern fishing areas, and consequently the live product has a higher value. However, the extended distance of Kerbe Huk from Lüderitz and longer travelling time back to port, often leads to high mortalities of these fish. This in turn results in fishermen receiving lower prices for the catch as only the tails rather than the whole lobster can be marketed (R. Cook, Rock Lobster Association, *pers. comm.*). As quotas for the region are often not filled, this has made negotiations with the export market increasingly difficult.

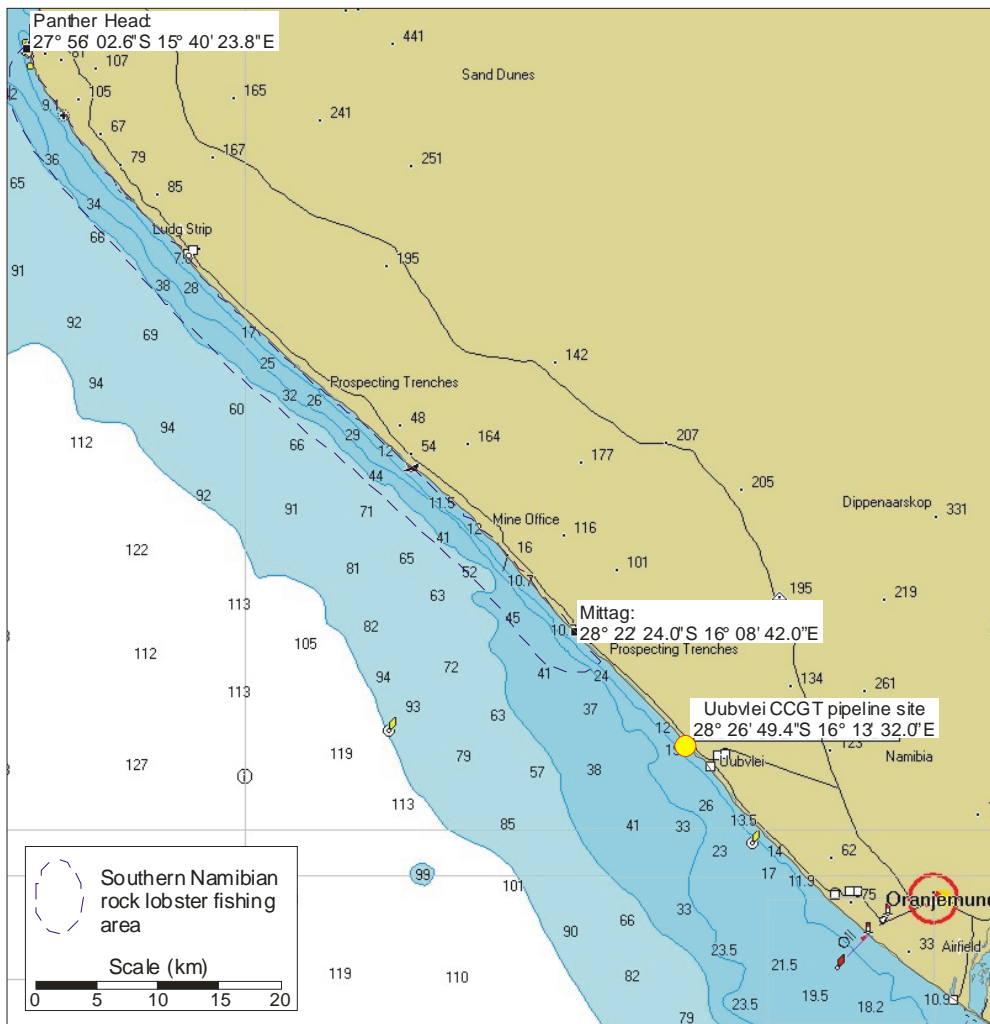


Figure 6: Southern Namibian rock lobster fishing area in relation to the proposed location of the CCGT pipeline at Uubvlei (after MDP, 2004).

The proposed position of the CCGT pipeline at Uubley (within about 500 m N or S of 28° 26' 49.4"S, 16° 13' 32.0"E) is located about 11 km south of the southern rock lobster fishing grounds (Figure 6). Although the rock lobster industry is fairly conservative in their fishing practices, and therefore tends to fish in the same places year after year, there remains some possibility that they may extend their fishing further south from Mittag in future. Compared to past declines in catches in this southern area, the southern rock lobster ground has become significantly more important over the 2003 / 2004 fishing season as a result of good catch rates in the southern ground, and poor catch rates in the northern fishing areas. As a result, the number of vessels and the fishing effort is increasing in the southern area. This is likely to result in vessels moving beyond the traditional southern fishing sites in search of other reefs. Lobsters are known to occur in deeper water to the south of Mittag. However, the area south of Mittag is mantled by the muds of the northward extension of the Orange River pro-delta (see Figure 5), and fishermen do not know of any suitable rock lobster reefs south of Mittag. While they may search further south for future fishing opportunities, substantial shift in fishing effort south of Mittag is considered unlikely (C. Grobler, MFMR Lüderitz, *pers. comm.*).

2.3.4 Cumulative Impacts on Resources

It is safe to assume that the alteration of more than 120 km of shoreline by mining activities has had considerable cumulative impacts on marine biota along the affected coast. This is particularly applicable to communities associated with reef habitats, which over the long-term would have experienced considerable sediment-related impacts. Changes in seabed structure, declining abundances or loss of biota, or significant long-term changes in community structure (*e.g.* loss of kelp bed habitat) in response to increased sediment loads, are likely to have ramifying cascade effects in the intertidal and nearshore ecosystem.

Although contributing in the past to one of the richest fishing grounds in the world, the southern Namibian living marine resources have over the last 30 years been over-exploited by commercial ventures, leading to a significant decline in abundance of some species, in particular rock lobsters (Pallett, 1995). Along the southern African west coast the commercial fishery for *J. lalandii* has existed since the late 19th century, and for many years it was the world's largest fishery for a *Jasus* species (Hampton *et al.*, 1999). During the 1950s, annual catches in Namibia totalled some 8 000 MT, whereas in South Africa 10 500 MT were landed. During the late 1960s, annual catches in both Namibia, and South Africa, declined dramatically due to over-exploitation resulting from reduced or abolished minimum size limits (Pollock, 1986; Tomalin, 1996). Although there is evidence that the decline was at least partly environmentally induced, it continued for twenty years, culminating in the

dramatic collapse of the Namaqualand resource in 1984, and Namibian resource a few years later, in the 1989/90 season.

As the cumulative effects of mining-related impacts remain unknown, and in the light of declining rock lobster catches, rocky shores, offshore reefs and kelp beds (and their associated biota) have been identified as being threatened habitats on the coastline of the Sperrgebiet (Pallett, 1995; Burke and Raimondo, 2001).

2.3.5 Future-use scenarios

The overall development objective for the *Sperrgebiet*, as identified in the *Sperrgebiet* Land-Use Plan (Ministry of Environment and Tourism, 2001), is to ensure the long-term sustainable economic and ecological potential of the area. All future developments are therefore to be viewed within the context and recommendations of the Land Use Plan.

Over and above the current mining operations and commercial fisheries, a number of future-use opportunities involving the coastal and marine environment have been identified for the *Sperrgebiet*. These include:

- Eco-tourism in areas of scenic interest (especially north of Chameis), whale and dolphin watching, seal colonies, seabirds.
- Excellent surf angling potential based on pre-determined quotas.

In view of the potential future uses, it is therefore important that a Vision for the Kudu Power Project be developed, and that this includes the following factors:

- to protect the fragile desert and coastal environments within a development context;
- to ensure that the proposed development is sustainable based on the inherent qualities of the area and that all physical, chemical and biological conditions defining the structure of, and processes within, the ecosystem are maintained;
- to allow for integration of multiple users where practical and possible;
- to prevent environmental degradation due to a lack of proper planning by ensuring that water quality is suitable from an aesthetic, safety and hygienic point of view;
- to ensure that the area has a long-term benefit for the whole of Namibia, and the southern regions in particular (Walmsley Environmental Consultants *et al.*, 1999).

These include objectives from the Sperrgebiet Land Use Plan as well as the South African water quality guidelines for coastal marine waters (RSA DWAF, 1995).

3. DESCRIPTION OF THE EFFLUENT DISCHARGES

3.1 Discharges from the cooling system

It is proposed to initially construct a 800 MW nominal capacity combined cycle gas turbine (CCGT) plant, with possible later development of the plant to 1600 MW nominal capacity. The plant will comprise two gas turbines, with one or two steam turbines. Potential cooling system options are a direct (once-through) cooling system³, and evaporative cooling system and a dry cooling system⁴.

While both water and air-cooled systems are under consideration, because of the lower overall efficiency of air cooled systems, the stated preference for Kudu CCGT Power Plant is for an evaporative system, subject to the availability of a suitable supply of make-up water and the long-term reliability of that supply. This specialist assessment is thus limited to assessing only purge water discharges from an evaporative cooling system for a 800 MW and 1600 MW nominal capacity gas fired combined cycle power station.

The proposed evaporative cooling system and the associated discharge are described briefly below:

Evaporative cooling using induced draught cooling towers incorporates a semi-closed water circulation system (see Figure 7). The cooling system includes a large storage capacity (approximately 50 000 m³) into which make-up water is introduced at a rate of 2 000 m³.h⁻¹. Sea water will be used as make-up water (Figure 8). Approximately 700 m³ of water is lost per hour through evaporation. In order to maintain the dissolved solids of the reservoir at acceptable levels, a further 1 300 m³ of water is purged from the system per hour. The

³ Direct seawater cooling entails cooling the steam turbine condensers by means of a once-through heat exchanger. The volumes required are large (ca. 50 000 m³/hour for a 800 MW plant) and the discharged water would be about 10°C hotter than the intake sea water. Direct seawater cooling is the most efficient method to condense exhaust steam. An anti-fouling agent, most likely Sodium Hypochlorite containing approximately 15% of chlorine, will be injected into the cooling water system on an intermittent or continuous basis to control the degree of fouling, and would be controlled such as to ensure a maximum residual oxidant level of 0.10 mg/l chlorine of the discharge from the condenser. For the 800 MW nominal capacity gas fired combined cycle power station under consideration, the characteristics of a direct (once-through) cooling system are as follows:

- Abstraction rate of 50 000 m³.hr⁻¹ (~ 13.9 m³.s⁻¹)
- Discharge rate of 50 000 m³.hr⁻¹ (~ 13.9 m³.s⁻¹)
- Water return will contain a trace of chlorine of 0.1 mg/l NaOCl that is unlikely to be de-chlorinated due to the excessive cost premium.
- Temperature rise in discharge waters of approximately 10°C relative to intake seawater temperature (*i.e.* ΔT=10°C).

⁴ In a direct dry cooling system the exhaust steam is channelled directly to a radiator-type fin-tubed heat exchanger. The steam's latent heat is transferred to the metal surface of the finned tube. Air to cool the fins is forced across the heat exchanger by electrically driven fans.

temperature of the discharged purge water will depend upon the prevailing atmospheric conditions, and will range from as little as 16°C to 22°C (wet bulb temperature + 5°C) to 32 to 35°C (ambient water temperature +10°C). An increase of 10°C above ambient is unlikely often to be exceeded.

The salinity of the purge water is expected to be about 50–55 psu, *i.e.* the purge water is a brine, as opposed to normal seawater with a salinity of 35 psu. As the water is predominantly re-circulated within the cooling water system it requires treatment to prevent deterioration of the plant components. Treatment will be by intermittent or continuous injection of a biocide to control the degree of fouling. Sodium hypochlorite (NaOCl), which typically contains approximately 15% of chlorine, will probably be used at very low concentrations. The use of sodium hypochlorite would be controlled such as to ensure a maximum residual oxidant level of 0.1 mg Cl.ℓ⁻¹ chlorine in the discharge from the condenser. Discharged water is unlikely to be de-chlorinated due to the potentially excessive cost premium.

The characteristics of an evaporative cooling system under consideration for an 800 MW nominal capacity gas fired combined cycle power station are conservatively estimated as follows:

- Sea water abstraction rate of 2 000 m³.h⁻¹ (~ 0.56 m³.s⁻¹).
- Cooling water discharge rate of 1 300 m³.h⁻¹ (~ 0.36 m³.s⁻¹).
- Water return will contain a trace of chlorine of 0.1 mg.ℓ⁻¹ NaOCl.
- Temperature rise in discharge waters of approximately 10°C relative to intake sea water temperature (*i.e.* ΔT=10°C), or approximately +5°C relative to wet bulb air temperature (John Jenkins, ESKOM, *pers comm.*)
- Salinity rise to approximately 1.5 x the salinity at the intake, *i.e.* a discharge salinity of approximately 55 psu.

It must be kept in mind, however, that should the capacity of the plant be increased to 1600 MW, the characteristics of the effluent discharges will remain the same, but the volumes discharged (and consequently the waste heat load of the discharge) will approximately double in magnitude.

The effluent discharged will be a dense, heated effluent having roughly the characteristics as listed in Table 4 below.

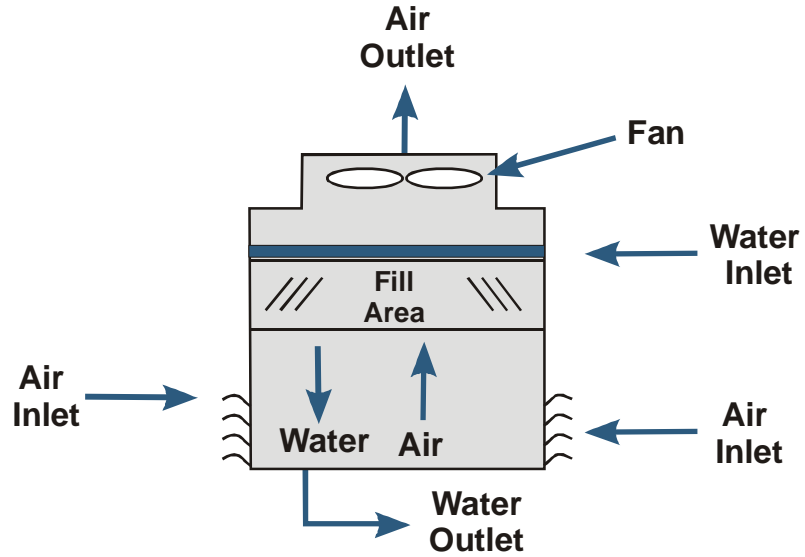


Figure 7: Semi-closed Evaporative Cooling System

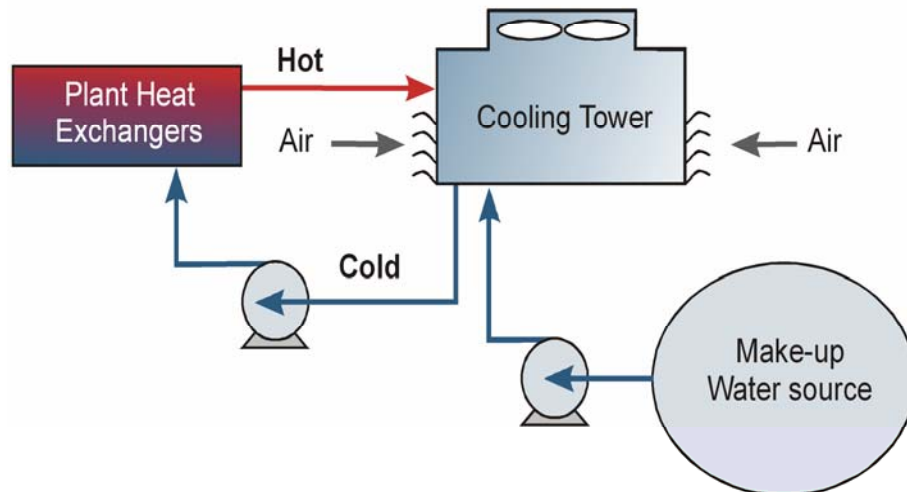


Figure 8: Make-up Water Cooling Tower System.

Table 4: Characteristics of discharged cooling/purge waters from an evaporative cooling system.

Variable	Ambient conditions (approximate)	Increase above ambient	Approximate discharge characteristics
Seawater temperature	Seawater temperature: Winter: 12 – 13°C Spring: 13 – 14°C Summer: 14 – 15°C Autumn: 13 – 14°C Mean daily wet bulb air temperature at Alexander Bay ranges between 11 and 17°C with variability in the means at 08:00 B, 14:00 B and 20:00 B ranging between 8 and 18°C.	$\Delta T = +10^\circ\text{C}$ above ambient seawater temperature or $\Delta T = +5^\circ\text{C}$ above wet bulb air temperature	$T = 22 - 25^\circ\text{C}$ under typical conditions, but $T = 33.5 - 34.5^\circ\text{C}$ under extreme conditions or $T = 16^\circ\text{C}$ to 22°C under typical conditions, but 12°C to 25°C under more extreme conditions
Salinity	34.8 to 34.85 psu	Approximately +20 psu (brine concentration factor = 1.5)* ¹	S = 55 psu
Biocide (free chlorine)	none	$0.1\text{mg}\cdot\ell^{-1}$ NaOCl* ²	$0.1\text{mg}\cdot\ell^{-1}$ NaOCl

*¹ The brine concentration value is a function of the purge quantity, which in principle can be manipulated according to environmental requirements. Increasing the purge water will however result in increased thermal impacts and an increased discharge of biocides (as well as increased costs associated with the increased volumes to be pumped and associated chlorination requirements.)

*² Typically a sodium hypochlorite (NaOCl) solution is pumped directly into the cooling system inlet by a controlled injection system, so as to maintain a residual level of $0.1\text{mg}\cdot\ell^{-1}$ NaOCl (or free chlorine) at the cooling water outlet from the condensing plant. De-chlorination of the effluent is possible for an evaporative cooling system but at an increased operational cost.

3.2 Low-volume aqueous discharges

In addition to the cooling water purge discharge, there are various chemical compounds either associated with the exploitation and transport of the Kudu gas itself, or with power generation. As some of these, for example aromatic hydrocarbons, have potentially deleterious human health effects if discharged to the atmosphere, the temptation exists to discharge these low volume effluents to the natural environment along with the cooling waters. Although these will most likely initially be discharged to the cooling tower basin to minimise the required cooling water make-up, on the basis of assessing a worst-case scenario, it is assumed that they are ultimately discharged to the marine environment in the purge water. It is important that these discharges are quantified and the concentrations and amounts that will potentially be discharged with the cooling water are specified. This will allow a proper assessment of the environmental implications.

Discharges that will arise frequently comprise treated water treatment plant effluents and treated sewage effluent⁵. Less frequent discharges will include heat recovery steam generator (HRSG) blowdowns and discharges from similar maintenance activities (*e.g.* infrequent discharges due to compressor cleaning). Other effluents that could be discharged together with the heated brine waters are discussed below, and are summarised in Table 7.

3.2.1 Water Treatment Plant Effluent

The steam-water cycle will be a closed-loop system with make-up water supplied from the incoming water supply via an on-site water treatment plant (demineralised water treatment plant) where water for use in the HRSG will be treated to achieve a high purity, mainly to limit corrosion within the HRSG. The water treatment process will consist of organic scavengers, and cation, anion and mixed bed ion-exchange.

Corrosion in the HRSG may be mainly caused by dissolved oxygen (O₂) or carbon dioxide (CO₂) in the feedwater. The feedwater must be pH controlled to prevent corrosion and it is desirable to use de-aerated water. It is anticipated that feedwater will be dosed with ammonia (NH₃), caustic soda (NaOH) or trisodium phosphate (Na₃PO₄). In addition, an oxygen scavenging chemical, dilute hydrazine (N₂H₄), may be required to achieve the required water quality by absorbing any traces of oxygen that get into the boiler.

Regeneration of the ion-exchange resins will be by sulphuric acid (H₂SO₄) and caustic soda (NaOH), leading to alternate acidic and alkaline waste streams. These waste streams will be directed to a sump for mixing where their combination will result in neutralisation prior to discharge. In the unlikely circumstances where combination of the two effluent streams does not achieve the required neutralization (pH6 – pH9), acid or caustic (same as used in the resin regeneration) will be added as necessary, resulting in a discharge of a neutralized effluent of salts.

Effluent discharge is expected to last up to one hour daily with a flow rate of up to 7 kg.s⁻¹ for a 800 MW plant. Volumes of discharge for a 2 x 800 MW plant are double those for a single 800 MW plant. It is assumed that other substances arising from the regeneration of ion-exchange resins constitute a daily concentration of substances naturally occurring in the intake waters and thus are unlikely to be of concern in the discharge waters unless they occur in excessive quantities.

⁵ The assessment of the impact of sewage effluents is excluded from the Terms of Reference of this specialist assessment of purge water and co-discharges, as they are dealt with elsewhere (decision taken during teleconference with the Nampower project team on 14 March 2005).

3.2.2 HRSG Blowdown

The water in the HRSG will be blown down intermittently to remove accumulation of impurities resulting in a boiler blowdown discharge comprising high purity water together with any accumulation of impurities as listed in the table below. This blowdown water will be discharged to a tank to reduce pressure prior to entering station drains before discharge via the purge water discharge system.

The boiler is blown down when coming on load and thereafter the frequency and duration of the blowdown are determined by the level of contaminants present. The average volume of the discharge will be approximately $150 \text{ m}^3.\text{day}^{-1}$ with a maximum discharge rate of $150 \text{ m}^3.\text{h}^{-1}$. Volumes of discharge arising for a 2 x 800 MW plant will be double those indicated here, *i.e.* approximately $300 \text{ m}^3.\text{day}^{-1}$ with a maximum discharge rate of $300 \text{ m}^3.\text{h}^{-1}$. This heated water may contain traces of hydrazine (N_2H_4), trisodium phosphate (Na_3PO_4), caustic soda (NaOH) and ammonia (NH_3) as indicated in Table 5 below. Note that the conditioning of this water in the water treatment plant is designed to remove all traces of oxygen from the water used in the HRSG, therefore the blowdown waters are expected to contain no dissolved oxygen.

Table 5: Constituents of the HRSG blowdown waters.

Parameter	Hydrazine (N_2H_4)	Ammonia ⁶ (NH_3)	Phosphate ⁷ (Na_3PO_4)	Sodium Hydroxide (NaOH)
Average Concentration	$0.02 \text{ mg}.\ell^{-1}$ (0.01 to $2.3 \text{ } \mu\text{g}.\ell^{-1}$)	$1.50 \text{ mg}.\ell^{-1}$ (1 to $175 \text{ } \mu\text{g}.\ell^{-1}$)	$5.00 \text{ mg}.\ell^{-1}$ (2.5 to $576 \text{ } \mu\text{g}.\ell^{-1}$)	$3.00 \text{ mg}.\ell^{-1}$ (1.5 to $350 \text{ } \mu\text{g}.\ell^{-1}$)

* The bracketed concentrations in the table above assumed that the blowdown water has been diluted with the purge waters

Given that the blowdown waters comprise a discharge of $150 \text{ m}^3.\text{day}^{-1}$ that could be discharged at a maximum rate of $150 \text{ m}^3.\text{h}^{-1}$. If co-discharged with $1\ 300 \text{ m}^3.\text{h}^{-1}$ of purge water discharge, the blowdown water effluent would be diluted by a factor of between approximately 10 (for the maximum discharge rate) to 200 (for a slow bleed over a 24 hour period). The concentrations of the constituents in the discharge would then be reduced accordingly and would range between the bracketed values indicated in Table 5. For a 1600 MW power plant this dilution would remain the same as both the blowdown and purge water flows would increase proportionately.

⁶ The concentration is assumed to be 1.50 mg/l of NH_3 .

⁷ The concentration is assumed to be 5.00 mg/l of Na_3PO_4 which would translate into an approximate 1 mg/l of the nutrient $\text{PO}_4\text{-P}$. After dilution with the purge water the range of $\text{PO}_4\text{-P}$ discharged would be 0.5 to 120 $\mu\text{g}/\ell$.

3.2.3 Plant and Surface Water Drainage

CCGT plant

The volume of surface water discharge is rainfall dependent. Drainage arising from paved surfaces within the power plant site, such as the turbine floor and maintenance areas, and from controlled discharges from bunds to bulk storage tanks, will be discharged to the cooling water system following passage through an appropriate oil interceptor/separator. Limit values for oil in these surface water discharges would commonly be expected to be about 20 mg.ℓ⁻¹. (Note: This limit value exceeds the Marpol 93/98 guideline of 15 mg.ℓ⁻¹) However, this represents a limit value and in reality no oil discharges would be expected or permitted.

Plant drainage is considered to be effectively non-existent. (All drainage from within the plant arising from leakage and cleaning will be collected by station drains).

Gas conditioning plant

The water from paved areas and storm water associated with the gas conditioning plant will be handled as follows.

All of the process vessels and storage tanks onshore will be paved and/or bunded (the expected total surface area of the process bunded areas will be a maximum of 5000 m³). All water run-off from these areas, including all water from process drains, will be routed to the oily water system. Water from the condensate tank bunded areas can either be routed via the oily water system (if contaminated) or the storm water system (if uncontaminated). The bund water drain valves will remain closed and only be opened to the desired system after a simple oil in water test.

This oily water from the pipeline end facilities will be combined with the oily water from the CCGT power plant and this combined oily water will be processed in a corrugated plate interceptor and coalescing unit (oil separator) to remove traces of oil. These oily waters, after being processed through the oil separator will be combined with the process water from the MEG unit (*i.e.* water from the gas conditioning plant – see Section 3.2.9 below) and exported to the purge water outfall line. The dissolved hydrocarbons in the water discharged will not exceed Marpol 93/98 standards (< 15 mg.ℓ⁻¹) but may need to meet more stringent guidelines such as the World Bank guidelines for new power plants (< 10 mg.ℓ⁻¹), European Standards for Class 1 waters (< 5 mg.ℓ⁻¹) or even the South African General Standards for discharge (< 2.5 mg.ℓ⁻¹).

Water from all other areas (*i.e.* stormwater) will be routed directly to the stormwater system via a holding pond. It is not anticipated that treatment of this stormwater will be required as no significant contamination of the stormwater is expected. It is assumed that the stormwater will be discharged via the purge water outfall. The volume and rate of discharge

of the stormwater will depend on a combination of rainfall and associated design of stormwater facilities.

As a safety measure it may be desirable to construct a small holding pond (approximately two days of storage) before the export pumps as a contingency measure to intercept any water quality problems that may occur due to upset conditions in the water processing units.

3.2.4 Plant Cleaning

Minimal deposits would be expected on the gas side of the HSRG with natural gas being used as the principal fuel. Cleaning of the gas side of HSRG will likely arise only if a facility for firing with liquid fuel is provided and only then in the unlikely event of such firing for a very extended period. (Consequently washing may arise only on a few occasions over the life of the plant.) The cleaning/water washing of the gas side of the HRSG tubes is carried out to remove deposits, which mostly comprise carbonaceous material, that build up and reduce plant efficiency. Deposits are removed by high-pressure, low-volume water washing (there are no chemicals involved). The deposits could contain carbonaceous materials and oxides and sulphates of iron, sodium, vanadium and silicon. The wash water is treated with caustic soda (NaOH) to precipitate materials present in soluble form and the sediments removed for disposal. The remaining liquid is then pH corrected (pH6 – pH9) by the addition of sulphuric acid (H₂SO₄) prior to its discharge via the purge water discharge system.

3.2.5 Gas Turbine Compressor Washing

Operation of the gas turbines associated with the combine cycle plant, whereby air is compressed, combusted and subsequently expanded, may result in the deposition of airborne impurities on the compressor blading. Fouling of the compressor blading results in deterioration of the thermal efficiency of the gas turbine, which needs to be minimised in order to limit the quantity of atmospheric emissions from the combined cycle plant.

Gas turbine compressor blading may be cleaned by a combination of on line and off line washing incorporating the injection of a solvents/surfactants into the compressor inlet. During on-line cleaning when the plant is in operation, the solvent and dissolved oil is subsequently burnt in the combustion chamber of the gas turbine. Off-line washing, undertaken when the plant is not in service, uses a biodegradable cleaner developed specifically for washing compressors in an environmentally acceptable manner. All wastes will be removed off-site for treatment/disposal.

3.2.6 HRSG Acid Cleaning

Acid washes during the life of the plant are carried out at intervals of between roughly 5 – 15 years, depending on many factors such as large-scale replacement of HRSG tubes, severe on-

load corrosion, or excessive magnetite or deposit build-up. The resulting effluents will be taken off-site for safe treatment/disposal at environmentally licensed facilities. HSRG acid cleaning also occurs during plant commissioning with the wastes being handled as indicated above.

3.2.7 HRSG Storage Solutions

The discharge of storage solutions only arises when the plant is out of use for extended periods. Two methods may be used to protect an HRSG when it is out of use for an extended period and these are referred to as dry storage and wet storage. Dry storage, which is the preferred method, will comprise circulation of dry air or the use of the inert gas nitrogen (N_2). There are no resulting discharges from dry storage. For wet storage a solution of hydrazine (N_2H_4) and ammonia (NH_3) are added to achieve pH10 – pH 10.5 and a 200–300 $mg.l^{-1}$ hydrazine residual in the storage water. The resulting discharges from wet storage, should they arise, will be either sent for disposal by an appropriate waste contractor or else suitably treated prior to release discharge.

3.2.8 Water from gas conditioning plant

The gas conditioning plant with its associated slug catchers will be constructed adjacent to the CCGT power station. The key components of the gas conditioning plant are presented schematically in Figure 9. Gas and liquids from the pipeline are led into a slug catcher, which permits the separation of the gas from the condensate and water/monoethylene glycol (MEG) mixture. The slug catcher for Phase 1 will have a volume of 200 m^3 .

The slug catcher is essentially a 3 phase separator. The gas stream from the slug catcher is first superheated using steam from the power station and supplied to the power stations via a gas measuring station. The wild condensate is first dried and heated before passing through the fiscal meter and on into the power station.

The liquids in the slug catcher are drained, heated and separated into two distinct phases: a water/MEG mixture and condensate. A small amount of gas which will be used as fuel probably in the MEG regenerator(s) is liberated in this process. Following this separation step the condensate is cooled and stabilised at atmospheric pressure before being stored in banded atmospheric tanks. The volume of condensate to be stored is still to be decided but it will probably be of the order of 25 000 bbls contained in a small banded tank farm.

The condensate and water/MEG mixture is passed through a separator. The MEG/water mixture separation is achieved by distillation. The water will be boiled off and turned into steam. The MEG will be cooled and sent to atmospheric banded storage tanks. The MEG/water mixture sent to the boiler contains a small amount of aromatic components, namely benzene, toluene and xylene (BTX). These aromatics also will be boiled off in the process and burnt in an enclosed combustion chamber.

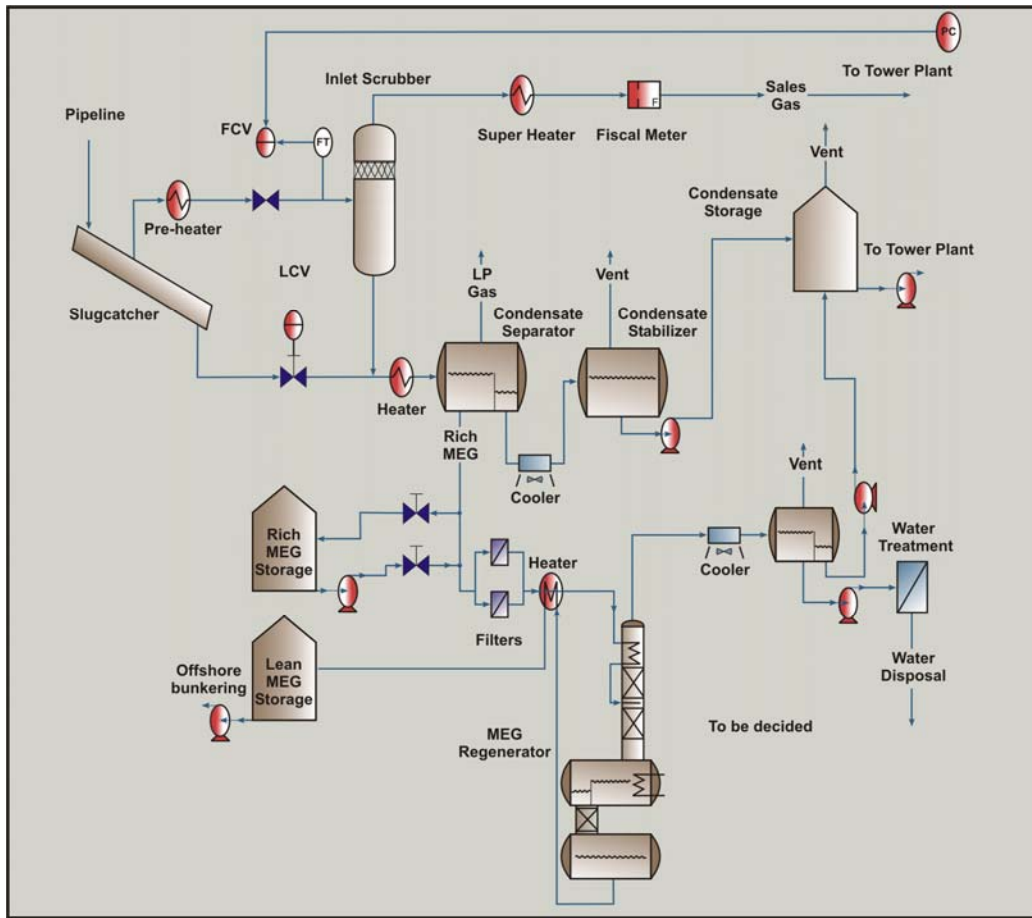


Figure 9: Main components of onshore Gas Conditioning Plant (after CSIR, 2004)

The water condensed out of the MEG recovery plant is expected to be of good quality due to the heat applied in the MEG recovery plant (120°C) and a steam stripping action. The water is expected to contain only traces of free and dissolved hydrocarbons to a specification of $< 10 \text{ mg}\cdot\text{l}^{-1}$. The dissolved hydrocarbons will be mainly traces of aromatics, cyclic compounds, un-recovered MEG and traces of methanol, MEG, methanol, benzene, m/p-xylenes, toluene, cyclo-pentane, cyclo-hexane. An analysis of hydrocarbons of feed condensate (Table 6) gives an idea of the constituents of the produced water prior to being processed in the MEG separator and consequently the potential constituents that may remain to a lesser or greater extent in the condensed water effluent for discharge.

The water from the gas conditioning plant ($5 \text{ m}^3\cdot\text{day}^{-1}$) will be at a temperature of 40°C , and will be co-discharged into the sea with the CCGT plant's cooling purge water ($31\,200 \text{ m}^3\cdot\text{day}^{-1}$). If the $5 \text{ m}^3\cdot\text{day}^{-1}$ of effluent from the gas conditioning plant is "bled" into the purge water discharge stream over a 24 hour period an effective 6250 times dilution can be achieved prior to discharge. This would result in a discharge concentration not exceeding

approximately $1.6 \mu\text{g}\cdot\ell^{-1}$ of dissolved hydrocarbons. By definition none of the toxic components in the discharge would then exceed $1.6 \mu\text{g}\cdot\ell^{-1}$ and in practise could be far lower.

Table 6: Hydrocarbon analysis of dead condensate from the Kudu gas field (Corelab, 1997)

Component	Mole%	Weight%
Hydrogen	0.00	0.00
Hydrogen sulphide	0.00	0.00
Carbon dioxide	0.00	0.00
Nitrogen	0.00	0.00
Methane	0.12	0.01
Ethane	0.15	0.03
Propane	0.28	0.09
i-Butane	0.28	0.11
n-Butane	0.58	0.24
neo-Pentane	0.02	0.01
i-Pentane	0.75	0.38
n-Pentane	0.80	0.40
Hexanes	2.80	1.67
Me-Cyclo-pentane	0.51	0.30
Benzene	2.64	1.43
Cyclo-hexane	1.40	0.82
Heptanes	5.44	3.78
Me-Cyclo-hexane	2.06	1.40
Toluene	1.64	1.05
Octanes	9.08	7.19
Ethyl-benzene	0.59	0.44
Meta/Para-xylene	1.74	1.28
Ortho-xylene	0.85	0.63
Nonanes	11.02	9.80
Tri-Me-benzene	0.76	0.64
Decanes	12.80	12.55
Undecanes	11.40	11.62
Dodecanes	8.65	9.66
Tridecanes	6.80	8.25
Tetradecanes	4.91	6.47
Pentadecanes	3.58	5.11
Hexadecanes	2.52	3.88
Heptadecanes	1.77	2.91
Octadecanes	1.26	2.19
Nonadecanes	0.87	1.59
Eicosanes plus	1.93	4.07
Totals	100.00	100.00

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Table 7: Potential aqueous discharges.

Discharge	Nature of discharge	Duration and flow rate of discharge	Constituents in discharge	Constituent concentrations in discharge	Alternative methods to handle waste
Cooling System Purge water Discharge	Purge water with constituents as specified in Table 4	<p>800 MW continuous 1300 m³.h⁻¹ (0.36 m³.s⁻¹)</p> <p>1600 MW continuous 2600 m³.h⁻¹ (0.72 m³.s⁻¹)</p>	Elevated temperature, salinity and a biocide, most probably sodium hypochlorite (NaOCl)	Elevated temperature, salinity and a biocide as specified in Table 4	<p>Once through cooling</p> <p>Dry cooling</p>
Water treatment plant effluent	Regeneration of the ion-exchange resins used in the water treatment plant will be by sulphuric acid and caustic soda, leading to alternate acidic and alkaline waste streams. Effluent will be neutralised prior to discharge	Discharge up to one hour daily with a flow rate of up to 7 kg.s ⁻¹ (or 25 m ³ .h ⁻¹) for a 800 MW plant and approximately 14 kg.s ⁻¹ (or 50 m ³ .h ⁻¹) for a 1600MW plant. .	Neutralised effluent of salts	The concentration of salts unknown but at most discharge would comprise only approximately 25 m ³ .h ⁻¹ for up to one hour a day compared to the continuous brine discharge of 1 300 m ³ .h ⁻¹ (<i>i.e.</i> water treatment plant effluent of neutralized salts would be diluted by a factor of approximately 50 before discharge). Due to a doubling of both the water treatment plant and purge water effluent stream for a 1600 MW plant the dilution factor remains 50.	Not specified

Discharge	Nature of discharge	Duration and flow rate of discharge	Constituents in discharge	Constituent concentrations in discharge	Alternative methods to handle waste
HRSG blowdown	The water in the HRSG will be blown down intermittently to remove accumulation of impurities. This blowdown water will be discharged to a tank to reduce pressure prior to entering station drains before discharge.	Average discharge volume will be approximately $150 \text{ m}^3.\text{day}^{-1}$ with a maximum discharge of $150 \text{ m}^3.\text{h}^{-1}$ for a 800 MW plant and roughly double that for a 1600 MW plant.	Quantities of: <ul style="list-style-type: none"> • hydrazine (N_2H_4), • trisodium phosphate (Na_3PO_4), • caustic soda (NaOH) and • ammonia (NH_3). Water is de-oxygenated, thus dissolved oxygen concentration conservatively assumed $\sim 0 \text{ mg O}_2.\ell^{-1}$	Actual concentrations as indicated in Table 4. As the maximum discharge is $150 \text{ m}^3.\text{h}^{-1}$ compared to the purge water discharge of $1\ 300 \text{ m}^3.\text{h}^{-1}$, the effluent will be diluted by a factor of approximately 10 but up to 200 times if the release was to take place over a 24 hour period..	Not specified
Plant and Surface water drainage	All potentially contaminated run-off / drainage from within the plant and bunded areas, together with controlled discharges, will be discharged to the cooling water system following passage through an appropriate oil interceptor/separator. All other stormwater, if uncontaminated, will be discharged directly to the stormwater system via a holding pond	The volume and rate of discharge is unknown (depends of rainfall and the design of facilities), but is expected to be controlled	Expect some dissolved hydrocarbons but constituents of the discharge unspecified.	Expect some oils but unspecified. Oil separator system will need to ensure that dissolved hydrocarbons do not exceed acceptable standards (<i>e.g.</i> not exceeding $2.5 \text{ mg}.\ell^{-1}$ to $15 \text{ mg}.\ell^{-1}$, depending on guidelines considered to be acceptable for the region)	Unknown, but could include specific waste management.

Discharge	Nature of discharge	Duration and flow rate of discharge	Constituents in discharge	Constituent concentrations in discharge	Alternative methods to handle waste
Plant cleaning (water washing of gas side of HSRG tubes)	Water washing to remove deposits of carbonaceous material	Only a few occasions over life-cycle of plant Volumes and rates of discharge are unknown but are likely to be limited.	Initial effluent will contain carbonaceous materials and oxides and sulphates of iron, sodium, vanadium and silicon, however the effluent will be treated with caustic soda to precipitate materials present in soluble form and the sediments removed for disposal. Final discharge expected to comprise neutralised effluent containing salts and only traces of metals, dissolved salts	Concentration of contaminants unknown but expected to be extremely limited	Unknown
GT Compressor Washing	Gas turbine compressor blading may be cleaned by a combination of on-line and off-line washing. Effluent from on-line washing is burnt in the combustion chamber of the gas turbine. Effluent resultant from off-line cleaning comprising a solvent and dissolved oil will be removed off-site for treatment or disposal.	No discharge - the resulting effluents will be taken off-site for treatment/disposal at environmentally licensed facilities	No discharge	No discharge	unspecified
HSRG acid cleaning	Acid washes at commissioning and during the life of the plant are carried out at intervals of roughly 5 – 15 years. The resulting effluents will be taken off-site for treatment/disposal at environmentally licensed facilities.	No discharge - the resulting effluents will be taken off-site for treatment/disposal at environmentally licensed facilities	No discharge	No discharge	unspecified

Discharge	Nature of discharge	Duration and flow rate of discharge	Constituents in discharge	Constituent concentrations in discharge	Alternative methods to handle waste
HRSR Storage Solutions	Storage may be used to protect an HRSR when it is out of use for an extended period, whereby a solution of hydrazine (N ₂ H ₄) and ammonia (NH ₃) is used.	The resulting discharges, should they arise, will be either sent for disposal by an appropriate waste contractor or else suitably treated prior to release.	hydrazine (N ₂ H ₄) residual and ammonia (NH ₃) concentration is unknown	200–300 mg.ℓ ⁻¹ hydrazine residual in the storage water, NH ₃ concentration is unknown Concentration information unnecessary as waste is likely to be sent for disposal by an appropriate waste contractor or else suitably treated prior to release.	unspecified
Water from gas conditioning plant	The water from the gas conditioning plant (5 m ³ .day ⁻¹) will be at a temperature of 40°C and will contain trace amounts of dissolved hydrocarbons (< 10 ppm maximum). This water can be co-discharged with the cooling purge water, resulting in dilution of the effluent by a factor of 6000. The anticipated effect on the environment is negligible.	5 m ³ per day	Dissolved hydrocarbons (< 10 ppm maximum) containing mainly trace quantities of aromatics, cyclic compounds, un-recovered MEG and traces of methanol *MEG, methanol, benzene, m/p-xylenes, toluene, cyclopentane, cyclo-hexane.	Exact concentrations unknown but may not be relevant as a dilution of greater than 6000 can be achieved prior to discharge	unknown

3.3. Discharge configuration options

Various intake and discharge configurations are being considered for the CCGT power plant. Much of the shoreline of MA1 is prograding due to the continuous, long-term discharge into the surf-zone of mining-related sediments from land-based gravel treatment and diamond extraction plants. The extent of the progradation of the coastline will depend on the exact nature of existing and future mining operations. As a worst case scenario based on future mining operations as presently envisaged, the coastline may prograde up to 300 m. Consequently, the intake pipeline needs to be located sufficiently far offshore of the present shoreline (*i.e.* in a future water depth of at least approximately 15 to 16 m, or a distance of more than ~1000 m offshore) to avoid the intake of excessive sediment, as well as smothering of the intake over the life-time of the project due to beach accretion. The discharge location, on the other hand, needs to be such that it does not stir up sediments that could be drawn into the intake, or result in significant re-circulation of heated brine from the discharge into the intake.

For a ***discharge located inshore of the intake***, the length of pipeline is determined by the requirement for the discharge to remain located beyond the surf zone for the life-time of the project. Given a maximum progradation of the shoreline of 300 m over the life-time of the project, a maximum surf zone width of 300 to 400 m, the requirement to keep the discharge structure away from the surf-zone (*e.g.* approximately 200 to 300 m offshore of the surf zone) and to minimise the probability of the discharge end of pipeline being buried, a discharge located inshore of the intake needs to be located between 900 m and 1000 m offshore of the present shoreline. (The present water depth at this location is approximately 18 m, while a future water depth will be approximately 15 m). To minimise re-circulation of purge waters the intake is assumed to be located 400 m offshore of the discharge location, *i.e.* approximately 1400 m offshore of the present coastline.

For a ***discharge located offshore of the intake***, the length of pipeline is determined by the need for the intake location to remain in a water depth exceeding 15 m to avoid the excessive intake of sediments. For both existing and future scenarios this requires that the intake be located 1 000 m or more offshore of the existing coastline where the present water depth exceeds 18 m. The discharge location, in turn, needs to be sufficiently distant from the intake (*i.e.* 300 m or more) to minimise re-circulation of purge waters. The discharge thus needs to be located 1 300 m or more offshore (*i.e.* in a present water depth presently exceeding 21 m but possibly shallowing to 18 m in the future).

In all cases the minimum depth is assumed at the discharge point, *i.e.* the depths as would occur in the future. In the case of a discharge located inshore of the intake, the assumed minimum depth of discharge is 15 m. For a discharge located offshore of the intake the assumed minimum water depth is 18 m.

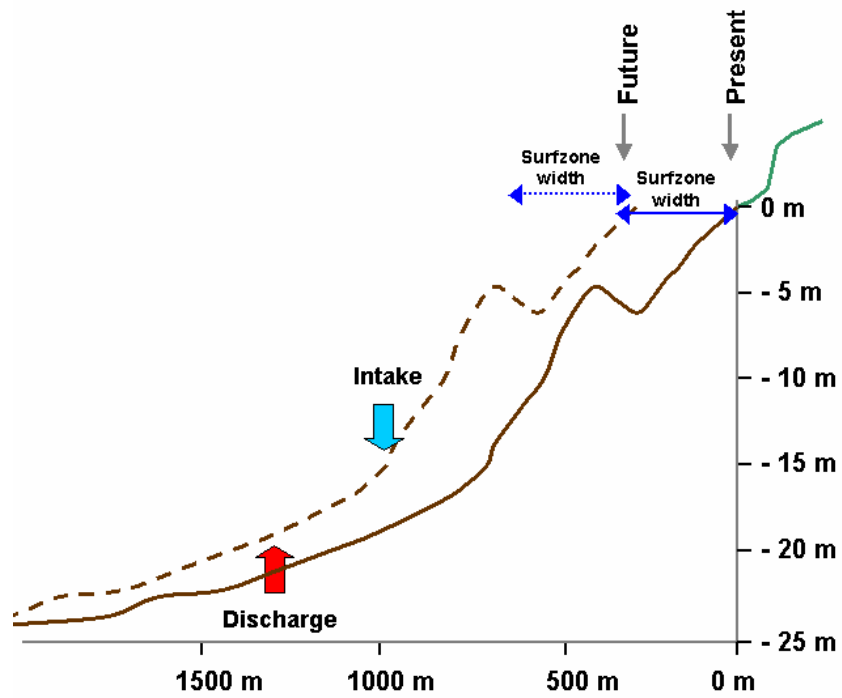


Figure 10: The proposed intake/discharge configuration with the discharge located offshore of the intake.

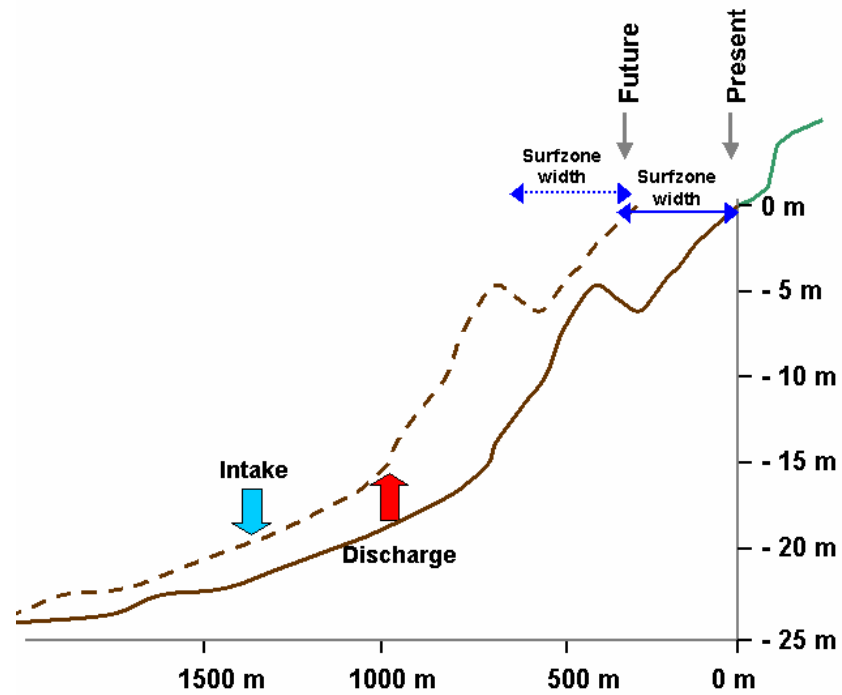


Figure 11: The proposed intake/discharge configuration with the discharge located inshore of the intake.

For the nearshore and offshore discharge options, either a single port or a multi-port discharge configuration is possible. A single port discharge configuration was simulated for the impact assessment, as this is likely to give the most conservative results. This leaves scope for optimising the outfall characteristics through the use of a more effective diffuser design. The single port discharge assessed is located in a 15 to 18 m water depth, is directed upwards at 60 degrees to the horizontal and is located approximately 1 m above the seabed. The discharge velocities from the single port are considered to range between 0.9 m.s⁻¹ and 5 m.s⁻¹. (The higher discharge velocity is typical of higher volume once-through hot water discharges).

A further discharge scenario is that the purge water and associated low volume aqueous wastes are disposed of via a ***shoreline discharge into the surf-zone***. The exact location of the discharge relative to the moving (accreting) shoreline is unknown, as is the engineering design of such a discharge. For the purposes of this assessment we have assumed a discharge at the shoreline at all times, *i.e.* the discharge point moves with the accretion of the coastline.

In summary, the possible discharge locations under consideration, and their associated constraints are as listed in Table 8 below:

Table 8: Summary of discharge options.

Discharge Option	Constraints
Shoreline discharge into the surf-zone	Both environmental and engineering constraints (see footnote on page 2 regarding discharges into the surf-zone).
Discharge through a submerged pipeline approximately 400 m inshore of the intake but beyond the surf-zone (900 to 1000 m offshore of the present surf-zone) in a water depth of 15 – 18 m (Figure 10)	Elevated risk of re-circulation of the (dense) heated brine
Discharge through a submerged pipeline located approximately 300 m seawards of the intake location at a water depth of approximately 18 – 21 m (Figure 11).	The discharge location would be approximately 1400 m offshore of the present shoreline

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4. ANTICIPATED CHANGES IN THE MARINE ENVIRONMENT DUE TO THE EFFLUENT

The discharge will add heat, a brine (elevated salinity) and residual biocide (free chlorine) to the natural environment. The heat and elevated salinities in the heated brine will directly modify the physical characteristics of the seawater in the vicinity of the discharge whilst the heat, brine, biocide and potential co-discharges can all negatively affect the marine biota. To determine the scale of their effect here we provide first order estimates of the impact area both offshore and in the surf-zone.

The rationale adopted to determine the scale of impact is to assume that heat acts as a conservative variable, *i.e.* heat is only dissipated to the receiving water body with no losses to the atmosphere. Given that the heated brine being discharged is denser than the ambient water into which the discharge occurs and is likely to have limited exposure to the atmosphere, this is a reasonable assumption. Furthermore, this provides conservative estimates of the area impacted by elevated seawater temperatures.

Under the assumption that temperature is a conservative parameter, these estimates of the thermal effluent distribution in the receiving environment will also generate information on the likely distribution of the elevated salinities, biocide and pollutants contained in potential co-discharges in the marine waters (*i.e.* the temperature, salinity, biocide and toxicants are all treated as conservative tracers). The modelling however ***cannot provide information on potential synergistic effects between the various potential pollutants.***

A once-through cooling system has previously been assessed off Oranjemund (Carter and van Ballegooyen, 1998). Furthermore, the probable distribution of the thermal effluent can be generalised from other coastal power stations (*e.g.* Koeberg, South Africa; Rattey and Potgieter, 1987). These assessments, however, are of limited value here, as the evaporative cooling system proposed is significantly different from these once-through cooling systems. The heated brine discharged from an evaporative cooling systems comprises a substantially smaller thermal load and, being a dense effluent, behaves significantly different to once-through cooling discharge waters (*i.e.* spreads as a dense plume along the seabed as opposed to the spread of a buoyant plume at the sea surface as occurs for a once-through cooling discharge).

Here we have adopted a predictive modelling approach to assess the potential changes in the marine environment for a pipeline discharge offshore of the surf zone as well as in the surf-zone.

4.1 Assessment of discharges offshore of the surf-zone.

The model we use to assess the pipeline discharges offshore of the surf-zone is the CORMIX mixing zone expert system which comprises a software system for the prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies developed for the United States Environmental Protection Agency (U.S. EPA) by the Cornell University during the

period 1985–1995 (Jirka *et al.*, 1996). The CORMIX system is applicable to all types of ambient water bodies, including small streams, large rivers, lakes, reservoirs, estuaries and coastal waters. The method has been extensively verified by the developers through comparison of simulation results with available field and laboratory data on mixing processes and has undergone extensive peer-review (for example, Summer *et al.*, 1994). Although the system’s major emphasis is on predicting the geometry and dilution characteristics of the initial mixing zone so that compliance with water quality regulatory constraints may be judged, the system also predicts the behaviour of the discharge plume at greater distances. The model is a steady-state model providing distributions of conservative pollutants and non-conservative pollutants with a specific allowance being made for heated effluents. This model has been successfully applied in other studies of thermal discharges by the CSIR (CSIR, 1995, 1996b, 1997b and Carter and van Ballegooyen, 1998, van Ballegooyen *et al.*, 2004).

However, a limitation of the model is that it assumes an infinite receiving body of water and consequently ***does not take into account the potential build-up of pollutants***. Where the potential for such build-up, for example, in temperature exists due to poor flushing, the results provided by the model will not be conservative. This is a potential concern for discharges into the surf zone, coastal embayments and similar enclosed semi-enclosed or enclosed bodies of water, however this is less likely to be of concern for an offshore pipeline discharge along an open and energetic coastline as being considered here. Nevertheless, in presenting the results of the modelling for the assessment of environmental impacts we have erred on the side of caution.

The model uses the input specification of an effluent flow of $1\,300\text{ m}^3\cdot\text{h}^{-1}$ ($\sim 0.36\text{ m}^3\cdot\text{s}^{-1}$) having a ΔT of $+10^\circ\text{C}$ (*i.e.* the thermal discharge is 10°C warmer than the ambient seawater temperatures at the seawater intake) and a salinity of 55 psu. The atmospheric heat loss coefficients in the model are set to zero. As noted above this results in a conservative estimate of the area impacted by the thermal effluent and allows one simultaneously to generate information on the potential distribution of the salinity, biocide and other toxicants using the excess temperature distributions.

The discharge scenarios considered comprise a range of environmental conditions and discharge velocities from the end of pipeline. The scenarios considered are as listed in Table 9 below that also includes a summary of classifications of the effluent behaviour after discharge into the marine environment for the various scenarios indicated.

The heated brine being discharged comprises a dense effluent. It is anticipated to have a temperature of 24°C ($+10^\circ\text{C}$ above the ambient seawater temperature of 14°C), a salinity of 55 psu (for a brine concentration factor of approximately 1.5) and a density of $1038.9\text{ kg}\cdot\text{m}^{-3}$. The ambient seawater density is approximately $1026\text{ kg}\cdot\text{m}^{-3}$. To ensure adequate dilution in the near field the port is configured to discharge at an angle of 60° above horizontal. The typical behaviour of the effluent upon discharge is schematised in Figure 12. A negatively buoyant discharge, when jetted into the water column almost vertically will rise up to a maximum height in the water column. Depending on the discharge velocity, the effluent plume may reach the surface. In shallow water the effluent may be mixed throughout the water column. The typical

effluent behaviours for each discharge scenario are given in Table 9 in terms of a behaviour classification. These behaviours are represented schematically in Figure 12.

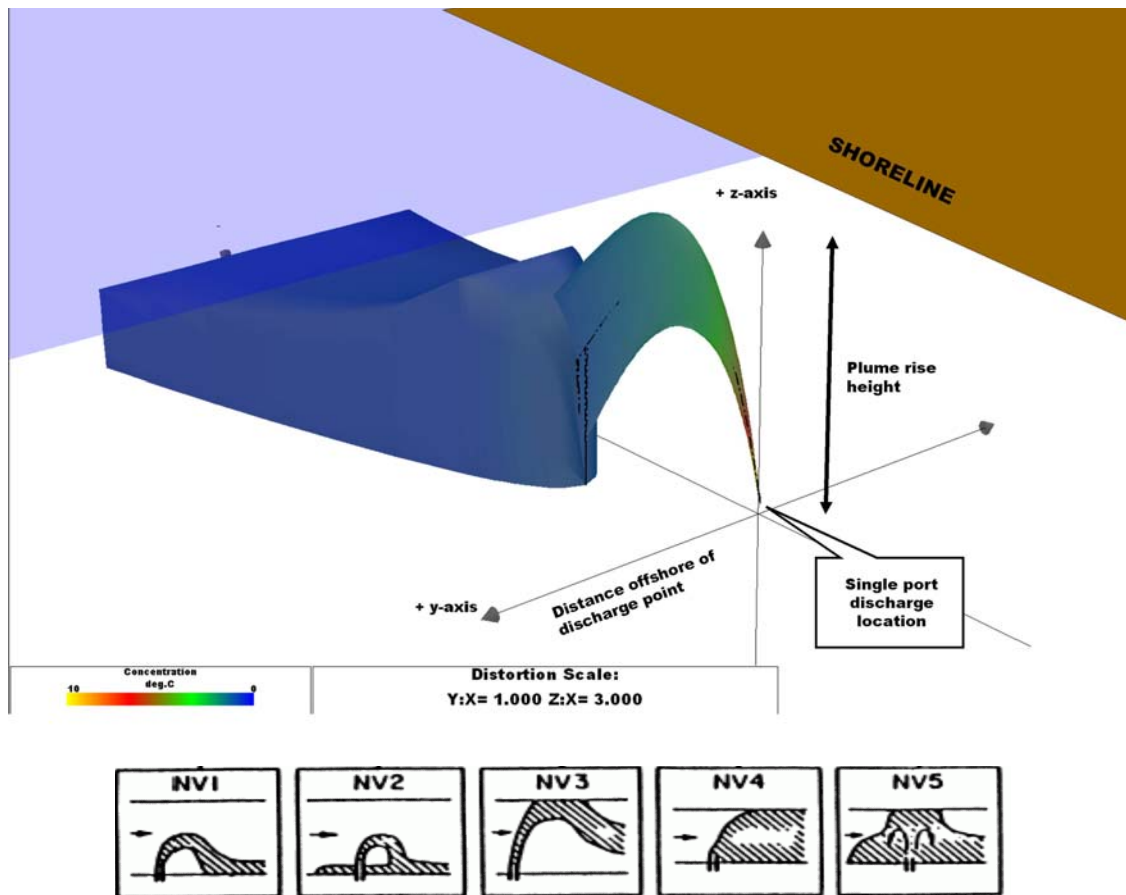


Figure 12: Schematised behaviour of a typical negatively buoyant effluent plume such as the heated brine being considered in this study.

In Figure 12 the effluent plume rises to a maximum rise height in the water column and then settles back to the seabed and continues to spread due to buoyancy spreading and advection. For the purposes of this study, the extent of the “footprint” of the effluent is given as contours of maximum temperature, salinity rise and concentration of biocide at any location within the water column. In general the effluent is trapped on or near the bottom thus the impacts are expected to be greatest at or near the seabed.

For each discharge scenario, the effluent behaviour can be characterized in terms of the effluent characterisations and plume dimensions (Figure 13). The typical effluent behaviour for each discharge scenario is indicated in Figure 12 and Table 9.

Table 9: Classification of effluent behaviours

Scenario	Discharge velocity m.s ⁻¹	Effluent behaviour classification
1 low current (0.02 m.s ⁻¹)	5.0*	NV5
	1.8	NV2
	0.9	NV2
2 average current (0.20 m.s ⁻¹)	5.0	NV3/NV4**
	1.8	NV2
	0.9	NV2
3 maximum current (0.65 m.s ⁻¹)	5.0	NV3
	1.8	NV1
	0.9	NV1

* an ambient current speed of 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.
 ** the effluent behaviour upon discharge changes from and a NV3 behaviour for ΔT = +10°C to a NV4 behaviour for a ΔT = +5C effluent.

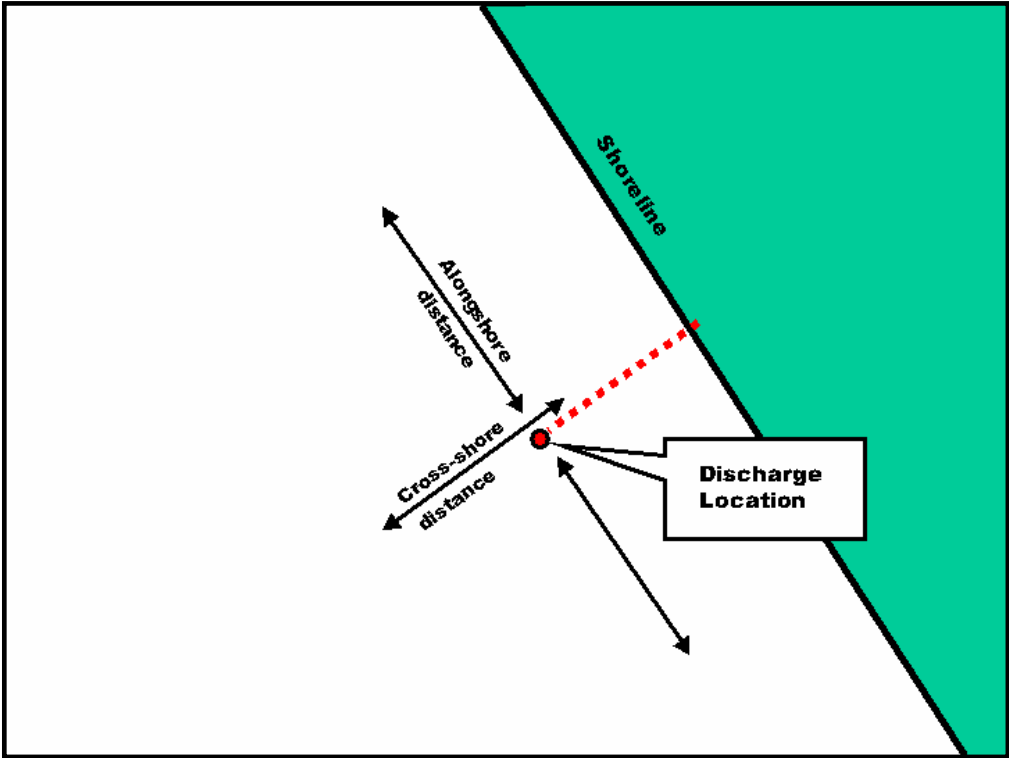


Figure 13: Schematised discharge pipeline and dimensions as listed in Tables 9 to 25.

The sensitivity of the model results have been tested for a number of discharge scenarios:

- Water column stratification: The model results are not unduly sensitive to typical variations in ambient water column stratification compared to the uniform ambient density assumed in the modelling study. This is due to the fact that the heated brine is substantially denser than the ambient seawater and consequently is not unduly sensitive to relatively small variations in surface and bottom ambient seawater density, *i.e.* water column stratification. The model results reported therefore are for a uniformly mixed water column.
- A temperature elevation $\Delta T = +10^{\circ}\text{C}$ above ambient seawater temperatures has been assumed. In reality the temperature elevation is typically wet bulb air temperature $+5^{\circ}\text{C}$. Analysis of wet bulb temperatures for Alexander Bay (SAWB, 1984, 1992) indicate that in summer the temperature of the hot water discharge typically is approximately 10°C above local sea surface temperature, *i.e.* the temperature elevation ($\Delta T = +10^{\circ}\text{C}$) assumed in this study is correct for summer scenarios. However in winter the mean discharge temperature is expected to be only 5°C above ambient sea water temperatures. While a lower discharge temperature is expected to limit thermal impacts, it may result in greater impacts in terms of salinity and biocide as lower discharge temperatures imply a more dense effluent that would not mix as easily with the ambient waters and may result in more extensive impacts near the seabed.

Simulations run using a temperature elevation of using $\Delta T = +5^{\circ}\text{C}$ indicated some increase in the plume dimension (in terms of salinity and biocides) due to the fact that the effluent is more dense and mixes less well with the overlying water column. The thermal impacts are somewhat reduced however this is not important as the thermal impacts are the least extensive of the impacts considered. The change in plume dimension typically is quite small ($< 5\%$) and therefore are not expected to affect the conclusions of this study. The maximum increase in plume dimensions assuming a reduced temperature effluent, typically increases the plume dimensions by approximately 5% (with a typical maximum increase of $< 10\%$) compared to the dimensions of the plume for a $\Delta T = +10^{\circ}\text{C}$, *i.e.* the changes in the “footprint” of the plume are not significant as they are typically within the uncertainty of the modelling results. Thus a $\Delta T = 10^{\circ}\text{C}$ has been used in both the assessment of the pipeline options and a discharge into the surf-zone.

4.1.1 Assessment of an offshore discharge located offshore of the intake.

Here the discharge being assessed is an offshore pipeline discharge where the discharge location lies offshore of the intake (see Section 3.3). The offshore pipeline discharges are assessed for both a 800 MW and a 1600 MW power plant.

Assessment for a 800 MW power plant

The results for the discharge from a 800 MW power plant are given below (Tables 10 to 13).

The extent of the thermal plume footprint for the various discharge scenarios is characterized in Table 10 below. Where it is stated that the radius < 20 m, this implies that the temperature elevation indicated (*i.e.* 1°C, 3°C, *etc*) does not extent beyond a 20 m radius of the discharge point. The longshore dimensions of the thermal “footprint” refer to a distance downstream of the discharge location, however given that the currents flow both north and south along the coast, the longshore extent of the thermal “footprint” can be considered to extend alongshore in both directions from the discharge location (see Figure 13). The offshore extent of the thermal “footprint” generally is considered to represent a distance offshore of the discharge location. Only under a few scenarios (*i.e.* under calm, low current conditions) is the plume predicted to extend significant distances shorewards and even then the thermal plume does not extend as far as the surf zone. Being a dense effluent, buoyancy spreading is not effective in extending the thermal plume shorewards into shallower waters.

Table 10: Model results indicating the magnitude and extent of seawater temperature rise for the various offshore discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔT = +1°C contour		Plume dimensions** ΔT = +3°C contour		Plume dimensions** ΔT = +5°C contour	
		Longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	200	80	radius < 20	radius < 20	radius < 10	radius < 10
3 maximum current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 11: Model results indicating the magnitude and extent of the salinity rise in the marine environment for the various offshore discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔS = +1□ psu contour		Plume dimensions** ΔS = +4□ psu contour	
		longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 20	25	radius < 20	radius < 20
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	70	55	Radius < 20	radius < 20
	0.9	450	120	230	80
3 maximum current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	100	< 20	radius < 20	radius < 20

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 12: Model results indicating the magnitude and extent of free chlorine for the various offshore discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** Free chlorine = 3 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 5 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 10 μg.ℓ ⁻¹	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	50	30	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	120	55	< 20	25	radius < 20	radius < 20
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	360	120	70	50	radius < 20	radius < 20
	0.9	660	150	450	120	200	75
3 max current (0.65 m.s ⁻¹)	5	35	<20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	100	< 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	160	25	95	radius < 20	radius < 20	radius < 20

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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Table 13: Model results indicating minimum achievable dilutions of the effluent in the marine environment for the various offshore discharge scenarios simulated for a 800 MW nominal capacity power plant

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 2 dilutions		Plume dimensions** 3.33 dilutions		Plume dimensions** 5 dilution		Plume dimensions** 10 dilution	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	200	80
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 20 dilution		Plume dimensions** 30 dilutions		Plume dimensions** 50 dilutions		Plume dimensions** 100 dilutions	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	50	25	120	55	520	180
	0.9	radius < 20	25	100	50	320	110	unreliable	unreliable
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	25	< 20	70	50
	1.8	70	55	300	110	585	155	990	220
	0.9	450	120	600	150	830	180	1200	220
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	30	< 20	220	30	65	< 20
	1.8	radius < 20	radius < 20	80	< 20	175	30	290	40
	0.9	100	< 20	150	25	220	30	320	40

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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Where required the co-discharges can be assessed using the plume dimensions for the relevant required achievable dilution as listed in Table 13. The potential co-discharges assessed are those listed in Table 7. Given optimal design and appropriate mitigation measures, the only co-discharges of potential concern are:

- The water treatment plant effluent, however the constituents of the effluent seem relatively benign given the discharge quantities, concentrations and the fact that the effluent can be diluted by a factor of 50 before discharge into the environment if appropriately “bled” into the purge water discharge.
- The HSRG blowdown effluent that will be oxygen deficient and also contain small quantities of the oxygen-scavenging substance hydrazine. If the HSRG blowdown effluents are “bled” into the purge water discharge, a minimum dilution of 8 to 10 of the effluent is achievable before discharge. This, together with relatively minor dilution after discharge to the environment, should result in sufficient oxygenation of the water for the impacts to be minimal. Certainly, in the surf-zone the waters are likely to be well-oxygenated and the low oxygen content of the effluent and the oxygen demand of the trace quantities of hydrazine are not likely to be of concern. Of potential concern is the ammonia and phosphates in the discharge. Should the HSRG effluent be combined with the purge water discharge, the maximum concentrations of $\text{PO}_4\text{-P}$ and NH_3 in the effluent discharged will be approximately 580 and 175 $\mu\text{g}\cdot\text{l}^{-1}$, respectively. The relevant required dilutions to ensure compliance with water quality guidelines for both $\text{PO}_4\text{-P}$ and NH_3 (see Table 37) under this discharge scenario are expected to be approximately 10. However should the HSRG effluent be “bled” into the purge water system over a full 24 hour period, then the maximum concentrations of $\text{PO}_4\text{-P}$ and NH_3 in the effluent discharged will be approximately 2.5 and 1 $\mu\text{g}\cdot\text{l}^{-1}$, respectively. Under these circumstances compliance with the relevant water quality guidelines is assured.
- The plant and surface water drainage will need to meet the relevant guidelines before discharge. It is uncertain as to which guideline may prevail, however the most stringent of these, if applicable, is likely to be the South African General Discharge Standard of < 2.5 $\text{mg}\cdot\text{l}^{-1}$. The oil separators will need to be designed to meet the relevant standards or, whilst not ideal, the oily water discharges could be managed to achieve appropriate maximum discharge concentrations by dilution with the purge waters. Similarly storm water run-off from the site will need to meet all of the relevant guidelines for oils, trace metals, *etc*, however, given good ‘house-keeping’ there is no reason why the relevant guidelines should be exceeded.
- Plant cleaning comprising the cleaning of the gas side of HSRG may result in trace metals being present in the effluent, however with adequate treatment as proposed there is no reason why the relevant guidelines should be exceeded. Being a relatively infrequent effluent stream, specialised treatment of the effluent, if required, should not pose an undue cost constraint.

- The water from the gas conditioning plant (i.e. the water condensed out of the MEG recovery plant) will be discharged into the sea at a temperature of 40°C and at a rate of 5 m³.day⁻¹ together with the CCGT plant's cooling purge water (31 200 m³.day⁻¹). The effluent from the gas conditioning plant is expected to contain only traces of free and dissolved hydrocarbons to a specification of < 10 mg.ℓ⁻¹. The dissolved hydrocarbons will be mainly traces of aromatics, cyclic compounds, un-recovered MEG and traces of MEG, methanol, benzene, m/p-xylenes, toluene, cyclo-pentane, cyclo-hexane. If the 5 m³.day⁻¹ of effluent is “bled” into the purge water discharge stream over a 24 hour period an effective 6250 times dilution can be achieved prior to discharge. This would result in a discharge concentration not exceeding approximately 1.6 µg.ℓ⁻¹ of dissolved hydrocarbons. (By definition none of the toxic components in the discharge would then exceed 1.6 µg.ℓ⁻¹ and in practice would be far lower). There should thus be compliance with all of the water quality guidelines (see Table 38) identified for the substances declared to be present in the effluent⁸.

Note that the approach used here is conservative as it assumes that there is no heat loss to the atmosphere and that there is no modification of the free chlorine concentration by organic material in the receiving waters.

In summary, for a pipeline discharge beyond the surf zone from a 800 MW nominal capacity power plant:

- For the worst case scenario modelled, heated effluent exceeding the most stringent target value of + 1°C above ambient seawater temperature extends no further than 200 m in a longshore direction from the discharge and < 80 m in an offshore direction. This maximum extent of the thermal “footprint” of concern however is for a low discharge velocity through the single port at the end of the pipeline. For higher velocity discharges ≥ 1.8 m.s⁻¹ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 20 m radius of the discharge location.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of S < 36 psu will extend 450 m alongshore and approximately 120 m offshore of the discharge location. Again these observations are for a low velocity discharge. For higher velocity discharges ≥ 1.8 m.s⁻¹ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 70 m alongshore distance and 55 m offshore distance from the discharge location.

⁸ Note that it is not possible to assess potential synergistic effects of the various toxic components using individual guidelines. For such a complex effluent, typically a total toxicity of mixtures approach is required where the summation of the toxicities of the individual components is considered to represent the overall toxicity (e.g. ANZECC, 2000). Such a assessment would require a detailed specification of the individual components such a complex effluent and therefore is not undertaken here.

- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of free chlorine $< 3 \mu\text{g}\cdot\ell^{-1}$ will extend 660 m alongshore and approximately 150 m offshore of the discharge location. If the less stringent but nevertheless conservative free chlorine value of $5 \mu\text{g}\cdot\ell^{-1}$ is used as the target value then this target value will be exceeded for a distance of 450 m alongshore and 120 m cross-shore. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m}\cdot\text{s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 360 m in an alongshore direction and 120 m in the offshore direction, while there will be compliance with the guideline of $5 \mu\text{g}\cdot\ell^{-1}$ at all times beyond a radius of 70 m. For a discharge velocity of $\geq 5 \text{ m}^3\cdot\text{s}^{-1}$ there will be compliance with the most stringent values within a 35 m alongshore distance and 25 m offshore distance of the discharge location.
- The only co-discharge effluent that after appropriate design and mitigation measures that may exceed water quality guidelines is the HSRG blowdown effluent that may contain phosphates and ammonia exceeding the relevant water quality guidelines. The relevant plume dimensions (*i.e.* extent the 10 dilution contour) where the guidelines (under the worst case scenario) may be exceeded are 200 m alongshore and 80 m cross-shore. For a well-designed discharge there will always be compliance within a 20 m radius of the discharge. However as indicated, the HSRG effluent can be “bled” into the purge water discharge to ensure compliance at the point of discharge for any outfall design (see Section 3.2.2).
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures, the discharges from the gas conditioning plant are expected to meet water quality guidelines at the point of discharge.⁹

Thus for a well-designed outfall (port exit velocity $\geq 1.8 \text{ m}\cdot\text{s}^{-1}$) in a water depth of 15 m, compliance with the water quality guidelines for an increase in seawater temperature is likely to occur within a 20 m radius of the discharge location, compliance with the guidelines for an increase in seawater salinity is likely to occur within a 70 m radius while there will be compliance with all but the most stringent water quality guidelines for free chlorine within a 70 m radius of the discharge location (For the most stringent water quality guideline for free chlorine, the guideline will be met within 360 m downstream of the discharge location and offshore distance of approximately 120 m.) With appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply the relevant water quality guidelines. However, it should be noted that is not possible to assess potential synergistic effects of the co-discharges.

Assessment of the discharge from a 1600 MW power plant

There is a possibility that the plant will be further developed to a 1600 MW capacity at some future date should it be viable to do so. For this reason we have assessed the potential discharges from such an increased capacity power plant. Should the capacity of the plant be increased to 1600 MW, the characteristics of the effluent discharges will remain the same, however the volumes discharges will approximately double in magnitude. The same assumption is generally true for the potential co-discharges.

The results for the discharge from a 1600 MW nominal capacity power plant are given below (Tables 14 to 17).

Note that the approach used here is conservative as it assumes that there is no heat loss to the atmosphere and that there is no modification of the free chlorine concentration by organic material in the receiving waters.

Table 14: Model results indicating the magnitude and extent of seawater temperature rise for the various offshore discharge scenarios simulated for a 1600 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔT = +1°C contour		Plume dimensions** ΔT = +3°C contour		Plume dimensions** ΔT = +5°C contour	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20 ^b	radius < 20	radius < 20	radius < 10	radius < 10
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	430	140	radius < 20	radius < 20	radius < 10	radius < 10
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	165	35	radius < 20	radius < 20	radius < 10	radius < 10

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 15: Model results indicating the magnitude and extent of the salinity rise in the marine environment for the various offshore discharge scenarios simulated for a 1600 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔS = +1° psu contour		Plume dimensions** ΔS = +4°psu contour	
		longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	< 20	40	radius < 20	radius < 20
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	325	140	radius < 20	radius < 20
	0.9	800	200	475	150
3 maximum current (0.65 m.s ⁻¹)	5	25	radius < 20	radius < 20	radius < 20
	1.8	50	radius < 20	radius < 20	radius < 20
	0.9	275	45	180	35

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 16: Model results indicating the magnitude and extent of free chlorine for the various offshore discharge scenarios simulated for a 1600 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** Free chlorine = 3 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 5 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 10 μg.ℓ ⁻¹	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	30	250	< 20	< 50	radius < 20	radius < 20
	1.8	80	55	35	25	radius < 20	radius < 20
	0.9	220	85	80	40	radius < 20	radius < 20
2 average current (0.20 m.s ⁻¹)	5	25	< 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	725	230	325	140	radius < 20	radius < 20
	0.9	1100	240	800	200	430	140
3 maximum current (0.65 m.s ⁻¹)	5	45	< 20	25	radius < 20	radius < 20	radius < 20
	1.8	175	35	50	radius < 20	radius < 20	radius < 20
	0.9	360	55	275	45	165	35

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

In summary for a pipeline discharge beyond the surf zone from a 1600 MW nominal capacity power plant:

- For the worst case scenario modelled, heated effluent exceeding the most stringent target value of + 1°C above ambient seawater temperature extends no further than 430 m in a longshore direction from the discharge and 140 m in an offshore direction. This maximum extent of the thermal “footprint” of concern however is for a low discharge velocity through the single port at the end of the pipeline. For higher velocity discharges ($\geq 1.8 \text{ m.s}^{-1}$) the zone in which the most stringent water quality guidelines are exceeded extends no further than a 20 m radius of the discharge location.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of $S < 36$ psu will extend 800 m alongshore and approximately 200 m offshore of the discharge location. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 325 m alongshore and 140 m offshore from the discharge location. For a 5 m.s^{-1} port exit velocity here will be compliance with the most stringent target value within 50 m of the discharge point.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of free chlorine $< 3 \mu\text{g.l}^{-1}$ will extend 1100 m alongshore and approximately 240 m offshore of the discharge location. If the less stringent but nevertheless conservative free chlorine value of $5 \mu\text{g.l}^{-1}$ is used as the target value then at worst this target value will be exceeded for a distance of 800 m alongshore and 200 m cross-shore. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 725 m in an alongshore direction and 230 m in the offshore direction, while there will be compliance with the guideline of $5 \mu\text{g.l}^{-1}$ at all times within a distance of 325 m alongshore and 140 m cross-shore.
- The only co-discharge effluent that after appropriate design and mitigation measures that may exceed water quality guidelines is the HSRG blowdown effluent that may contain phosphates and ammonia exceeding the relevant water quality guidelines. The relevant plume dimensions (*i.e.* extent the 10 dilution contour) where the guidelines (under the worst case scenario) may be exceeded are 450 m alongshore and 120 m cross-shore, For a well-designed discharge (port exit velocity $\geq 1.8 \text{ m.s}^{-1}$) there will always be compliance within a 70 m radius of the discharge. However as indicated, the HSRG effluent can be “bled” into the purge water discharge to ensure compliance at the point of discharge for any outfall design.
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures, the discharges from the gas conditioning plant are expected to meet water quality guidelines at the point of discharge.

Table 17: Model results indicating minimum achievable dilutions of the effluent in the marine environment for the various offshore discharge scenarios simulated for a 1600 MW nominal capacity power plant

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 2 dilutions		Plume dimensions** 3.33 dilutions		Plume dimensions** 5 dilution		Plume dimensions** 10 dilution	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	< 20	25
2 avg current (0.20 m.s ⁻¹)	5	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	70	50
	0.9	radius < 10	radius < 10	radius < 10	radius < 10	65	60	450	120
3 max current (0.65 m.s ⁻¹)	5	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 10	radius < 10	radius < 10	radius < 10	55	< 20	95	radius < 20

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 20 dilution		Plume dimensions** 30 dilutions		Plume dimensions** 50 dilutions		Plume dimensions** 100 dilutions	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	< 20	< 50	30	<50	550	170	3650	2000
	1.8	35	25	40	66	200	90	300	280
	0.9	80	40	70	180	700	800	unreliable	unreliable
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	<20	<20	30	< 20	320	150
	1.8	325	140	650	200	1050	270	1625	240
	0.9	800	200	1050	240	1380	290	2000	360
3 max current (0.65 m.s ⁻¹)	5	25	< 20	40	<20	60	<20	60	< 20
	1.8	50	< 20	160	30	275	45	450	60
	0.9	275	45	345	55	440	65	610	80

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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Thus for a well-designed outfall (port exit velocity $\geq 1.8 \text{ m.s}^{-1}$) in a water depth of 15 m, compliance with the water quality guidelines for an increase in seawater temperature is likely to occur within a 20 m radius of the discharge location, compliance with the water quality guidelines for an increase in seawater salinity is likely to occur within a alongshore distance of 315 m and a 120 m offshore from the discharge location (for a 5 m.s^{-1} there will be compliance with the most stringent target value within 25 m of the discharge point) and there will be compliance with all but the most stringent water quality guidelines for free chlorine within a 325 m alongshore and 140 m cross-shore distance of the discharge location (for a 5 m.s^{-1} discharge velocity there will be compliance with the most stringent target value for free chlorine within a distance of 30 m alongshore and 250 m cross-shore). With appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply the relevant water quality guidelines. However, it should be noted that is not possible to assess potential synergistic effects of the co-discharges.

The results in Section 4.1 and 4.2 above indicate that whether target values for water quality are met is very much dependant on the design of the discharge, *i.e.* discharge velocities, number and configuration of ports, *etc.* Through careful engineering design it is anticipated that the potential “footprint” of the heated brine effluent can be limited to the minimum footprints indicated above.

4.1.2 Assessment of an offshore discharge located inshore of the intake.

Here the discharge being assessed is an offshore pipeline discharge where the discharge location lies inshore of the intake (see Section 3.3), *i.e.* a discharge just beyond the surf-zone. The discharges are assessed for both a 800 MW and a 1600 MW power plant

Assessment for a 800 MW power plant

The results for the discharge from a 800 MW nominal capacity power plant are given below (Tables 18 to 21). The extent of the thermal plume footprint for the various discharge scenarios is characterized in Table 18 below. Where it is stated that the radius < 20 m, this implies that the temperature elevation indicated (*i.e.* 1°C, 3°C, *etc*) does not extent beyond a 20 m radius of the discharge point. As before, the longshore dimensions of the thermal “footprint” refer to a distance downstream of the discharge location, however given that the currents flow both north and south along the coast, the longshore extent of the thermal “footprint” can be considered to extend alongshore in both directions from the discharge location (see Figure 13). The offshore extent of the thermal “footprint” generally is considered to represent a distance offshore of the discharge location. Only under a few scenarios (*i.e.* under calm, low current conditions) is the plume expected extend a significant distance shorewards and, although the discharge is located closer inshore (*i.e.* inshore of the intake), even then the thermal plume does not extend as far inshore as the surf zone. Being a dense effluent, buoyancy spreading is not effective in extending the thermal plume shorewards into shallower waters.

Table 18: Model results indicating the magnitude and extent of seawater temperature rise for the various beyond the surf-zone discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔT = +1°C contour		Plume dimensions** ΔT = +3°C contour		Plume dimensions** ΔT = +5°C contour	
		Longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	200	75	radius < 20	radius < 20	radius < 10	radius < 10
3 maximum current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location, however, on occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 19: Model results indicating the magnitude and extent of the salinity rise in the marine environment for the various beyond the surf-zone discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** ΔS = +1° psu contour		Plume dimensions** ΔS = +4°psu contour	
		longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 20	25	radius < 20	radius < 20
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	70	50	Radius < 20	radius < 20
	0.9	465	125	230	80
3 maximum current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	100	< 20	radius < 20	radius < 20

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location, however, on occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 20: Model results indicating the magnitude and extent of free chlorine for the various beyond the surf-zone discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** Free chlorine = 3 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 5 μg.ℓ ⁻¹		Plume dimensions** Free chlorine = 10 μg.ℓ ⁻¹	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 20	40	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	< 20	55	< 20	25	radius < 20	radius < 20
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	370	120	70	50	radius < 20	radius < 20
	0.9	660	150	450	120	200	75
3 max current (0.65 m.s ⁻¹)	5	35	25	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	100	< 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	160	< 20	95	radius < 20	radius < 20	radius < 20

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location, however, on occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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Table 21: Model results indicating minimum achievable dilutions of the effluent in the marine environment for the various nearshore discharge scenarios simulated for a 800 MW nominal capacity power plant

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 2 dilutions		Plume dimensions** 3.33 dilutions		Plume dimensions** 5 dilution		Plume dimensions** 10 dilution	
		longshore m	*offshore m	longshore m	*offshore m	longshore m	*offshore m	longshore m	*offshore m
1 low current (0.02 m.s ⁻¹)	5*	Radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	1.8	Radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	0.9	Radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
2 avg current (0.20 m.s ⁻¹)	5	Radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	1.8	Radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	0.9	radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	200	75
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	1.8	radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
	0.9	radius < 20	radius < 20	radius < 10	radius < 10	radius < 10	radius < 10	radius < 20	radius < 20
Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 20 dilution		Plume dimensions** 30 dilutions		Plume dimensions** 50 dilutions		Plume dimensions** 100 dilutions	
		longshore m	*offshore m	longshore m	*offshore m	longshore m	*offshore m	longshore m	*offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	< 20	< 20	30	25	110	45
	1.8	radius < 20	radius < 20	45	25	125	55	520	180
	0.9	< 20	25	110	45	325	110	unreliable	unreliable
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	< 20	< 20	25	< 20	420	150
	1.8	70	50	310	110	610	160	1050	230
	0.9	450	120	630	140	855	200	1240	230
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	30	< 20	50	<20	65	radius < 20
	1.8	radius < 20	radius < 20	80	< 20	175	30	300	40
	0.9	95	radius < 20	155	25	220	35	330	40

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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Where required the co-discharges can be assessed by using the plume dimensions for the relevant achievable dilution as listed in Table 21. The potential co-discharges are those listed in Table 7. Given optimal design and appropriate mitigation measures, the only co-discharges of potential concern are as indicated previously in section 4.1.1. The assessment of the co-discharges is the same as for the discharge offshore of the intake.:

Note that the approach used here is conservative as it assumes that there is no heat loss to the atmosphere and that there is no modification of the free chlorine concentration by organic material in the receiving waters.

In summary, for a pipeline discharge beyond the surf zone from a 800 MW nominal capacity power plant:

- For the worst case scenario modelled, heated effluent exceeding the most stringent target value of + 1°C above ambient seawater temperature extends no further than 200 m in a longshore direction from the discharge and < 75 m in an offshore direction. This maximum extent of the thermal “footprint” of concern however is for a low discharge velocity through the single port at the end of the pipeline. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 20 m radius of the discharge location.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of $S < 36$ psu will extend 465 m alongshore and approximately 125 m offshore of the discharge location. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 70 m alongshore distance and 50 m offshore distance from the discharge location.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of free chlorine $< 3 \mu\text{g.l}^{-1}$ will extend 650 m alongshore and approximately 150 m offshore of the discharge location. If the less stringent but nevertheless conservative free chlorine value of $5 \mu\text{g.l}^{-1}$ is used as the target value then this target value will be exceeded for a distance of 450 m alongshore and 120 m cross-shore. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 370 m in an alongshore direction and 120 m in the offshore direction, while there will be compliance with the guideline of $5 \mu\text{g.l}^{-1}$ at all times beyond a radius of 70 m. For a discharge velocity of $\geq 5 \text{ m}^3\text{s}^{-1}$ there will be compliance with the most stringent values within a 35 m alongshore distance and 25 m offshore distance of the discharge location.

- The only co-discharge effluent that, after appropriate design and mitigation measures, may exceed water quality guidelines is the HSRG blowdown effluent that may contain phosphates and ammonia exceeding the relevant water quality guidelines. The relevant plume dimensions (*i.e.* extent the 10 dilution contour) where the guidelines (under the worst case scenario) may be exceeded are 200 m alongshore and 75 m cross-shore, For a well-designed discharge (port exit velocity $\geq 1.8 \text{ m.s}^{-1}$) there will always be compliance within a 20 m radius of the discharge. However as indicated, the HSRG effluent can be “bled” into the purge water discharge to ensure compliance at the point of discharge for any outfall design.
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures (see Section 4.1.1), the discharges from the gas conditioning plant are expected to meet water quality guidelines at the point of discharge.
- Thus for a well-designed outfall (port exit velocity $\geq 1.8 \text{ m.s}^{-1}$) in a water depth of 18 m, compliance with the water quality guidelines for an increase in seawater temperature is likely to occur within a 20 m radius of the discharge location, compliance with the guidelines for an increase in seawater salinity is likely to occur within a 70 m radius while there will be compliance with all but the most stringent water quality guidelines for free chlorine within a 70 m radius of the discharge location (For the most stringent water quality guideline for free chlorine, the guideline will be met within 370 m downstream of the discharge location and offshore distance of approximately 120 m.) With appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply with the relevant water quality guidelines. However, it should be noted that is not possible to assess potential synergistic effects of the co-discharges.

Assessment of the discharge from a 1600 MW power plant

There is a possibility that the plant will be further developed to a 1600 MW capacity at some future date should it be viable to do so. For this reason we have assessed the potential discharges from such an increased capacity power plant. Should the capacity of the plant be increased to 1600 MW, the characteristics of the effluent discharges will remain the same, however the volumes discharges will approximately double in magnitude. The same assumption is generally true for the potential co-discharges.

The results for the discharge from a 1600 MW nominal capacity power plant are given below (Tables 22 to 25).

Note that the approach used here is conservative as it assumes that there is no heat loss to the atmosphere and that there is no modification of the free chlorine concentration by organic material in the receiving waters.

Table 22: Model results indicating the magnitude and extent of seawater temperature rise for the various beyond the surf-zone discharge scenarios simulated for a 1600 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** $\Delta T = +1^\circ \text{C}$ contour		Plume dimensions** $\Delta T = +3^\circ \text{C}$ contour		Plume dimensions** $\Delta T = +5^\circ \text{C}$ contour	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	radius < 20	radius < 20 ^b	radius < 20	radius < 20	radius < 10	radius < 10
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	445	140	radius < 20	radius < 20	radius < 10	radius < 10
3 max current (0.65 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	1.8	radius < 20	radius < 20	radius < 20	radius < 20	radius < 10	radius < 10
	0.9	170	25	radius < 20	radius < 20	radius < 10	radius < 10

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 23: Model results indicating the magnitude and extent of the salinity rise in the marine environment for the various beyond the surf-zone discharge scenarios simulated for a 1600 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** $\Delta S = +1$ psu contour		Plume dimensions** $\Delta S = +4$ psu contour	
		longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	< 20	< 20	radius < 20	radius < 20
	1.8	35	25	radius < 20	radius < 20
	0.9	80	35	radius < 20	radius < 20
2 average current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	325	140	radius < 20	radius < 20
	0.9	830	200	490	150
3 maximum current (0.65 m.s ⁻¹)	5	25	radius < 20	radius < 20	radius < 20
	1.8	50	radius < 20	radius < 20	radius < 20
	0.9	285	50	180	35

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

Table 24: Model results indicating the magnitude and extent of free chlorine for the various beyond the surf-zone discharge scenarios simulated for a 800 MW nominal capacity power plant.

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** Free chlorine = 3 µg.ℓ ⁻¹		Plume dimensions** Free chlorine = 5 µg.ℓ ⁻¹		Plume dimensions** Free chlorine = 10 µg.ℓ ⁻¹	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	30	50	< 20	< 20	radius < 20	radius < 20
	1.8	80	45	35	25	radius < 20	radius < 20
	0.9	200	85	80	35	radius < 20	radius < 20 ^b
2 average current (0.20 m.s ⁻¹)	5	25	< 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	740	220	325	140	radius < 20	radius < 20
	0.9	1140	250	830	200	445	140
3 maximum current (0.65 m.s ⁻¹)	5	45	< 20	25	Radius < 20	radius < 20	radius < 20
	1.8	185	30	50	radius < 20	radius < 20	radius < 20
	0.9	365	55	285	50	170	25

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

In summary for a pipeline discharge beyond the surf zone from a 1600 MW nominal capacity power plant:

- For the worst case scenario modelled, heated effluent exceeding the most stringent target value of + 1°C above ambient seawater temperature extends no further than 445 m in a longshore direction from the discharge and 140 m in an offshore direction. This maximum extent of the thermal “footprint” of concern however is for a low discharge velocity through the single port at the end of the pipeline. For higher velocity discharges ($\geq 1.8 \text{ m.s}^{-1}$) the zone in which the most stringent water quality guidelines are exceeded does not extend beyond a 20 m radius of the discharge location.
- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of $S < 36$ psu will extend 830 m alongshore and approximately 200 m offshore of the discharge location. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m.s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 325 m alongshore and 140 m offshore from the discharge location. For a 5 m.s^{-1} port exit velocity there will be compliance with the most stringent target value within 25 m of the discharge point.

Table 25: Model results indicating minimum achievable dilutions of the effluent in the marine environment for the various nearshore discharge scenarios simulated for a 1600 MW nominal capacity power plant

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 2 dilutions		Plume dimensions** 3.33 dilutions		Plume dimensions** 5 dilution		Plume dimensions** 10 dilution	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20 ^b	radius < 20	radius < 20 ^b
2 avg current (0.20 m.s ⁻¹)	5	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 10	radius < 10	radius < 20	radius < 20	65	55	445	140
3 max current (0.65 m.s ⁻¹)	5	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	1.8	radius < 10	radius < 10	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20	radius < 20
	0.9	radius < 10	radius < 10	radius < 20	radius < 20	60	<20	160	<20

Scenario	Discharge velocity m.s ⁻¹	Plume dimensions** 20 dilution		Plume dimensions** 30 dilutions		Plume dimensions** 50 dilutions		Plume dimensions** 100 dilutions	
		longshore m	offshore m	longshore m	offshore m	longshore m	offshore m	longshore m	offshore m
1 low current (0.02 m.s ⁻¹)	5*	< 20	< 20	<20	<20	55	940	unreliable	unreliable
	1.8	35	25	70	40	200	90	840	285
	0.9	80	35	165	70	230	170	2250	2230
2 avg current (0.20 m.s ⁻¹)	5	radius < 20	radius < 20	<20	<20	30	<20	315	155
	1.8	325	140	660	205	1040	260	1100	265
	0.9	830	200	1075	240	1425	290	2000	360
3 max current (0.65 m.s ⁻¹)	5	25	radius < 20	40	<20	60	<20	150	30
	1.8	50	radius < 20	160	30	285	45	470	65
	0.9	285	50	350	55	450	65	620	80

* an ambient current speed have 0.05 m.s⁻¹ was specified to ensure a robust model result for such a high port velocity.

** a longshore distance refers to distances downstream of the discharge location while the offshore distance refers to predominantly a distance offshore of the discharge location. On occasion, there may be inshore movement of the plume due to buoyancy spreading however such behaviour is generally limited.

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- For the worst case scenario modelled, the heated brine exceeding the most stringent target value of free chlorine $< 3 \mu\text{g}\cdot\ell^{-1}$ will extend 1140 m alongshore and approximately 250 m offshore of the discharge location. If the less stringent but nevertheless conservative free chlorine value of $5 \mu\text{g}\cdot\ell^{-1}$ is used as the target value then at worst this target value will be exceeded for a distance of 830 m alongshore and 200 m cross-shore. Again these observations are for a low velocity discharge. For higher velocity discharges $\geq 1.8 \text{ m}\cdot\text{s}^{-1}$ the zone in which the most stringent water quality guidelines are exceeded extends no further than a 740 m in an alongshore direction and 220 m in the offshore direction, while there will be compliance with the guideline of $5 \text{ g}\cdot\ell^{-1}$ at all times within a distance of 325 m alongshore and 140 m cross-shore.
- The only co-discharge effluent that after appropriate design and mitigation measures that may exceed water quality guidelines is the HSRG blowdown effluent that may contain phosphates and ammonia exceeding the relevant water quality guidelines. The relevant plume dimensions (i.e. extent the 10 dilution contour) where the guidelines (under the worst case scenario) may be exceeded are 445 m alongshore and 140 m cross-shore, For a well-designed discharge (port exit velocity $\geq 1.8 \text{ m}\cdot\text{s}^{-1}$) there will always be compliance within a 20 m radius of the discharge. However as indicated, the HSRG effluent can be “bled” into the purge water discharge to ensure compliance at the point of discharge for any outfall design.
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures (see Section 4.1.1), the discharges from the gas conditioning plant are expected to meet water quality guidelines at the point of discharge.

Thus for a well-designed outfall (port exit velocity $\geq 1.8 \text{ m}\cdot\text{s}^{-1}$) in a minimum water depth of 15 m, compliance with the water quality guidelines for an increase in seawater temperature is likely to occur within a 20 m radius of the discharge location, compliance with the water quality guidelines for an increase in seawater salinity is likely to occur within a alongshore distance of 325 m and a 140 m offshore from the discharge location (for a $5 \text{ m}\cdot\text{s}^{-1}$ port exit velocity there will be compliance with the most stringent target value within 25 m of the discharge point) and there will be compliance with all but the most stringent water quality guidelines for free chlorine within a 325 m alongshore and 140 m cross-shore distance of the discharge location (for a $5 \text{ m}\cdot\text{s}^{-1}$ discharge velocity there will be compliance with the most stringent target value for free chlorine within a radius of 50 m of the discharge location). With appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply the relevant water quality guidelines. However, it should be noted that is not possible to assess potential synergistic effects of the co-discharges.

The results for discharges through a pipeline into the offshore zone or beyond the surf-zone (Section 4.1 and this section) indicate that whether target values for water quality are met is very much dependant on the design of the discharge, *i.e.* port exit velocities, number and configuration of ports, *etc.* Through careful engineering design it is anticipated that the potential “footprint” of the heated brine effluent can be limited to the minimum footprints indicated above.

4.2 Assessment of discharges into the surf-zone.

Here a discharge into the surf-zone is assessed for both a 800 MW and a 1600 MW power plant. The proposed intake/discharge configuration to be assessed is as follows:

- The intake structure remains at 1400 m offshore.
- The discharge is located on the shoreline. The exact location of the discharge relative to the moving (accreting) shoreline is unknown, as is the engineering design of such a discharge. For the purposes of this assessment we have assumed a discharge at the shoreline at all times, *i.e.* the discharge point moves with the accretion or erosion of the coastline.

4.2.1 Description of surf zone processes and associated dispersion characteristics

Wave-driven flows predominate in the surf zone where dispersion of pollutants is rapid within the surf zone due to the vigorous mixing processes and strong longshore and cross-shelf transports. Longshore transport is driven by the momentum flux of shoaling waves approaching the shoreline at an angle, while cross-shelf transport is driven by the shoaling waves. The magnitude of these transport processes is determined primarily by wave height, wave period, angle of incidence of the wave at the coast and bathymetry.

In terms of dispersion of pollutants the surf zone is relatively isolated from the waters further offshore. Pollutants in the surf-zone are rapidly mixed across the surf-zone and then transported for long distances alongshore with relatively little dilution of the pollutant. Most of the exchange between the surf zone and the offshore waters occurs due to rip currents that transport surf zone waters further offshore (Figure 14). Some of the water mixed beyond the surf zone may be transported back into the surf zone with the next set of waves. This will reduce the effective dispersion of a pollutant. While high wave conditions often result in rapid dispersion within the surf zone and rapid alongshore dispersion of the pollutant, observations indicate a higher degree of re-entrainment of pollutant dispersed into the offshore zone, thus effectively reducing the overall pollutant dispersion within the surf zone under these conditions.

Nearshore circulation is highly complex. At times there is meandering alongshore flow, while at other times the flow is straight and uniform. Some periods exhibit clear indications of rip currents, others not. The prediction of the fate of a waste field in this highly variable, non-linear surf zone regime is difficult and not easy to provide quantitative answers on the degree of mixing or transport which can be expected, even for a specific day. During field exercises in False Bay

(South Africa), the behaviour of a waste field changed drastically within hours (meandering of the flow, change in direction along the shore, change of rip currents, *etc.*) without observable changes of the weather or sea state (RSA DWAF, 2004b).

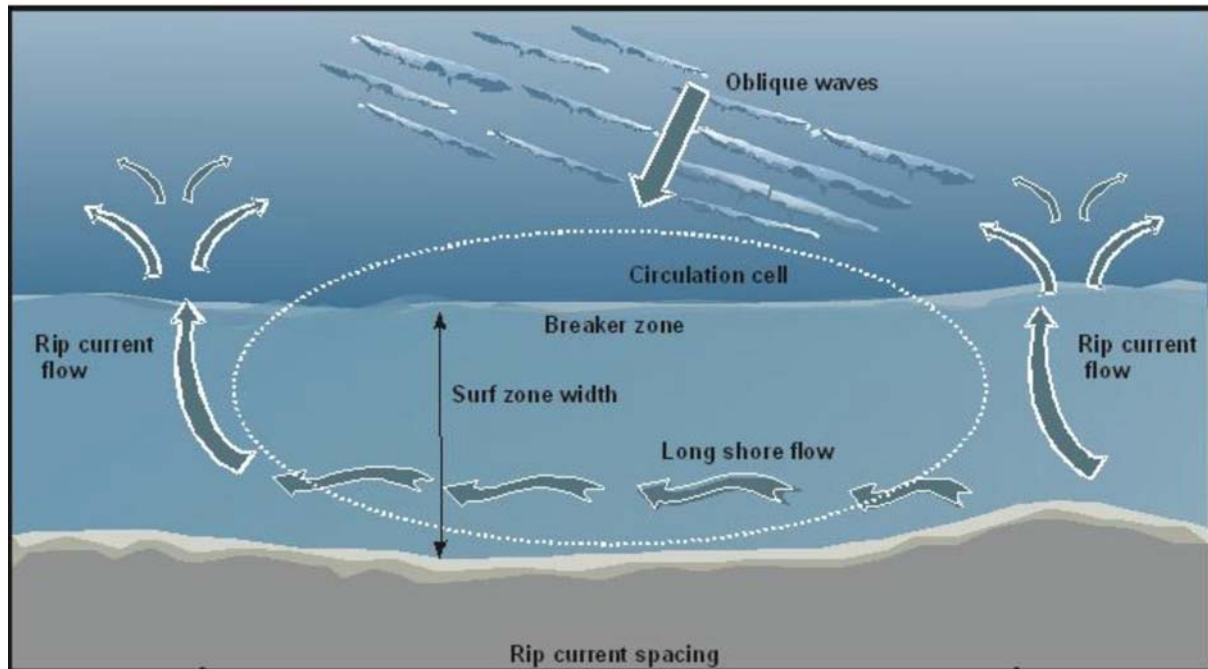


Figure 14: Characterisation of the mixing processes in the near shore zone (after RSA DWAF, 2004b)

4.2.2 Approach and Method

Other than highly sophisticated and potentially costly modelling studies, no real satisfactory methods exist, in a simple manner, to quantify mixing in the surf zone and between the surf zone and offshore waters. Consequently the pollution “footprints” have been assessed using two, essentially analytical, methods (method of Inman and CORMIX modelling) and by referring to existing observations along the South African coastline, *i.e.* measurements of dilution in the surf-zone. The assessment has been undertaken for a range of wave conditions as listed in Table 26 below. It is intended that these wave conditions encompass both typical and extreme conditions. For each wave height and direction a typical cross-shore integrated surf-zone current was estimated for the bathymetry of the region.

Table 26: Environmental conditions used in the model predictions

ID	RMS breaker height (m)	Wave direction	Peak wave period (s)	Surf zone width (m)	Mean surf zone depth (m)	Cross-shore averaged surf zone current (m.s ⁻¹)
1	1.5	WNW	8	250	2.1	-0.50
2	3.0	W	15	350	4.3	-0.40
3	2.0	SSW	12	400	2.0	0.18
4	4.5	SSW	12	620	6.4	0.3
5	2.0	S	10	350	2.9	0.35
6	3.5	SSE	10	420	5.0	0.42
7	2.0	SSE	10	250	2.9	0.25
8*	1.0	SSW	12	80	1.4	0.2

* Condition 8 represent calm conditions and as such constitutes a “worst case” scenario where effluent will accumulate in the surf zone. Such relatively quiescent conditions are not expected to prevail for extended periods in the region of interest.

A. Method of Inman *et al.* (1971)

Possibly the most robust and commonly used methods are those of Inman *et al.* (1971) who describes the mixing process in the surf zone as the transport of water between ‘nearshore circulation’ cells formed between adjacent rip currents as well as the exchange of water from the surf zone to the offshore region. As noted above, the major mechanisms which contribute to the *dispersion of surf zone discharges include:

- Breaking waves which cause ‘rapid’ mixing normal to the shoreline within the breaker zone.
- Rip currents which result in the longshore advection of the waste field.

Both of these mechanisms are accounted for in the basic methods of Inman *et al.* (1971). We have applied the methods of Inman *et al.* for a range of representative wave conditions (see Table 26), however the basic method does not take cognisance of the fact that there may be significant ongoing accumulation of a pollutant under calm conditions, *i.e.* the method does not distinguish between high or low volume discharges but merely uses the concentration of the effluent as an input parameter. Applied simply the method predicts achievable dilutions as indicated in Figure 15 below. These predictions suggest dilutions that are significantly higher than other observations along the South African coastline (*e.g.* CSIR, 1991). Conversely, assuming the accumulation of pollutants (thermal load, increased salinity, *etc*) to the extent that

the pollutant concentrations within the circulation cell into which the discharge occurs approaches those of the discharge, results in overly conservative results.

In all cases the ratio between the alongshore cell dimension and surf zone width is assumed to be 3.5, *i.e.* the alongshore circulation cell dimension is more than three times the cross-shore dimension of the surf-zone. For the range of conditions considered this implies that the alongshore circulation cell dimension can vary from 350 m to 2170 m.

The required dilutions to achieve the concentration values used to define the “footprint” of the plume for the various effluent constituents are given in Table 27. These are used to interpret the achievable dilutions presented in Figure 15.

Table 27: Required dilutions to achieve the concentrations of the constituent as indicated.

Constituent				
Temperature	Target concentration	+1°C	+3°C	+5°C
	Required dilutions	10	3.3	2
Salinity	Target concentration	36 psu	40 psu	–
	Required dilutions	20	11	–
Biocide	Target concentration	3 $\mu\text{g}\cdot\text{l}^{-1}$	5 $\mu\text{g}\cdot\text{l}^{-1}$	10 $\mu\text{g}\cdot\text{l}^{-1}$
	Required dilutions	33	20	10

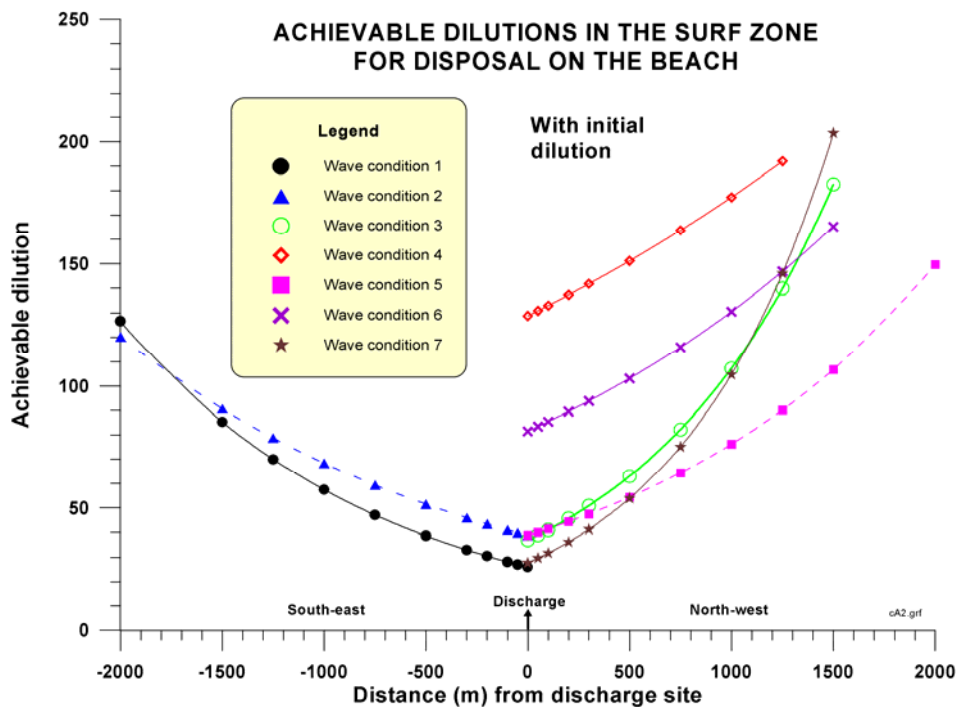


Figure 15: Achievable dilutions as a function of alongshore distance from the discharge site for the range of environmental conditions considered.

Figure 15 indicates that after initial dilution in the surf-zone into which the discharge occurs, the achievable dilutions exceed 33 times (*i.e.* even the most stringent criteria for biocides are complied with) for all but wave conditions 1 and 7. Thus there is compliance with the strictest Water Quality target value (*i.e.* biocide concentrations $< 3 \mu\text{g}\cdot\text{l}^{-1}$) for wave conditions 1 and 7 within approximately 200 m beyond the alongshore dimensions of the initial circulation cell (see Table 27).

Based on these data the maximum plume dimensions are as indicated in Table 28 below. Note that the method is not able confidently to resolve plume dimensions that are smaller than the alongshore dimensions of the initial cell. For this reason the plume footprint indicated in Table 28 is the maximum footprint for the most stringent water quality target value. In many cases (such as for temperature) the water quality criteria are met well within the dimensions listed in Table 28. Note that in all cases the effluent is assumed to fully mixed across the full offshore extent of the surf zone. It should be noted that elevated temperatures, salinities and biocide concentrations will extend offshore of the surf zone but not at concentrations that are expected to be of concern.

Table 28: Maximum dimensions of the plume footprint defined by the most stringent Water Quality target value (*i.e.* $3 \mu\text{g}\cdot\text{l}^{-1}$ for biocide).

ID	Maximum alongshore dimension (m)	Maximum cross-shore dimension (m)
1	550	250
2	1225	350
3	1400	400
4	2170	620
5	1225	350
6	1470	420
7	1075	250

B Observations

Given the uncertainty and the lack of resolution in the above model results it is best to rely on observational data for dilutions in the nearshore (*e.g.* the surf zone discharge at Zeekoevlei in False Bay – Figure 16). Data for the northern shoreline of False Bay (Figure 17) should provide a reasonably conservative assessment of the plume dimension to be expected at the discharge site offshore of Oranjemund. Dilution nomographs for the northern shores suggest the most likely plume dimensions as listed in Table 29 (for an 800 MW plant) and Table 30 (for a 1600 MW

plant). For example, the data for the northern shores of False Bay suggest a plume footprint of approximately 100 m to 200 m alongshore and 250 m to 600 m offshore (surf zone width) for +3°C contours and 200 m to 600 m alongshore and 250 m to 600 m offshore (surf zone width) for +1°C contours. The alongshore plume dimension is reported as a distance downstream of the discharge location, *i.e.* an alongshore plume dimension of 600 m implies a possible plume extent of 600 m either north or south of the discharge.

The plume dimensions in the above tables are likely to be fairly realistic but nevertheless conservative as the dilution nomographs are for a more sheltered environment than the exposed coastline in the region of interest. However the higher surf zone currents may advect the pollutants rapidly along shore and result in a more extensive (and possibly less well-mixed) alongshore plume than would be indicated by these observations in False Bay, South Africa.

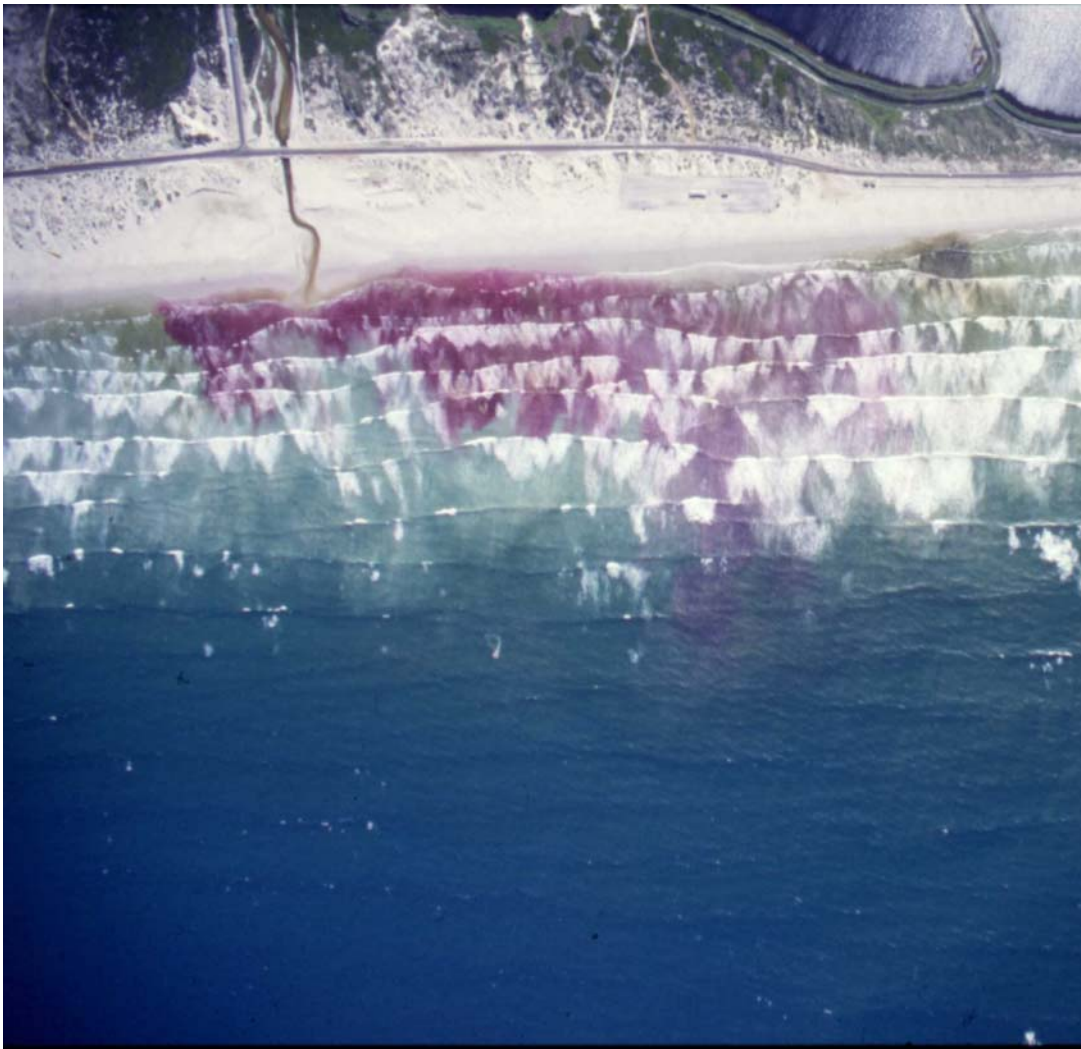


Figure 16: Photograph of dispersion of dye for a continuous release from the Zeekoevlei outlet (van Ballegooyen and Botes, 2000).

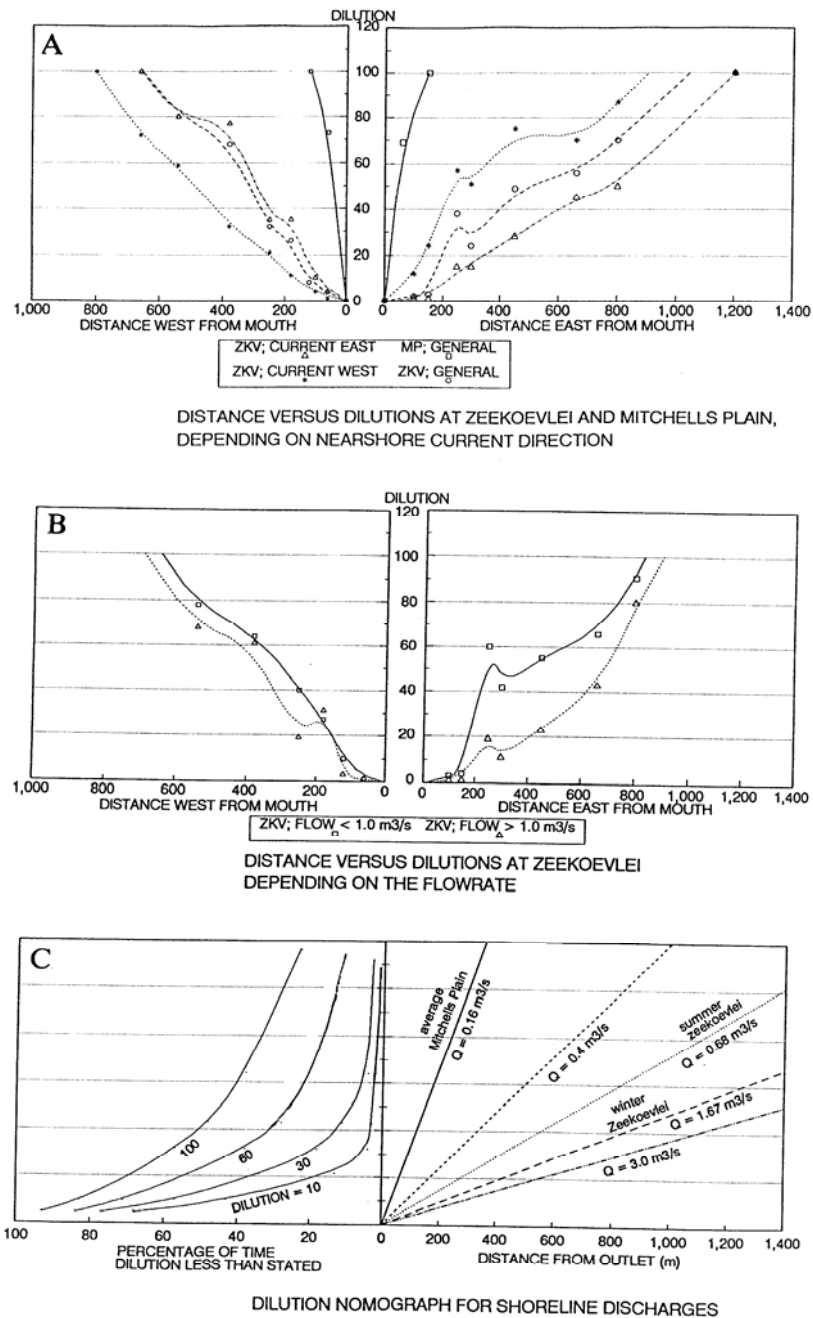


Figure 17: Summary of the results of a study of the physical dilutions of water column pollutants in the surf zone along the northern shoreline of False Bay (after CSIR, 1991) comprising:

- dilutions versus distance from the point of discharge depending on nearshore current,
- dilutions versus distance depending on the flow rates, and
- dilution nomograph for shoreline discharges in northern False Bay.

Table 29: Approximate plume dimensions for the various constituents for the various water quality guidelines for a 800 MW nominal capacity power plant.

Constituent		Concentration values		
		+1°C	+3°C	+5°C
Temperature	Alongshore dimensions (m)	200–250	< 150	< 150
	Cross-shore dimensions (m) *	250–600	250–600	250–600
Salinity		36 psu	40 psu	–
	Alongshore dimensions (m)	200–400	200–250	–
	Cross-shore dimensions (m) *	250–600	250–600	–
Biocide		3 µg.l⁻¹	5 µg.l⁻¹	10 µg.l⁻¹
	Alongshore dimensions (m)	600–700	250–400	200–250
	Cross-shore dimensions (m) *	250–600	250–600	250–600

* Note, that if one assumed full and rapid dilution across the full cross-shore extent of the surf-zone, the cross-shore dimension listed will be reported as a rather conservative distance representing the full surf zone width.

Table 30: Approximate plume dimensions for the various constituents for the various water quality guidelines for a 1600 MW nominal capacity power plant.

Constituent		Concentration values		
		+1°C	+3°C	+5°C
Temperature	Alongshore dimensions (m)	200–300	< 200	< 200
	Cross-shore dimensions (m) *	250–600	250–600	250–600
Salinity		36 psu	40 psu	–
	Alongshore dimensions (m)	400–500	200–300	–
	Cross-shore dimensions (m) *	250–600	250–600	–
Biocide		3 µg.l⁻¹	5 µg.l⁻¹	10 µg.l⁻¹
	Alongshore dimensions (m)	800–900	400–500	200–300
	Cross-shore dimensions (m) *	250–600	250–600	250–600

* Note, that if one assumed full and rapid dilution across the full cross-shore extent of the surf-zone, the cross-shore dimension listed will be a conservative distance representing the full surf zone width.

C. CORMIX results

An alternative to predicting plume dimensions using the Inman *et al.* method is that of schematising the surf zone as a channel and using the CORMIX expert modelling system to predict plume dimensions. Using this approach we have estimated plume dimension for a range of environmental conditions (Table 26) and for the discharge flows expected from a 800 MW (Table 31) and a 1600 MW nominal capacity power plant (Table 32).

Table 31: Estimated plume dimensions for a 800 MW nominal capacity power plant using the CORMIX modelling system.

Parameter	WQ Target	Environmental Scenarios							
		1	2	3	4	5	6	7	8
All parameters		Cross-shore dimension of plume (m)							
		250	350	400	620	350	420	250	50
Temperature		Alongshore dimension of plume (m)							
	+5°C	-5	-5	5	5	5	5	5	10
	+3°C	-40	-5	150	5	5	5	40	150
	+1°C	-140	-160	500	30	185	10	360	470
Salinity		Alongshore dimension of plume (m)							
	40 psu	-150	-180	590	50	210	25	380	500
	36 psu	-230	-290	840	260	340	180	580	700
Biocide		Alongshore dimension of plume (m)							
	10 µg.l ⁻¹	-140	-160	550	30	185	10	360	470
	5 µg.l ⁻¹	-230	-290	840	260	340	180	580	700
	3 µg.l ⁻¹	-300	-400	1100	460	450	310	750	1200

Table 32: Estimated plume dimensions for a 1600 MW nominal capacity power plant using the CORMIX modelling system

Parameter	WQ Target	Environmental Scenarios							
		1	2	3	4	5	6	7	8
All parameters		Cross-shore dimension of plume (m)							
		250	350	400	620	350	420	250	250
Temperature		Alongshore dimension of plume (m)							
	+5°C	-10	-5	5	5	5	5	25	20
	+3°C	-80	-30	280	10	40	15	200	230
	+1°C	-250	-330	820	400	365	290	600	>2000
Salinity		Alongshore dimension of plume (m)							
	40 psu	-265	-350	880	425	380	300	645	>2000
	36 psu	-380	-525	1280	700	570	485	930	>2000
Biocide		Alongshore dimension of plume (m)							
	10 µg.l ⁻¹	-140	-330	820	400	365	290	600	>2000
	5 µg.l ⁻¹	-380	-525	1280	700	570	485	930	>2000
	3 µg.l ⁻¹	-480	-700	1600	970	750	650	1200	>2000

To obtain the above results the surf zone was schematised as a channel having a fixed average depth, a width equal to the relevant surf-zone width and a flow equal to the cross-shore averaged surf zone current as indicated in Table 26. Based on these assumptions CORMIX was utilized to estimate the plume dimensions for the discharge flows expected from a 800 MW and a 1600 MW power plant. This schematisation is conservative in that all of the effluent necessarily is assumed to be trapped in the surf zone. In reality there will be mixing with the waters offshore of the surf zone. In all cases the cross-shore dimension of the plume is assumed to be represented by the surf-zone width for the environmental conditions under consideration.

4.2.3 *Estimate of plume dimensions*

Based on the CORMIX model results and observations, the estimated dimensions of the plume for the various Water Quality target values are tabulated in Tables 33 and 34.

The plume dimensions reported are biased towards those estimated from the observational data as the CORMIX results assume no mixing out of the surf zone and consequently, on occasion, suggest very large plume dimensions. It is not believed that these footprints are realistic and, if they do occur, it is assumed that these extensive plumes do not persist for any great length of time.

The alongshore dimensions of the spatial area exceeding the various Water Quality guidelines is substantially greater than those for an offshore or a beyond the surf-zone pipeline discharge. This is primarily due to the surf zone trapping that occurs, resulting in the extensive spreading of the plume alongshore. The consequence of this increase in plume size is assessed below.

It should be noted that there is considerable uncertainty around the exact plume dimensions due to the lack of simple quantitative methods to assess surf zone dilutions. (This inherent uncertainty in assessing surf zone discharges is one of the reasons that the South African Water Quality guidelines declare the surf zone a sensitive area into which there should not be discharge of waste water / effluents unless there is a very strong motivation for doing so.) Consequently there is inherent uncertainty in the assessment of ecological impacts of a surf zone discharge.

Based on the World Bank Water Quality guideline of not exceeding a 3°C temperature rise beyond a 100 m radius, there is marginal non-compliance for the surf zone discharge option for a 800MW nominal capacity power plant. For a 1600 MW nominal capacity power plant the non-compliance is more extensive however a 3°C temperature rise is not exceeded beyond a radius of 300 m. There is compliance, by default, with the World Bank guideline for biocides, *i.e.* the discharge concentration (0.1 mg. ℓ⁻¹) at the point of discharge is below the World Bank guideline (0.2 mg. ℓ⁻¹).

However, given our reservations regarding these guidelines, we have also assessed the impacts against other international and regional guidelines that we believe to be of greater relevance.

Table 33: Estimated plume dimensions for a 800 MW nominal capacity power plant based on both CORMIX modelling results and dilution nomographs derived from observations.

Parameter	WQ Target	Estimated Plume Dimensions	
All parameters		Cross-shore dimension of plume (m)	
		80 – 620	
Temperature		Alongshore dimension of plume (m)	
		+5°C	< 20
		+3°C	20 – 150
		+1°C	200 – 250
Salinity		Alongshore dimension of plume (m)	
		40 psu	200 – 250
		36 psu	200 – 500
Biocide		Alongshore dimension of plume (m)	
		10 µg.l ⁻¹	200 – 250
		5 µg.l ⁻¹	250 – 500
		3 µg.l ⁻¹	300 – 800

Table 34: Estimated plume dimensions for a 1600 MW nominal capacity power plant based on both CORMIX modelling results and dilution nomographs derived from observations.

Parameter	WQ Target	Estimated Plume Dimensions	
All parameters		Cross-shore dimension of plume (m)	
		80 – 620	
Temperature		Alongshore dimension of plume (m)	
		+5°C	< 20
		+3°C	40 – 300
		+1°C	200 – 600
Salinity		Alongshore dimension of plume (m)	
		40 psu	200 – 500
		36 psu	400 – 800
Biocide		Alongshore dimension of plume (m)	
		10 µg.l ⁻¹	200 – 600
		5 µg.l ⁻¹	400 – 800
		3 µg.l ⁻¹	600 – 1200

5. LEGISLATIVE AND ADMINISTRATIVE REQUIREMENTS

The Republic of Namibia follows an Environmental Assessment Policy that aims to achieve and maintain sustainable development, particularly the wise utilisation of natural resources and the responsible management of the biophysical environment. Accordingly, there are several regulatory requirements, at international, national and regional level, to which the proposed Kudu Power Project activities will have to conform. These are outlined briefly below and summarised in Table 35.

Table 35: Relevant Acts and the Regulations for industrial activities in and adjacent to Namibian waters.

Law/Ordinance	Applicability
Article 95 (1) of the Constitution of the Republic of Namibia (1990)	<ul style="list-style-type: none"> • Preservation of Namibia's ecosystems, essential ecological processes and biological diversity • Sustainable use of natural resources
Environmental Assessment Policy of 1995	<ul style="list-style-type: none"> • Prescribes Environmental Impact Assessments for any developments with potential negative impacts on the environment.
Draft Environmental Management Bill (2002)	<ul style="list-style-type: none"> • Pollution control and waste management
Sea Birds and Seals Protection Act 46 of 1973	<ul style="list-style-type: none"> • No disturbance of seabirds and seals, particularly on islands
Seashore Ordinance 37 of 1958	<ul style="list-style-type: none"> • Removal of living and non-living resources from seashore or seabed and depositing of rubbish within 3 nautical miles of the shore
Sea Fisheries Act 29 of 1992	<ul style="list-style-type: none"> • Dumping at sea • Discharge of wastes in marine reserves • Disturbance of rock lobsters, marine invertebrates or aquatic plants • Prohibited areas for catching/disturbing fish, aquatic plants or disturbing/damaging seabed
Nature Conservation Ordinance 4 of 1975	<ul style="list-style-type: none"> • Protection of various species
Marine Resources Act 27 of 2000 (and accompanying regulations)	<ul style="list-style-type: none"> • Discharges into the sea
Convention of Biological Diversity	<ul style="list-style-type: none"> • Protection of various species
Atmospheric Pollution Prevention Ordinance No. 11 of 1976	<ul style="list-style-type: none"> • Pollution prevention
Hazardous Substances Ordinance 14 of 1974, and amendments	<ul style="list-style-type: none"> • Pollution prevention
Petroleum Products and Energy amendment Act of 2000	<ul style="list-style-type: none"> • Disposal of used oil
Territorial Sea and Exclusive Economic Zone of Namibia Act 3 of 1990	<ul style="list-style-type: none"> • Exploitation of natural resources in the EEZ
Namibian Ports Authorities Act 2 of 1994	<ul style="list-style-type: none"> • Pollution prevention
Prevention and Combating of Pollution of the Sea by Oil Act 6 of 1981	<ul style="list-style-type: none"> • Discharge of oil • Prevention/removal of marine pollution by oil

Law/Ordinance	Applicability
Draft Pollution Control and Waste Management Bill (1999)	<ul style="list-style-type: none"> • Protection for particular species, resources or components of the environment
Water Act 54 of 1956, and amendments and Artesian Water Control Ordinance No. 35 of 1995.	<ul style="list-style-type: none"> • Water related pollution and abstraction • Plant discharges
SADC Protocol on Shared Water Systems	<ul style="list-style-type: none"> • Water related pollution and abstraction
The Labour Act 6 of 1992	<ul style="list-style-type: none"> • Recruitment and remuneration procedures
Immigrations Control Act 7 of 1993	<ul style="list-style-type: none"> • Employment/Work permits • Priority to be given to employment of Namibians
United Nations Law of the Sea Convention of 1982	<ul style="list-style-type: none"> • Marine pollution from seabed activities and land-based sources
Dumping at Sea Control Act 73 of 1980	<ul style="list-style-type: none"> • Control of dumping of substances in the sea within 12 nautical miles of the Low Water Mark. • Prevent pollution of the sea and marine life, damage to amenities and interference with other marine users.

5.1 International Standards and Guidelines

The environmental impact assessment is undertaken in accordance with:

- the **operational policies of the International Finance Corporation** (IFC, 1998) that, *inter alia*, require that the assessment is undertaken within the country's overall policy framework and national legislation.
- the **World Bank Water Quality Guidelines** for new thermal power plants (World Bank, 1998)
- and **international best practice** that includes principles such as the **precautionary approach** (whereby, where there is uncertainty in the nature and severity of a potential impact, conservative assumptions are made with respect to the significance and potential severity of the impact being assessed).

As signatory to the Convention of Biological Diversity and Convention to Combat Desertification, Namibia is committed to the preservation of rare and endemic species, and to provide protection for ecosystems and natural life-support processes within the country's boundaries. As a signatory of the United Nations Law of the Sea Convention of 1982, Namibia is required to adopt legislation to reduce marine pollution from seabed activities in the Exclusive Economic Zone (EEZ) and on the continental shelf, and from land-based sources.

As the Namibian Water Act has yet to be legislated (see below), the water quality guidelines from a range of international sources were utilised in assessing the potential environmental impacts of the power plant discharges, including:

- World bank Water Quality guidelines that state that emissions levels for the design and operation of each thermal power project must be established through the Environmental Assessment process on the basis of country legislation and the World Bank Pollution Prevention and Abatement Handbook (World Bank, 1998), as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group. The maximum emissions levels normally acceptable to the World Bank Group in making decisions regarding the provision of World Bank Group assistance are contained in Table 36 below. These levels need to be achieved daily without dilution.
- Other generally accepted Water Quality Guidelines used in similar environments (*e.g.* RSA DWAF, 1995, 2004a,b; ANZECC, 2000).

5.2 National Policies and Guidelines

Following the Environmental Assessment Policy of 1995, an environmental clearance certificate is required from the Directorate of Environmental Affairs (DEA) prior to commencement of operations for the Kudu Power Project. This Policy stipulates that an Environmental Impact Assessment is required for any policy, programme or project with potential negative impacts on the environment, whether initiated by Government or private sector.

To assist the Environmental Impact Assessment process, the Directorate of Environmental Affairs (DEA) provides guidelines for environmental assessments for new development projects (Ministry of Environment & Tourism, 2001). These address obvious environmental aspects such as pollution and waste management, as well as operational procedures and rehabilitation measures.

A draft version of the Pollution Control and Waste Management Bill (1999) has amalgamated a variety of Acts and Ordinances that provide protection for particular species, resources or components of the environment. These include, but are not limited to, the Nature Conservation Ordinance No.4 of 1975, the Sea Fisheries Act 29 of 1992, the Sea Birds and Seals Protection Act 46 of 1973, Seashore Ordinance No. 37 of 1958, Hazardous Substances Ordinance No. 14 of 1974 and amendments, and the Atmospheric Pollution Prevention Ordinance No. 11 of 1976. All construction, disturbance, effluent and pollution resulting from the Kudu Power Project will be required to be in strict accordance with the regulations outlined in the Pollution Control and Waste Management Bill.

The South African Water Act 54 of 1956 is still used in Namibia today. A new Water Act more suitable to Namibian circumstances is nearing completion (*e.g.* Schachtschneider, 2001) and is presently under consideration by the Namibian legislature. This Act will be based on the recently accepted National Water Policy (Ministry of Agriculture, Water and Rural Development, 2000).

Presently the new Water Act does not contain any target values for water quality. These will form part of the regulations associated with the new Water Act and will be implemented at a future date. Target values contained in the South African Water Act 54 are based on Special and General Standards that, in general, are highly unsuited for marine disposal of effluents.

5.3 Water quality guidelines

5.3.1 *Heated brine discharge*

The water quality guidelines of potential relevance for heated brine discharges and the associated required dilutions of the effluent to meet the most stringent of these target values are listed in Table 36 below.

5.3.2 *Monocyclic aromatic hydrocarbons (BTEX)*

Although BTEX are not addressed in the South African Water Quality guidelines, some guidance can be obtained from Canadian freshwater water quality guidelines (CCME, 1987) and the U.S. Environmental Protection Agency quality criteria for both fresh and marine waters (US EPA, 1986). The latter guidelines for sea water are more comprehensive and are listed in Table 37 below. More recent guidelines were acquired from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).

In the context of BTEX, additivity of toxic effects (*i.e.* mixture toxicity) also needs to be considered (ANZECC, 2000). Danger for the environment will also exist if significant amount of trace metals are contained in these chemicals. Synergistic effects in the toxicology of the various pollutants may be significant. It needs to be confirmed (*e.g.* using direct toxicity assessment) that such a co-discharge does not result in unacceptable toxic effects.

5.3.3 *Chlorinated Benzenes*

There is a direct relationship between the toxicity to fish, invertebrates and plant species and the degree of chlorination of benzene (CCME, 1987), consequently the guideline values decrease with increasing degree of chlorination. The half-life of chlorinated benzenes is typically 9 hours.

5.3.4 *Dissolved nutrients*

Dissolved nutrients typically include nitrates, nitrites phosphates and ammonia. Ammonia ($\text{NH}_3\text{-N}$) can act as a toxicant. Typically ammonia is reported as total ammonia ($\text{NH}_3\text{-N} + \text{NH}_4\text{-N}$). For this reason, the South African Water Quality Guidelines for the Natural Environment (DWAF, 1995) specifies both ammonia and total ammonia guidelines (see Table 38). The suggested target value for $\text{PO}_4\text{-P}$ is roughly 50 to 60 $\mu\text{g}\cdot\ell^{-1}$.

Table 36: Water quality guidelines for the discharge of a heated brine into the marine environment.

Parameter	SA Water Quality Guidelines (RSA DWAF, 1995)	World Bank Guidelines ^a	International Water Quality Guidelines	Minimum required dilutions
Zone of impact / mixing zone	To be kept to a minimum, the acceptable dimensions of this zone informed by the EIA and requirements of licensing authorities, based on scientific evidence.	100 m radius from point of discharge for temperature	–	
Temperature	< 1 °C above ambient seawater temperature	< 3° C above ambient at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge when there are no sensitive aquatic ecosystems within this distance.	Mean temperature of seawater in receiving environment not to exceed 80 percentile seawater temperature to be obtained from the seasonal distribution of temperature from a reference site (ANZECC, 2000)	3 to 10
Salinity	33 – 36 psu, however intertidal species may tolerate 40 psu or more	–	< 5% change in salinity from ambient/background (ANZECC, 2000) ^b Human activities should not cause the salinity (expressed as parts per thousand) of marine and estuarine waters to fluctuate by more than 10% of the natural level expected at that time and depth. (CCME, 2002)	7 to 20
Residual Chlorine	no guideline, however deleterious effects recorded for concentrations as low as 2 – 20 µg Cl.ℓ ⁻¹	0.2 mg Cl.ℓ ⁻¹ at the point of discharge prior to dilution ^c	3 µg Cl.ℓ ⁻¹ measured as total residual chlorine (low reliability trigger value at 95% protection level, to be used only as an indicative interim working level) (ANZECC, 2000)	5 to 50

^a The World Bank guidelines are based on maximum permissible concentrations at the point of discharge and do not explicitly take into account the receiving environment, i.e. no cognisance is taken of the fact of the differences in transport and fate of pollutants between, for example, a surf-zone, estuary or coastal embayment with poor flushing characteristics and an open and exposed coastline. It is for this reason that we include in this study other generally accepted Water Quality guidelines that take the nature of the receiving environment into account.

^b The ANZECC (2000) Water Quality guideline for salinity is less stringent than, but roughly approximates, the South African Water Quality guideline that requires that salinity should remain within the range of 33 psu to 36 psu.

^c Chlorine “shocking” may be preferable in certain circumstances. This involves using high chlorine levels for a few seconds rather than a continuous low-level release. In this case the target value is a maximum value of 2 mg Cl.ℓ⁻¹ for up to 2 hours, not to be repeated more frequently than once in 24 hours, with a 24-hour average of 0.2 mg Cl.ℓ⁻¹. (The same limits would apply to bromine and fluorine.)

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Table 37: International guidelines for benzene, toluene, chlorinated benzenes and xylene.

Pollutant	Canadian Water Quality Guidelines	US EPA guidelines					ANZECC	Minimum Required Dilution
		Acute toxicity	Chronic toxicity	Fish consumption	Tainting	*Carcinogenic risk levels	**Trigger Values	
Benzene	110 µg. ℓ ⁻¹ for marine waters	5.1 mg. ℓ ⁻¹	0.7 mg. ℓ ⁻¹	40 µg. ℓ ⁻¹	At low concentrations. No value given	4 – 400 µg.ℓ ⁻¹	500 µg.ℓ ⁻¹	
Ethyl benzene	25 µg. ℓ ⁻¹ for marine waters			29 mg.ℓ ⁻¹			5 to 80 µg.ℓ ⁻¹	
Toluene	330 µg. ℓ ⁻¹ for fresh water	6.3 mg. ℓ ⁻¹	5.0 mg. ℓ ⁻¹	200 mg.ℓ ⁻¹	At low concentrations. No value given	–	180 µg.ℓ ⁻¹	
Chlorinated benzenes		160 µg. ℓ ⁻¹	129 µg. ℓ ⁻¹			–	–	–
Monochlorobenzene		–	–	488 µg.ℓ ⁻¹	20 µg. ℓ ⁻¹	–	–	–
Trichlorobenzene 1,2,4,		–	–	–	–	–	–	–
Tetrachlorobenzenes	25 µg. ℓ ⁻¹	–	–	48 µg.ℓ ⁻¹	–	–	–	–
Pentachlorobenzene	5.4 µg. ℓ ⁻¹	–	–	85 µg.ℓ ⁻¹	–	–	–	–
Hexachlorobenzene		–	–	–	–	0.074 ng. ℓ ⁻¹ to 7.4 ng. ℓ ⁻¹ .	–	–
<i>o</i> -Xylene	None found	None found					350 µg.ℓ ⁻¹	
<i>m</i> -Xylene							75 µg.ℓ ⁻¹	
<i>p</i> -Xylene							200 µg.ℓ ⁻¹	

* for consumption of aquatic organism only. Levels given are those estimated to result in an incremental increase in cancer risk over a lifetime of 10⁻⁷ to 10⁻⁵

** Trigger values recommended for slightly-moderately disturbed systems at the 95% protection level (except benzene 99%) (ANZECC, 2000).

Note:

In most cases Trigger Values have been derived from an incomplete data set using either assessment factors or from modelled data using the statistical method. As they have a low degree of confidence they should only be used as interim indicative working levels. Exceedances of the trigger values are an ‘early warning’ mechanism to alert the natural resource manager of a potential problem. ***They are not intended to be an instrument to assess ‘compliance’ and should not be used in this capacity.***

Table 38: International guidelines for ammonia and inorganic nutrients.

VARIABLE	SOUTH AFRICA (RSA DWAF, 1995)	AUSTRALIA/NEW ZEALAND (ANZECC, 2000)	US-EPA (US-EPA, 2004)	EUROPEAN COMMUNITY (CEC, 1979)
Dissolved inorganic nutrients for protection of the natural environment	<p>Waters should not contain concentrations of dissolved nutrients that are capable of causing excessive or nuisance growth of algae or other aquatic plants or reducing dissolved oxygen concentrations below the target range indicated for dissolved oxygen</p> <p>For the West Coast a guideline of $60 \mu\text{g}\cdot\text{l}^{-1}$ for $\text{PO}_4\text{-P}$ is suggested as being appropriate.</p>	<p>Where an appropriate local reference system(s) is available, and there are sufficient resources to collect the necessary information for the reference system, the trigger concentrations should be determined as the 80%ile of the reference system(s) distribution. Where possible, the trigger value should be obtained for that part of the seasonal or flow period when the probability of aquatic plant growth is most likely.</p> <p>Test data: Median (or mean) concentrations measured during growth periods</p>	<p>Phosphorus: $0.1 \mu\text{g}\cdot\text{l}^{-1}$ (elemental)</p> <p>Refer to US-EPA (2001) for further details on criteria</p>	<p>Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.</p>
Dissolved inorganic nutrient guidelines for mariculture	–	<p>$\text{NO}_3\text{-N}$: $100\ 000 \mu\text{g}\cdot\text{l}^{-1}$ $\text{NO}_2\text{-N}$: $100 \mu\text{g}\cdot\text{l}^{-1}$ Total Available N: $1000 \mu\text{g}\cdot\text{l}^{-1}$ $\text{PO}_4\text{-P}$: $50 \mu\text{g}\cdot\text{l}^{-1}$</p>	–	–
Total Ammonia-N as a toxicant	<p>$600 \mu\text{g}\cdot\text{l}^{-1}$ ($20 \mu\text{g}\cdot\text{l}^{-1}$ as $\text{NH}_3\text{-N}$)</p>	<p>$910 \mu\text{g}\cdot\text{l}^{-1}$ (M)</p>	<p>Target value are pH and Temperature dependent - refer to US-EPA (1989) for further details on criteria.</p> <p>Total ammonia-N at pH 8.2 and 15°C: 6700 (CMC); 1000 (CCC)</p>	<p>21 (un-ionised) (recommended Seager <i>et al</i>, 1988)</p>

NOTE:

H = High reliability; M = Moderate reliability; L= Low reliability; CCC = Criteria Maximum concentration; CMC = Criteria Continuous Concentration

6. IDENTIFICATION OF POTENTIAL ENVIRONMENTAL IMPACTS

The major potential effects of discharging a heated brine effluent into the marine environment are:

- Increased temperature in the receiving water and its impact on the biota and/or ecological processes,
- Increased salinity in the receiving water and its impact on the biota and/or ecological processes, and
- Biocidal action of the residual chlorine and low volume discharges of aromatic hydrocarbons.

Other potential impacts may be associated with the momentum transfer from the discharge and/or the discharge structure itself. The effect of a body of warm brine and its role as a potential barrier or as a cue to marine organisms is also discussed. While these effects are expected regardless of the discharge configuration, the magnitude, duration and extent of the impacts will largely be determined by the extent of the discharge plume, which in turn is determined by the location of the discharge pipeline and environmental factors.

6.1 Temperature

The extent of the thermal “footprint” of concern for each of the three discharge options is given in Tables 10, 18 and 33 for a 800 MW nominal capacity power plant and Tables 14, 22, 34 for a 1600 MW nominal capacity power plant. Here the potential environmental impacts for each scenario are assessed based on the extent of the thermal “footprint” and the potential deleterious thermal impacts described below.

Bamber (1995) defined four categories for direct effects of thermal discharges on marine organisms:

- Increase in mean temperature
- Increase in absolute temperature
- High short term fluctuations in temperature
- Thermal barriers

The latter category is discussed in a later section.

6.1.1 Increased mean temperature

The natural seasonal mean sea surface temperatures for the region extrapolated from Boyd and Agenbag (1985) are winter 12 – 13°C, spring 13 – 14°C, summer 14 – 15°C and autumn 13 – 14°C. The maximum seasonal mean temperatures close to the outfall are therefore estimated to be 24°C (14°C + ($\Delta T = 10^\circ\text{C}$)) near the discharge, 17°C (14°C + ($\Delta T = 3^\circ\text{C}$))

within a radius of < 20 m (150 m for the surf zone discharge scenario), and 15°C (15°C + ($\Delta T = 1^\circ\text{C}$)) approximately 445 m downstream for the offshore discharge options (worst case scenario) and 600 m along- and cross-shore for the surf zone scenario. Depending on atmospheric conditions the purge waters may, however, reach 25°C or more, with shorter term peaks exceeding this.

The $\Delta T = 10^\circ\text{C}$ value assumed above is not necessarily valid for all seasons. For an evaporative cooling system the temperature elevation is that of the wet bulb atmospheric temperature + 5°C rather than ambient seawater temperature + 10°C. Due to varying atmospheric conditions during the year the mean ΔT typically varies between + 5°C and 10°C above ambient seawater temperature.

The South African water quality guidelines (RSA DWAF, 1995) set a target value of $\Delta T \leq 1^\circ\text{C}$ that is the most stringent of the reviewed water quality guidelines for thermal impacts (Table 36). Very rarely will any significant area exceed this target value for the offshore discharge options (see Tables 9, 13, 19, 21) whereas the heated plume is slightly larger for the surf-zone discharge scenario (Tables 32 and 33). That which follows is aimed at assessing the impacts in those areas where the target value is exceeded (*i.e.* $\Delta T > 1^\circ\text{C}$).

Changes in water temperature can have a substantial impact on aquatic organisms and ecosystems, with the effects being separated into two groups:

- influences on the physiology of the biota (e.g. growth and metabolism, reproduction timing and success, mobility and migration patterns, and production);
- influences on ecosystem functioning (e.g. through altered oxygen solubility).
- The latter group of effects is discussed in a later section.

Most reports on adverse effects of changes in seawater temperature on southern African West Coast species are for intertidal (e.g. the white mussel *Donax serra*) or rocky bottom species (e.g. abalone *Haliotis midae*, kelp *Laminaria pallida*, mytilid mussels, Cape rock lobster *Jasus lalandii*). Cook (1978) specifically studied the effect of thermal pollution on the commercially important rock lobster *Jasus lalandii*, and found that adult rock lobster appeared reasonably tolerant of increased temperature of 6°C and even showed an increase in growth rate. The effect on the reproductive cycle of the adult lobster female was, however, more serious as the egg incubation period shortened and considerably fewer larvae survived through the various developmental stages at +6°C above ambient temperature. Zoutendyk (1989) also reported reduction in respiration rate of adult *J. lalandii* at elevated temperatures. Other reported effects include an increase in biomass of shallow water hake *Merluccius capensis* and West Coast sole *Austroglossus microlepis* at 18°C (MacPherson and Gordo, 1992) but no influence of temperatures of <17.5°C on chub-mackerel *Scomber japonicus* (Villacastin-Herrero *et al.*, 1992). In contrast, 18°C is the lower lethal limit reported for larvae and eggs of galjoen *Distichius capensis* (Van der Lingen, 1994).

Internationally, a large number of studies have investigated the effects of heated effluent from coastal power stations on the open coast. These concluded that at elevated temperatures of

<5°C above ambient seawater temperature, little or no effects on species abundances and distribution patterns were discernable. This was reported for bacteria and heterotrophic nanoflagellates (Choi *et al.*, 2002), phytoplankton (Lee *et al.*, 1998; Marano *et al.*, 2000; Martinez-Arroyo *et al.*, 2000), meio- and macrobenthos (Marano *et al.*, 2000; Lardicci *et al.*, 1999; Wardiatno *et al.*, 2001), molluscs (Wardiatno *et al.*, 2001), calanoid copepods (Wong *et al.*, 1998) and fish assemblages of shallow sandy habitats (Golani and Lerner, 2003). A possible exception is the study by Castilla and Camus (1992), who reported that the density of the octopus *Octopus* spp. in northern Chile increased about 100-fold in response to El Niño - induced temperature increases.

On the physiological level, however, some adverse effects were observed, mainly in the development of eggs and larvae (see also Cook, 1978 above). For example, spawning of the Baltic Sea perch (*Perca fluviatilis*) exposed to heated effluent occurred earlier and was more prolonged (Sandstrom *et al.*, 1997). However, although the fertilization rate increased, most egg strands did not develop to hatching and egg mortality was high. Exposure to high temperatures during the final maturation of the gonad influenced the follicular mechanism producing the jelly membrane which constitutes the matrix of the egg strand. High temperature in Swedish and Lithuanian thermal effluent areas negatively influenced gametogenesis of female perch, roach (*Rutilus rutilus*) and pike (*Esox lucius*), indicating reduced reproductive capacity (Luksiene *et al.*, 2000). Interestingly, the fish did not avoid the thermal impact by moving out of the heated areas (Luksiene *et al.*, 2000). Other effects include alterations in the photosynthesis behaviour of algal assemblages (Martinez-Arroyo *et al.*, 2000), decreases in the duration of larval development (*e.g.* barnacle larvae, Thiyagarajan *et al.*, 2003), and suppressed growth in the post larvae of the spiny lobster *Panulirus argus* due to prolonged intermoulting periods and reduced size increments with each moult (Lellis and Russel, 1990).

In view of the negligible effects of thermal plumes on benthic assemblages reported elsewhere and the fact that, for all scenarios tested, the CORMIX model simulations that a ΔT of +5°C or more (which could potentially affect larval or egg development) will be limited to a maximum radius of <20 m around the discharge point, the significance of the impact of the thermal plume is regarded as low.

6.1.2 Increased absolute temperature

The maximum observed sea surface temperature in the region under investigation is 24.5°C (above). A ΔT of +10°C would increase the temperatures in the receiving water to 34.5°C, however only in the immediate vicinity of the discharge. A 20 year temperature record from Port Nolloth indicates a natural (*i.e.* not influenced by flood water) maximum of 20 – 24°C in summer (Greenwood and Taunton-Clark, 1992). The maximum ΔT of + 10°C combined with these maximum observed ambient temperatures in the environment will lead to direct mortality of some of the benthic fauna in the immediate vicinity of the outfall. Although optimal growth of post larvae of the spiny lobster *Panulirus argus* was reported at temperatures between 29–30°C (Lellis and Russel, 1990), Bamber (1990) showed that lethal temperatures for marine crustacea range between 31°C and 34.5°C. However, due to the naturally high sedimentation fluxes experienced in this area, the resident benthic community is likely to consist mostly of

opportunistic species (see above). Such communities recover relatively rapidly after disturbance. Due to the nature of the cooling system and atmospheric conditions (and seawater temperatures) very high temperature events are likely to be rare. Lethal impacts are therefore expected to be minimal.

6.1.3 High short-term temperature fluctuations and thermal barriers

Temperature fluctuations are caused by variability in flow or circulation driven by frequently reversing winds or tidal streams. These are not characteristic features of the MA1 coastline and strong, short term temperature fluctuations are therefore not expected to occur. However, it should be noted that changes in the receiving environment (such as changes in the longshore currents) are expected to result in significant movement of the thermal plume. Nevertheless, it is not expected that the magnitude of the consequent temperature changes will be of sufficient rapidity or magnitude to have a major impact on the biotic communities in the area.

6.2 Salinity

Aquatic organisms are classified as stenohaline (able to adapt to only a narrow range of salinities) or euryhaline (able to adapt to a wide salinity range), with most organisms being stenohaline.

Salinity changes may affect aquatic organisms in two ways:

- direct toxicity through physiological changes (particularly osmoregulation), and
- indirectly by modifying the species distribution.

However, in marine ecosystems adverse effects or changes in species distribution are anticipated more from a reduction rather than an increase in salinity (ANZECC, 2000). Very little information exists on the effect of an increase in salinity on organisms in coastal marine systems, most studies being done either on effects of a decline in salinity due to an influx of freshwater or on salinity fluctuations in estuarine environments, where most of the fauna can be expected to be of the euryhaline type. The limited data available include a reported tolerance of adults of the mussel *Mytilus edulis* of up to 60 ppm (Barnabe, 1989), and successful fertilization (Clark, 1992) and development (Bayne, 1964) of its larvae at a salinity of up to 40 psu. The shrimp *Penaeus indicus* was capable of tolerating a salinity range of 1 to 75 psu if allowed an acclimation time of around 48 hours (McClurg, 1974), the oyster *Crassostrea gigas* tolerated salinities as high as 44 psu (King, 1977) and the shrimp *Penaeus monodon* survived in 40 psu saline water (Kungvankij *et al.*, 1986a,b, cited in RSA DWAF, 1995). Chen *et al.* (1992) reported a higher moulting frequency in juveniles of the prawn *Penaeus chinensis* at a salinity of 40 psu.

One of the main factors of a change in salinity is its influence on osmoregulation, which in turn affects uptake rates of chemical or toxins. In a review on the effects of multiple stressors on aquatic organisms Heugens *et al.* (2001) summarize that in general metal toxicity increases with decreasing salinity, the toxicity of organophosphate insecticides increases with higher salinity, while for other chemicals no clear relationship between toxicity and salinity was observed. Some

evidence, however, also exists for an increase in uptake of certain trace metals with an increase in salinity (Roast *et al.*, 2002).

The South African Water Quality guidelines (RSA DWAF, 1995) set an upper target value for salinity of 36 psu. The paucity of information on the effects of increased salinity on marine organisms makes an assessment of the high salinity plume difficult. While it appears that many species are capable of tolerating slight increases in salinity, the dynamic nature of the MA1 coastline suggests that the benthic organisms in the area are unlikely to exhibit much tolerance to salinity variations beyond perhaps 1 – 2 psu above the typical ~35 psu of seawater in this region. This applies particularly to the larval stages of fishes and benthic organisms in the area, which are likely to be damaged or suffer mortality due to osmotic effects, particularly if the encounter with the discharge effluent is sudden. If the heated brine is discharged onto the beach and into the surf-zone, it is also likely that the meiofauna and macrofauna in the immediate vicinity of the discharge point will be adversely affected by the brine percolating into the sandy sediment causing unfavourable osmotic conditions. In the worst case scenario some extreme stenohaline organisms might be displaced, with potential knock-on effects throughout the food chain (*e.g.* reduction or loss of macrobenthic food source for shore birds which forage on the beaches). However, due to the relatively small “footprint” of the salinity plume, this impact is regarded as having a low significance.

6.3 Barrier and cueing effects of the discharge plume

Twenty nine species of fishes have been recorded from the Orange Estuary (Lamberth, 2004). Of these, three species white steenbras *Lithognathus lithognathus*, leervis *Lichia amia* and flathead mullet *Mugil cephalus* are dependent on estuaries for at least the first year of their lives. Another two species, elf *Pomatomus saltatrix* and harder *Liza richardsonii* are partially dependent on estuaries. Various environmental cues, including thermal and salinity gradients, olfactory cues, and tidal currents, are known to guide the larval stages of fishes into estuaries (Whitfield and Marais, 1999). While it is not known which of these cues is the most important to southern African fish species which make use of estuaries during a portion of their life histories, there is some concern that a heated brine discharge could form a barrier, which may interfere with one or more of the cues used by the larval fishes to locate the estuary. As the discharge from the Orange River estuary is less saline and warmer than the receiving sea water, the larvae may cue on the decreasing salinity and increasing temperature as the mouth is approached. The discharge of a heated hypersaline effluent into the surf-zone will cause a reversed salinity and thermal gradient in an alongshore direction thus giving the incorrect cue to the larval fishes and hence failure to locate the estuary. However, the proposed location for the power plant and its discharge pipeline is 25 km north of the estuary and even under the worst case scenario will the plume not reach that far south.

Although no tagging studies have been undertaken on the five species known to use the Orange River estuary to determine where individuals disperse to after the estuarine nursery period, there is no reason to suppose that they do not move both northwards along the Namibian coast and southwards along the Namaqualand coast. The effluent could therefore form a thermal/brine barrier, which disrupts the recruitment of larval fishes from the Namibian coastline into the Orange River Estuary. Likewise, the effluent could form a barrier preventing the dispersal in the

longshore drift of larvae of the commercially important rock lobster *Jasus lalandii*, thereby affecting recruitment onto the Kerbe Huk fishing grounds.

For thermal or brine barriers to be effective in altering or limiting marine organism migration paths they need to be persistent over time and cover a large proportion of the water body through which migration occurs. As the discharge plumes from a CCGT power plant purge water discharge via a pipeline located offshore of the surf-zone is predicted to affect a very small proportion of the receiving water body, the potential impacts for this barrier effect are considered negligible. The effect in the surf zone, however, may be significant where the surf zone comprises the primary migration pathway as the thermal and brine barrier will persist in the surf-zone for most of the time.

6.4 Biocidal effects of residual chlorine

Chlorination is undertaken to ensure that the heat exchange and water pumping systems are maintained free from biofouling organisms. Normally chlorine is added as hypochlorite at a constant concentration of approximately 1.0 ppm¹⁰ in the inlet water. Freely available chlorine (FAC) or residual chlorine at the outlet is specified to be approximately 0.1 mg Cl.ℓ⁻¹ or 0.1 ppm. However, in extreme cases outlet concentrations may attain 2.0 mg Cl.ℓ⁻¹ if shock doses are used to clean the plant (*e.g.* Stenton-Dozey and Brown, 1994).

For the offshore discharge scenarios, the CORMIX model results predict that at a discharge velocity of $\geq 1.8 \text{ m.s}^{-1}$ under normal dose levels, the FAC concentration at the outlet will decline to 0.01 mg Cl.ℓ⁻¹ (10 µg Cl.ℓ⁻¹) within a small radius of $< 20 \text{ m}$ and compliance with the most stringent guidelines will be achieved at a maximum distance of 730 m downstream and 230 m offshore (Tables 12, 16, 20, and 24). Compliance with the less stringent but still conservative target value of 5 µg Cl.ℓ⁻¹ will be achieved within 325 m downstream and 140 m offshore of the outlet. For the surf-zone discharge option, the maximal plume dimension for the guideline value of 3 µg Cl.ℓ⁻¹ are 620 m cross-shore and 1200 m alongshore, and 620 m cross-shore and 800 m alongshore for the less stringent guideline value of 5 µg Cl.ℓ⁻¹ (Tables 33 and 34).

The chemistry associated with seawater chlorination is complex and only a few of the reactions are given below, summarized from RSA DWAF (1995) and ANZECC (2000). Chlorine does not persist for extended periods in water but is very reactive. Its by-products, however, persist longer. Seawater chlorination differs greatly from that of fresh water primarily due to the high bromide concentration of seawater (average bromide concentration in seawater is 67 mg. ℓ⁻¹). In the presence of bromide, free residual chlorine cannot exist in seawater as it instantaneously oxidises bromide into bromine. When chlorine additions remain below bromide concentrations, the oxidation of bromide is quantitative in less than ten seconds at a pH of 8 (the pH of seawater). Due to the rapid hydrolysis of bromine, hypobromous acid (HOBr) and its ionic counterpart OBr are the active species. Under usual seawater conditions (pH between 7.8 and 8.2), the undissociated form (HOBr) predominates with consequently higher reactivity and

¹⁰ Note that 1.0 ppm \sim 1.0 mg.ℓ⁻¹

biocidal activity. In chlorinated seawater, bromine and any other oxidants disappear very rapidly. Naturally occurring organic substances (*e.g.* ammonia) contribute to the major part of oxidant consumption. In coastal seawater, ammonia concentrations are usually lower (typically less than $28 \mu\text{g N}\cdot\ell^{-1}$) and therefore bromine remains as hypobromous acid. When ammonia increases, bromamines may be formed. At pH 8.1, ammonia and bromine reacts with chlorine at comparable rates. Monochloramine, the more persistent species among the various oxidised chlorine-produced oxidants, may be found when ammonia concentrations increase or in lower pH conditions. In most cases, bromamines are the only combined forms and tri- and di-bromamines are the main species. These bromamines are highly oxidising species and thus behave similarly to free bromine. Bromamines disappear rapidly; organic bromamines are rapidly formed. Hypobromous acid can also disproportionate into bromide and bromate. Bromate is formed during seawater chlorination and this reaction is accelerated by sunlight.

Paradoxically, chlorine chemistry thus establishes that no free chlorine is found in chlorinated seawater where bromide oxidation is instantaneous and quantitative. The chlorinated compounds, however, which constitute the combined chlorine, are far more persistent than the free chlorine. After seawater chlorination, the sum of free chlorine and combined chlorine is referred to as total residual chlorine (TRC).

Chlorine can also combine with phenolic compounds to form chlorophenols, some of which can taint fish flesh at concentrations as low as $0.001 \text{ mg}\cdot\ell^{-1}$.

Marine organisms are extremely sensitive to residual chlorine, making it a prime choice as a biocide to prevent the fouling of marine water intakes. Values listed in the South African Marine Water Quality Guideline (RSA DWAF, 1995) show that $1500 \mu\text{g Cl}\cdot\ell^{-1}$ is lethal to some phytoplankton species, $820 \mu\text{g Cl}\cdot\ell^{-1}$ induced 50% mortality for a copepod and 50% mortality rates are observed for some fish and crustacean species at values exceeding $100 \mu\text{g Cl}\cdot\ell^{-1}$ (see also ANZECC, 2000). The lowest values at which lethal effects are reported are $10 - 180 \mu\text{g Cl}\cdot\ell^{-1}$ for the larvae of a rotifer, followed by $23 \mu\text{g Cl}\cdot\ell^{-1}$ for oyster larvae. Sublethal effects include valve closure of mussels at values $<300 \mu\text{g Cl}\cdot\ell^{-1}$ and inhibition of fertilisation of some urchins, echinuroids, and annelids at $50 \mu\text{g Cl}\cdot\ell^{-1}$. However, some deleterious effects are also recorded for values as low as $2 \mu\text{g Cl}\cdot\ell^{-1}$, which is the start of the range ($2 - 20 \mu\text{g Cl}\cdot\ell^{-1}$) of effective concentrations at which fertilisation of some sea urchins was reduced by 50% (RSA DWAF, 1995). It is important, therefore, to ensure that the residual chlorine concentration in the discharged purge water are specifically reduced to a level below that which may have lethal or sublethal effects on the biota, particularly the larval stages. For very sensitive species, some deleterious effects on the sublethal level may, however, occur. On the other hand, it was shown above that the biomass of benthic fauna in this area is expected to be low, and potential interaction between the residual chlorine and organisms contained in the receiving water is therefore also likely to be low. Consequently it is assumed that, despite the extent of the biocide “footprint” (for the most stringent of the water quality target values), the effects of chlorine will be minimal and the significance of this impact is thus regarded as low.

6.5 Discharge of monocyclic aromatic hydrocarbons (BTEX)

BTEX is the collective name for benzene, toluene, ethyl benzene, and xylenes, the monocyclic aromatic hydrocarbons often found in discharge waters containing petroleum oils and products (Rabalais *et al.*, 1991a,b; Wang and Fingas, 1996). As the behaviour of the four compounds is somewhat similar when released to the environment, they are usually considered as a group.

BTEX compounds are volatile and, if discharged close to the sea surface, the major removal mechanism is volatilization with subsequent atmospheric oxidation, with half-lives for evaporation ≤ 5 hours at 20°C (EPA, 1986; HSDB 1996). More specifically, for benzene, volatilization half-lives of 4.81 hours at 25°C and 5.03 hours at 10°C have been predicted from a one metre column of water, whereas estimated atmospheric half-lives vary from 2,4 to 24 hours (CCME, 1987; HSDB 1996). The half-life of toluene as a result of volatilization from a water column of one metre depth is estimated to be approximately 5 hours with an atmospheric half-life of 15 hours. Biodegradation and photodegradation of these compounds is also very rapid. The BTEX compounds have relatively low solubility in water; the solubility of benzene is about 1400 mg. ℓ^{-1} and xylenes about 120 mg. ℓ^{-1} . Furthermore, benzene and toluene are not expected to adsorb strongly to sediments (ANZECC, 2000).

Aromatic hydrocarbons can have deleterious effects on organisms at relatively low concentrations of their soluble fractions and are acutely toxic to aquatic organisms if contact is maintained. Studies have indicated that if the produced water from production platforms is discharged to well-flushed, dispersive environments, rapid initial dilution of the effluent by 1000–fold within the first 50–100 m downstream of the discharge point occurs (Riksheim and Johnsen, 1994; Furuholt and Kinn, 1998; Rabalais *et al.* 1991a,b). Furthermore, the volatility of BTEX, allied to dispersive mixing, results in 50 000 to 150 000–fold reduction of the benzene concentration in sea water, 20 m from the discharge point (Rabalais *et al.*, 1991a, b; Terrens and Tait, 1996). Depending on the salinity and thermal properties of the discharge, the concentration of aromatics and the local hydrodynamic conditions, the chemical contaminant signal may thus be negligible 500 m beyond the discharge point. In general, a dilution factor of 1000 or less is sufficient to reach the environmental threshold concentrations (predicted no effect concentrations - PNEC) (OGP, 2002). The required dilution is also likely to occur within a few minutes after the produced water plume hits the sea, and consequently the exposure of aquatic organisms to aromatic hydrocarbon concentrations higher than the PNEC is short enough to avoid toxic effects. In shallower, less dispersive environments, however, the effluent plume may spread in a thin, dense plume across the surface sediments of the receiving environment, and the chemical signature of the produced waters could be detected further away (i.e. 1000 m or more) from the point of discharge (Rabalais *et al.*, 1991a, b).

The mechanisms of toxic action of aromatic hydrocarbons are still subject to considerable discussion (van Brummelen *et al.*, 1996). It appears that different toxicity mechanisms play a role depending on the compound, the exposure (acute or chronic), the organism and the trophic level. BTEX are generally reported to be neurotoxic to target organisms, with benzene in particular,

being found to be carcinogenic to mammals and humans (National Research Council, 2003). The International Association of Oil and Gas Producers (OGP, 2002) list the toxicological characteristics of selected aromatic compounds. While polycyclic aromatic hydrocarbons display a variety of toxic mechanisms including non-polar narcosis, phototoxicity and biochemical activation that, in turn, may result in mutagenicity, carcinogenicity and teratogenicity, no such toxicity has been reported for the BTEX compounds. This is because the monocyclic aromatics tend to have lower molecular weights, and therefore reflect low bioconcentration factor values¹¹, particularly for fish and clams (HSDB, 1996). Consequently, the lower molecular weight BTEX compounds are less toxic to aquatic organisms.

Table 39: Lowest toxicity levels of monocyclic aromatic compounds in the aquatic environment (Frost, 2001).

Compound	Endpoint	Trophic Level	Conc. Value ($\mu\text{g}\cdot\text{l}^{-1}$)	Predicted No Effect Concentration ($\mu\text{g}\cdot\text{l}^{-1}$)
Benzene	NOEC ¹² (20 days)	Crustacea	170	17
Ethylbenzene	LC ₅₀ (96 hours)	Crustacea	490	0.49
Toluene	NOEC (21 days)	Crustacea	1000	100
Xylene	LC ₅₀ (96 hours)	Fish	1200	1.2

Table 40: Acute toxicity data from short-term tests on marine organisms considered for guideline derivation for benzene, toluene, ethylbenzene, and xylenes (EC50 & LC50 $\text{mg}\cdot\text{l}^{-1}$, i.e. $\times 1000\ \mu\text{g}\cdot\text{l}^{-1}$) (ANZECC, 2000).

Compound	Fish	Crustaceans	Molluscs	Algae
Benzene	6 – 94	3.3 – 380	165 – 924	10 – 20
Ethylbenzene	4.3 – 360	0.5 – 88	–	4.9 – 7.5
Toluene	6.4 – 90	4.3 – 149	–	5
<i>o</i> -xylene	9.5	1.1 – 38	–	–
<i>m</i> -xylene	8	3.2 – 33	–	–
<i>p</i> -xylene	1.7	1.7	584	–

EC₅₀ (median effective concentration) - The concentration of material in water that is estimated to be effective in producing some lethal response in 50% of the test organisms.

LC₅₀ (median lethal concentration) - The concentration of material in water that is estimated to be lethal to 50% of the test organisms. The LC₅₀ is usually expressed as a time-dependent value, e.g. 24-hour or 96-hour LC₅₀, the concentration estimated to be lethal to 50% of the test organisms after 24 or 96 hours of exposure.

¹¹ The bioconcentration factor (BCF) is a unitless value describing the degree to which a chemical can be bioaccumulated in the tissues of an organism in the aquatic environment. At apparent equilibrium during the uptake phase of a bioconcentration test, the BCF is the concentration of a chemical in one or more tissues of the aquatic organisms divided by the average exposure concentration in the test.

¹² No observable effect concentration.

Frost (2001), in a comprehensive literature review of the effects of aromatic compounds in the aquatic environment, provides the lowest toxicity levels for BTEX compounds. These are summarised in Table 39. Short-term acute toxicity data on marine organisms as specified by ANZECC (2000) are provided in Table 40. The *meta* and *para* isomers of xylene cannot currently be distinguished analytically. It is assumed that the mode of action is the same and that the toxicity of the isomers is additive.

The limited potential for exposure of marine organisms living near produced water discharges, is supported by observations that fish and shellfish living near discharge points do not accumulate aromatic compounds to a significant degree (Offshore Operators Committee, 1997). From this one can conclude that the potential risks to the environment associated with the discharge of BTEX compounds, is low.

However, one of the sublethal effects of BTEX compounds include the potential of tainting – described as a flavour or odour foreign to the product – of fish and mollusc flesh at low concentrations (RSA DWAF, 1995). Although marine organisms will cleanse themselves naturally of hydrocarbon contaminants over time, the presence of taint in a food product may lead consumers to believe that the food has been contaminated. This can lead to a loss of confidence in a product and concern that it may be unfit to eat¹³. This would be of particular concern to the Namibian rock lobster industry, as any damage to the international reputation of this product would impact on fish exports, with potentially disastrous effects on the fisheries economics of Lüderitz.

Given the optimal dilution of the effluents from the gas conditioning plant (*i.e.* the effluent is “bled” into the purge water discharge over a full 24 hours), the maximum dissolved hydrocarbon concentration in the discharged effluent (purge water plus gas conditioning plant effluent) would be $1.6 \mu\text{g}\cdot\ell^{-1}$. Constituent concentration levels likely to cause tainting effects in the marine environment are typically $1.0 \mu\text{g}\cdot\ell^{-1}$ (RSA DWAF 1995, ANCEZZ, 2000; US-EPA, 2000). Only 3,4-dichlorophenol and 2,3 dichlorophenol (should these substances be present in the gas conditioning plant effluent) have lower tainting concentration thresholds (0.04 and $0.3 \mu\text{g}\cdot\ell^{-1}$, respectively). The fact that any such tainting substances are likely to be a small proportion of the $10 \text{ mg}\cdot\ell^{-1}$ of dissolved hydrocarbons discharged from the gas conditioning plant into the purge water, suggests that tainting thresholds will not be exceeded after 2 to 10 dilutions of the effluent after discharge¹⁴, *i.e.* possible tainting effects are likely to be restricted to within 500 m of the discharge, 1 km at the most for the proposed optimal discharge of the gas conditioning plant effluent as proposed above.

¹³ If present in the discharge, there also is the possibility for the accumulation of substances such as hexachlorobenzene in animal tissue resulting in potential carcinogenic risks if consumed (see Table 36).

¹⁴ In order to avoid tainting the dilution requirements for 3,4-dichlorophenol and 2,3 dichlorophenol, if present in the gas conditioning plant effluent, range between 6 and 40 and would thus have a very conservatively estimated maximum “footprint” of approximately 1 km for a pipeline discharge offshore of the surf-zone and approximately 2 km for a surf-zone discharge.

6.6 Discharge of HRSG blowdown effluent

The HRSG blowdown effluent will contain ammonia (NH_3), phosphates ($\text{PO}_4\text{-P}$) and traces of the oxygen-scavenging substance hydrazine. Further, it will be oxygen deficient. A dilution of the effluent with the purge water will achieve a minimum dilution factor of 8 to 10. This should result in sufficient oxygenation of the discharged water to minimise impacts. Furthermore, the turbulent waters in the surf-zone and within the wave base (<40 m) are likely to be well oxygenated and the low oxygen content of the purge water and the small quantities of hydrazine are thus unlikely to be of concern.

Whereas a dilution factor of 10 is sufficient for oxygenation of the purge water, the concentrations of ammonia and phosphates will, however, be above the guideline values (see Table 38). NH_3 is regarded as the toxic form of ammonia because it is uncharged and lipid soluble and can cause growth deficiencies and mortalities (RSA DWAF, 1995). Furthermore, both nitrate and phosphate can cause eutrophication. The South African Water Quality Guidelines (RSA DWAF, 1995) state that the target for the South African coastal zone is that waters should not contain concentrations of dissolved nutrients that are capable of causing excessive or nuisance growth of algae or other aquatic plants or reducing dissolved oxygen concentrations below the target range indicated for dissolved oxygen. The South African water quality guidelines for $\text{NH}_3\text{-N}$ as a toxicant is given as a maximum of $20 \mu\text{g}\cdot\ell^{-1}$ as $\text{NH}_3\text{-N}$ and $600 \mu\text{g}\cdot\ell^{-1}$ as total ammonia ($\text{NH}_3\text{-N} + \text{NH}_4^+\text{-N}$).

It is therefore recommended that the effluent will be “bled” into the purge water system over a 24 hour period which will reduce the maximum concentrations of $\text{PO}_4\text{-P}$ and NH_3 to approximately $2.5 \mu\text{g}\cdot\ell^{-1}$ and $1 \mu\text{g}\cdot\ell^{-1}$, thus assuring compliance with the relevant water quality guidelines.

6.7 Oxygen levels

Dissolved oxygen is an essential requirement for most heterotrophic marine life. Its natural levels in seawater are largely governed by local temperature and salinity regimes, as well as organic content. Coastal upwelling regions are frequently exposed to hypoxic conditions ($<0.5 \text{ ml O}_2\cdot\ell^{-1}$) owing to extremely high primary production and subsequent oxidative degeneration of organic matter. Along the southern African coast, low-oxygen waters are a feature of the Benguela system. Two local zones of formation of oxygen-deficient water have been identified on the southern African west coast, one of which is in the vicinity of the Orange River mouth (Chapman and Shannon, 1985; Shannon, 1985).

Advancing hypoxic water has the potential to cause mass mortalities of benthos and fish (Diaz and Rosenberg, 1995). Marine organisms respond to hypoxia by first attempting to maintain oxygen delivery (*e.g.* increases in respiration rate, number of red blood cells, or oxygen binding capacity of haemoglobin), then by conserving energy (*e.g.* metabolic depression, down regulation of protein synthesis and down regulation/modification of certain regulatory enzymes), and upon exposure to prolonged hypoxia, organisms eventually resort to anaerobic respiration (Wu, 2002).

Hypoxia reduces growth and feeding, which may eventually affect individual fitness. The effects of hypoxia on reproduction and development of marine animals remains almost unknown. Many fish and marine organisms can detect, and actively avoid hypoxia (*e.g.* rock lobster “walk-outs”). Some macrobenthos may leave their burrows and move to the sediment surface during hypoxic conditions, rendering them more vulnerable to predation. Hypoxia may eliminate sensitive species, thereby causing changes in species composition of benthic, fish and phytoplankton communities. Decreases in species diversity and species richness are well documented, and changes in trophodynamics and functional groups have also been reported. Under hypoxic conditions, there is a general tendency for suspension feeders to be replaced by deposit feeders, demersal fish by pelagic fish and macrobenthos by meiobenthos (see Wu, 2002 for references). Further anaerobic degradation of organic matter by sulfate reducing bacteria may additionally result in the production of hydrogen sulphide, which is detrimental to marine organisms (Brüchert *et al.*, 2003).

Because oxygen is a gas, its solubility in seawater is dependent on salinity and temperature, whereby temperature is the more significant factor. Increases in temperature and/or salinity result in a decline of dissolved oxygen levels. For example, saturation levels of dissolved oxygen in seawater decrease with rising temperature and salinity from 5.8 mL.L⁻¹ at 15°C and 35 psu, to 4.3 mL.L⁻¹ at 25°C and 55 psu (RSA DWAF, 1995) not taking into account any biological use of oxygen due to respiration, oxidation and degradation. The latter values are the approximate characteristics of the discharged purge water (see Table 5), thereby translating into a 25% reduction in dissolved oxygen in the heated effluent. The potential for a reduction in dissolved oxygen levels will drastically reduce within a few metres of the outlet as the effluent mixes with the receiving waters. Within a 20 m radius from the discharge point a decrease of < 10% in dissolved oxygen might occur, and at distances > 20 m the potential reduction will fall below 2% (5.8 mL O₂.L⁻¹ at 15°C and 35 psu to 5.7 mL O₂.L⁻¹ at 16°C and 36 psu). The upwelled waters in the Benguela system typically contain 5 mL O₂.L⁻¹ of dissolved oxygen on reaching the surface (Chapman and Shannon, 1985). It is anticipated that the impact of potential reduction in dissolved oxygen levels will be extremely localised and can be considered largely insignificant, particularly if the discharge occurs within the surf-zone or wave base regime (< 40 m). This, however, assumes that none of the various chemical compounds that may be co-discharged with the heated seawater will significantly reduce the dissolved oxygen levels in the thermal effluent (see section 6.6).

6.8 Flow field distortion due to momentum transfer

Thermal effluent discharges are typically high volume and, depending on the outfall design, may impart a great deal of momentum to the receiving waters. The intermediate field of a thermal discharge is typically characterised by large induced velocities that may persist over considerable distances and cause a modification of the ambient coastal circulation system (Jirka, 1982).

The discharged effluent is expected to flow into the receiving environment at a velocity of $\geq 1.8 \text{ m.s}^{-1}$, the actual velocity depending on the specifics of the outfall design. The transfer of momentum that occurs could result in induced flows causing distortion of the receiving water circulation. Of potential concern is the effect of these induced flows on natural sediment

transport in the vicinity of the outfall through direct impacts on the sediment dynamics or through wave-current interactions leading to wave refraction or focussing (Jirka, 1982). However, given appropriate outfall design (*i.e.* for a pipeline or shoreline discharge), it should be possible to minimise flow field distortion. For the small volumes being considered and by taking the outfall configuration into account (*i.e.* near vertical discharge), these effects are thus expected to be limited if not negligible.

6.9 Discharge and intake structures

Potential of scouring of sediment around the discharge outlet is a serious design issue for a once-through cooling system discharging into a shallow receiving water body (Carter and van Ballegooyen, 1998). However, the discharge volumes being considered here (*i.e.* for an evaporative cooling system) are substantially lower than for a once-through cooling option and the configuration being assessed is such that the potential impacts on bottom sediments are limited. Should such impacts occur they will be confined to the immediate vicinity of the discharge point.

The cooling-water intake may pose a hazard for marine life, as fish or lobster may die on the intake screens (Robin, 1991; Pawson and Eaton, 1999). While most of the fauna entrained within the power-station cooling-water system may survive the passage (Bamber and Seaby, 2004), some may die. However, the intake volume of an evaporation cooling system is relatively low, and this impact is thus regarded as minor. When the pipeline is lying on the sea bottom it may cause behavioural changes in rock lobsters as they potentially could seek it out for shelter.

The location of a discharge infrastructure on the shoreline, or even the shore-crossing of the pipeline may distort sediment transport pathways in the nearshore environment (and may even extend to the distortion of aeolian sand transport pathways if the infrastructure associated with the discharge is located in, or extends through, the mid- and upper shore) and consequently will alter the natural environment to some degree. However, the area under consideration falls within Mining Area 1 (MA1) where diamond mining has been conducted for decades. Compared to the impacts on the coastline and nearshore environment from mining, any alteration as a consequence of the shore-crossing of the pipeline can be considered as minor.

The dynamic nature of the beaches north of the Orange River mouth may, however, present a problem for the location of intake and discharge infrastructures and the shoreline crossing of the pipeline(s). Studies have indicated that shoreline migration (accretion) may on occasion be as much as 40 m per year (CSIR, 1996a). It is anticipated that for some mining operations under consideration the shoreline may prograde as much as 300 m over the life-time of the power plant (Geoff Smith, *pers comm.*). This needs to be taken into account during the engineering design of a surf-zone discharge or the installation of a pipeline to discharge further offshore, both in terms of environmental performance and risk of damage/dysfunction. The firm sandy sediment characterising the continental shelf inshore of the 40 m isobath north of the Orange River mouth, thins towards Mittag. Consequently increasing areas of Precambrian bedrock in the nearshore region are devoid of sediment. The bedrock may similarly be exposed in the intertidal zone of the beach as isolated rocky outcrops. This needs to be considered when developing any infrastructure associated with the intake or discharge infrastructure.

6.10 Summary of impacts for an offshore pipeline discharge

Here the impacts associated with both an offshore pipeline discharge (discharge location offshore of the intake) and a pipeline discharge just beyond the surf-zone (discharge location inshore of the intake) are summarised. The impacts, although similar in magnitude, are marginally higher for a *discharge located shorewards of the intake* than for a *marine discharge located seawards of the intake*. Further, the risks of pollutants entering the surf-zone are higher for the discharge inshore of the intake.

Under most hydrodynamic scenarios the effluent from the *offshore marine discharge either inshore or offshore of the intake* will be trapped on or near the seabed, and any potential impacts are therefore expected to be greatest for the benthic communities of shallow subtidal soft-sediments offshore and downstream of the discharge outlet. The thermal plume is not expected to extend significant distances shorewards and is unlikely to ever extend as far as the surf-zone, even when in the future the shoreline has advanced by some 300 m due to beach accretion. No impact is thus expected on communities of intertidal sandy beaches and on surf-zone assemblages. The plume also will not extend greatly into the deeper waters. Based on the CORMIX model results for a 1600 MW power plant, an assessment of the identified potential impacts are provided for:

- an offshore discharge (located seawards of the intake) on the receiving communities of nearshore unconsolidated sediments and emergent reefs
- a pipeline discharge beyond the surf-zone (located shorewards of the intake) on the receiving communities of nearshore unconsolidated sediments and emergent reefs.

For the “worst case” scenario of a 1 600 MW power plant the modelling results are as follows. The most stringent target value of + 1°C above ambient sea temperature, under the worst case scenario, will extend 430 m in a longshore and 140 m in an offshore direction. For higher velocity discharges ($\geq 1.8 \text{ m.s}^{-1}$), the guideline exceedance zone is restricted to a 20 radius around the outlet. The upper target value for salinity of 36 psu (RSA DWAF, 1995) will be complied with approximately 800 m downstream and 200 m offshore of the discharge point. If the port velocities of the purge water discharge are maintained at velocities $\geq 1.8 \text{ m.s}^{-1}$, increases in salinity up to and exceeding 36 psu will be limited to a 325 m longshore and 140 m offshore distance of the outlet. The most stringent target value of $<3 \mu\text{g.l}^{-1}$ for free chlorine will be exceeded for a maximum distance of 1140 m alongshore and 250 m offshore of the discharge location. If the less stringent but still conservative target value of $5 \mu\text{g.l}^{-1}$ is used, the exceedance zone will be 800 m alongshore and 200 m cross-shore. A higher velocity discharge ($\geq 1.8 \text{ m.s}^{-1}$) reduces the exceedance zone of $3 \mu\text{g.l}^{-1}$ to 740 m alongshore and 230 m offshore and the exceedance zone of $5 \mu\text{g.l}^{-1}$ to 325 m alongshore and 140 m offshore. The water from the gas condition plant, discharged at a rate of $5 \text{ m}^3.\text{day}^{-1}$, will contain $<10 \text{ mg.l}^{-1}$ of dissolved hydrocarbons with lesser concentrations of monocyclic aromatic hydrocarbons (BTEX) and other oil-based toxic components. “Bleeding” of this effluent into the purge waters over a 24 hour period will achieve an effective 6250 times dilution, reducing all toxic components of the effluent to a maximum concentration of $1.6 \mu\text{g.l}^{-1}$ or less. The ammonia and phosphates in the HRSG blowdown effluent can be reduced to 2.5 and $1 \mu\text{g.l}^{-1}$ respectively, when the effluent is “bled” into the purge water over a 24 hour period.

Nature of impact: Effects of thermal plume	
Extent	Local: Compliance with target value at discharge velocities of $\geq 1.8 \text{ m.s}^{-1}$ will occur within $< 20 \text{ m}$ radius of the discharge location.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects are anticipated.
Probability	Definite: The discharged purge water will have an elevated temperature.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	No mitigation possible, but is not required

Nature of impact: Effects of salinity plume	
Extent	Local: Compliance with target value at discharge velocities of $\geq 1.8 \text{ m.s}^{-1}$ will occur with 325 m downstream and 140 m offshore of the discharge location.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects are anticipated, as adverse effects on biota are usually associated with decreases in salinity.
Probability	Definite: The discharged purge water will have an increased salinity.
Status of Impact	Negative
Degree of Confidence	Medium: Little information available on effects of high salinity on marine biota.
Significance without mitigation	Low
Significance with mitigation	No mitigation possible, but not required

Nature of impact: Effects of biocide plume	
Extent	Local: Compliance with most stringent target value at discharge velocities of $\geq 1.8 \text{ m.s}^{-1}$ will occur with 730 m downstream and 215 m offshore of the discharge location. For less stringent but none-the-less conservative target values, compliance will be achieved 315 m downstream and 120 m offshore of outlet.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects expected for this impact; for very sensitive species, some deleterious effects at the sublethal level may occur.
Probability	Definite: The discharged purge water will contain residual chlorine. Could be mitigated at a cost.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of aromatic hydrocarbons	
Extent	Local: Effluent from the gas conditioning plant if 'bled' over a 24 hour period into purge water, will dilute the effluent by a factor of 6250, and thus reducing the discharge concentration to 1.6 $\mu\text{g}\cdot\text{l}^{-1}$. Similarly, the oil separator for the plant and surface water drainage needs to be set to meet the relevant standards.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects expected for this impact; some deleterious effects (e.g. tainting of fish and shellfish flesh) at the sublethal level may occur.
Probability	Definite: The discharged purge water will contain only traces of aromatic compounds. Could be mitigated at a cost.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of HRSG blowdown effluent	
Extent	Local: When effluent is 'bled' over a 24 hour period into the purge water system, concentrations of ammonia and phosphates will comply with guidelines at point of discharge. The HRSG blowdown effluent should contain only trace quantities of hydrazine to avoid potential impacts due to reduced dissolved oxygen concentrations.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal or sublethal effects expected.
Probability	Definite: The HRSG blowdown effluent will contain traces of hydrazine, ammonia and phosphates.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of a decline in dissolved oxygen levels	
Extent	Local: Reduction of dissolved oxygen levels restricted to the extent of the thermal and high salinity plumes.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: A potential 25% reduction in dissolved oxygen levels in the heated effluent will only result in < 2% drop in dissolved oxygen for any significant area.
Probability	Definite: The heated and high saline effluent will cause a reduction in dissolved oxygen levels.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low (opportunity for mitigation is limited)

Nature of impact: Flow field distortion due to momentum transfer	
Extent	Local: Restricted to the vicinity of the outlet.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: Due to the small volumes and the design of the outlet.
Probability	Definite
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of discharge and intake structures	
Extent	Local: Restricted to the vicinity of the outlet and the construction site of the pipeline.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low
Probability	Definite
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Compliance with World Bank guidelines

For all environmental conditions assessed for an offshore pipeline discharge, there is compliance with the World Bank Water Quality guidelines for temperature and biocides, and with international guidelines on aromatic hydrocarbons. No World Bank Water Quality guideline could be located for salinity, however the impacts are assessed to be low based on other Water Quality guidelines deemed to be of relevance (*e.g.* RSA DWAF, 1995).

6.11 Summary of impacts for a shoreline discharge into the surf-zone

Nearshore circulation is highly complex and extremely variable. The surf-zone is relatively isolated from the waters further offshore. While pollutants in the surf-zone are rapidly mixed across the surf-zone, they may subsequently be transported for long distances alongshore with relatively little further dilution. This reduces the effective dispersion of a pollutant. Most of the exchange between the surf-zone and the offshore waters occurs due to rip currents that transport surf-zone waters further offshore. However, some of the water mixed beyond the surf-zone may be transported back into the surf-zone with the next set of waves. Observations have indicated that in high wave conditions, there is a higher degree of re-entrainment of pollutants dispersed into the offshore zone, and that the overall dispersion of pollutants within the surf-zone is thus effectively reduced.

The “footprint” of an effluent plume discharged into the surf-zone is thus somewhat more extensive than for either of the other two offshore pipeline discharge options. For an 800 MW nominal capacity power plant, the thermal “footprint” marginally exceeds World Bank Water Quality guidelines, but the spatial extent remains relatively small (*i.e.* confined to approximately 150 m alongshore and 80 m to approximately 620 m offshore of the discharge point). The exceedance of the South African water quality guidelines is somewhat greater (*i.e.* confined to approximately 250 m alongshore and 80 m to approximately 620 m offshore of the discharge point). For a 1600 MW nominal capacity power plant the non-compliance with the World Bank Water Quality guidelines is somewhat more spatially extensive (*i.e.* confined to approximately 300 m alongshore and 80 m to approximately 620m offshore of the discharge point), while the exceedance of the South African water quality guidelines is even greater (*i.e.* confined to approximately 600 m alongshore and 80 to approximately 620 m offshore of the discharge point). However, the direct thermal impacts on benthic assemblages and potentially on egg and larval development is expected to be limited.

The South African Water Quality guidelines (RSA DWAF, 1995) sets an upper target value for salinity of 36 psu, which for a 800 MW nominal capacity power plant will be complied with approximately 200 m to 500 m downstream and between 80 m and 620 m offshore (*i.e.* the surf-zone width) of the discharge location and for a 1 600 MW nominal capacity power plant will be complied with approximately 400 m to 800 m downstream and between 80 m and 620 m offshore. The assessment of the impacts of elevated salinity on the biota of the Oranjemund coastline is of necessity speculative as little published information exists on this topic. Since the area in question is a high energy, open, sandy coastline with a small tidal range (*ca.* 1.8 m) the benthic organisms are unlikely to exhibit much tolerance to salinity variations, perhaps 1 –2 psu above and below the approximate 35 psu typical of seawater in this region.

There is a possibility that the larvae of a variety of species, including those of the commercially important rock lobster *Jasus lalandii*, could be transported by the longshore drift. In this case the heated brine could act as a barrier to their dispersal.

The scale of the impacts is somewhat uncertain but are expected to be proportional to the plume extent (estimated 200 to 500 m for a salinity of 40 psu).

It must be pointed out that the cumulative effect of elevated salinity and temperature, and of co-discharges, on the larval and juvenile stages of fish and invertebrates is not known, but could well be greater than the sum of the individual impacts. For example, on the southern Namibian coastline shallow, nearshore reef regions are thought to be important as recruitment habitats for rock lobsters. Furthermore, the population often becomes concentrated in very shallow waters in response to low oxygen concentrations near the seabed. The effect of an effluent plume discharged into the surf-zone could thus have far-reaching effects on the commercial fishery for this species. Based on the uncertainty of the impacts, the likely sensitivity of marine biota to elevated salinities, and the spatial extent and likely persistence of the plume in the surf-zone, the precautionary principle requires that the potential impacts be considered to be of medium significance or greater.

Based on the CORMIX model results for a 1600 MW power plant, an assessment of the identified potential impacts of a pipeline discharge into the surf-zone on the receiving communities of intertidal sandy beaches and rocky shores and surf-zone assemblages is provided below.

Nature of impact: Effects of thermal plume on marine biota	
Extent	Local: Compliance with target value at alongshore distances of < 600 m of the discharge location.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects are anticipated.
Probability	Definite: The discharged purge water will have an increased temperature.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	No significant mitigation possible

Nature of impact: Effects of salinity on beach and surf-zone communities	
Extent	Local: Estimated plume dimension of 200 to 500 m for a salinity of 40 psu.
Duration	Long-term: As long as the plant is in operation.
Intensity	Locally high
Probability	Definite: The discharged purge water will have an increased salinity.
Status of Impact	Negative
Degree of Confidence	Medium: Little information available on effects of high salinity on marine biota.
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of elevated salinity interfering with physiological function of larval fish and invertebrates	
Extent	Local to regional: The surf-zone is potentially a migration or dispersal medium
Duration	Long-term: As long as the plant is in operation.
Intensity	High
Probability	Uncertain.
Status of Impact	Negative
Degree of Confidence	Low: Little information available on the ichthyofauna of the region
Significance without mitigation	Medium
Significance with mitigation	Medium: Mitigation possibilities uncertain

Nature of impact: Effects of biocide on beach and surf-zone communities	
Extent	Local: Compliance with most stringent target value will occur with 600 m to 1200 m. For less stringent but still conservative target value of $5 \mu\text{g}\cdot\text{l}^{-1}$, compliance will be achieved within in 400 to 800 m.
Duration	Long-term: As long as the plant is in operation.
Intensity	Locally high: Potential lethal effects in a limited area (<i>i.e.</i> 600 m on either side of the discharge point) and some deleterious effects within a 1200 m alongshore distance.
Probability	Definite: The discharged purge water will contain residual chlorine. Could be mitigated at a cost.
Status of Impact	Negative
Degree of Confidence	Medium
Significance without mitigation	Medium
Significance with mitigation	Low

Nature of impact: Effects of aromatic hydrocarbons	
Extent	Local: Effluent from the gas conditioning plant will be 'bled' over a 24 hour period into purge water diluting the effluent by a factor of 6250, and thus reducing the discharge concentration to $1.6 \mu\text{g}\cdot\text{l}^{-1}$. Similarly, the oil separator for the plant and surface water drainage needs to be set to meet the relevant standards (e.g. South African General Discharge Standard)
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal effects expected for this impact; some deleterious effects (<i>e.g.</i> tainting of fish and shellfish flesh) at the sublethal level may occur.
Probability	Definite: The discharged purge water will contain only traces of aromatic compounds. Could be mitigated at a cost.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of HRSG blowdown effluent	
Extent	Local: When effluent is 'bled' over a 24 hour period into the purge water system, concentrations of ammonia and phosphates will comply with guidelines at point of discharge. Only trace quantities of Hydrazine.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: No lethal or sublethal effects expected.
Probability	Definite: The HRSG blowdown effluent will contain traces of hydrazine, ammonia and phosphates.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of a decline in dissolved oxygen levels	
Extent	Local: Reduction of dissolved oxygen levels restricted to the extent of the thermal and high salinity plumes.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low
Probability	Definite: The heated and high saline effluent will cause a reduction in dissolved oxygen levels.
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Elevated salinity acting as a barrier to larval migration	
Extent	Local to regional: Depends on actual effect on overall populations of fishes and invertebrates.
Duration	Long-term: As long as the plant is in operation.
Intensity	Medium to high
Probability	Uncertain
Status of Impact	Negative
Degree of Confidence	Low
Significance without mitigation	Medium
Significance with mitigation	Low to medium

Nature of impact: Elevated salinity & temperature of brine interfering with larval fish cueing.	
Extent	Local to regional: Depends on actual effect on overall populations of fishes and invertebrates.
Duration	Long-term: As long as the plant is in operation.
Intensity	Medium to high
Probability	Uncertain
Status of Impact	Negative
Degree of Confidence	Low
Significance without mitigation	Medium
Significance with mitigation	Low to medium

Nature of impact: Flow field distortion due to momentum transfer	
Extent	Local: Restricted to the vicinity of the outlet.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low: Due to the small volumes and the design of the outlet.
Probability	Definite
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Nature of impact: Effects of discharge and intake structures on sediment transport	
Extent	Local: Restricted to the vicinity of the outlet and the construction site of the pipeline.
Duration	Long-term: As long as the plant is in operation.
Intensity	Low
Probability	Definite
Status of Impact	Negative
Degree of Confidence	High
Significance without mitigation	Low
Significance with mitigation	Low

Compliance with World Bank guidelines

Based on the World Bank Water Quality guideline of not exceeding a 3°C temperature rise beyond a 100 m radius, there is marginal non-compliance for the surf zone discharge option for a 800MW power plant. For a 1600 MW power plant the non-compliance is more extensive, however, a 3°C temperature rise is not exceeded beyond a radius of 300 m. There is compliance, by default, with the World Bank guideline for biocides, *i.e.* the concentrations at the point of discharge are below the World Bank guidelines.

7. MITIGATION MEASURES & MANAGEMENT RECOMMENDATIONS

The discharge of the heated brine from the CCGT Power Plant is unavoidable, and no mitigation is feasible. However, the outfall characteristics (extent and duration of the plume “footprint”) could be optimised through the use of the most effective diffuser design. The impacts due to biocides can be mitigated by de-chlorination of the purge water before discharge into the marine environment. This would, however, be associated with a significant cost.

The recommendations of the assessment are:

- Depending on the final location of the discharge pipe, a more detailed study may be required to ensure that, relative to the seawater intake, the discharge point is located so as to limit or prevent re-circulation of the effluent to an extent that is deemed unacceptable in terms of plant operational efficiencies.
- The engineering and environmental implications of the infrastructure associated with the cooling water system need to be carefully studied as there are high structural risks associated with locating these structures in such a dynamic environment.
- Although this assessment used the results of the CORMIX model for the discharge of purge water from a 1600 MW nominal capacity power plant, a re-assessment of the impacts, incorporating the knowledge gained during the operation of the 800 MW nominal capacity power plant, should be conducted prior to the upgrading of the power plant.
- An appropriate physical monitoring program needs to be initiated, which includes both baseline measurements and subsequent operational monitoring. More specifically, this should include:
 - Regular reporting on the volume and composition of the discharge.
 - Water column monitoring including measurements of biocides and aromatic hydrocarbons on a regional scale in order to improve the understanding of the environmental fate of the effluent.
 - Bioaccumulation monitoring using mussels (possibly in combination with membrane-based techniques – see Prest *et al.*, 1995; Peven *et al.*, 1996; Hofelt and Shea, 1997) as indicator organisms due to their ability to accumulate trace levels of pollutants from the water column.
- An appropriate biological monitoring program needs to be initiated, which includes both baseline measurements and subsequent operational monitoring.

- Given the important role of the surf-zone and immediate subtidal habitats in the ecosystem functioning of the region, should the surf-zone discharge option be considered, the following should be incorporated:
 - A baseline survey of the zooplankton and ichthyoplankton along the Oranjemund coast to elucidate species distributions and seasonal variations.
 - A baseline survey, and subsequent monitoring, of the beach macrofaunal communities, and surf-zone fish communities in the vicinity of the discharge.
 - A range of toxicity tests for the most sensitive biota in the surf-zone to determine their vulnerability to elevated salinity and biocides.
- At present, the southern limit of the southern rock lobster fishing grounds are approximately 11 km north of the proposed discharge location. Although substantial extension of these grounds further southwards is considered unlikely due to the scarcity of suitable fishing reefs south of Mittag (MFMR, Lüderitz, pers. comm.), this possibility cannot be excluded. It is therefore recommended to liaise with the rock lobster fishing industry on this issue to avoid potential confrontation in the future. Given that it is possible for BTEX compounds to taint rock lobster flesh (with potentially serious consequences for the rock lobster export market), the importance of a conservative discharge design and strict compliance with the most stringent guidelines for the discharge of hydrocarbons is emphasized.
- Develop guidelines for the characterisation of produced water from the Kudu Gas Project. A method of risk assessment should form the basis for the development of an Environmental Impact Factor, to be used as an effluent management tool, such as described by the EU Technical Guideline Document (EC, 1996).

8. CONCLUSIONS

The biological communities potentially impacted by the purge water discharged from a 800 and a 1600 MW nominal capacity power plant at Uubvley can be summarised as follows:

- The intertidal beach fauna has a low species diversity and biomass. Although the beach fauna is extremely dynamic, changing in community composition with alterations of physical state, any significant, particularly long-term, changes are thus likely to have ramifying cascade effects, especially if impacted species are involved in higher-order biological interactions.
- Low biomass, dynamic communities are likewise expected for shallow water soft-bottom communities due to the high depositional nature of this area, and the frequent natural disturbances (*e.g.* Orange River floods, low oxygen events).
- The mud belt in deeper waters (70 – 120 m depth) is rich in benthic macrofauna, whereas biomass and diversity decline further offshore.
- Intertidal and subtidal reef communities are typical of the Namaqua biogeographic province differing with exposure to wave action. Subtidal habitats may be dominated by kelp, which provides a habitat for the commercially important rock lobster *Jasus lalandii*.

The potential impacts on these communities by an effluent discharge will vary depending on the type of cooling water system installed, the position of the discharge pipeline, and the design of the diffuser. The impacts are the greatest for scenarios where a seawater temperature rise in the effluent of 5°C is assumed (*i.e.* evaporative cooling system). Although the thermal impacts are somewhat reduced compared to an effluent characterised by a 10°C temperature rise, the effluent is more dense, resulting in more limited mixing of the effluent with the receiving waters. This reduced mixing results in a slightly larger thermal plume “footprint” within which the guidelines for biocides are exceeded. Consequently there is a larger impact due to the biocides in the effluent discharged into the marine environment for an effluent with a 5°C temperature rise compared to that having a 10°C temperature rise above ambient conditions in the marine environment.

8.1 Pipeline discharge offshore or beyond the surf-zone

The preliminary environmental assessment for the discharge of a heated hypersaline effluent from a 800 and a 1600 MW nominal capacity power plant to an area approximately 1000 m to 1300 m offshore of Uubvley and in between a 15 m and 18 m water depth identified that :

- The “footprint” of the heated brine discharged through a shorter pipeline into shallower water will be greater than for an offshore discharge, *i.e.* the area of non-compliance with water quality guidelines is larger.
- For likely port discharge velocities ($\geq 1.8 \text{ m}\cdot\text{s}^{-1}$) the zone in which the most stringent water quality guidelines for a rise in seawater temperature are exceeded extends no further than a 20 m radius of the discharge location for the quantities of heated brine

discharged from both a 800 MW and 1600 MW power plant. These results are conservative in that it is assumed that there is no heat loss to the atmosphere, however, atmospheric heat loss for such a dense effluent is likely to be limited. Temperature elevations under normal conditions are unlikely to reach lethal or significant sublethal levels. At maximum temperature conditions, biota may be killed but are expected to have a fast recovery rate.

- For likely port discharge velocities ($\geq 1.8 \text{ m.s}^{-1}$) the zone in which the most stringent water quality guidelines for an increase in salinity are exceeded extends no further than a 70 m radius of the discharge location for the quantities of heated brine discharged from a 800 MW power plant. For a 1600 MW power plant the zone in which the most stringent water quality guidelines are exceeded extends no further than a 325 m alongshore and 140 m offshore from the discharge location. (For a 5 m.s^{-1} port discharge velocity there will be compliance with the most stringent target value within 25 m of the discharge point for the quantities of heated brine discharged from a 1600 MW power plant.) Little information exists on impacts of high salinity on marine biota, but adverse effects can be anticipated, particularly for stenohaline species.
- For likely port discharge velocities ($\geq 1.8 \text{ m.s}^{-1}$) the zone in which the most stringent water quality guidelines for biocides are exceeded extends no further than 370 m in an alongshore and 120 m in an offshore direction for the quantities of heated brine discharged from a 800 MW power plant, however for these higher port discharge velocities there will be compliance with the less stringent guideline of $5 \mu\text{g}.\ell^{-1}$ at all times beyond a radius of 70 m. For a 1600 MW power plant and port discharge velocities $> 1.8 \text{ m.s}^{-1}$, the zone in which the most stringent water quality guidelines are exceeded extends no further than a 735 m in an alongshore direction and 230 m in the offshore direction, while there will be compliance with the guideline of $5 \mu\text{g}.\ell^{-1}$ at all times within a distance of 325 m alongshore and 140 m cross-shore for the quantities of heated brine discharged from a 1600 MW power plant at these higher port velocities. The residual chlorine concentrations around the outlet, under normal operational conditions, are specified to be below the levels which may have lethal effects on the biota. For very sensitive species, some deleterious effects on the sublethal level may, however, occur.
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to comply with the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures, the discharges from the gas conditioning plant and the HSRG effluent are expected to meet water quality guidelines at the point of discharge or in close proximity ($< 20 \text{ m}$) of the discharge. (Note: Substances identified to have the lowest tainting thresholds, should these substances be present in the gas conditioning plant effluent, may result in tainting of flesh in marine biota but only within a conservatively estimated of approximately 500 m of the discharge, possibly 1 km at the most for the proposed optimal discharge of the gas conditioning plant effluent as proposed.)

For a pipeline discharge either offshore or inshore of the intake point, all potential environmental impacts as assessed in this study are considered to be of low significance, however the impacts increase on moving inshore, i.e. with the shortening of the discharge pipeline length.

However, it should be noted that:

- The model results are strongly dependent on the assumed currents in the ambient waters and are also strongly dependent on the detailed design of the discharge (*e.g.* on port discharge velocity).
- While with appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply the relevant water quality guidelines, it should be noted that is not possible to assess all potential synergistic effects of the co-discharges.

8.2 Shoreline Discharge into the Surf-zone

The preliminary environmental assessment for a discharge of a heated hypersaline effluent from a 800 and a 1600 MW nominal capacity power plant into the surf-zone at Uubvley identified that :

- The alongshore dimensions of the spatial area of the plume that exceeds the various Water Quality guidelines is substantially greater for a surf-zone discharge than for the two offshore discharge scenarios. This is primarily due to the surf-zone trapping that occurs, resulting the extensive spreading of the plume alongshore. There is, however, considerable uncertainty around the exact plume dimensions due to the lack of simple quantitative methods to assess surf-zone dilutions.
- Based on the World Bank Water Quality guideline of not exceeding a 3°C temperature rise beyond a 100 m radius, there is marginal non-compliance for the surf-zone discharge option for a 800MW power plant. Although the non-compliance is more extensive for a 1600 MW power plant, a 3°C is not exceeded beyond a radius of 300 m. There is compliance with the World Bank and other international guideline for biocides and aromatic hydrocarbons.
- The plume dimensions are approximately 40–300 m for the +3°C contour and between 200 and 600 m for the +1°C contour. These results are conservative in that it is assumed that there is no heat loss to the atmosphere. Temperature elevations under normal conditions are unlikely to reach lethal or significant sublethal levels. At maximum temperature condition, biota may be killed but are expected to have a fast recovery rate.

- The South African Water Quality guidelines (RSA DWAF, 1995) set an upper target value for salinity of 36 psu, which will be complied with approximately 400 m to 800 m downstream and between 80 m and 620 m offshore (*i.e.* the surf-zone width) of the discharge point. Based on 40 psu contours, the plume is estimated to extend 200 to 500 m alongshore. The significance of the potential salinity impacts on beach and surf-zone benthic communities is considered to be low, however, the impacts of elevated salinity on physiological function of larval fish and invertebrates is uncertain. Based on the precautionary principle these impacts presently should be considered to be of at least medium significance or greater until shown otherwise.
- The plume extent for biocides is significantly more extensive for a surf-zone discharge than for the offshore discharge options. Based on the sensitivity of marine biota and the likely extent of the biocide plumes, the potential impact of this co-discharge on the marine biota in the surf-zone should be considered to be of medium significance.
- The cumulative effect of elevated salinity and temperature, and of co-discharged substances on the larval stages of marine organisms is not known but could well be greater than the sum of the individual impacts.
- Impacts associated with reduced dissolved oxygen levels, if they occur, are expected to be extremely local and can be considered insignificant in the turbulent surf-zone.
- Elevated salinities and temperatures in the surf-zone may have a significant barrier effect on the dispersive larval stages of fishes and invertebrates that are transported in the littoral drift. The extent and significance of this impact is highly uncertain.
- Elevated salinities and temperatures in the surf-zone may have a significant impact of the cueing effects that guide larval/juvenile fish to nursery areas such as the Orange River estuary. The extent and significance of this impact is highly uncertain.
- The exact nature and quantity of the oily water waste streams are relatively uncertain, however they should be able to be managed to comply with the relevant water quality guidelines before discharge.
- With appropriate design of the discharge and mitigation measures, the discharges from the gas conditioning plant and the HSRG effluent are expected to meet water quality guidelines at the point of discharge or in close proximity (< 20 m) of the discharge. (Note: Substances identified to have the lowest tainting thresholds, should these substances be present in the gas conditioning plant effluent, may result in tainting of flesh in marine biota but only within a conservatively estimated of approximately 500 m of the discharge, possibly 1 km at the most for the proposed optimal discharge of the gas conditioning plant effluent as proposed.)

For a discharge into the surf-zone, all potential environmental impacts as assessed in this study are considered to be of low significance, except for:

- the potential impacts of elevated salinity on physiological function of larval fish and invertebrates.
- impacts due to biocides associated with a larger and more persistent plume in the surf-zone.
- elevated temperatures and salinity acting as a barrier for the movement of the larvae of fishes and invertebrates that are transported by the littoral drift.
- potential impacts on the cueing effects that guide larval/juvenile fish to nursery areas such as the Orange River estuary.

There is considerable uncertainty in the significance of these impacts. Based on this uncertainty, the lack of information on the sensitivity of marine biota and the likely extent and persistence of the plume, the precautionary principle requires that the above potential impacts be considered of medium significance or greater until proven otherwise.

However, it should be noted that:

- The model results are strongly dependent on the assumed currents and mixing processes in the ambient waters.
- There is considerable uncertainty around the exact plume dimensions due to the lack of simple quantitative methods to assess surf-zone dilutions. (This inherent uncertainty in assessing surf-zone discharges is one of the reasons that the South African Water Quality Guidelines declare the surf-zone as a sensitive area into which there should be no discharge of waste water / effluents, unless there is a strong motivation for doing so). Consequently there is inherent uncertainty in the assessment of ecological impacts of a surf-zone discharge.
- The “footprint” of the heated brine discharged through a shorter pipeline into shallower water will be significantly greater than for an offshore discharge, *i.e.* the area of non-compliance with water quality guidelines is significantly larger.
- While with appropriate design and implementation of mitigation measures, it is expected that all co-discharges will comply with the relevant water quality guidelines, it should be noted that it is not possible to assess all potential synergistic effects of the co-discharges.

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